3rd International Conference on ESAR „Expert Symposium on Accident Research“

Berichte der
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Fahrzeugtechnik Heft F 72

3rd International Conference on ESAR „Expert Symposium on Accident Research“

Reports on the ESAR-Conference on 5th/6th September 2008 at Hannover Medical School

organized by

Accident Research Unit at Hannover Medical School (MHH)
Federal Highway Research Institute, Bergisch Gladbach (BASt)
Research Association of German Car Manufacturers, Frankfurt/M., (FAT)
University of Technologie, Dresden

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Kurzfassung – Abstract

3. Internationale Konferenz ESAR, „Expertensymposium Accident Research“

Im Jahr 2004 fand an der Medizinischen Hochschule Hannover die erste ESAR (Expert Symposium on Accident Research) Konferenz statt. Die Idee einer internationalen Konferenz war aus der Notwendigkeit entstanden, doch diejenigen Experten zusammen zu bringen, die weltweit tätig sind und Verkehrsunfälle wissenschaftlich analysieren, um Ihre Ergebnisse gemeinsam diskutieren und einem Zielpublikum von Behördenvertretern, Entwicklungsingenieuren der Automobilindustrie und anderen Wissenschaftlern darzubringen. Die erste Konferenz war sehr erfolgreich, so dass eine zweite Konferenz 2006 folgte und in einem Zweijahreszeitraum die dritte Konferenz 2008 stattfand.

ESAR kann als wissenschaftliches Kolloquium und Plattform für einen Informationsaustausch der Unfallforscher angesehen werden, die sich speziell mit Methoden der Unfalluntersuchung, Verletzungsmechanismen und Bewertung von Verletzungen, Unfallursachen und anderen Bereichen der statistischen Unfalldatenanalyse befassen. Experten der verantwortlichen Behörden, aus den Gebieten der Medizin und der Technik kommen hier zusammen um die Erfahrungen in der Unfallprävention und dem komplexen Feld der Unfallrekonstruktion zu diskutieren, um auch neue Felder der Forschung zu öffnen. Speziell soll bei ESAR auch den Belangen der Europäischen Gemeinschaft Rechnung getragen werden, die gerade das Ziel verfolgt die Anzahl Getöteter bei Verkehrsunfällen binnen eines 10 Jahreszeitraumes von 2000 bis 2010 um 50 Prozent zu senken und durch die Zunahme auf nun 27 Mitgliedstaaten mit unterschiedlichen Standards an bestehender Verkehrssicherheit und unterschiedlichen Unfallszenarien, besondere Anforderungen an die Unfallanalysen setzt. Bestehende Ergebnisse langjähriger Forschungsarbeiten in Europa, USA, Australien und Japan beinhalten unterschiedliche infrastrukturelle Zusammenhänge und geben Erkenntnisse über Population, Fahrzeugbestand und Fahrereigenschaften, derartige Informationen bilden eine exzellente Basis für abzuleitende Empfehlungen und Maßnahmen für die Erhöhung der Verkehrssicherheit.

Besonderer Schwerpunkt von ESAR ist die Berücksichtigung der Forschungen auf der Basis von sogenannten „Unfallerhebungen am Unfallort“, diese sind durch umfassende Dokumentationen vom Unfallort, den Fahrzeugen und den Verletzungen geprägt. Auch beinhalten derartige Analysen häufig die Einbeziehung mehrere Fachdisziplinen. ESAR hat sich als Aufgabe gemacht hier multi-disziplinär die wissenschaftlichen Erkenntnisse zusammenzutragen und auf einer wissenschaftlich internationalen Ebene zu diskutieren

3rd International Conference on ESAR, „Expert Symposium on Accident Research”

In September 2004 the first international symposium called ESAR (Expert Symposium on Accident Research) was carried out at the University of Hannover (Germany). The idea for such international conference was to bring together experts from the fields of accident investigation teams worldwide to present their results for a common audience of people from government, industry and other universities. The first conference was a really sufficient one and followed by the second symposium also at the Hannover Medical School two years later in 2006. This two year rhythm was now continued with the third conference in Hannover again in 2008. It is planned to carry out ESAR every two years also in the future.

ESAR is a scientific colloquium and can be seen as a platform for exchange of information on accident research issues based on methodologies of investigation, injury mechanisms and injury assessment, accident causation and other issues of statistical accident data analysis. Representatives from authorities as well as from medical and technical institutions come together to discuss new research issues and exchange experiences on accident prevention and the complex field of accident reconstruction. Special focus was given to the target the European Union set for itself in 2000 which stipulates that within 10 years the number of person killed in road traffic accidents must be cut in half. To reach this goal, optimized measures, comprehensive research and analysis are necessary. A key hurdle comes from the European Union extension to 27 member states, each featuring different levels of traffic safety standards and different accident scenarios. Existing results from long term research projects in Europe, the USA, Australia and Japan including analyses of infrastructure, population, vehicle fleet and driver behaviour offer an excellent basis for understanding and improving countermeasures and research support needs in underdeveloped countries.

ESAR's goal is to bring together researchers from all parts of the world, who will report on their methods and recommendations to improve traffic safety based on "In-Depth-Investigations" of real world accidents. These In-depth-investigations of accidents require thorough documentation and an accident data analysis on multi-disciplinary levels which must be carried out immediately after it occurs. ESAR presents scientists the opportunity to present their studies on a common basis of research level.

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Conference Program of the 3rd International Conference ESAR „Expert Symposium on Accident Research“

Prof. Dietmar Otte
Hannover Medical School

Welcome to Hannover for the third ESAR conference!

My special welcome is given to our representatives from Government and Industry and our University.
Professor Reichelt, Federal Highway Research Institute BAST
Dr. Schöneburg, Head of Passive Safety Daimler
Professor Krettek, Director Department of Trauma Surgery Medical School Hannover

As we started with the first conference in September 2004 at the Hannover Medical School, we were very afraid of the acceptance of such conference, because many conferences are existing especially on topics of safety issues and especially during these months. But after the response of our second symposium two years later and this year 2008 conference, I am proud to open this third EXPERT SYMPOSUM ON ACCIDENT RESEARCH again here in Hannover. Also all responses from outside I received over the time induced me to go on with this conference.

ESAR is a scientific colloquium and can be seen as a platform for exchange of information on accident research issues. Representatives from authorities as well as from medical and technical institutions come together to discuss new research issues and exchange experiences on accident prevention and methodologies of accident reconstruction.

ESAR's goal is to bring together researchers from all parts of the world,
this year we have participants from 17 countries: Australia, Austria, Belgium, China, France, Germany, Ireland, Italy, Japan, Netherlands, Portugal, Spain, Sweden, UK, Ukraine and United States.- Welcome. participants from the fields of medicine, engineering and traffic psychology - ESAR thus stands for an internationally interdisciplinary event.

ESAR´s goal is also to give the opportunity for scientists to present their studies on Accident Investigation Methodologies, Accident Analysis and active and passive safety aspects and on Injury mechanisms and injury prevention. There are a lot of conferences around the world, but most of them have other special focus and orientation, i.e STAPP, DGU, IRCOBI, FISITA, AAAM or others.

ESAR is fulfilling this hole and find his position as a new trend-setting international conference on In-Depth-Accident-Analysis, taken part continuously every two years always in the first week of September.

This year we will have beside our scientific program with **46** oral presentations, we will have **3** excellent keynote speakers, thank you for coming:

Professor Kunz
Director General Road Construction and Road Traffic
Represent the state secretary of Federal Ministry of Transport Building and Urban Affairs

Dr. Cesari
Director of Inrets and chairman of Enhanced Vehicle Safety

Mr. Repussard
From Directorate General Energy and Transport of European Commission Brussels

Before we start with the program, let me say some words for organisation:
All papers will be published by the Federal Highway Research Institute
with ISBN number. My thanks is going to BAST who is supporting this publication.

As happened also at the last conferences, not all papers sent before and the print process will take some months. Therefore in your conference-handbag you will find a special CD with all papers which are currently submitted to us!
In your handbag there are also:

- Day-ticket for tram, you can use it to our evening event, a description how to go, will given later after the last session today.
- For lunch please take the voucher in your bag.

If you have any question, please don´t hesitate to ask our staffs which have blue coloured nameplates or our secretary at the registration desk.

Now I whish you a successful conference and a pleasant time here in Hannover.

Thank you!

Dr. Rodolfo Schöneburg
Head of Passive Safety Durability Vehicle Functions, Daimler AG
Sindelfingen

Good morning, Ladies and Gentlemen,
Dear Prof. Otte,

as the representative of the automobile industry, I am honoured to welcome you to the third ESAR conference this year.

The “Expert Symposium on Accident Research” has become an established international conference for the German In-Depth Accident Study GIDAS.

Again, this year the presentations cover a wide range of subjects. They vary from investigation of the effects of active and passive safety systems on real world accidents to the medical treatment after an accident.

This underlines the conference’s special focus: the close link between medical science and automotive engineering.

While dealing with a great variety of subjects, a large number of the presentations have one thing in common: irrespective of the addressed question and field of application, most of the studies are based on GIDAS data.

In almost 10 years of its history, GIDAS has evolved into the leading accident investigation project in Europe. It is an excellent example of successful cooperation between federal institutions and Industry – in this case the Federal Highway Research Institute BASt and the Research Association for Automotive Technology FAT as part of the German VDA.

I am delighted that Mercedes-Benz was one of the initiators and supported this important project from the very beginning.

A representative database like GIDAS, with respect to the accident scenario in Germany, is an indispensable source of data. The detailed and comprehensive description of traffic accidents is an essential basis for innovation in the field of vehicle safety.

Especially, the PRE-CRASH phase and causation of the accident are becoming more and more important. The earlier we introduce effective systems to

- avoid accidents,
- mitigate their outcome,
- and pre-condition restraint systems in case of an imminent collision,

the greater the benefit for all participants in road traffic will be.

In particular, the integration and linking of different technologies in the car leads to new and effective vehicle safety systems.

Real world accidents are and will always be the most important benchmark for us. There is good reason why Mercedes-Benz introduced its own systematic accident research as early as 1969: Recording real world accidents with their various types of collisions and maintaining continued communication with other experts in the field of accident research is of great importance for automotive safety development.

In this context, I would also like to mention the FISITA congress in Munich this month and the 21st ESV conference taking place in Stuttgart in June 2009.

Ladies and gentlemen, the ESAR conference offers an excellent opportunity to establish and strengthen ties with experts in accident research.

I wish all participants fruitful discussions, a successful conference and interesting days in Hanover.

Thank you!

Prof. Dr. Christian Krettek

Director Department of Trauma Surgery at Hannover Medical School

Hannover

Dear Ladies and Gentlemen.

Welcome to ESAR in Hannover. This international meeting celebrates already its third birthday which demonstrates its success. In the 1970s the accident research unit was formed within the Department of Trauma Surgery at Hannover Medical School. My surgical teacher Professor Harald Tscherne was lucky to employ Dietmar Otte. He then successfully built up and structured our accident research unit over more than 30 years. The intensive research has found appreciation worldwide and many units at other places were formed like our model here in Hannover. In the late 90s GIDAS was formed with another research unit in Dresden and the successful story written by Dietmar continued with two teams in two different areas. Many research results let to technical progress in cars, but even vulnerable road users had profit from the activities in Hannover. E.g. already more than 15 years ago the protective effect of bicyclists' helmets was proven here in Hannover by Dietmar which today no one would doubt. Today clinicians are happy to see less severe head injuries in all cyclists. The strong interdisciplinary network here in Hannover led to cooperation through a variety of departments. During the next days you are all part of this network of technicians, other scientist and physicians. I wish you all a successful and interesting congress! Enjoy your time with us in Hannover.

In-Depth Crash Investigation at the Centre for Automotive Safety Research

MRJ Baldock, JE Woolley, G Ponte, LN Wundersitz and VL Lindsay

Centre for Automotive Safety Research, The University of Adelaide, South Australia, 5005

Abstract - The Centre for Automotive Safety Research (formerly the Road Accident Research Unit) at the University of Adelaide in South Australia has a history of in-depth crash investigation going back to the 1970s. In recent years, our focus has been on studying factors that contribute to road crashes, with an emphasis on the role of road infrastructure.

Our method involves crash notification by the South Australian Ambulance Service and detailed investigation of the crash scene usually before the crash-involved vehicles have been moved. This at-scene data collection is supplemented with police crash reports, Coroner's reports including autopsy findings for fatal crashes, case notes from hospitals for all injured persons, structured interviews with crash participants and witnesses, and computerised reconstruction of the events of the crash.

One of the most notable research findings to emerge from our in-depth work has been the relationship between travelling speed and the risk of crash involvement. By comparing the calculated free speeds of crash-involved vehicles (cases) with the measured speeds of non-crash-involved vehicles travelling on the same roads at the same time of day (controls), we were able to establish that an exponential relationship exists between travelling speed and the likelihood of involvement in a casualty crash. This was the case for both metropolitan and rural areas. This research prompted the reduction of some speed limits in Australia, which has resulted in notable decreases in crash numbers.

Another finding of interest in our recent investigation of 298 mostly daytime crashes in metropolitan Adelaide was that medical conditions make a sizeable contribution to the occurrence of road crashes. We found that almost half of the drivers, riders and pedestrians involved in the collisions had at least one pre-existing medical condition, and half of these individuals had two or more such conditions. We found that a medical condition was the direct causal factor in 13% of the casualty crashes investigated and accounted for 23% of all hospital admission or fatal crash outcomes. A follow-up study of all hospital admissions for road crashes in Adelaide is now going ahead to look further at this problem.

The paper also describes studies looking specifically at pedestrian crashes. These include studies of the relationship between travelling speed and the risk of a fatal pedestrian crash, and studies utilising real crash data to validate headforms and test dummies used in the assessment of the safety of new vehicles in the event of a collision with a pedestrian.

INTRODUCTION

In-depth crash investigation at the University of Adelaide in South Australia began with the work of Robertson, McLean and Ryan of the Department of Pathology, sponsored by the Human Factors Committee of the Australian Road Research Board. This study ran from 1963 to 1965 and collected a representative sample of crashes to which an ambulance was called between the hours of 10am and 11pm. This study was the first in the world to report that pedestrians are run under and not over, and, therefore that the design of the front of vehicles is a major determinant of the injuries suffered by pedestrians.

In 1973, the Road Accident Research Unit was formed at the University of Adelaide and a second in-depth study was conducted, with data collection running for 12 months from March 1976. This study involved a representative sample, by time of day and day of week, of crashes to which an ambulance was called. Crash investigators were on-call seven days a week. There were two teams of investigators, each including a medical doctor, an engineer and a psychologist. More than 3,000 items of information were collected in a two car crash with two occupants in each car. The detailed analysis of these crashes filled seven volumes and was recognised as a benchmark by the World Health Organisation.

In-depth crash investigation has continued since that time, usually alternating between investigation of crashes in metropolitan Adelaide and investigation of crashes in rural areas. Currently, the Centre for Automotive Safety Research (formerly the Road Accident Research Unit) at the University of Adelaide is investigating crashes in rural areas, with a boundary of 100 km from the centre of Adelaide.

The following section describes the general method we use for in-depth crash investigation. This is followed by a description of some of the specific studies we have undertaken based on in-depth crash data.

METHOD

The Centre for Automotive Safety Research employs a specially-trained team of crash investigators that includes two engineers (one mechanical and one automotive engineer), a psychologist and a health professional. Teams of two investigate the crashes and the information collected is presented to a review panel consisting of all the crash investigators and the project management team, which consists of a psychologist and a civil engineer.

A crash is eligible for inclusion if it involves the transportation by ambulance of at least one crash participant to a hospital or if it involves a fatality. In the case of metropolitan crash studies, the crash has to have occurred within the Adelaide metropolitan area (nominally within 10 km of CASR's offices in the City centre), while for non-urban studies, the crash must occur outside of the metropolitan area but within 100 km of CASR's offices. The outer boundary is defined as such so that investigators are able to attend the scene within an hour or so of the time of the crash.

Crash investigators are alerted to the occurrence of a crash by an automatic pager system provided by the South Australian Ambulance Service. They immediately drive to the scene of the crash so that as much information and data can be collected prior to the loss of physical evidence.

The sequence of events for crash investigation is as follows:

- Notification of the crash on the SA Ambulance Service radio or pager
- Attend the crash at-scene
- Photograph the scene and involved vehicles
- Discussions with police attending the crash
- Mark the positions of the vehicles and any skid or gouge marks
- Brief introduction and discussion with participants and witnesses at-scene (where appropriate)
- Record an engineering survey of the site
- Examine the vehicle(s) at the scene and/or elsewhere
- Record video footage of the approach to the crash site from a driver's perspective

Follow-up investigations include:

- Obtain the police report on the crash
- Obtain injury information from hospitals
- Conduct a detailed interview with consenting crash participants and witnesses
- Review site design and crash history of the site
- Review crash history of the drivers
- Review Coroner's file where appropriate (fatal crashes)
- Computer aided crash reconstruction where relevant and practicable
- Perform a multidisciplinary case review

The engineering survey that is made of the site involves recording the road geometry, land marking and any traffic control measures, together with the location of any roadside objects. Engineering drawings of the road section are also obtained from the road authority. Sites may also be revisited for more detailed follow-up survey work or reassessment from a road engineering perspective.

Follow up inspections are made of the involved vehicles as needed to gather any missing information or reconfirm crash injury mechanisms. The information collected for each vehicle includes:

- Photographic record of the vehicle, including detailed photos of any visible damage and evidence of occupant (or pedestrian) contact
- Recording of VIN (Vehicle Identification Number) and current registration details
- Inspection of tyres: dimensions, tread and pressure
- Inspection of seatbelts for condition and load marks
- Measurement of vehicle deformation
- Inspection for any vehicle modifications or defects

Follow up personal interviews are conducted whenever possible with those involved in the crash and any witnesses. The information sought during these interviews includes:

- Personal details (age, sex and, for pedestrians, height and weight)
- Driving experience, traffic violation and crash history
- Familiarity with the road and the vehicle driven in the crash

- Trip details
- Possible distractions
- Alcohol and drug use, if any, prior to the crash
- Emotional and fatigue factors
- Pre-existing medical and physical disabilities
- Perception of the crash and its contributing factors
- Current state of injuries and resulting disabilities
- Clarification of vehicle/pedestrian movements, positions and the crash sequence

Our investigators are authorised to obtain data on injuries from hospital records, as noted above. Police accident reports are obtained to provide information about the crash as reported to, and interpreted by, the police. Where appropriate, Coroners files are also examined to check consistency of findings or shed further light on the case with previously unobtainable evidence. These contain full reports from the Police Major Crash Investigation Unit, autopsy and toxicology reports, together with information on any medical issues that may have been affecting the deceased individual. (All road crash fatalities are autopsied in South Australia.)

When all the evidence has been collected, a review is conducted of each case by a multidisciplinary group of CASR staff, and factors which contributed to the causation of the crash and the resulting injuries are established.

SPECIFIC STUDIES

The following provides a brief account of some of the studies conducted by CASR staff based on in-depth crash investigation data. These include studies relating travelling speed to the risk of crash involvement, studies into pedestrian injuries, and studies examining the role of medical conditions in contributing to road crashes.

Travelling speed and the risk of crash involvement

Method

The aim of this study [1] was to quantify the relationship between free travelling speed and the risk of involvement in a casualty crash for sober drivers of cars in 60 km/h speed limit zones in the Adelaide metropolitan area. “Free travelling speed” refers to the speed of a vehicle not constrained by other traffic and not accelerating or braking to enter or leave a road. Using a case-control study design, the speeds of cars involved in casualty crashes (cases) were compared with the speeds of cars not involved in casualty crashes but travelling in the same direction, at the same location, time of day, day of week, and time of year (controls). The pre-crash travelling speeds of the case vehicles were determined using computer-aided crash reconstruction (M-SMAC), with input consisting of tyre marks, impact points, final positions of vehicles, damage to vehicles, and participant and witness statements. The speeds of the control vehicles were measured with a laser speed device [1].

Results

It was found that 68 percent of casualty crash involved vehicles were exceeding the 60 km/h speed limit compared to 42 percent of control vehicles. The difference between cases and controls was greater at higher speeds, with 14 percent of case vehicles exceeding 80 km/h compared to less than one percent of controls [1].

None of the travelling speeds below 60 km/h was shown to be associated with a risk of involvement in a casualty crash that was statistically significantly different from the risk at 60 km/h. Above 60 km/h there is an exponential increase in the risk of involvement in a casualty crash with increasing travelling speed such that the risk approximately doubles with each 5 km/h increase in speed. Thus, the risk of involvement in a casualty crash is twice as great at 65 km/h as it is at 60 km/h, and four times as great at 70 km/h. Although the risk of involvement in a casualty crash increases rapidly with increasing speed, the overall contribution of speeding to crash causation is still considerable at speeds below 75 km//h because the majority of speeding drivers are travelling in the speed range from 61 to 74 km/h. A graph showing the relative risk of involvement in a casualty crash by travelling speed is provided in Figure 1 [1].

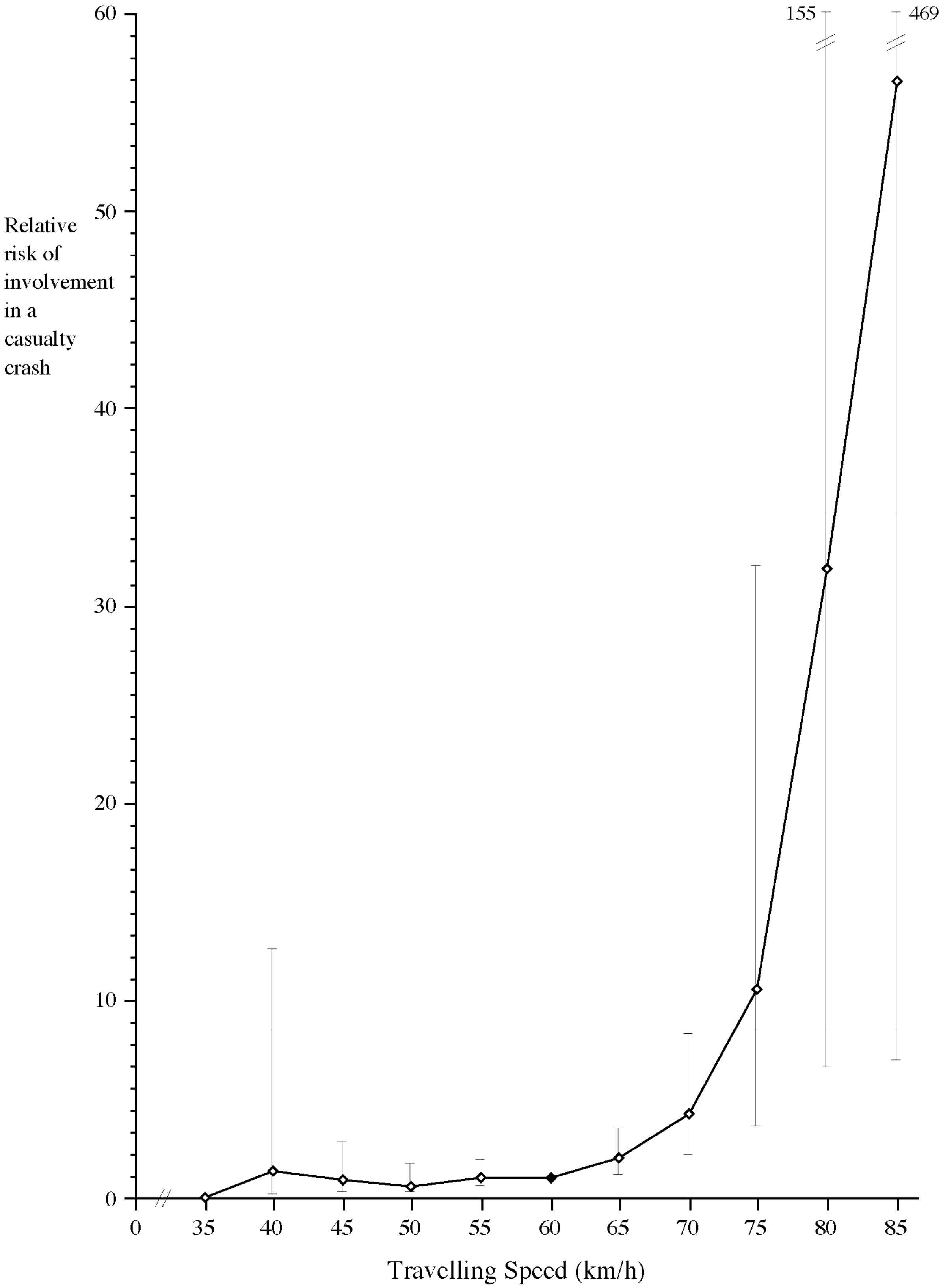

Figure 1. The relative* risk of a casualty crash according to travelling speed

*Relative to the risk at the 60 km/h speed limit

By working back from the risk estimates we concluded that nearly half (46 per cent) of these free travelling speed casualty crashes probably would have been avoided, or reduced to non-casualty crashes, if none of the case vehicles had been travelling above the speed limit. A more conservative estimate, based on calculation of stopping distances and impact speeds, indicates that 29 per cent of crashes would have been avoided altogether, with an average reduction of 22 percent in the impact energy of the remaining cases [1].

Using the second, more conservative, method we also estimate that a 10 km/h reduction in the travelling speeds of the crash involved cars in this study would probably have resulted in a reduction of at least 42 per cent in the number of crashes. A 5 km/h reduction showed much less effect but would still have resulted in a reduction of at least 15 per cent in the number of crashes [1].

These findings were a key factor in the decision to reduce the default urban speed limit from 60 to 50 km/h. In South Australia, the change in the speed limit occurred in March, 2003. In the following year, on local and collector roads for which the speed limit changed, there were decreases in the average vehicle speed, the average free travelling speed, the number of casualty crashes, the number of casualties, and the number of fatalities. Additionally, on arterial roads for which the speed limit remained at 60 km/h, there were also reductions in the same set of variables. Although the percentage changes were smaller on the arterial roads than on the local roads, the total effects were similar because of the higher frequency of crashes on arterial roads [2]. Similar findings have been found in studies of the speed limit reduction in other jurisdictions in Australia [3-6].

A more recent study was conducted in which the methodology for the urban speed study was repeated in rural areas in South Australia [7]. In this study, because of the speed limits ranging from 70 to 110 km/h at the different crash sites, the relative risk of crash involvement by travelling speed was calculated using deviation from the average speed of control vehicles at each site. This ensured that the data were appropriately normalised for the analysis. It was found, again, that higher travelling speeds are associated with an exponential increase in the risk of crashing, and that there is no evidence of an increased risk for slow moving vehicles. Specifically, it was found that the risk of involvement in a casualty crash is more than twice as great when travelling 10 km/h above the average speed of non-crash involved vehicles and nearly six times as great when travelling 20 km/h above the average speed [7]. This study was also followed by reductions in speed limits, in this case on South Australian rural roads.

Pedestrian injury

The relationship between travelling speed and crash involvement has also been analysed with respect to urban pedestrian collisions [8]. This study analysed 118 fatal pedestrian crashes in which the striking vehicle was travelling at a free speed and there was sufficient information available to obtain a measure of that speed. The information required was comprised of physical evidence from the vehicle and the crash scene, and witness and driver statements. Combining the calculated travelling speeds and calculated impact speeds with previously established relationships between impact speeds and the likelihood of a fatality, Anderson et al. were able to determine the likely reductions in fatal crashes associated with various scenarios of reductions in travelling speed. It was found that if all vehicles had been travelling 5 km/h slower, there would have been a 32 percent reduction in fatalities, including 10 percent of crashes avoided altogether (i.e. the vehicle would have stopped prior to striking the pedestrian). If all vehicles had been travelling 10 km/h slower, there would have been a 48 percent reduction in fatalities, with 22 percent of crashes avoided altogether. If the speed limit had been 50 km/h instead of 60 km/h, and assuming a similar level of compliance with the speed limit, there would have been a 30 percent reduction in crashes, with 14 percent of crashes not occurring. The finding that a large proportion of the reductions in fatalities was associated with elimination of the crash altogether also suggests likely savings in serious injuries with reductions in travelling speed [8].

In-depth investigation of pedestrian crashes has also been used to validate the pedestrian subsystem testing methods used in vehicle design safety assessments. For example, one study involved the simulation of three fatal pedestrian crashes using MADYMO and the Polar-II dummy developed by Honda R&D in conjunction with GESAC [9]. The head kinematics of the computer simulation and the Polar-II test were compared with the vehicle-pedestrian contacts known to have occurred in the actual cases. The cases selected for the study involved pedestrians whose height and weight were close to the 50th percentile adult male. The investigation of the cases had provided good estimates of impact speed and complete injury data, which was obtained from attendance at autopsies, and all contact points between the pedestrian and the vehicle had been recorded. MADYMO simulations were made to determine the kinematics of the pedestrian during the collision, and a full-scale Polar-II dummy and the same make and model of the vehicle in each case were then used to reconstruct the crash. The results showed good agreement between some aspects of the different measures of head kinematics but also some discrepancies. The Polar-II head impacts tended to be closer to vertical and the impact location more forward on the car than those found with the MADYMO simulations and the actual cases. Leg kinematics were noticeably different, with the Polar-II legs remaining engaged with the front of the vehicle for a longer period of the collision. In contrast to the simulations, the Polar-II legs were in some instances still engaged as the head stuck the vehicle. The behaviour of the model and/or the Polar-II will be the focus of further validation and refinement [9].

Another example of such a study involved validation of the headform impactors designated by the European Enhanced Vehicle-safety Committee (EEVC) Working Group 10 for assessing pedestrian head protection [10]. This study compared data collected from real crashes with the outcomes of computer simulations and laboratory reconstructions of the crashes using the headforms specified by the EEVC. It was found that the EEVC headform results correlated well with the severity of head injuries, as measured by the AIS, in the real crashes. Specifically, head impacts exceeding a HIC value of 1,000 were positively associated with head injuries of AIS3 and above [10].

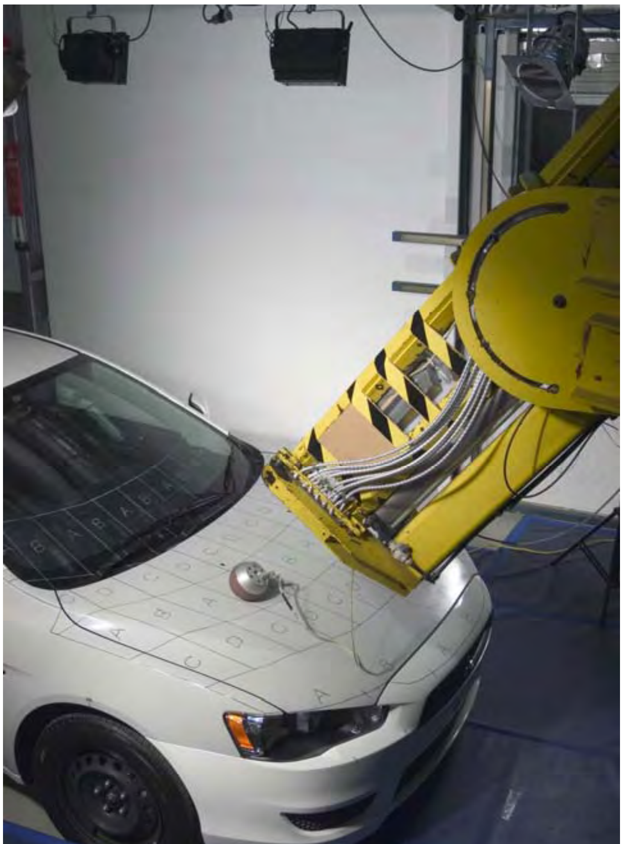

Figure 2. Headform laucher at the Streeter Impact Laboratory, CASR.

Medical conditions

A sample of 301 metropolitan crashes was analysed for the contribution of medical conditions to crash causation [11]. These 301 crashes involved a total of 607 active participants (493 drivers, 83 pedestrians, 20 motorcyclists, and 11 pedal cyclists). Of these, 325 required either medical treatment at a hospital or admission to a hospital, or were fatally injured. The medical records of these crash participants were analysed for the following:

- Documentation related to existing medical conditions
- Medication use at the time of the crash
- Results of blood screening for alcohol and other drugs
- Medical documentation that gave support to or refuted medical conditions as a contributing factor in crash causation
- Injuries incurred as a result of the crash
- Length of hospitalisation as a result of injuries
- Long term health outcomes as a result of involvement in the crash.

It was found that there were 138 crashes in which at least one active participant was identified as having a pre-existing medical condition. Half of these cases had two or more medical conditions, while nine participants had four or more. The most common pre-existing medical conditions were hypertension (36 cases), depression (24) and Non-Insulin-Dependent Diabetes (21). In 39 of the 301 crashes (13%), there was medically documented evidence to support a pre-existing medical condition as a direct causal factor in the crash. Fourteen of these 39 were pedestrians, with the remainder being drivers of cars. Seven cases involved cardiac events, seven involved crash participants with psychiatric conditions making deliberate suicide attempts, six involved non-suicidal mental health related events such as psychotic episodes, and five involved epileptic events. The most common outcome of the medical events for drivers was loss of control of the vehicle, either running off the road or crossing the centre line and into the path of oncoming traffic. In 11 of these cases, there were licensing decisions taken on the basis of the crash. These included five licence suspensions pending investigation, three suspensions for an undefined time, one driving assessment advised, one two-year suspension, and one single-year suspension. There were also a number of crashes in which the involvement of medical conditions was highly probable. These crashes were not explicitly identified by treating medical practitioners as being due to medical conditions of the crash participants but were judged to be probably due to these conditions by our investigators [11].

The study demonstrates a significant role played by medical conditions in crash involvement. It is also important to note that 57 percent of the drivers in the crashes were uninjured and did not undergo medical scrutiny. Therefore, the extent of medical conditions contributing to crashes is likely to be greatly under-estimated by the study. Additionally, the figures here exclude cases in which the contributing factors were related to alcohol, medication or illicit drug use. A limitation of the study is that 95 percent of the crashes investigated occurred between 0800 and 2000 hours, and so the sample is not truly representative of all metropolitan crashes [11].

In response to the findings of the study, and in order to address this limitation, a follow-up study is being conducted by CASR in which the role of medical conditions is being examined in all crashes involving admission of a crash participant to the major metropolitan emergency hospital. All drivers and motorcycle riders who are treated at, or admitted to, a major metropolitan hospital in Adelaide over a 24 month period will be included in the study. The study will involve analysis of the following:

- Driver/rider hospital medical records
- Police reports on the actual crash
- Driver/rider crash histories, as recorded in the Traffic Accident Reporting System maintained by the South Australian Department for Transport, Energy and Infrastructure
- Driver/rider licensing records maintained by the Registrar of Motor Vehicles

Drivers or riders who are judged to have had a medical condition that may have contributed to the occurrence of the crash will be contacted for an in-depth interview.

TEACHING

In addition to our on-going research, we have been able to train researchers from other countries. In 2005, we described the benefits arising from in-depth crash investigation at a seminar we convened in Bangkok in collaboration with Khon Kaen University, and sponsored by Takata Corporation. This led to the Thai Government Office of Transport Planning (OTP) decision to fund crash investigation teams at five universities in Thailand and a request for CASR to conduct a one week training course in Adelaide in March 2006. This course was attended by 18 engineers from these universities and Thai government agencies.

The Director General of the newly formed Malaysian Institute for Road Safety Research (MIROS) recently requested that CASR train two engineers in at-scene crash investigation. The two engineers trained with CASR for a period of two months in late 2007/early 2008, and have returned to MIROS to co-ordinate crash investigation activities there.

CONCLUSIONS

The Centre for Automotive Safety Research at the University of Adelaide has a proud history of in-depth at-scene road crash investigation, and continues to undertake this activity to add to road safety knowledge. Studies have been conducted into many aspects of road crashes using the data we have collected using in-depth crash investigation and this paper has outlined just a few of these. We have also been active in training researchers from South East Asia to assist in the use of in-depth crash investigation to identify the key road safety problems that need to be addressed in those countries.

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Recommendations for establishing Pan European Transparent and Independent Road Accident Investigations

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Abstract

A set of recommendations for pan-European transparent and independent road accident investigations has been developed by the SafetyNet project. The aim of these recommendations is to pave the way for future EU scale accident investigation activities by setting out the necessary steps for establishing safety oriented road accident investigations in Member States. This can be seen as the start of the process for establishing road accident investigations throughout Europe which operate according to a common methodology.

The recommendations propose a European Safety Oriented Road Accident Investigation Programme which sets out the procedures that need to be put in place to investigate a sample of every day road accidents. They address four sets of issues; institutional addressing the characteristics of the programme; operational describing the conditions under which data is collected; data storage and protection; and reports, countermeasures and the dissemination of data.

INTRODUCTION

The prevention of road accidents and casualties has been the focus of both National and European policy makers for several years. The European Commission has identified a need for independent road traffic accident investigations that are focused on the causes of accidents rather than apportioning blame. These investigations should generate data that can be used to identify areas of priority and develop accident countermeasures. The data that is generated by in-depth safety oriented investigations should be more detailed than that which is produced for national statistics. Investigations should be conducted on a national level following a European methodology.

SafetyNet is a large European Commission supported 6th Framework project which commenced in 2004 and is due to be completed in October 2008. Its aim is to build a framework for the European Road Safety Observatory as well as to collect new data and to develop new data collection methodologies. The project's consortium is made up of 22 partner organisations from 17 countries. SafetyNet comprises of seven work packages that cover three areas of work namely, 'Macroscopic Data', 'In-depth Data' and 'Data Application'. As part of its work in the area of 'In-depth Data' SafetyNet has developed a set of recommendations for independent and transparent safety oriented road accident investigation.

The aim of these recommendations is to set out the requirements for establishing a European Safety Oriented Road Accident Investigation Programme. The recommendations specifically address the safety oriented investigation of a statistical sample of accidents, which aims ultimately to feed evidence based policy making. This can be seen as the start of the process for establishing safety oriented road accident investigations in all Member States which operate according to a common methodology. Setting out the exact characteristics of this common methodology, in terms of the specific data to be collected however, was beyond the scope of the SafetyNet project.

As the recommendations represent the culmination of four years of work this paper will firstly explain the issues and considerations that were important in their development before briefly discussing how the recommendations were devised and finally describing the recommendations in their current form.

ROAD SAFETY IN EUROPE

In 2001, the European Commission published its white paper, *European Transport Policy for 2010: A time to decide*, detailing policy objectives for the transport sector as a whole. In response to concerns raised about the number of road fatalities in EU Member States the Commission set the ambitious target to reduce the 40,000 road deaths in 2000 (EU15) to half that number by 2010 [1]. Reducing the number of road accident fatalities to 20,000 would also mean substantial overall enhancement of road safety across Europe.

The white paper stated that a road safety action programme was to be published that would detail the measures needed to meet its road death reduction target. This action programme, *Saving 20,000 lives on our roads – a shared responsibility* was published by the European Commission in 2003. It asserted that

> *The collection and analysis of data on accidents and physical injuries is essential to be able to make an objective evaluation of road safety problems, to identify the priority fields of action and to monitor the effects of the measures.* [2]

Currently, across Europe, various types of investigations are conducted on road accidents by the police, insurance companies, researchers and other accident investigators. This produces a range of data including macroscopic data giving a general overview of the accidents that is included in Member States' national statistics, and highly detailed data on the roadway, vehicles and/or injuries that results from in-depth investigations.

Road accident investigation practices have been examined by the Road Strategy for Accidents in Transport working group (ROSAT). ROSAT was part of a group of 12 experts set up by the European Commission in 2004 to assist in defining strategy for transport accident investigations. The ROSAT report and recommendations for road accident investigation was published in 2006 [3]. The ROSAT group identified four levels of accident investigation; the collection of statistical data for national and European databases; collection of intermediate level data by the police and insurance companies for reports and black spot analysis; in-depth investigations by multidisciplinary teams collecting large numbers of variables to identify safety countermeasures; and special investigations into a small number of out of the ordinary accidents with the aim of preventing future occurrence.

The ROSAT group concluded that all these levels of investigation are important in making up a national investigation system, but that in-depth multidisciplinary investigations are required in addition to the collection of statistical data and intermediate level data in order to fully learn from road accidents. The collection of statistical data and data by the police and insurance companies is widespread across Europe, however in-depth investigations by multidisciplinary teams is less so. Therefore the focus of the SafetyNet recommendations is on in-depth 'safety oriented' road accident investigations, which aim primarily to develop road accident countermeasures.

THE DEVELOPMENT OF RECOMMENDATIONS

As previously stated, SafetyNet was tasked with developing a set of recommendations for transparent and independent road accident investigation. The starting point was examining the characteristics which made air, rail and maritime accident investigation boards 'independent' and comparing them with existing road accident investigation activities. This process allowed 'independence' in terms of accident investigation, to be defined. The concept of independence as defined by SafetyNet relates to the organisation responsible for investigating and the investigators themselves [4]. An investigative organisation must be independent in terms of its structure, finances and functioning. Structural independence is gained when an investigation body is separate from regulatory bodies, including the judiciary, and ideally when the body and its investigators are granted a legal status.

Financial independence is secured when the body has a stable budget and autonomy over its use. The third aspect, functional independence, occurs when legislation governs the categories of accidents to be investigated but the body has the autonomy over the decision to investigate and the focus and scope of the investigation. The body should also have the legal right to fully access all evidence and witnesses and be able to publish reports without further scrutiny.

There are however some important differences between road accident investigation and that of the other modes [5]. The rail, air and maritime transport modes are dominated by public service and commercial vehicles whereas the road network is used much more frequently for and by private transport. Subsequently, the responsibilities for safety lie with a more diverse range of individuals. There are also much larger numbers of road traffic accidents than there are in the other transport modes, as illustrated by Table 2.

Table 1 Fatalities in 2004 for the Road, Rail and Air transport modes [6]

	EU15 (population: 387,600,000)	EU25 (population : 461,700,000)
Road	32.637	43.472
Rail	75	105
Air	[a]	6 (135 in 2005)

Population information source: http://europa.eu/abc/european_countries/eu_members/index_en.htm
[a] Figure not available
Figures for the Maritime transport mode are not available for EU25/15

These differences lead to a difference in perception with regards to the need for independent accident investigations. In most countries, the rail, air and maritime transport modes have independent bodies responsible for the investigation of accidents, however very few countries have an independent body responsible for road accident investigation. This does not mean that the investigation of road accidents has been viewed as unimportant. There are a great many different organisations in existence that conduct road accident investigations. Many of these however, would not be regarded as independent in the same way that the rail, air and maritime boards are independent.

By exploring the differences between the road and other transport modes which are likely to explain the differences in the perceived need for independence in investigation activities, SafetyNet highlighted the fact that the quality of road accident investigation data is a more important issue than the status of the investigating entity [5]. Good quality data is essential in producing effective countermeasures and therefore reducing the number of casualties. It is the transparency of the investigation process and of the subsequent data that allows a quality assessment to be made.

SafetyNet has devised the following definition of transparency. Transparency applies to the investigation activities and results. It can be defined as the full, accurate, and timely disclosure of information. For accident investigations this means making available information on what the organisation does and how it does it as well as on the results of the investigations. This includes the conditions under which investigations are carried out and the ways in which data is managed.

Based on the early work of SafetyNet a set of Draft Recommendations was developed [7]. This early work included a review of the practices and procedures for the investigation of road accidents employed by commercial companies, police forces and existing independent accident boards; and the gathering of opinion from safety stakeholders.

A larger stakeholder consultation was then undertaken in order to assess whether the Draft Recommendations were appropriate and necessary. This aimed to gather expert opinion from both national and European road safety stakeholders. The main consultation activity was a workshop where stakeholders representing a variety of professional backgrounds heard presentations on the Draft Recommendations and were invited to give their opinions by participating in discussion sessions and filling in a questionnaire [8]. The feedback provided by these experts allowed the recommendations to be refined and developed.

RECOMMENDATIONS FOR TRANSPARENT AND INDENPENDENT ROAD ACCIDENT INVESTIGATIONS

The key recommendation of SafetyNet is that a European Safety Oriented Road Accident Investigation Programme (European Programme) should be established to fulfil the need for data to feed evidence based policy making. Safety oriented road accident investigations should be carried out in each Member State according to the methodology set out by the European Programme. Such a programme would set out the key objectives and harmonised methodologies needed to collect data that can be generalised to accidents in Europe. A European level database should be developed to compile the data collected within Member States. The European Programme should set out the variables and values to be collected and entered into the database. The process of accident investigation cannot be viewed as linear. In developing a European Programme consideration should be made of how the data is going to be used to develop safety countermeasures. This should inform the development of a common methodology and database.

Safety oriented road accident investigation can be defined as the acquisition of all relevant information to enable the identification of one or several of the following:

- the cause or causes of the accident
- injuries, injury mechanisms and injury outcomes
- how the accident and injuries could have been prevented

Such an investigation is conducted by one or several investigators with specialised knowledge in accident investigation and other fields of knowledge, relevant for the purposes of the investigation. It aims to prevent future accidents and injuries through the development of countermeasures and does not contribute to any judicial enquiry or take a stand on responsibilities.

The investigation therefore needs to adopt a holistic view of accident analysis. In order to get a holistic picture of an accident the investigation adopts a broader perspective than investigations aimed to gather data for the judiciary system. The SafetyNet recommendations therefore address the issues that seem fundamental for guaranteeing that such a holistic view can be obtained. They aim to set out the conditions under which safety oriented transparent and independent road accident investigations can be efficiently conducted.

The establishment of a European Programme will necessitate each Member State to set up safety oriented road accident investigations in their country. As part of the SafetyNet project the Department of 'Idraulica Transporti Strade' (DITS), University of Rome, worked with the local authorities to establish a safety oriented investigation programme in Italy. The short term goal was to contribute to the SafetyNet accident causation database (In-depth Data area), but with the long term aim of continuing the investigations beyond the end of the project. The experience gained in Italy in setting up the investigation programme and the evaluation by DITS of this programme, will be used to illustrate the importance of the recommendations discussed here [9].

The recommendations are divided in four categories and will be described in turn in the following sections:
Institutional
Operational
Data storage and protection
Reports, countermeasures and dissemination

Institutional recommendations

The institutional recommendations primarily address the characteristics of the European Programme and its implementation at the national level, including the status of the investigators and sampling plan.

Investigations should be conducted independently from those with differing purposes (insurance, judicial). It is important to cooperate with safety stakeholders but control should remain with safety oriented investigators to prevent the biasing of results. The European Programme should aim to be transparent so that the general public will trust the resulting safety conclusions and recommendations.

It is unrealistic to suggest that all accidents should be investigated; therefore the European Programme should set out the sampling criteria that each Member State should follow. It is unlikely that all Member States will have the resources to set up teams that operate throughout the whole country. In those cases an operational area should be identified. When choosing the area, consideration should be given to the relationship between the accidents that could potentially be investigated and the national picture. This is because it is necessary to generalise data collected in Member States in order to devise accident countermeasures on a European scale.

There were a number of barriers to be overcome before safety oriented investigations could be established in Italy. Permission from the local authorities had to be gained before investigations could commence and there were organisational problems such as funding and a lack of investigators experienced in road accident investigation. There was also a cultural issue of whether those involved in accidents would be open with investigators or more ‘creative’ in their comments.

As suggested in the recommendations detailed above, the organisational barriers were overcome by focusing on one region of Italy. The support of the local government authorities in the Marche region of Italy was gained, allowing 13 investigation teams to be established using people with experience of investigating work related accidents.

Good quality data can only be gained through good quality investigations. This requires road accident investigators to have undertaken training to ensure that they gain both specialist knowledge of conducting safety oriented road accident investigations and adequate experience. There is currently no officially recognised standard for safety oriented road accident investigation. It is important that the good practice and expertise of existing investigation organisations is shared between countries to enable countries who do not currently conduct in-depth safety oriented road accident investigations to gain the experience and expertise to do so.

The Italian investigation teams undertook training in road accident investigation. 62% of the investigators found the task of investigating road accidents ‘difficult’ or ‘very difficult’, however 94% of investigators considered the quality of their training ‘high’ or ‘very high’. DITS identified several areas where additional training could make investigating easier, for example in identifying in-car safety systems and how to approach people at accident scenes.

Operational recommendations

The operational recommendations relate to the actual investigation process. All accident investigations begin with notification that an accident has occurred. Currently many road accident investigation activities in Europe have local arrangements with the emergency services that are not protected by legislation. The procedures for notification differ according to the methodologies used, but whichever methods are adopted by the European Programme, timely notification is important so that the investigation team can quickly identify accidents that meet their sampling criteria.

To gain a holistic picture of an accident, data should be collected about each of the three components of an accident, 'human', 'vehicle' and 'environment'. There are many different data collection methodologies current employed in Europe and as yet there is little consensus about which are the best methods. However it is possible to identify best practice ways of collecting data which correspond to the three components of an accident:

- visit the accident scene as soon as is reasonably practical (either while vehicles are in their post crash rest position or within a few days of the accident);
- examine the vehicle, either at the scene or in a recovery garage;
- speak to the involved road users and witnesses and to collect injury data from trained medical personal (e.g. hospital data).

It is also important for investigators to have access to the most appropriate equipment to enable them to investigate accidents in the most efficient manner. For example teams which aim to attend the accident scene should have access to a rapid response vehicle.

In Italy, safety oriented investigations were initiated at the scene of the accident, with teams using a rapid response vehicle to reach the scene within 30 minutes of the accident's occurrence. Examination of the scene was usually completed within an hour of the accident taking place and information was gathered from involved road users either at the scene or the hospital or at their home.

The cooperation of involved road users was thought to be generally quite high (75%) and investigators believed people to be most sincere when interviewed at the accident scene. This was thought to be related to the time elapse between accident occurrence and the interview as interviews at hospital or in the home occurred later than interviews at the scene. The cooperation of the police was less high with 50% of investigators reporting police cooperation to be 'very low'. Other emergency services were more willing to cooperate. Around 55% of investigators felt that the other emergency services' cooperation was 'quite high' or 'very high'.

A good quality accident investigation is only possible if the investigators can gain access to the accident scene and all evidence. Ideally the investigators should be granted a legal status which gives them the right to access the information they need. However it is acknowledged that this could be a difficult and lengthy process in some Member States. The problem of access to evidence has been solved within existing safety oriented investigation activities by establishing local agreements between the investigators and the relevant bodies. It is important that the investigation teams establish good relationships with the emergency services – especially the police, again as illustrated in the Italian example.

A further requirement of a safety oriented investigation is that information collected is protected from use within a court of law. Investigators should not be called upon to be witnesses for safety oriented investigations that they have conducted. This applies particularly to information gathered from and about road users and witnesses to the accident. People are less likely to be willing to talk to investigators if they feel that the information which they provide could be used against them.

The safety oriented investigations would not have been possible in Italy without the support of and formal agreement with the police. DITS believe that there is a strong need for a legal status as detailed in the SafetyNet recommendations. They believe that if this was granted to the investigators then cooperation with the police would be greater. In addition, if investigators were protected from the need to give evidence in court then a greater cooperation of involved road users is likely and they would be less likely to be 'creative'.

An important part of establishing the European Programme is the development of a manual which details the investigation procedures and the data to be collected. This is necessary in order to harmonise investigations across Europe – if many countries are contributing to the same database then it is important hat they all collect the same data in a similar way. The European manual should also be publically available to increase the transparency of investigations.

Data storage and protection recommendations

That a common European database should be established is the first in the data recommendations. The other recommendations deal with legal aspects of data security and protection. The European database should only contain anonymous data. Information such as names and vehicle registration numbers should not be stored as this would allow the identification of those involved in the accident.

The exact characteristics of a European database and the variables to be included are beyond the scope of the SafetyNet recommendations. However there are examples of European projects where a number of different countries have contributed to a shared database such as PENDANT (www.vsi.tugraz.at/pendant/), and the SafetyNet accident causation and fatal accident databases (www.erso.eu/safetynet/content/safetynet.htm).

Reports, dissemination and the development of countermeasures recommendations

One of the criticisms of in-depth accident investigation is that it is not always clear what to do with the data once it has been collected. As a European Programme has not yet been established, how data is used cannot be addressed in detail. Nevertheless SafetyNet have made some key recommendations. The data collected in a European database should be analysed in such a way that allows the identification of areas for safety improvement. This will allow recommendations for countermeasures to be made. These recommendations could then be considered by the European Commission. The activities of Member States and the conclusions of data analysis should be reported and such reports should be made public.

In conclusion, the recommendations discussed here can be considered 'finalised' only in the sense that they represent one of the conclusions of the SafetyNet project. These recommendations should be viewed as the starting point for the establishment of a European Safety Oriented Road Accident Investigation Programme and as working towards a common European accident investigation methodology. The full version of the recommendations are published in *SafetyNet deliverable D4.5 Recommendations for Transparent and Independent Road Accident Investigation* [10] which can be downloaded from the ERSO website (www.ERSO.eu).

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All of the above SafetyNet reports can be downloaded from:
http://www.erso.eu/safetynet/content/wp_4_independent_accident_investigation.htm

Crash Involvement Studies Using Routine Accident and Exposure Data: A Case for Case-Control Designs

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Abstract – Fortunately, accident involvement is a rare event: the chance of an individual road user trip to end up in a crash is close to zero. Thus, according to general epidemiological principles one can expect the case-control study design to be especially suitable for quantifying the relative risk (odds ratio) of accident involvement of road users with a certain risk factor as compared to road users that do not have this characteristic. Ideally, of course, the database for such a case-control study should be established by drawing two independent random samples of cases (accidental units) and controls (non-accidental units), respectively. If, however, special data collection is not an option, it is nevertheless possible to analyze routine accident and exposure data under a case-control design in order to fully exploit the information contained in already existing databases. As a prerequisite, accident and exposure data from different sources are to be combined in a single file of micro or grouped data in a way consistent with the case-control study design. Among other things, the proposed methodological approach offers the possibility to use in-depth data of the GIDAS type also in investigations of active vehicle safety by combining this data with appropriate vehicle trip data collected in mobility surveys.

NOTATION

Ψ population odds ratio
Λ population relative risk
ψ sample odds ratio
λ sample relative risk

INTRODUCTION

Basic idea

As is well known, the case-control study design is useful for risk factor assessment in situations where the disease in question is rare. Accident-involvement is such a rare event: the chance of a road user trip to end up in a crash is close to zero. Thus, one can expect the case-control design to be efficient for quantifying the relative risk (odds ratio) of traffic accident involvement of road users with a certain risk factor as compared to road users that do not have this characteristic. A case-control design is characterised by a dataset of accident-involved road users ("cases") and a second independent dataset of road users not involved in an accident ("controls") belonging to the same general population. Ideally, of course, the database for such a case-control study should be established by drawing two independent random samples of cases and controls, respectively.

Quite often, however, such special data collection is not an option and the researcher is restricted to the use of already existing data (secondary or routine data). In this situation it may nevertheless be possible to analyze routine accident and exposure data available from external sources under a case-control design in order to fully exploit the information contained in these databases. The most crucial prerequisite for such an approach is that accident and exposure data from different sources can be combined in a single file of micro or grouped data in a way consistent with the case-control study design. The methodology presented in this paper has been developed under the TRACE project [1].

Example

Accident data and vehicle registration data can be combined under a case-control study design in order to assess risk factors for accident involvement. Cases may, for instance, be accident-involved vehicles recorded in an in-depth study like GIDAS and controls could be vehicles randomly selected from the national vehicle register. If cases are vehicles involved in an accident during a specific study year, controls should be vehicles registered in the country under consideration during the same year (the sample of controls may, for instance, be drawn from the mid-year vehicle stock).

In the above context, “vehicle-years” would normally be considered as units at risk and, consequently, the case-control study could be conducted at the vehicle-year level. In this situation, the population at risk consists of all vehicle-years coinciding with the study period (e.g. calendar year 2007). Obviously, this population can be considered as being decomposed into the subpopulations of “accidental” and “non-accidental” vehicle-years, respectively. Thus, accident-involved vehicles recorded in the in-depth study (“cases”) may be interpreted as a sample from the subpopulation of all accidental units at risk. Similarly, vehicles drawn from the national vehicle register (“controls”) may be considered as sampled from the subpopulation of non-accidental units at risk.

Clearly, any risk factor to be assessed must be recorded both for cases and controls. Thus, in studies using routine traffic accident and vehicle registration data, the assessment of risk factors for accident involvement is restricted to vehicle and vehicle-holder characteristics which are contained in both data sources. This, of course, limits the scope of purely “secondary” studies. Sometimes, however, it might be possible to “enrich” the data files of cases and controls. If, for instance, an appropriate vehicle identification number is contained in both files, one can augment the list of variables with various technical characteristics of the vehicle.

If vehicles with and without the risk factor of interest differ substantially with respect to possible confounding variables like vehicle mileage, simple group comparisons under the case-control design might be biased. As mileage information is frequently not available, one could, however, adjust relative accident involvement risk for variables known to be strongly associated with vehicle mileage (e.g. engine power and vehicle age).

ASSESSMENT OF RISK FACTORS FOR ACCIDENT INVOLVEMENT

Preparation of the case-control database

Under the approach outlined above one may, for instance, assess the effect of a certain in-vehicle safety system like ESP on the risk of accident involvement. In order to obtain the desired case-control database, vehicles recorded routinely in an in-depth accident study or in national road traffic accident statistics are considered as a random sample from the subpopulation of all accident-involved vehicles. These accident-involved cars (more precisely, accidental vehicle-years) are considered as „cases“. Similarly, vehicles contained in the national vehicle register are considered as a random sample of cars that have not been involved in an accident during the specified time period (possibly screening to eliminate accident-involved cars). These cars are considered as „controls“. Both for cases and controls it is to be ascertained whether or not the corresponding car is equipped with the device to be assessed.

The routine accident and exposure data thus obtained may be displayed in a 2 × 2 contingency table showing the joint frequency distribution of accident involvement status (rows) and risk factor status (columns):

	equipped	not equipped
accident-involved	*a*	*b*
not involved	*c*	*d*

The above table contains sample data. The corresponding population values of the cell frequencies may be denoted by capital letters *A*, *B*, *C* and *D*.

Measuring comparative chance of accident involvement

Since the sampling fractions f and g for cases („accident-involved") and controls („not involved"), respectively, will normally be different, the expected values in the sample are given by the following products

[1] fA, fB, gC and gD .

In case-control studies where the sampling fractions f and g are not equal (in our context f will normally be considerably larger than g) only the odds ratio can be estimated, but not risk, relative risk or odds. The expected value of the sample odds ratio ψ = (a/c)/(b/d) equals the population odds ratio:

[2] $(fA/gC) / (fB/gD) = (A/C) / (B/D) = \Psi.$

Thus, the odds ratio is the appropriate measure of comparative chance of traffic accident involvement of equipped ("exposed") vehicles as compared to those not equipped ("not exposed").

As accident-involvement is a very rare event, the odds A/C are approximately equal to the empirical risk $R_1 = A/(A+C)$ and the odds B/D will differ only slightly from the empirical risk $R_0 = B/(B+D)$. Thus, the odds ratio Ψ is a good approximation to the relative accident-involvement risk

[3] $\Lambda = R_1 / R_0$

of cars equipped with the device as compared to cars without the safety system of interest.

Consequently, both the population odds ratio Ψ and the relative risk Λ may be estimated by the sample odds ratio

[4] $\psi = (a/c) / (b/d) = (ad)/(bc)$.

Clearly, the above measure ψ of comparative chance of accident-involvement can also be calculated for subgroups of vehicles. If in addition to point estimates of the population odds ratio also confidence intervals are to be calculated standard statistical theory can be applied [2].

Controlling for confounding variables

Accident-involvement is, of course, not only affected by the dichotomous risk factor „equipment with safety device of interest" (actually, equipment will be a protective factor rather than a risk factor). Cell frequencies in the above 2 × 2 table of accident involvement counts will, for instance, also depend on car mileage. If average annual mileage differs between cars with and without the safety device under consideration the above comparison is biased.

In order to account for structural differences between cases and controls one can use multiple logistic regression models to analyse the case-control sample data. In these models the accident involvement or case-control status of a sample unit (involved / not involved in accident during study period) is the binary outcome variable whereas risk factor status (equipped yes/no) and vehicle mileage (kilometres driven during study period) are explanatory variables. Such an approach requires mileage data to be ascertained for the sample vehicles. In principle, this could be accomplished by interviewing the holders and/or drivers of the cars in the study. If such a retrospective vehicle mileage survey cannot be conducted, one could alternatively use vehicle characteristics known to be correlated with mileage and car use (e.g. vehicle age, engine power, car make and model etc.) as additional explanatory variables in the logistic regression model.

PRACTICAL APPLICATION OF THE CASE-CONTROL APPROACH

Description of the routine accident and exposure data sets used

In order to illustrate the approach using real-world data, a case-control study has been carried out based on routine data from German road traffic accident statistics 2002 (for cases) and from the German mobility survey MiD 2002[1] (for controls), respectively. In this study the effect of the individual's age and gender on accident involvement risk of car drivers was investigated. According to the nature and content of the two independent routine databases, the case-control study was conducted at the trip level [1].

Cases are accident-involved car drivers selected from the records of German traffic accident statistics (year 2002, all accident-involved car drivers). The number of cases is 455886. It is easy to see that every accident-involved road user corresponds to an *accidental trip*. Thus, the cases are a 100 percent sample from the actual and finite population of accidental car driver trips in Germany 2002. Clearly, this population is a subpopulation of all car driver trips of the year 2002 which is to be considered as the population at risk.

Controls are car driver trips sampled under the above mentioned mobility survey MiD 2002, where representative trip data covering the year 2002 have been collected using the trip diary technique. Just as with all mobility surveys, the MiD survey has been conducted under a cluster sampling design (households as clusters of persons and trips). The number of car driver trips in the MiD survey amounts to 69443. For the purpose of this example we can assume that all these trips are non-accidental, i.e. controls. As the annual total number of car driver trips for Germany 2002 is estimated at 41561×10^6, the sampling fraction for controls is very small (1.67×10^{-6}); on average, information is available only for less than 2 trips out of 1 million car driver trips.

As usual, the method of data analysis depends on the scaling of the risk factor.

Assessing a dichotomous risk factor

In order to assess the effect of the dichotomous risk factor driver gender on accident involvement risk, the sample data are presented in the following 2 × 2 table:

Risk factor status Driver gender	**Accident involvement status** **cases** accidental trips	**controls** non-accidental trips
- male	293002	38688
- female	162885	30755
Total	455886	69443

From the sample data shown in this table one may estimate the population odds ratio Ψ for accident involvement (male as compared to female drivers) as follows:

[5] $$\psi = (293002 \times 30755) / (38688 \times 162885) = 1.430.$$

[1] MiD is an acronym for „Mobilität in Deutschland“ (=mobility in Germany).

The approximate standard error of the log of the sample odds ratio[2] is calculated to be

[6] $\sqrt{[1/293002 + 1/162885 + 1/30755 + 1/38688]} = 0.00824.$

Thus, approximate 95 percent confidence limits for the population odds ratio Ψ are

[7] $\exp\{\log_e 1.43 \pm 1.96 \times 0.00824\}$

that is, (1.407, 1.453).

Consequently, being a male car driver increases the chance of accident involvement by a factor of around 1.43 (male car drivers have 143% of the involvement risk of female car drivers). We are 95 percent sure that the interval from 1.407 to 1.453 contains the true odds ratio Ψ (which is a good approximation to the population relative risk Λ).

Under a case-control design the chi-square test (or where necessary Fisher's exact test) may be used without modification to test the null hypothesis of no association between risk factor status (gender) and case-control status (accident involvement yes/no).

As with any kind of study, the results obtained for a single risk factor may be compromised by confounding or interaction with other variables. In addition to the Mantel-Haenszel method logistic regression models and other more complex generalised linear models may be used to adjust for confounding or to deal with interaction.

An example is presented in a subsequent sub-section.

Assessing a polytomous risk factor

When the risk factor is a polytomous attribute, one level or category of the risk factor is chosen as a base level and all other levels are compared to this base. This comparison to the base is made level by level ignoring at a time all other levels. Consequently, level-specific odds ratios and confidence intervals can be calculated as previously described. We consider "driver age class" as an example:

Risk factor status Driver age	**Accident involvement status** **cases** accidental trips	**controls** non-accidental trips	**Odds Ratio**
- 18-24	111661	7245	2.292
- 25-44	201639	28661	1.000
- 45-59	86376	21575	0.569
- 60-64	21661	5465	0.563
- 65+	34549	6488	0.757
Total	455886	69443	

[2] The standard error as calculated here is based on the assumption of two independent simple random samples of cases and controls. Actually, however, controls have been selected under a cluster sampling design. For simplicity, the corresponding design effect (variance of the estimate obtained from the more complex sample to the variance of the estimate obtained from a simple random sample of the same number of units) is ignored here.

Drivers aged 25 to 44 years were chosen as the base group because they are the largest group in number, and thus most accurately measured. Obviously, the risk of car drivers aged 18 to 24 years to be involved in a traffic accident is more than twice as high as the involvement risk of drivers aged 25 to 44 years ($\psi_{18\text{-}24|25\text{-}44}$ = 2.292). The standard error of the log of the odds ratio is estimated at

[8] $\sqrt{[1/111661 + 1/7245 + 1/201639 + 1/28661]} = 0.01367.$

Consequently, approximate 95 percent confidence limits for the population odds ratio $\Psi_{18\text{-}24|25\text{-}44}$ are

[9] $\exp\{\log_e 2.292 \pm 1.96 \times 0.01367\}$

that is, (2.231, 2.354). As stated above, this confidence interval might be somewhat too narrow because the design effect has been neglected. For the remaining three age groups the odds ratio can be estimated analogously. According to the above table, there is some relationship between odds ratio and age class. If this relationship is to be analysed, one can use logistic regression models for categorical or ordinal risk factors (dependent variable is case-control status of car driver trip).

Assessing several risk factors simultaneously

A multiple logistic model can be applied to assess the joint effects of driver age group and driver gender on car driver accident involvement risk. The variables of the model are specified as follows:

Y: case-control status	(response variable coded 1 for cases and 0 for controls)
A: age group	(explanatory variable, 5 classes)
G: gender	(explanatory variable, 2 classes)

The data are supplied to the computer package (SAS) in grouped form. As there are 2 × 5 × 2 = 20 combinations of the outcomes of the three variables, the data matrix consist of 20 rows. The first 3 columns of the data matrix correspond to the 3 variables Y, A and G. Column 4 contains the frequency counts for all combinations; these counts are used as weights in the regression analysis.

case-control status (Y)	age group (A)	gender (G)	count
1	18-24 years	male	71506
1	18-24 years	female	40155
1	25-44 years	male	122787
1	25-44 years	female	78852
1	45-59 years	male	56435
1	45-59 years	female	29941
1	60-64 years	male	15864
1	60-64 years	female	5797
1	65+	male	26410
1	65+	female	8139
0	18-24 years	male	3992
0	18-24 years	female	3253
0	25-44 years	male	13436
0	25-44 years	female	15225
0	45-59 years	male	12288
0	45-59 years	female	9287
0	60-64 years	male	3852
0	60-64 years	female	1613
0	65+	male	5114
0	65+	female	1374

The total number of units in the database is 525320 (cases: 455886; controls: 69434).

The logistic model can be formulated as follows:

[10] $P_{ij} = \exp(u_{ij})/[1+\exp(u_{ij})] = 1/[1+\exp(-u_{ij})]$.

where P_{ij} denotes the probability for a unit (car driver trip) to be a "case" given age class i and gender category j and u_{ij} is defined as

[11] $u_{ij} = \mu + \alpha_i + \beta_j + \gamma_{ij}$.

In the logistic model the effects are centred, i.e. the coefficients α_i and β_j sum up to zero, respectively. Analogously, the interaction effects γ_{ij} sum up to zero for each row i and column j in the 5 × 2 table corresponding to the combinations of A and G. The logistic model can easily be extended to consider more than two risk factors.

The main elements of the output of the SAS procedure CATMOD[3] are shown in the following display:

```
The SAS System

The CATMOD Procedure

                       Data Summary

Response           ccs            Response Levels       2
Weight Variable    COUNT          Populations          10
Data Set           CASECONTROL    Total Frequency  525320
Frequency Missing  0              Observations         20


             Population Profiles

Sample    AGECLASS       GENDER    Sample Size
----------------------------------------------
    1     18-24 years    female          43408
    2     18-24 years    male            75498
    3     25-44 years    female          94077
    4     25-44 years    male           136223
    5     45-59 years    female          39228
    6     45-59 years    male            68723
    7     60-64 years    female           7410
    8     60-64 years    male            19716
    9     65+            female           9513
   10     65+            male            31524

               Response Profiles

Response    ccs  case-control status
---------------------------------------------
    1       0    case
    2       1    control (reference category)


                   Maximum Likelihood Analysis

           Maximum likelihood computations converged.


     Maximum Likelihood Analysis of Variance

Source              DF   Chi-Square    Pr > ChiSq
--------------------------------------------------
Intercept            1     102090.0        <.0001
AGECLASS             4     10004.60        <.0001
GENDER               1       523.00        <.0001
AGECLASS*GENDER      4       513.48        <.0001

Likelihood Ratio      0           .            .
Analysis of Maximum Likelihood Estimates

                                                Standard        Chi-
Parameter                             Estimate      Error      Square    Pr > ChiSq
-----------------------------------------------------------------------------------
Intercept                               1.8066    0.00565    102090.0        <.0001
```

[3] In order to obtain the SAS output in the form presented here the coding of cases and controls has to be reversed (i.e. 1 for controls and 0 for cases).

AGECLASS	18-24 years	0.8927	0.0110	6559.47	<.0001
	25-44 years	0.1219	0.00749	265.02	<.0001
	45-59 years	-0.4591	0.00825	3099.58	<.0001
	60-64 years	-0.4593	0.0141	1058.72	<.0001
GENDER	female	-0.1293	0.00565	523.00	<.0001
AGECLASS*GENDER	18-24 years female	-0.0569	0.0110	26.60	<.0001
	25-44 years female	-0.1546	0.00749	426.13	<.0001
	45-59 years female	-0.0476	0.00825	33.35	<.0001
	60-64 years female	0.0612	0.0141	18.80	<.0001

Given the case-control database, the probability of a car driver trip to be a case, i.e. to be an accidental trip, given that the driver is aged 18-24 years (i=1) and male (j=1) is estimated at

[12] P_{11} = 1/[1 + exp(-1.8066 – 0.1293 – 0.8927 – 0.0569)] = 1/ [1 + exp(-2.8855)] = 1/1.0558 = 0.9471.

This quantity, of course, can *not* be used to describe the absolute risk of young male car drivers! The reason is that the database has not been created by drawing a random sample from the complete population at risk, i.e. from the population of all car driver trips made occurring in Germany 2002. Rather, two independent samples with extremely different sampling fractions have been drawn from the subpopulations of accidental and non-accidental units, respectively. As can be seen, the probability P_{11} = 0.9471exactly corresponds to the empirical proportion of cases in the subgroup of male drivers aged 18-24 years. According to the above data matrix this proportion equals 71506/(71506+3992) = 0.9471 = 94.71%.

The above model estimation results can be interpreted as follows:

- According to the case-control design of the study one can only make statements on the *relative* risk of accident involvement (comparisons between the different combinations of age group and gender).
- The model constant 1.8066 simply reflects the fact that in the database used the number of cases is by far larger than the number of controls. The quantity exp(1.8066)/(1+exp(1.8066)) = 0.859 approximately equals the empirical proportion of cases in the database (which is 86.8%).
- Age class of driver is a highly significant explanatory variable for traffic accident involvement (Chi-square 10004.60; 4 degrees of freedom).
- The effect of driver age class on accident involvement risk is nonlinear (U-shaped) with highest risk for young drivers (18 to 24 years) and lowest risk for drivers aged 45 to 64 years. The estimate for the parameter α_5 (age class 65+) is not shown in the SAS display and must be calculated by hand. As the parameters for the five age classes must sum up to zero, one obtains the estimate -0.0962 indicating that accident involvement risk increases again once driver's age exceeds 64 years. The parameters associated with the different age classes are to be interpreted as "partial" regression coefficients.
- Driver gender also determines accident involvement risk significantly. As compared to driver age class, the effect of gender, however, is less important (Chi-square 523.00; 1 degree of freedom). The coefficients associated with the two categories (male and female, respectively) are showing the partial effect of gender. As before, the estimate for parameter β_1 (male) has to be calculated by hand; here, one simply has to reverse the sign of the parameter for the female category. The positive sign of the parameter estimate for the male category (0.1293) indicates that male drivers are at higher risk as compared to female drivers.
- In addition to the two main effects (age class and gender, respectively), the two-way interaction effect is also significant (Chi-square 513.48; (5-1)(2-1)=4 degrees of freedom). Significance of the two-way interaction means that the effect of driver gender on accident involvement risk is not the same for all age groups. Generally, there is higher risk for male

drivers as compared to female drivers; for specific age groups, however, this effect may even be reversed.

In order to quantify the relative risk of traffic accident involvement for certain subgroups of car driver trips (defined by age class and gender of driver), the odds of accident involvement given an arbitrary risk factor status combination (i, j) has to be related to the corresponding odds for a certain base or reference combination (r, s). Under the above logistic model with main and interaction effects, the odds ratio (relative chance of accident involvement given risk factor status combination (i, j) as compared to risk factor status combination (r, s) may be written as

[13] $\Psi_{ij/rs} = [P_{ij}/(1- P_{ij})] / [P_{rs}/(1- P_{rs})] = \exp(u_{ij}) / \exp(u_{rs}) = \exp[(\alpha_i - \alpha_r) + (\beta_j - \beta_s) + (\gamma_{ij} - \gamma_{rs})]$.

As before, for instance, age class "25-44 years" and gender category "female" may be considered as the reference categories (r and s, respectively) of the two risk factor status variables.

Due to the significance of the two-way interaction, the odds ratio for male drivers (j) as compared to female drivers (s) is not constant. Rather, this measure of relative risk of traffic accident involvement varies over driver age classes i:

[14] $\Psi_{ij/is} = [P_{ij}/(1- P_{ij})] / [P_{is}/(1- P_{is})] = \exp(u_{ij}) / \exp(u_{is}) = \exp[(\beta_j - \beta_s) + (\gamma_{ij} - \gamma_{is})]$

The following estimated odds ratios are obtained:

Driver age class (i)	Estimated odds ratio $\psi_{ij/is}$ (male vs. female drivers)
18-24	exp[(0.1293 - (-0.1293)) + (0.0569 - (-0.0569))] = exp(0.3724) = 1.45
25-44	exp[(0.1293 - (-0.1293)) + (0.1546 - (-0.1546))] = exp(0.5678) = 1.76
45-59	exp[(0.1293 - (-0.1293)) + (0.0476 - (-0.0476))] = exp(0.3538) = 1.42
60-64	exp[(0.1293 - (-0.1293)) + (-0.0612 - 0.0612)] = exp(0.1362) = 1.15
65+	exp[(0.1293 - (-0.1293)) + (-0.1979 - 0.1979)] = exp(-0.1372) = 0.87

As long as driver age does not exceed 64 years, the chance of a car trip to end up in an accident is 15 up to 76% higher if the driver is male. Among car trips made by elderly drivers (65 years and over), however, trips made by female drivers are more prone to accident involvement than trips made by male drivers.

Similarly, it appears that the effect of driver age class on the risk of traffic accident involvement may be different for trips made by male and female drivers, respectively:

Driver gender (j)	Estimated odds ratio $\psi_{ij/rj}$ (driver age class 18-24 vs. age class 25-44)
male	exp[(0.8927 - 0.1219) + (0.0569 - 0.1546)] = exp(0.6731) = 1.96
female	exp[(0.8927 - 0.1219) + (-0.0569 - (-0.1546))] = exp(0.8685) = 2.38

As can be seen, being a novice driver is a risk factor for accident involvement (involvement risk is roughly doubled as compared to drivers aged 25-44 years); this is especially true for female beginners.

Clustering of cases[4] and controls[5] has not been accounted for in this analysis. Random effects models could be used for this purpose.

CONCLUDING REMARKS

Usage of routine data versus special data collection

Empirical studies on traffic accident involvement risk may be carried out under different research designs: Surveys, cohort studies and case-control studies appear to be the most relevant. Ideally, under

[4] Two or more car drivers can be involved in the same accident. Therefore, accidents are clusters of road users involved.

[5] The set of trips made by a specific person on a given day is also to be considered as a cluster.

a given study design special data on traffic participation and accident involvement should be collected in order to answer the research questions. According to basic epidemiological principles, “special data collection” means sampling from the population at risk.

As a low cost alternative to special traffic participation and accident involvement data collection, the use of “routine” accident and exposure data for scientific purposes is of importance. As can be expected, traffic accident statistics on the one hand and household mobility surveys or vehicle mileage surveys on the other hand play a dominant role in this context. Studies based on routine data are generally not especially useful for demonstrating causality, but are useful for descriptive purposes ([2], p. 18-22). In studies on accident involvement risk the potential of routine data is further limited due to the reasons described below.

Limitations of routine data in risk studies at the trip level

Whereas the annual number of accidental trips Y_A is quite well documented in official traffic accident statistics, the total annual number Y of all road user trips - and thus the size of the population at risk - is never known from a complete census. Rather, this number (usually called “total trip volume”) can only be estimated from sufficiently large sample surveys on individual travel behaviour. As large-scale mobility surveys are costly, they are conducted in most countries only every 5 or 10 years.

Limitations of routine data in risk studies at the person-year level

The number N_A of accident-involved road users is not known from statistical sources. As, however, multiple accident involvement of individuals is rare, the annual number of accidental trips Y_A (which is recorded routinely by police) will be only slightly larger than the number N_A of road users involved in an accident in the course of the calendar year under consideration. Thus, N_A may be approximated sufficiently precise by Y_A.

In contrast to this, the total number N of trip makers under risk is extremely difficult to estimate for longer study periods (e.g. one year) as in most mobility surveys the respondents are reporting their trips only for a single day of the year. Thus, for instance, the number $N_{bicycle}$ of persons participating in traffic as cyclists (at least one bicycle trip per year) is simply unknown and could only be estimated from a specifically designed mobility survey where the reporting period of the sample units corresponds to one calendar year. In such a survey the interviewee had to be asked whether or not he or she has used the bicycle as a travel mode during the last twelve months.

Individual versus grouped routine data

Clearly, generic data on individual units at risk offer the best basis for risk analysis. Routine data on accident involvement, however, are quite often only available in grouped form, i.e. as tables where accident involvement counts are broken down by one or more characteristic of the accident or the accident-involved road users. Fortunately, if appropriate exposure quantities are available at the same level of aggregation, grouping does not unduly restrict the possibilities of statistical risk analysis.

Sources of routine data on accident involvement

The most important sources of data on traffic accident involvement and accident causation are

- official road traffic accident statistics (police-recorded data),
- in-depth traffic accident studies, and
- vehicle insurance data files.

However, also hospital data may be used [3]. As compared to other fields of epidemiological research, routine data from national traffic accident statistics already offer a wide variety of possibilities for analysis. This is especially true if the accident records contain sufficiently detailed information on the accident-involved vehicles.

Sources of routine data on exposure to accident involvement risk

Exposure data contain information on the number and characteristics of the units at risk (irrespective of traffic accident involvement). Depending on the analysis level, the corresponding data can be obtained from different routine sources.

Typical data sources for accident involvement risk studies at the trip level are mobility surveys (trip diaries). Sources for risk studies at the person- or vehicle-year level are (*i*) population census data, (*ii*) vehicle registration data and (*iii*) vehicle mileage surveys.

Problems of combining accident and exposure data from different sources

In situations where special data collection is not an option, the analyst has to combine routine accident and exposure data from different sources. While doing so, one regularly is faced with the problem of harmonizing the data (e.g. definition of variables and variable values) which can be an extremely cumbersome task.

Summarising, it can be said that accident involvement risk studies should be based on accident and exposure data. The so-called quasi-induced exposure method where only accident data are analysed is normally a less-than-ideal solution. As for reasons of economy the collection of special data on accidental and non-accidental units is frequently not possible, researchers are restricted to the use of routine accident and exposure data in many situations. If the combined data set is prepared in a way consistent with the case-control design, the potential of epidemiological methods for this type of study can be exploited.

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Integrated traffic accident database for accident analysis considering driver's accident and violation records

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Abstract

A lot of factors are related to a road traffic accident; particularly human factors such as road use characteristic, driving maneuver characteristic and safety attitude are the major ones. As a random factor is also included, so it is necessary to minimize the contribution of a random factor to identify human factors related to a road traffic accident. There are several standpoints for traffic accident analysis, such as vehicle-based, location-based and driver-based. And it is effective to analyze driver-based traffic accident data for discussion on the relation between human factors and accidents. An integrated traffic accident database system was developed for analysis considering driver's accident and violation records by ITARD, and several studies were carried out for the evaluation. Useful data for discussion on the relation between types of collision and traffic violations, and the effect of accident experience to the following accident were obtained.

INTRODUCTION

Factors related to a road traffic accident are classified into human, road and vehicle factors. Among human factors, road use characteristic and physical driving performance are thought to be related to sex and age, so if these variables are included in accident data, the relation between road use characteristic/physical driving performance and sex/age are able to be discussed without other database. But most of accident data do not include variables related to an individual physical and mental characteristic data, such as safety attitude and driving behavior characteristic, and it is impossible to discuss these topics with accident data only.

Black spot study is a useful technique to identify a dangerous site. But if drivers involved in accidents at a black spot have a common characteristic, for example "an old male driver with a speeding violation record", it is more efficient to focus on such old drivers instead of the spot. Because a benefit of safety measures applied to a road and road facilities is limited to the spot where the measures are implemented, but a benefit of measures applied to old drivers may be expected at other spots of which a road characteristic is similar to the black spot. To discuss these subjects, it is necessary to collect accident data with road user characteristics, accident records and violation records by driver and by spot or road section.

Some drivers are involved in a traffic accident with high frequency, and they are divided into two groups. One is with high-exposure to road traffic and the other is with a high accident rate. And it is hard to analyze a driving characteristic of the latter group without any information about driving characteristics. But if some database with accident and violation records is obtainable, these studies are possible by statistical analysis of these database.

The effect of a random factor to an accident could be minimized by analyzing plural accidents caused by one driver. And some driving characteristics might be extracted. In addition not only accident characteristics but also relation between type of collision and accident characteristic could be discussed by intervention of accidents caused by drivers with special features. And the same idea could be applied to a traffic violation.

The hypothesis for this study is as follows; an accident or a violation occurs randomly at some rate related with driving characteristics (accident characteristics and violation characteristics), road traffic environment and road use characteristics (Fig.1). Factors of accident characteristics and violation characteristic might be unified as factors of driving characteristics.

OBJECT

It is the main object of this study to develop a new database system for road traffic accident analysis considering driver's traffic accident record and traffic violation record. Other objects are 1) to categorize types of collision and traffic violations for a driver model simulating a mechanism of traffic accident and traffic violation as shown in Figure 1., 2) to develop several methods applied to the developed database system, and 3) to evaluate the usefulness of the developed database system.

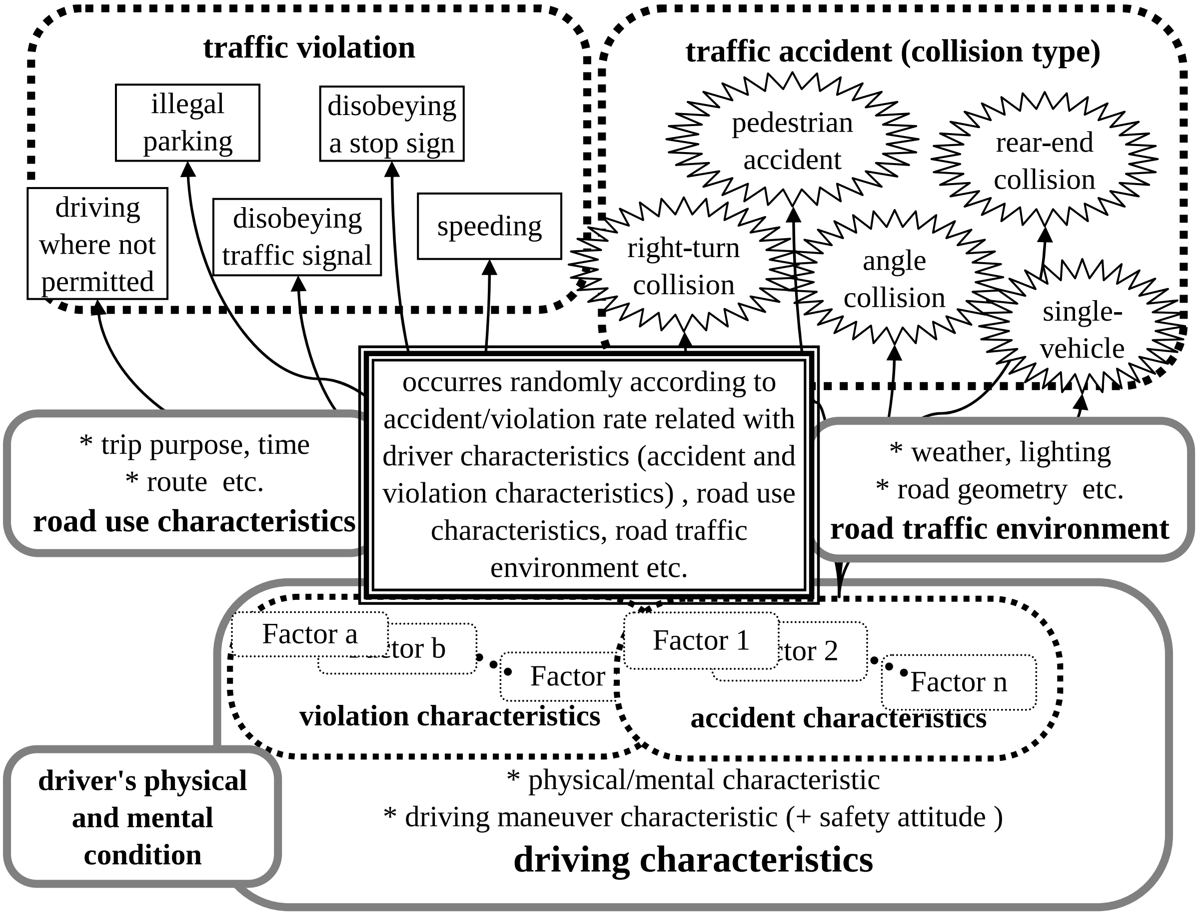


Figure 1. Accident and violation model considering driving characteristics

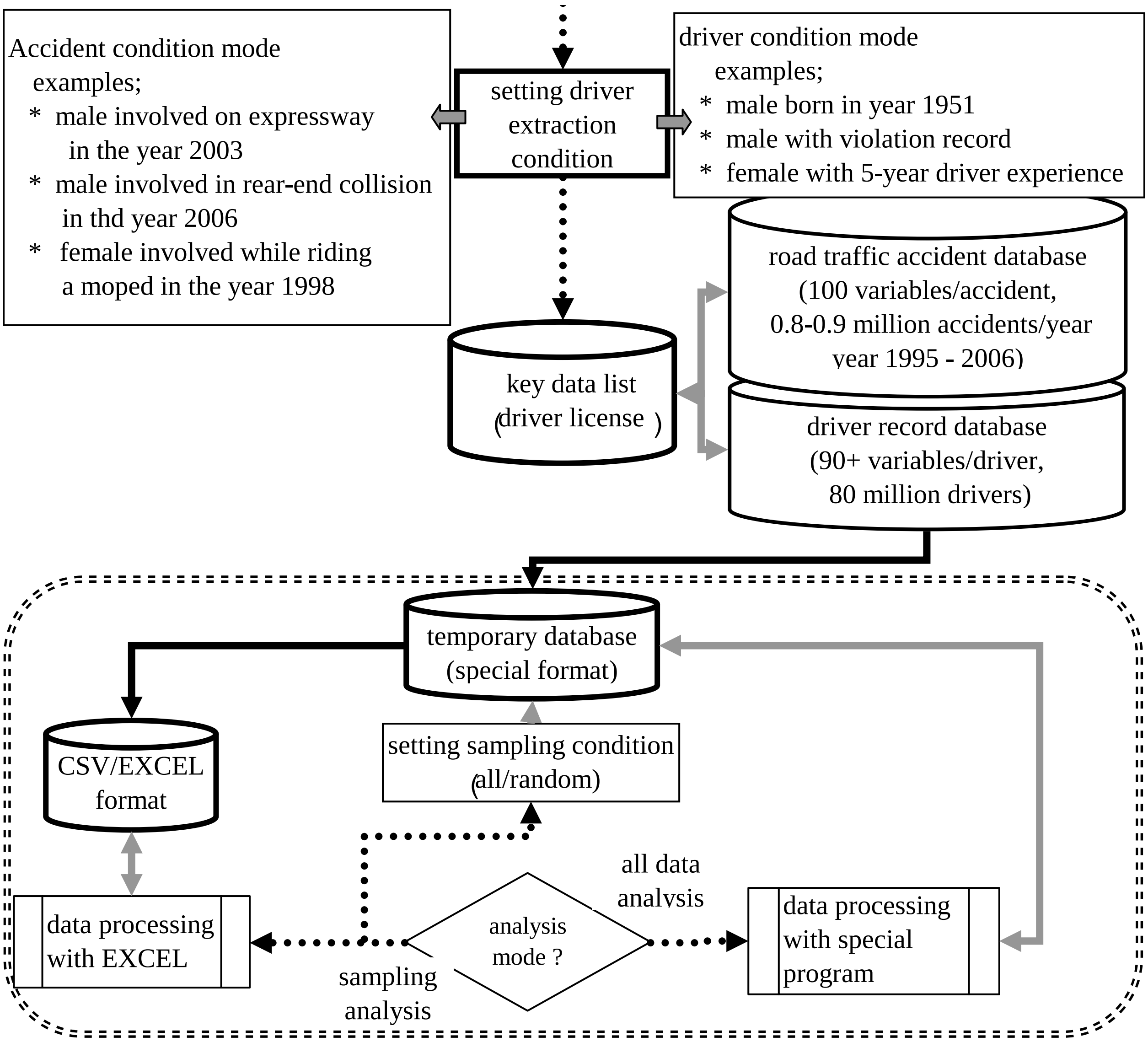
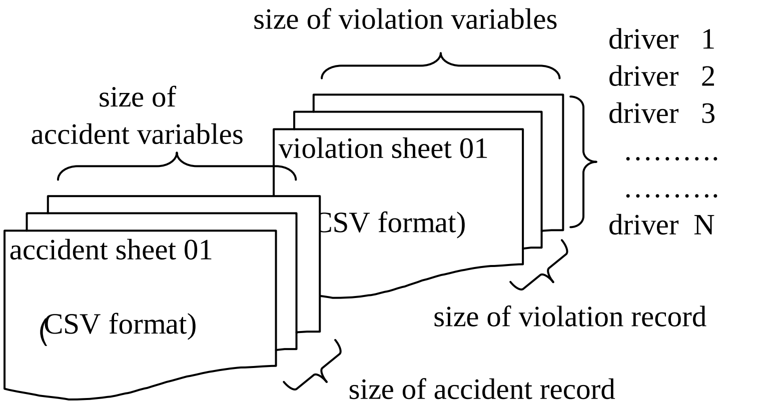


Figure 2. The developed database system



The size of accident/violation record is the maximum value of the driver group concerned.

Figure 3. the structure of the temporary database

DEVELOPED SYSTEM

ITARD (Institute for Traffic Accident Research and Data Analysis) constructed a database by integrating road traffic accident data and road traffic census data in the year 1997 and developed a new database system for analysis considering driver's accident record and violation record in year 2007. The outline of the new database system is shown in Figure 2.

Integration mode

The new database system extracts necessary data from source database by the driver or the accident condition mode. In the both modes, a driver license number is used as key code data for extraction.

Driver condition mode: Key code data is selected with variables of the driver record database, for example, sex, age, city/prefecture, issued date.

Accident condition mode: Key code data is selected with variables of the road traffic accident database, for example, date, type of collision, type of road, age of party, type of vehicle.

Followings are examples of extraction condition;

1) drivers involved in road traffic accidents at a designated section of expressway,

2) drivers with a speeding violation record,

3) drivers involved in a rear-end collision.

Source database

The new database system builds a temporary database extracting required data from the road traffic accident database and the driver record database.

Road traffic accident database: Injured and fatal accidents are recorded, about 100 variables/accident, 0.8-0.9 million accidents/year, and from the year 1995 to 2006.

Driver record database: Driver's general information, accident and violation record are recorded, 90+ variables/driver, 80 million drivers. he size (dimension) of driver record is variable.

Temporary database

The size of integrated database is increased exponentially by integrating two databases, and it is not cost-effective to keep a huge integrated database permanently. So the new database system builds a temporary database according to the object of study. The structure of the temporary database is three dimensional as shown in Figure.3.

Data Analysis

A temporary database is so large that a specific data processing programs is required to analyze all data. But formalized data processing program have not yet be developed, so some of data analyses of this paper are done by EXCEL with data sampled from a temporary database.

RESULTS

Results of example studies using the new database system are shown in this section.

Study 1: Principal Component Analysis for accident and violation characteristics

<Data integrate condition> 943,009 male drivers born in the year 1951
<Sampled data> 56,580 drivers sampled (at 6%) randomly out of 943,009 male drivers
<Analyzed data> Drives who were involved in a traffic accident or committed a traffic violation, while driving a car or wagon, were analyzed. 7,686 drivers have committed 2 and more traffic violations in the last 5 years, and 347 drivers have 2 and more accident records in the last 5 years.

If plural accidents caused by one drivers are analyzed together, the effect of a random factor is thought to be relatively small and it is possible to discuss accident characteristic or violation characteristic. Data was controlled to reduce the effect of sex, age and type of vehicle in this study. Collision type and traffic violation data of drivers who caused several accidents or violations are respectively analyzed with PCM (Principal component analysis), and Table 1, 2 and 3 show the results. The following explanations for selected vectors are reasonable.

Types of collision (Table 2);

1st Axis: the low level of culpable

2nd Axis: the poor performance of coordinating to other vehicle and road environment

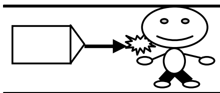
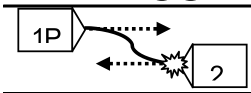
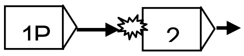
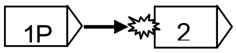
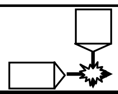
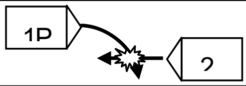
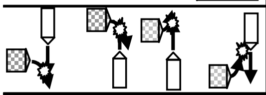
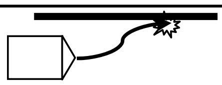
3rd Axis: the lack of courtesy to other road user, especially pedestrian

4th Axis: the high severity of damage

Table 1. Eigenvalues of the correlation matrix

	collision type				traffic violation		
valuables	Eigen value	proportion (%)	cumulative (%)	variables	Eigen value	proportion (%)	cumulative (%)
1	**1.376**	**8.598**	**8.598**	**1**	**1.316**	**10.123**	**10.123**
2	**1.323**	**8.270**	**16.869**	**2**	**1.226**	**9.427**	**19.550**
3	**1.274**	**7.962**	**24.831**	**3**	**1.086**	**8.355**	**27.906**
4	**1.182**	**7.388**	**32.219**	**4**	**1.057**	**8.133**	**36.039**
5	1.141	7.128	39.347	5	1.037	7.976	44.015
6	1.098	6.861	46.208	6	1.018	7.829	51.844
7	1.072	6.697	52.905	7	1.010	7.771	59.615
8	1.045	6.532	59.437	8	1.000	7.692	67.307
9	0.997	6.232	65.669	9	0.983	7.562	74.869
10	0.958	5.988	71.657	10	0.970	7.458	82.327
11	0.942	5.889	77.546	11	0.955	7.346	89.673
12	0.918	5.740	83.286	12	0.935	7.191	96.864
13	0.869	5.429	88.715	13	0.408	3.136	100.000
14	0.831	5.195	93.910				
15	0.804	5.026	98.936				
16	0.170	1.064	100.000				

Table 2. Axes of PCA for collision types

	collision type	level of culpable	1st Axis	2nd Axis	3rd Axis	4th Axis
	vehicle - pedestrian		-0.341	0.284	**0.470**	-0.109
	head-on collision	1P	0.036	-0.201	0.207	-0.262
		2P	-0.044	-0.110	0.056	**0.439**
	rear-end collision with a moving vehicle (rear-end A)	1P	-0.078	**0.395**	0.246	-0.014
		2P	0.397	0.326	-0.261	-0.027
	rear-end collision with a stopping vehicle (rear-end B)	1P	0.009	-0.679	0.074	-0.299
		2P	**0.765**	0.249	-0.025	0.064
	collision with a vehicle coming from left or right approach (angle)	1P	-0.265	-0.160	-0.713	0.128
		2P	-0.257	-0.244	0.186	0.287
	collision with an oncoming vehicle while <u>turning right</u>	1P	-0.194	0.084	-0.097	0.156
		2P	-0.056	0.029	0.219	**0.592**
	collision with a vehicle coming from left or fight approach while turning	1P	-0.119	0.033	0.089	-0.532
		2P	**0.436**	-0.213	0.173	-0.041
	other vehicle-vehicle	1P	-0.208	0.332	-0.291	-0.179
		2P	0.217	-0.182	0.311	0.138
	single vehicle		-0.190	**0.350**	0.227	-0.071

<level of culpable> 1P: A person having caused the most culpable failure or the least injured among parties concerned when their culpable failure are at the same level. 2P: A person having caused the lower culpable failure.

Table 3. Axes of PCA for traffic violations

traffic violation	1st Axis	2nd Axis	3rd Axis	4th Axis
drunk driving	0.073	0.091	-0.536	0.336
disobeying traffic control signal	-0.083	0.102	**0.434**	0.302
driving where not permitted	0.100	**0.405**	0.157	0.108
failing to drive within a designated lane	-0.136	0.129	-0.078	0.159
illegal crossing	0.091	0.317	0.251	-0.206
failing to stop at railway crossing	0.023	-0.177	0.361	-0.150
disobeying a stop sign	0.004	-0.162	**0.545**	**0.425**
illegal parking	**0.280**	**0.712**	-0.088	-0.171
operating a defective vehicle	0.020	-0.037	-0.018	**0.353**
speeding	-0.859	-0.160	-0.108	-0.260
failing to use a seat belt	**0.662**	-0.577	-0.108	-0.147
using a cellular phone while driving	0.076	0.026	0.241	-0.544
unsafely driving	0.074	-0.025	0.014	-0.180

Traffic violation (Table 3);

1st Axis: seatbelt violation or none moving violation

2nd Axis: intentional violation without vicious

3rd Axis: related to recognition error

4th Axis: decision error, optimistic decision

The number of drivers who commit plural accidents or violation is so small that the covariance is not large enough for the PCM. And significant relation between scores of accident vectors and scores of violation vectors was not found (Table 1.).

Study 2: Risk of drivers without accident/violation record

<Data integrate condition> Male drivers born in the year 1930, 1935, 1940, 1945,,, 1975 and 1980
<Sampled data> 40,000 drivers sampled randomly for each group (about 440,000 male drivers)
<Analyzed data> Accident data violation data were analyzed. An active driving-year was estimated to discuss the relation between non-accident/non-violation record and accident involvement.

A road use characteristic may change after retirement and mental and physical performance of driving a car may decrease with age.
There is one scenario for old drivers in Japan. One driver who has neither traffic accident nor traffic violation record may consider himself a safe driver. He may not recognize the declining of his driving performance because he has few near miss or accident. But the reason is not his performance but the low exposure to road traffic (he drives a car weekend only before retirement). But after his retirement an accident risk may increase rapidly because he has enough time to drive and increases exposure and his performance declines with age. Then he may be involved in a traffic accident. It is an accident for him, but it is a reasonable conclusion for society.
Figure 4 shows that the accident involvement in the year 2006 of drivers who have neither accident record nor violation record in the last 3-year (from the year 2003 to 2005). To be a driver without an accident record is not the same, and 50 or 55 years old driver without accident record is more dangerous than 45 years old driver.

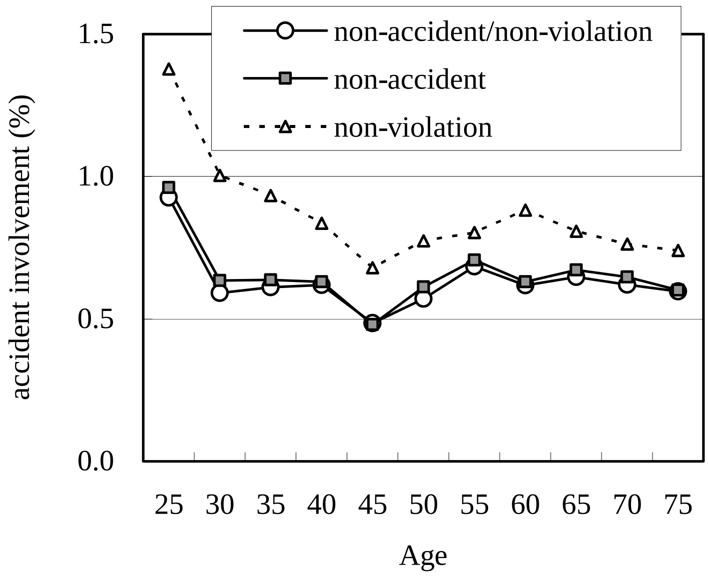


Figure 4. Relation between accident involvement and driver record in the last 3

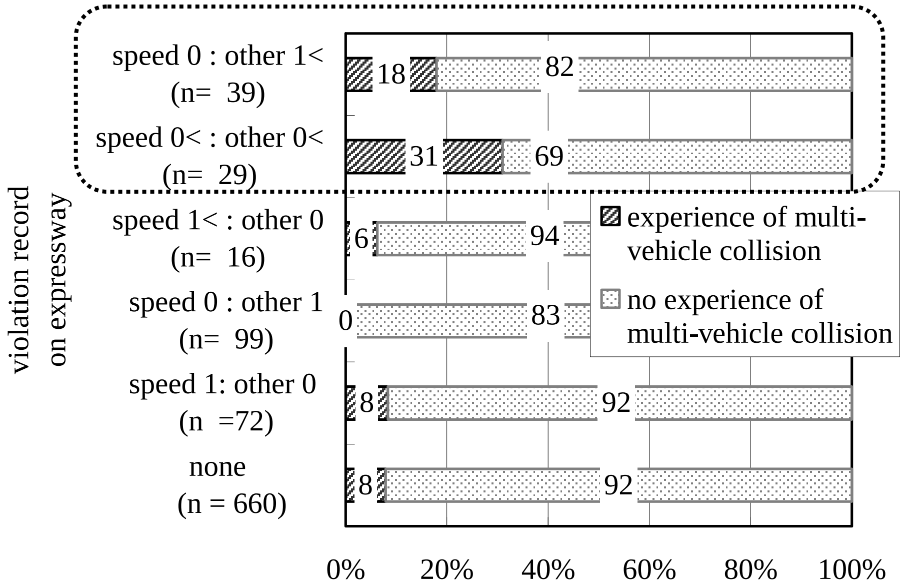


Figure 5. Relation between violation record and multi-collision on expressway

Study 3: Multi-vehicle accident on expressway

<Integrate condition> Drivers involved in traffic accident on Chuoh Expressway in the year 2005
<Analyzed data> All drivers of integrated database (915 drivers) were analyzed. Ninety two drivers out of 915 drivers were involved in a multi-vehicle collision on Chuoh Expressway, and 660 drivers have no violation record on expressways and 117 drivers have speeding violation on expressways.

Multi-vehicle collision on expressway is one of major problem on expressway safety. Major causes of multi-vehicle collision are insufficient headway and speeding, and a driver who commits insufficient headway violation or speeding violation is thought to be involved in a multi-vehicle collision more easily.
Figure 5 shows the relation between violation record and multi-vehicle collision on Chuoh expressway. The result shows that the multi-vehicle collision involvement is high for drivers who have no speeding violation and more than 2 non-speeding violations on expressway. This result is curious, but it is not necessarily unreasonable. A driver may commit a speeding violation when he convinces of his safety, and the correlation between violation and accident is not necessarily strong.

Study 4: The effect of accident experience

<Integrated data> 431,427 male drivers involved in a traffic accident in the year 2006
<Sampled data> 43,142 male drivers sampled randomly (at 10%)
<Analyzed data> Drives involved in a traffic accident while driving a car or wagon were analyzed to eliminate the effect of vehicle type to collision type. Collision type, such as “rear-end B/2P” or “angle/1P” is explained in Table 2.

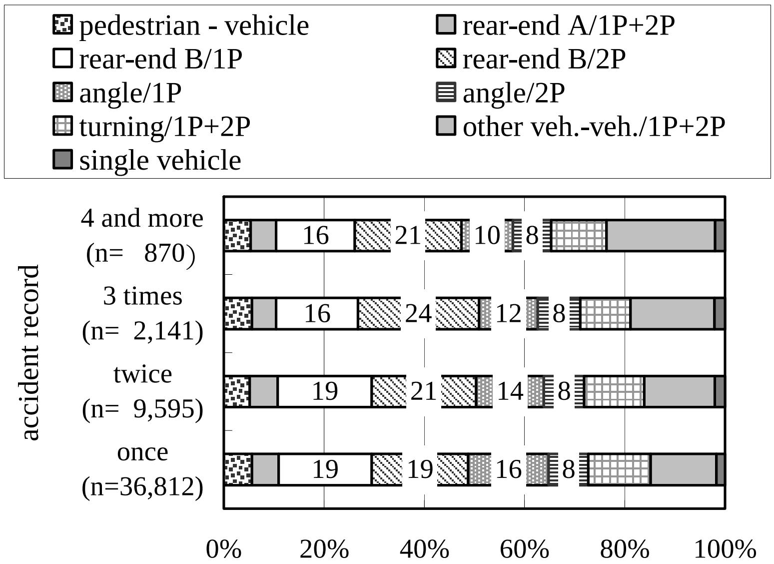


Figure 6. Relation between accident record and collision type

Figure 6 shows the relation between collision type and accident record in the last 5 years. The percentages of rear-end B/1P and angle/1P are decreasing with increase of accident record, but that of rear-endB/2P is increasing (except 4 and more). The result means that an accident characteristic may be changed by an accident experience.

Table 4 shows the effect of collision type to the following accident or sequence of collision type. A percentage of rear-end B/1P is almost 20% and not affected by the type of previous collision, while that of angle/1P is not the same level, especially between 1st and 2nd. The result means that the effect of an accident experience may differ in the collision type.

Table 5 shows that there is a relation between collision type and accident interval. In this analysis, an interval between accidents was controlled, because a driver might pay extra-attention on safety driving just after an accident. An accident occurred in 5 years and longer after the previous accident was selected as a base accident. And only a base accident and the next accident are analyzed for this study. Occurrence rate of rear-end B/2P is thought to be not changed by the driving maneuver of collided drivers, therefore the number of rear-end B/2P could be considered an index of exposure to road traffic. If there is not any effect of driver's safety attitude nor driving maneuver to the next accident, the ratio of the number of collision types concerned to that of rear-end B/2P might be constant. Then using this relation, the number of potential accidents was estimated and shown in Table 5, and accident reductions were estimated by the number of existed accidents dividing by the number of potential accidents. Fig. 8 shows the accident reduction by accident interval.

The result shows;

1) a reduction is large just after the accident and getting smaller year by year,

2) a reduction of angle/1P is greater than any other type of collision, and

3) a reduction is shown for not only primary party (1st party) but also 2nd party.

Table 4. The effect of collision type to the following accident

sequence of collision type	collision type	rear-end B /1P	angle /1P	rear-end B /2P	angle /2P
Z: number of drivers with 3 straight accident experience while driving a car or wagon		931	931	931	931
	A/Z(%)	19.4	12.0	21.6	8.1
A: number of drivers whose 1st accident is thecollision type concerned		181	112	201	75
	B/A(%)	21.5	8.9	32.3	9.3
B: number of drivers whose 1st and 2nd accidents were thecollision type concerned		39	10	65	7
	C/B(%)	23.1	30.0	44.6	28.6
C: number of drivers whose 3 accidents were the collision type concerned		9	3	29	2
D: number of drivers whose 1st and 3rd accidents were the collision type concerned		43	19	64	8
	D/A(%)	23.8	17.0	31.8	10.7

Male drivers involved in an accident while driving a car or wagon in the year 2006 were analyzed.

Table 5. Potential accident and existed accident by accident interval

	collision type	base accident	less than 1 year	1-2 years	2-3 years	3-4 years	4-5 years	5 years and more
			accident interval (between a base and the next accident)					
Existed accident	rear-end B/1P	4,065	260	250	194	174	149	211
	angle/1P	3,947	204	207	151	133	138	178
	rear-end B/2P	4,503	376	325	237	187	187	225
	angle/2P	1,791	115	114	90	79	73	75
Potential accident	rear-end B/1P	4,065	339	293	214	169	169	203
	angle/1P	3,947	330	285	208	164	164	197
	rear-end B/2P	4,503	376	325	237	187	187	225
	angle/2P	1,791	150	129	94	74	74	89

Accident records of male drivers involved in accidents while driving a car or wagon in the year 2006 were analyzed. A base accidents is an accident that occurred more than 5-year after the previous accident. Collision type: refer to Table 2.

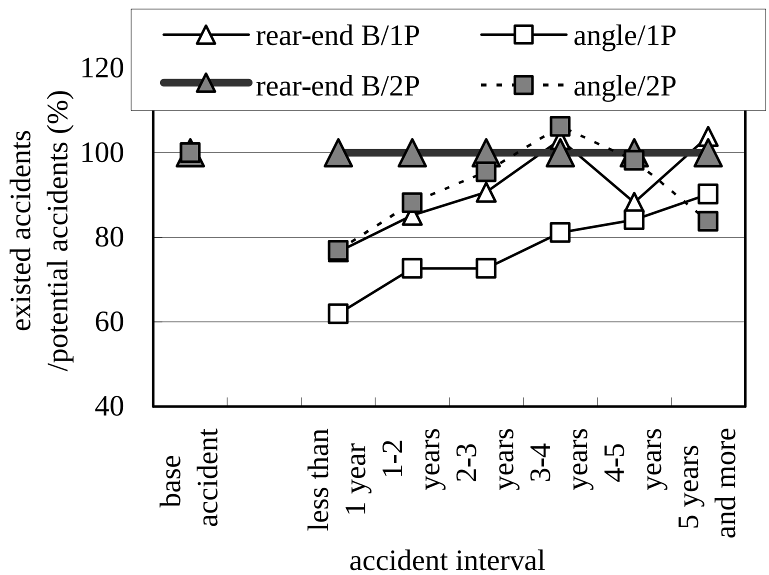


Figure 7. Accident reduction by accident interval

DISCUSSION

Study 1: Principal Component Analysis for accident characteristics

The author tried to derive driving characteristics by studying the relation accident characteristics (Table 2.) and violation characteristics (Table .3). But it was failed because there was not a significant correlation between accident characteristics (scores) and traffic violation characteristics (scores). One of the reasons could be explained by the result of Study 4. The author has supposed that driving characteristics might be so stable that it is possible to derive driving characteristics related to traffic accident and violation. But a driver's attitude and a driving maneuver characteristic may be changed after the driver experiences an accident. Other reason might be the choice of analysis method, and Principal Component Analysis is not suitable method for those data whose correlation coefficient is low. It is required to examine other method and transform those data for the purpose of analysis.

Most of traffic accidents were committed with a human error or unconsciously, but most of traffic violations were committed consciously. So unless the effect of conscious and unconscious behavior is well understood, it is impossible to discuss or construct a driver model for a traffic accident and a traffic violation.

Study 2: Risk of drivers without accident/violation record

A lot of studies showed that 40's is the safest and 20's is the most dangerous age group, and the result of Study 2 is consistent with it. The decreasing of accident involvement at 60's and 70's is thought to be owing to the decreasing of driving exposure of those age groups.

Study 3: Multi-vehicle accident on expressway

Most of traffic accident measures are discussed without considering accidents caused by drivers with accident record. Some of them might try to drive safely and it was shown in Figure 7. There is the difference between the accident rate of drivers with 1 accident record and that of drivers with 2 and more accident records [1]. It means that a counter measures should be changed depending on driver's accident record. Some drivers with a single accident record have ability to control by themselves to prevent an accident, and it is useless to spend a lot of times and effort for them.

Study 4: The effect of accident experience

One of the differences of accident mechanism of rear-end B/1P and angle/1P is the possibility that a driver percepts the other party in advance. It may be preferable for a driver to have such a possibility. But it sometimes has a driver make an error, because "to be visible" is not always "to be perceived".

On the other hand, “not be visible” is always “not to be perceived”. So if a driver intends to avoid an angle collision, he has to reduce his speed and pay attention to others when crossing an intersection. It is not difficult for a driver who has experienced an angle collision once, to avoid another angle collision. A driver assist system to prevent a rear-end collision may be more effect than a driver assist system to prevent an angle collision.

Twenty percents of drivers who were involved in a road traffic accident in the year 2006 have accident record in the last 5 years. It means that if 50% of accidents by those drivers were reduced, 10% of accidents in the year 2006 could have had been reduced.

According to analysis of driver record, only 5 % of drivers are free from a traffic accident or a traffic violation in their lifetime [2]. That is, most of drivers have an experience of accident or violation in their lifetime. And most of these drivers have succeeded to avoid an accident after their unique experience. It is worth analyzing this mechanism.

CONCLUSION

An integrated traffic accident database system for accident analysis considering driver’s accident and violation record was developed. The system was developed to discuss driver characteristics related to both of accident characteristics and violation characteristics, and to obtain useful data for discussion of road safety measures. Unfortunately any driving characteristics related with traffic accident and violation was not obtained, but some useful information was obtained.

The major findings of example studies and points of discussion were as follows;

1) an accident risk of drivers without an accident record is changed by aging (Study 2),

2) there is no correlation between an involvement of a multi-vehicle collision and speeding violation record on Chuoh expressway (Study 3),

3) an accident risk is low just after accident, but a risk is increasing gradually year by year (Study 4),

4) these effects are thought to be owing to the change of driver’s safety attitude and driving maneuver characteristic (Study 4),

5) it is necessary to examine traffic safety measures from the standpoint of preventing a driver from repeating accident (Discussion), and

6) analysis using the developed database system is useful for not only driver education but also for designing driver assist system corresponded to driver’s accident or violation characteristics (Discussion).

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Study on Characteristics of Event Data Recorders Using J-NCAP Data

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Abstract - The aim of this study was to evaluate the performance and accuracy of Event Data Recorders (EDRs). The analysis was based on J-NCAP crash tests from 2006–2007, with the corresponding EDR datasets. The pre-crash velocity, maximum delta-V and delta-V versus time history data recorded in the EDRs were compared with the reliable crash test data. The difference between the EDR pre-crash velocity and the laboratory test speed was less than 4 percent. In contrast, in several cases the maximum delta-V and delta-V versus time history data obtained from the EDRs showed uncertainty of measurement in comparisons with the reliable delta-V data. The difference in maximum delta-V in these comparisons was more than 5 percent in 10 of 14 tests and more than 10 percent in 4 of 14 tests. The EDRs underestimated the maximum delta-V in almost all tests. It was also concluded that the calculated acceleration from the EDR delta-V versus time history data showed good agreement with the instrumented accelerometer signal during the collision in almost all tests.

INTRODUCTION

In August 2006, National Highway Traffic Safety Administration (NHTSA) in the USA published a final rule on Event Data Recorders (EDRs) which are devices installed in motor vehicles to record vehicle and occupant information for a brief period of time before, during and after a crash or a near-crash event [1]. In January 2008, NHTSA published a revised final rule on EDRs and responded to several petitions for reconsideration of the August 2006 rule [2]. In March 2008, the Japanese Ministry of Land, Infrastructure, Transport and Tourism (J-MLIT) decided on the technical requirements for the application of EDRs to light vehicles (3500 kg GVWR or less) [3]. This rule—the so called J-EDR technical requirement—is comparable to the US regulation (49 CFR Part 563). EDRs are now being installed as standard equipment by several automakers in the USA and in Japan.

The EDR is a promising device for accident reconstruction. It directly records such details as delta-V (ΔV), vehicle speed, engine speed, information on brake and accelerator pedals, and seat positions and seat-belt use in the case of drivers and front passengers. However, if EDRs are to be utilized for accident investigation, then it is first necessary to examine the reliability and accuracy of EDR readout data.

The characteristics of EDRs were evaluated in this study in order to assess the devices' ability to improve accident reconstruction through the supply of more reliable and accurate crash information.

ANALYSIS

The analysis was based on data obtained from J-NCAP full-lap frontal barrier (FLB) tests at 55 km/h and 40 percent overlap offset frontal deformable barrier (ODB) tests at 64 km/h from 2006–2007, with the corresponding EDR datasets in 14 separate crash tests involving 7 vehicle models. Pre-crash velocity recorded in each EDR (V_{EDR}) was compared with the data from an optical speedometer placed in front of the barrier (V_{OP}). The maximum delta-V and delta-V versus time history data recorded in EDRs were compared with the J-NCAP test data from three accelerometers—on the left-side sill (A-L), right-side sill (A-R), and centre floor (A-C)—and from a high-speed video

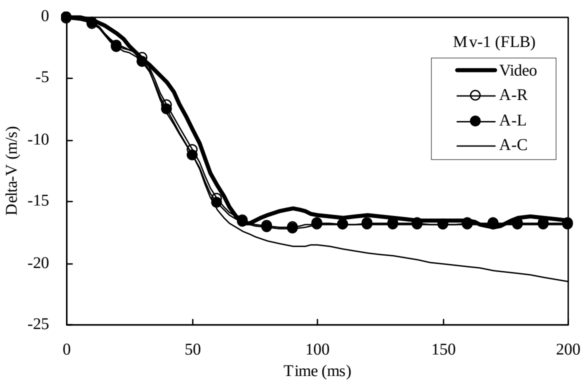

Figure 1. Delta-V time history curves obtained from Video and accelerometers

camera (Video).

Figure 1 is an example of a curve comparing delta-V time histories obtained from the accelerometers with that from Video. In several tests the delta-V time history curves obtained from the accelerometers differed markedly from the reliable Video results. Even a small error in the accelerometer signal can cause marked deviation in the velocity after integration of the acceleration.

Accordingly, after an intensive analysis of the J-NCAP crash test data, reliable J-NCAP data for use in the comparisons with the EDR data were chosen, as follows:

- For the maximum delta-Vs, the data obtained from the Video were chosen as reference values.
- For the delta-V time histories, the data obtained from the centre-floor accelerometer (A-C) and the Video were chosen.
- However, when the delta-V time history from the A-C differed markedly from the Video result, the average of the delta-V time history from the accelerometers at the left-side sill (A-L) and right-side sill (A-R) was used.

RESULTS AND DISCUSSIONS

Table 1 compares the results for pre-crash velocity. In all cases, the difference between the EDR pre-crash velocity (V_{EDR}) and the J-NCAP test speed (V_{OP}) was less than 4 percent (average: about 2 percent). The EDR pre-crash velocities were very accurate and reliable, but generally lower than the optically derived ones (V_{OP}).

Table 2 compares the results for post-crash maximum delta-V. The maximum delta-Vs recorded by the EDR (Max ΔV_{EDR}) showed uncertainty of measurement in several cases when compared with the Video results (Max ΔV_{Video}) or the reference values. The difference was more than 5 percent in 10 of 14 tests and more than 10 percent in 4 of 14 tests. The average difference in maximum delta-V was about 7 percent. The EDR maximum delta-V values were generally lower than the Video ones (Max ΔV_{Video}).

We examined the degree of deviation of the maximum delta-Vs recorded by the EDR or calculated by accelerometer signals (A-C, Ave. A-R and A-L) from the Video results in FLB tests and ODB tests, as shown in Figure 2. The deviation of the maximum delta-V calculated from the accelerometer signals was more than 10 percent in 4 tests. Accordingly, the accuracy and reliability of the EDR maximum delta-V seemed to be of the same order as those of the data obtained from the accelerometers in the crash tests. The accelerometers utilized in EDRs could have the same performance as the instrumented accelerometers used in crash tests. The maximum delta-Vs recorded by the EDRs were slightly lower than the Video results in the FLB and OBD tests (see Table 2, Fig. 2): that is, the EDRs underestimated the maximum delta-V in almost all tests.

We compared the delta-V time history curves obtained by EDR with those from accelerometers and Video in the FLB and ODB tests (Fig. 3). In the case of the passenger car-1 (PC-1), the delta-V time history from EDR was very comparable with those from the accelerometers and Video in both the FLB test and the ODB test. In other cases, there was an apparent difference between the EDR data and the results from the accelerometers and Video. However, when we focused on the initial short time window of the delta-V curve, the EDR data were very comparable with those from the accelerometers. This initial short time window was up to about 60 ms in the FLB test and about 100 ms in the ODB test. This result suggests that the acceleration calculated by the EDR data agrees well with the accelerometer signal in these short time windows.

Figure 4 compares the calculated EDR acceleration and the accelerometer signal. The calculated EDR acceleration agreed well with the accelerometer signal for the entire period of 200 ms. Even in the worst cases (PC-3(FLB) , Mv-1(FLB), Mv-2(FLB) and Mv-2(ODB)), in which the EDR maximum delta-V (Max ΔV_{EDR}) differed by more than 10 percent from the Video results (Max ΔV_{EDR}), the calculated EDR acceleration plots were almost comparable with the accelerometer signals (Fig. 4).

A previous study [4] of EDRs reached conclusions similar to ours. For pre-crash velocity the difference was less than 1 mph in all cases (average difference: 1.1 percent). The average difference in maximum delta-V was about 6 percent, and in nearly all cases the maximum delta-V recorded by the EDRs was less than the reliable delta-V, for which instrumented accelerometers were used. These authors explained that EDR data loss caused this difference, since in their study the majority of the

EDRs did not record the entire event. In contrast, even though the EDRs used in our study could record the entire event up to 200 ms, the EDRs still underestimated the maximum delta-V in almost all tests.

Table 1 Comparison results of pre-crash velocity

Test	Model	V_{OP} m/s	V_{EDR} m/s	Difference m/s	Difference %
FLB	PC-1	15.3	15.0	-0.3	-2.0
	PC-2	15.3	15.6	0.3	2.0
	PC-3	15.3	15.0	-0.3	-2.0
	PC-4	15.3	15.0	-0.3	-2.0
	PC-5	15.3	15.0	-0.3	-2.0
	Mv-1	15.3	15.0	-0.3	-2.0
	Mv-2	15.3	14.9	-0.4	-2.6
ODB	PC-1	17.9	17.2	-0.7	-3.9
	PC-2	17.8	17.8	0.0	0.0
	PC-3	17.8	17.2	-0.6	-3.4
	PC-4	17.8	17.2	-0.6	-3.4
	PC-5	17.8	17.2	-0.6	-3.4
	Mv-1	17.9	17.8	-0.1	-0.6
	Mv-2	17.7	17.1	-0.6	-3.4
		Average		-0.3	-1.8

Table 2 Comparison results of post-crash maximum delta-V

Test	Model	Max ΔV_{Video} m/s	Max ΔV_{EDR} m/s	Difference* m/s	Difference* %	Max ΔV_{A-C} m/s	Difference* m/s	Difference* %	Max $\Delta V_{Ave.\ A-R\ and\ A-L}$ m/s	Difference* m/s	Difference* %
FLB	PC-1	17.2	16.5	-0.7	-4.1	17.0	-0.2	-1.2	17.7	0.5	2.8
	PC-2	16.9	15.3	-1.6	-9.5	17.1	0.2	1.2	17.8	0.9	5.1
	PC-3	17.1	14.9	-2.2	-12.9	16.4	-0.7	-4.3	18.1	1.0	5.5
	PC-4	17.3	16.2	-1.1	-6.4	17.9	0.6	3.4	18.5	1.2	6.5
	PC-5	17.0	16.7	-0.3	-1.8	18.8	1.8	9.6	17.6	0.6	3.4
	Mv-1	17.1	14.7	-2.4	-14.0	21.4	4.3	20.1	17.1	0.0	0.0
	Mv-2	17.0	15.2	-1.8	-10.6	18.1	1.1	6.1	17.5	0.5	2.9
ODB	PC-1	20.3	19.1	-1.2	-5.9	19.0	-1.3	-6.8	19.3	-1.0	-5.2
	PC-2	19.4	19.2	-0.2	-1.0	22.1	2.7	12.2	19.4	0.0	0.0
	PC-3	20.0	18.4	-1.6	-8.0	21.7	1.7	7.8	19.4	-0.6	-3.1
	PC-4	20.7	18.7	-2.0	-9.7	20.2	-0.5	-2.5	19.9	-0.8	-4.0
	PC-5	20.1	18.7	-1.4	-7.0	19.4	-0.7	-3.6	19.4	-0.7	-3.6
	Mv-1	18.4	18.5	0.1	0.5	22.4	4.0	17.9	20.8	2.4	11.5
	Mv-2	19.9	17.5	-2.4	-12.1	18.8	-1.1	-5.9	20.1	0.2	1.0
			Average	-1.3	-7.3	Average	0.9	3.9	Average	0.3	1.6

*: Reference value is Max ΔV_{Video}.

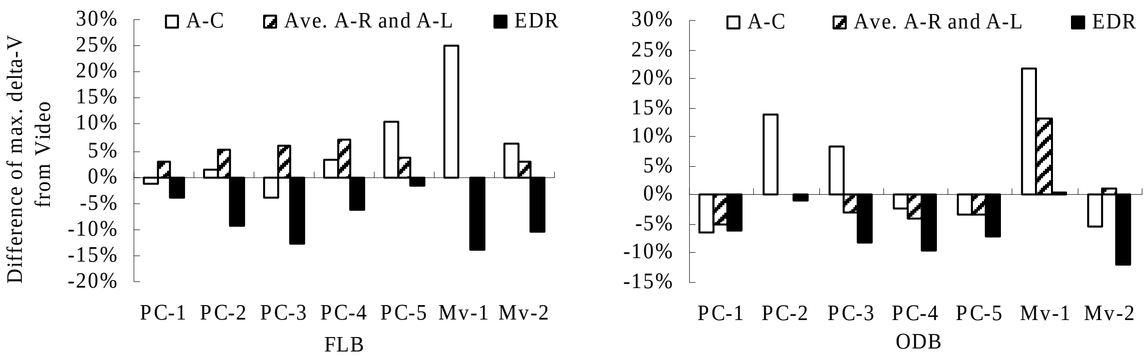

Figure 2. Deviation of the maximum delta-Vs recorded by the EDR or calculated by accelerometer signals (A-C, Ave. A-R and A-L) from the reliable Video results (Max ΔV_{Video}) in FLB and ODB tests.

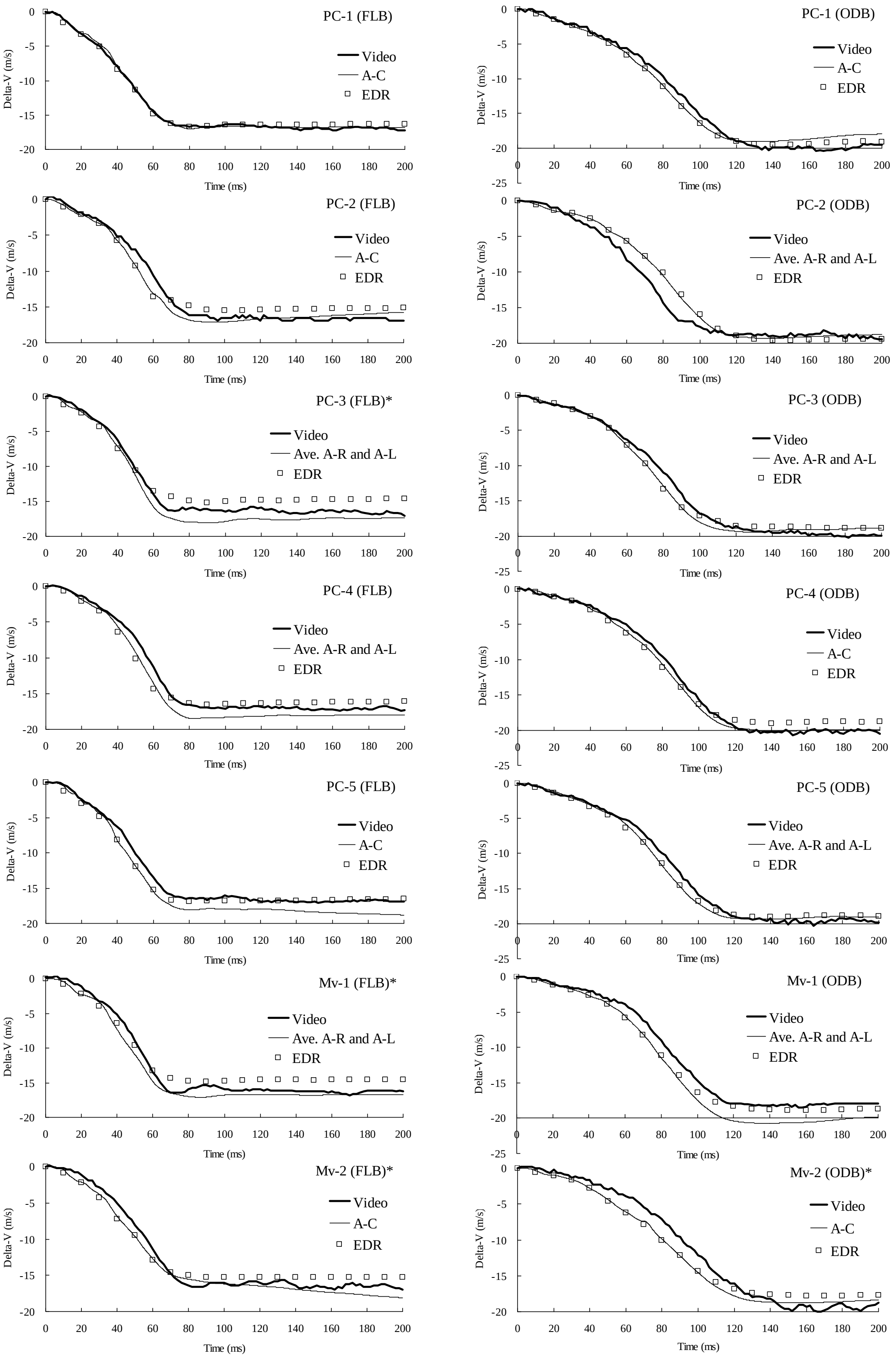

Figure 3. Comparison of delta-V time histories from EDR, Video and Accelerometer.
(*: Max ΔV_{EDR} differed more than 10 percent compared with Max ΔV_{Video}.)

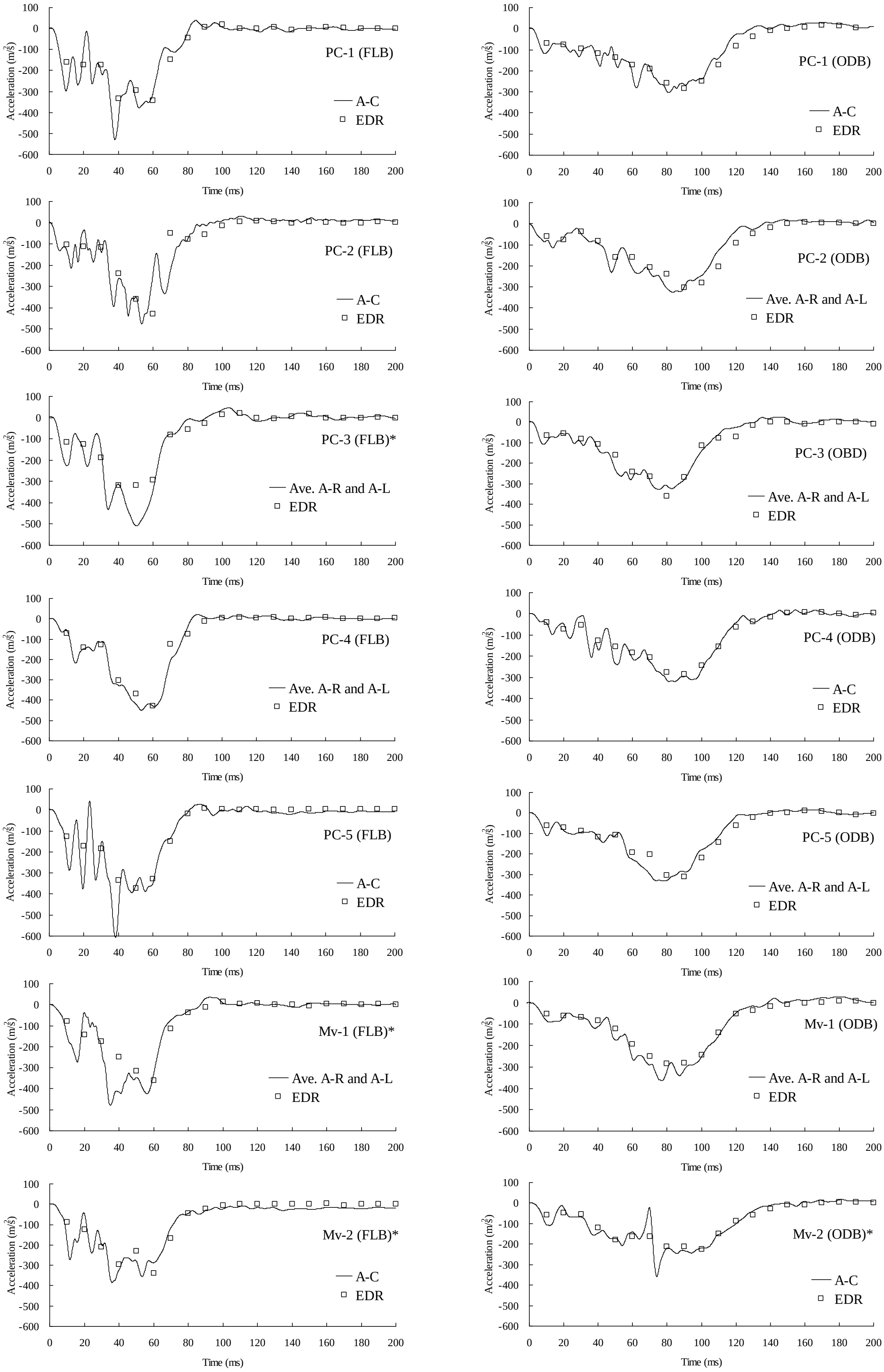

Figure 4. Comparison of acceleration time histories from EDR and Accelerometer.
(*: Max ΔV_{EDR} differed more than 10 percent compared with Max ΔV_{Video}.)

CONCLUSIONS

The pre-crash velocity, maximum delta-V and delta-V versus time history data recorded in EDRs were compared with those of the data obtained from the 2006–2007 J-NCAP crash tests in order to evaluate the performance and accuracy of EDRs. The EDR datasets of 14 separate crash tests involving 7 vehicle models were used in this study. Conclusions are summarized as follows:

- The EDR pre-crash velocities were very accurate and reliable. The difference between the EDR recording value and the laboratory test speed was less than 4 percent (average: about 2 percent).
- The maximum delta-V and delta-V versus time history data obtained from the EDRs showed uncertainty of measurement in several cases in comparisons with the reliable delta-V data. The difference in maximum delta-V was more than 5 percent in 10 of 14 tests and more than 10 percent in 4 of 14 tests (average: about 7 percent).
- The EDRs underestimated the maximum delta-V in almost all tests.
- The delta-V time history curves from EDRs were very comparable with those from the instrumented accelerometers when we focused on the initial short time window of the delta-V curves. This initial short time window was up to about 60 ms in the FLB test and about 100 ms in the ODB test.
- The calculated acceleration from the EDR delta-V versus time history data agreed well with the instrumented accelerometer signal for the entire period of 200 ms in almost all tests.

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Characteristics of Passenger Car Side to Pole Impacts - Analysis of German and UK In-depth data using different approaches

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ABSTRACT – The national accident statistics demonstrate that the situation of passenger car side impacts is dominated by car to car accidents. Car side to pole impacts are relatively infrequent events. However the importance of car side to pole impacts is significantly increasing with fatal and seriously injured occupants.
For the present study the German in-depth database GIDAS (German In-Depth-Accident Study) and the UK based database CCIS (Co-operative Crash Injury Study) were used. Two approaches were undertaken to better understand the scenario of car to pole impacts. The first part is a statistical analysis of passenger car side to pole impacts to describe the characteristics and their importance relevant to other types of impact and to get further knowledge about the main factors influencing the accident outcome. The second part contains a case by case review on passenger cars first registered 1998 onwards to further investigate this type of impact including regression analysis to assess the relationship between injury severity and pole impact relevant factors.

1. DATABASES

National accident statistics are not detailed enough to get information on the characteristics of impact types therefore two in-depth databases were used, the German In-Depth Accident Study (GIDAS, Germany) and the Cooperate Crash Injury Study (CCIS, UK).

GIDAS

GIDAS (German In-Depth Accident Study) is a joint project of the Federal Highway Research Institute (BASt) Germany and the German Association for Research in Automobile Technology (FAT). It started in 1999 in the two research areas Dresden and Hanover based on the established research activities of the Medical University Hannover. About 2,000 accidents involving all kinds of traffic participants are recorded each year in a statistical random procedure resulting in a representative sample of the national German accident statistics. The teams consisting of technical and medical students investigate the data at the accident scene and the hospitals. Each case is encoded in the database with about 3,000 variables. The database contains detailed information about: environment (meteorological influences, road environment), vehicle (deformations, technical characteristics, safety measures), person (first aid measures, therapy, rehabilitation) and injury (severity, description, causation). On the basis of this comprehensive information completed with a detailed image documentation of the car, the accident scenery and accident tracks every accident is fully reconstructed.

CCIS

The objective of CCIS (Co-operate Crash Injury Study) is to investigate and correlate car crash data, with a view to increase the understanding of human injury mechanisms, and the effectiveness of car secondary safety systems. The study provides the mechanism to monitor in-depth crash performance of car structures, occupant protection systems and the benefits of countermeasures now becoming available. CCIS is a collaborative project. The UK Department for Transport, several motor vehicle manufacturers (including Ford) and a vehicle component supplier jointly fund the programme of research. Currently, information on approximately 1300 vehicles is gathered each year for inclusion into the database. It is not currently possible to weight the CCIS data in order to address the sampling bias towards serious injury. Data collection consist of sampling criteria, i.e. passenger cars 7 years old or younger at the time of accident, injury occurred to an occupant in the car and the vehicle was towed from the accident scene.

In detail the following basic query criteria/parameter were examined for the present study:

Basic inquiries applied to GIDAS 07/2007 and CCIS 2007 (combined phase 6y, 7o and 8c)
Passenger cars
o Impacts to vulnerable road users were excluded from GIDAS (not necessary in CCIS dataset) o All vehicles which had only one impact to the side (single side impacts) o Cars with rollover before or after the side impact where excluded.
Pole impacts
o Cars with single impact to pole (tree, lamp post, traffic light post…) o Resulting injury severity and individual injuries for belted occupants only

2. INTRODUCTION

The national accident statistics demonstrate that the situation of passenger car side impacts is dominated by car to car accidents. Car side to pole impacts are relatively infrequent events. However the importance of car side to pole impacts is significantly increasing with fatal and seriously injured occupants.

Pole impacts, especially lateral, comprise one of the most aggressive impact environments for automobile structures. Due to the close proximity of occupants to the side structure, these pole impacts represent a more severe crash exposure than comparable impacts to other structures for instance to the front of a car [1]. Especially if the pole impact is directly to the compartment area the risk to receive severe injuries is high. A study of Zaouk et al [2] postulated by using NASS and FARS data for 1988 to 1997 with respect to side impacts, that direct impacts of narrow objects with the occupant compartment have a high portion of MAIS3+ injuries.

A considerable step in the improvement of side impact protection for passenger cars has already been done. With additional and improved structures in the doors and/or pillars of a vehicle and with the industry wide introduction of various types of side airbags, occupant protection has reached a high level.

The regulatory frameworks for these developments are the FMVSS 214 [3] on the US side and the ECE 95 [4] in Europe. In addition consumer testing by US-NCAP and EU-NCAP established also side impact testing protocols not only for the car-to-car side impact but also for pole impacts. The latter are the focus for the current study, which was part of the work of the European Enhanced Vehicle Safety (EEVC) working group 21 (Accident Studies) for the EEVC WG13 (Side Impact) to develop recommendations for future regulatory side impact test procedures. The working group 21 was founded for compiling experiences and scientific results from existing in-depth-investigations of European research teams supporting the different activities of EEVC.

Two approaches were undertaken within this study to better understand the characteristics of car to pole impacts. The first part is a statistical analysis of pole impacts to describe the characteristics and their importance relevant to other types of impact and to get further knowledge about the main factors influencing the accident outcome. The second part contains a case by case review on cars registered 1998 onwards only, to further investigate car side to pole impacts focussing on factors that influence the injury severity and finding injury mechanisms of struck side occupants.

3. STATISTICAL ANALYSIS OF SIDE TO POLE IMPACTS

3.1. Relevance of Side to pole impacts

Beside the frontal impact the side impact is the most common impact type. In GIDAS 16% of the passenger cars have single side impacts in CCIS 18.4% (fig. 1). The passenger car side impacts are dominated by car-to-car impacts. Car side to pole impacts are relatively infrequent events with a share of less than 2% in both databases.

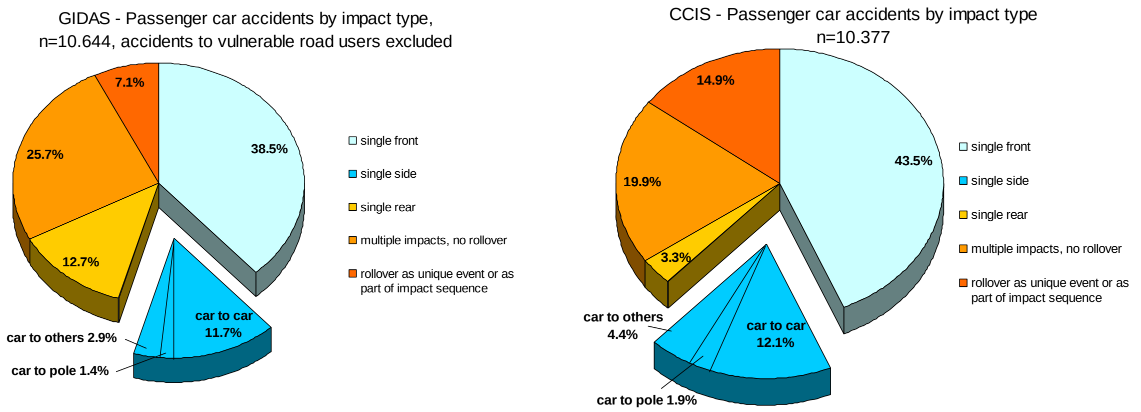

Figure 1: Passenger Car Accidents by Impact Type

However the importance of car side to pole impacts is significantly increasing with fatal and seriously injured occupants. Single side to pole impacts have the highest proportion of MAIS3+ injured occupants compared to the other accident types (fig. 2).

The obvious difference in the injury severity distribution between GIDAS and CCIS with a higher share of MAIS3+ injured occupants is caused by the difference in sample criteria of the studies.

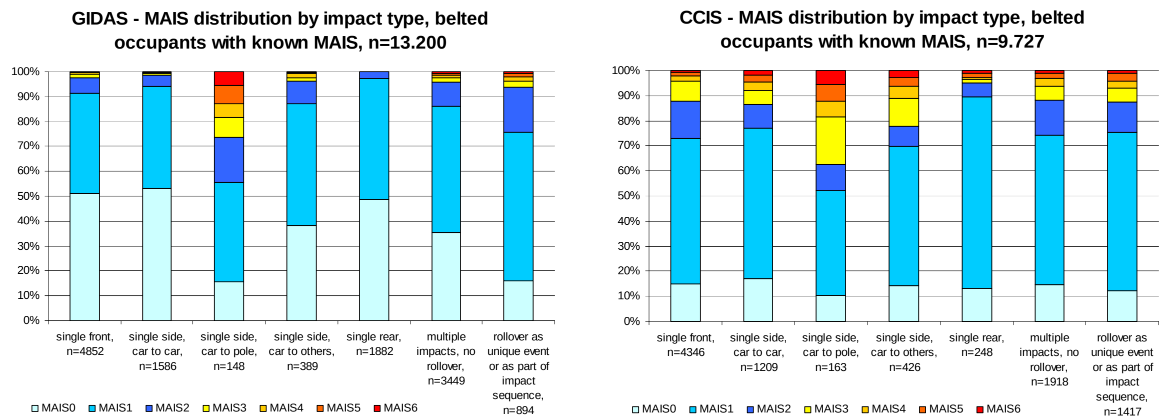

Figure 2: MAIS Distribution by Impact Type, Belted Occupants only

3.2 Effect of ESC on the Occurrence of Car Side to Pole Impacts

Several studies have already demonstrated the potential of ESC in terms of traffic safety. The list below (tab. 1) provides a brief overview of what has been investigated so far.

Reference	**Estimated traffic safety effect**	**Source of data**
Sferco et al. (2001)	34% reduction of fatal accidents 18% reduction of injury accidents	EACS
Aga and Okado (2003)	35% reduction of single car accidents	ITARDA
Grömping et al. (2004)	44% reduction of loss of control accidents	GIDAS
Lie et al. (2004)	22.1% (± 21) reduction of accidents more efficient on slippery road conditions	Insurance data (Folksam)
Lie et al. (2006)	16.7% (± 9.3) reduction of all injury crash types 21.6% (± 12.8) reduction of fatal and serious crashes more efficient on slippery road conditions	Insurance data (Folksam)
Page and Cuny (2006)	44% reduction of relative risk of ESP pertinent accidents	French national accident census
Farmer (2004)	41% (27-52) reduction of single vehicle crashes involving personal injury	State data System maintained by NHTSA
Langwieder et al. (2003)	25-30% reduction of all car crashes involving personal injury	Several data bases

Table 1: Estimated Traffic Safety Effect of ESC [5]

To further demonstrate the effectiveness of ESC in reducing car to pole impacts GIDAS data were analysed as GIDAS is the only dataset to provide a suitable number of ESC equipped vehicles.

Especially the share of accidents with rollover and pole impacts is definitely lower for cars equipped with ESC compared to cars without ESC.

1.5%/2.8% of the cars (in GIDAS) without ESC have single side/front to pole impacts, for cars with ESC these shares are with 0.6%/1.5% less than half. The share of accidents with rollover is halved as well from 7.5% to 3.8%.

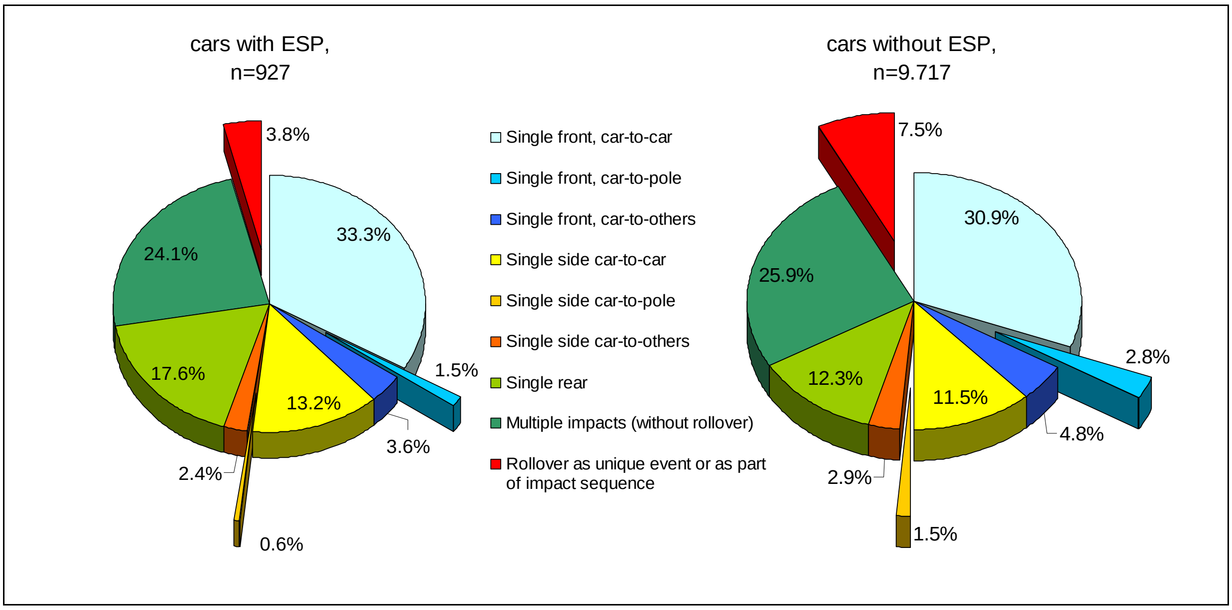

Figure 3: Passenger Car Accidents by Impact Type with and without ESC; accidents to vulnerable road users are excluded (GIDAS)

3.3 Characteristics of Car Side to Pole Impacts

Delta v and Impact Speed

To differentiate the impact severity relative to the injury severity the delta v was analysed on the occupant level. In GIDAS 50% of the occupants in single side to pole impacts receive a delta v less than 35 km/h, in CCIS this 50% rate is reached at 29 km/h (fig. 4). The differences between the values might be caused by the different ways of calculating delta v. This difference is even more remarkable because in contrast the share of MAIS3+ injured occupants in single side to pole impacts is in CCIS with 37.5% clearly higher than in GIDAS 26.4%.

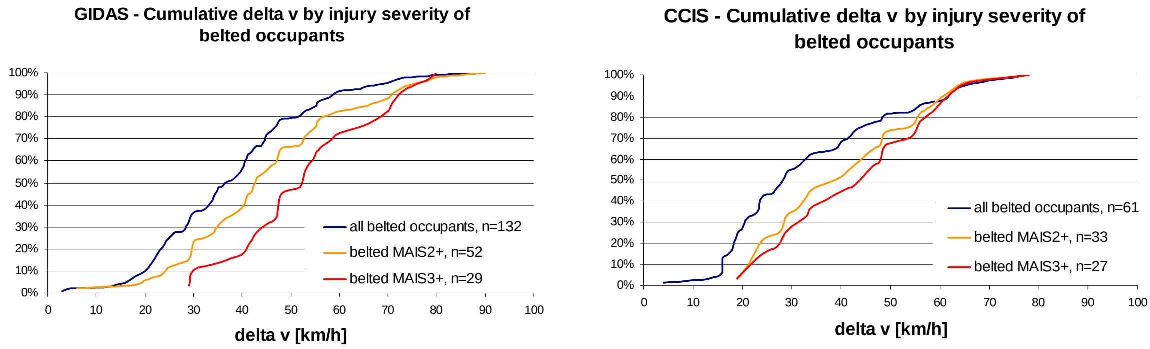

Figure 4: Cumulative Delta v Distribution for Different MAIS Classes in Pole Impacts, Belted Occupants only

The GIDAS database provides also the possibility to analyse the impact speed of the passenger car, due to the full reconstruction of the accident. 50% of all occupants had a side to pole impact with an impact speed below 46 km/h (fig. 5).

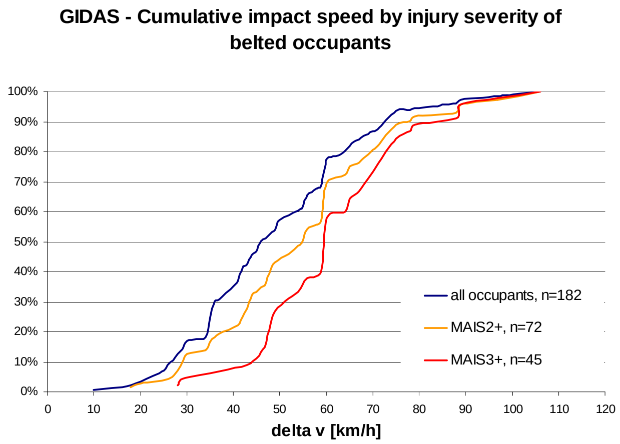

Figure 5: Cumulative Impact Speed Distribution by MAIS Classes in Single Side to Pole Impacts, Belted Occupants only

Impact Force Angle

The CDC direction of principle force with its clockwise differentiation of directions was used to analyse the impact force angle. The most frequent direction of impact force with 40% is perpendicular or 90° ± 15° (3 and 9 o'clock) in both databases (fig. 6), with the majority of impacts to the drivers side (left in GIDAS and right in CCIS).

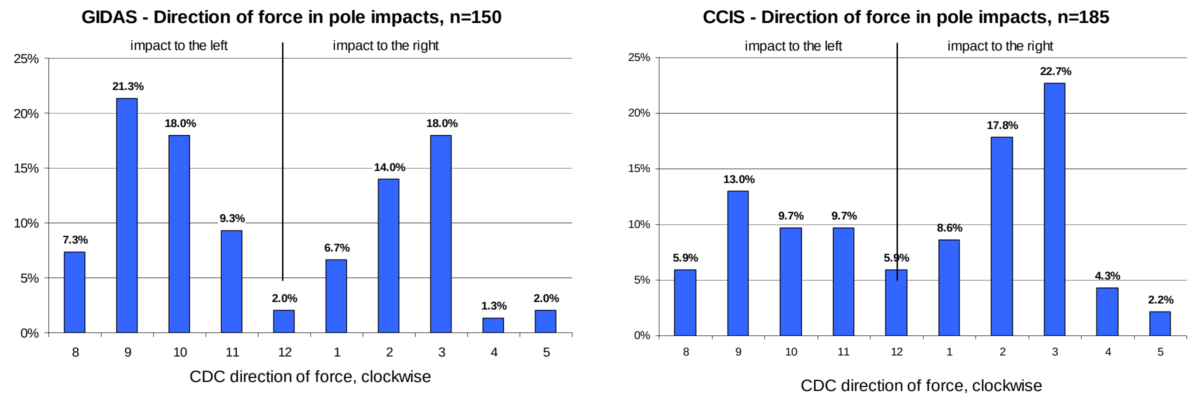

Figure 6: CDC Direction of Force in Single Side to Pole Impacts

The majority of the MAIS3+ injured occupants have also been found in perpendicular ± 15° impacts biased to the drivers side (fig. 7).

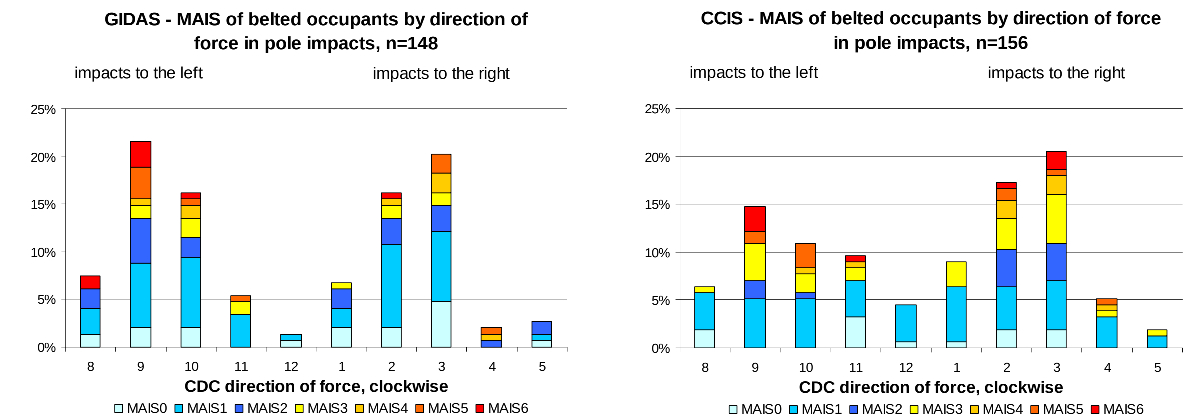

Figure 7 MAIS Distribution by Direction of Force, Belted Occupants only

Damage Area

The by far highest proportion (50%) of all pole impacted passenger cars show damages exclusively in the passenger compartment (fig. 8). Pole impacts affecting the area in front of the A-pillar occur second most (around 20%), impacts behind the C-pillar occur rarely (around 3%).

Severe and especially fatal injuries only occur when the passenger compartment is affected (fig. 9).

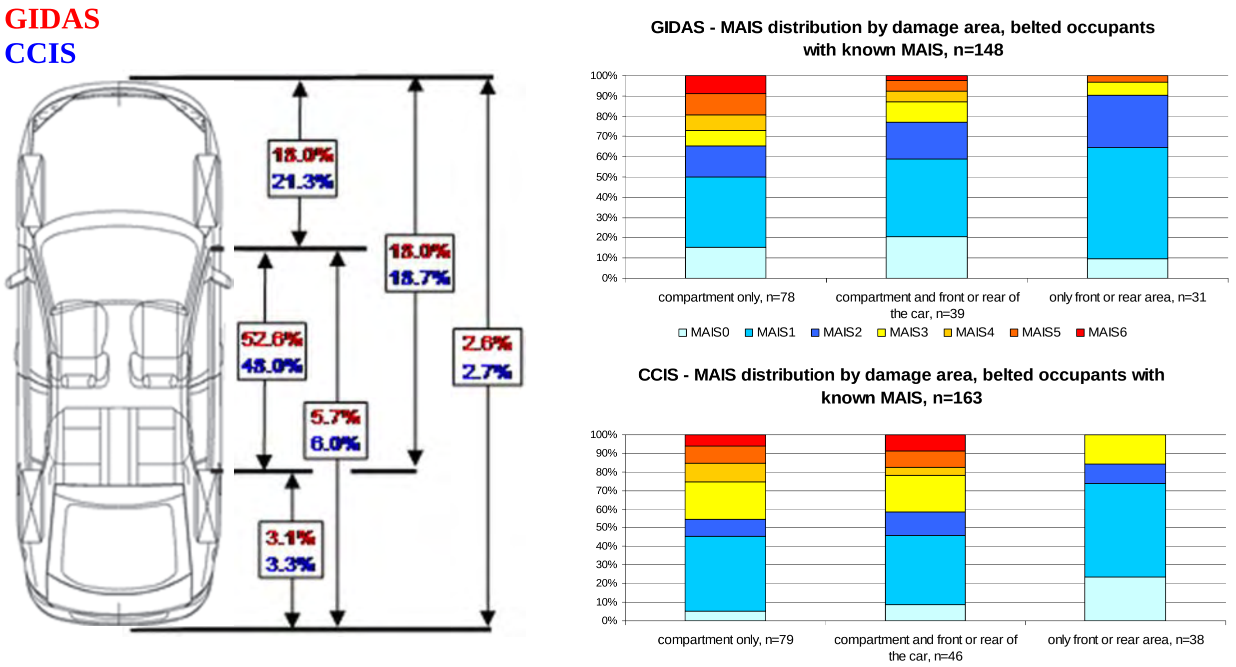

Figure 8 Damage Area in Pole Impacts and MAIS distribution by damage area

Crash weight of the car

In the GIDAS data there seems to be a correlation between MAIS and crash weight of the car, but the numbers of cars in the individual weight groups are very small. In CCIS there is no correlation visible. Finally it can be stated that in side impacts to pole the crash weight of the car has no, or only minor influence on the injury severity (fig. 9).

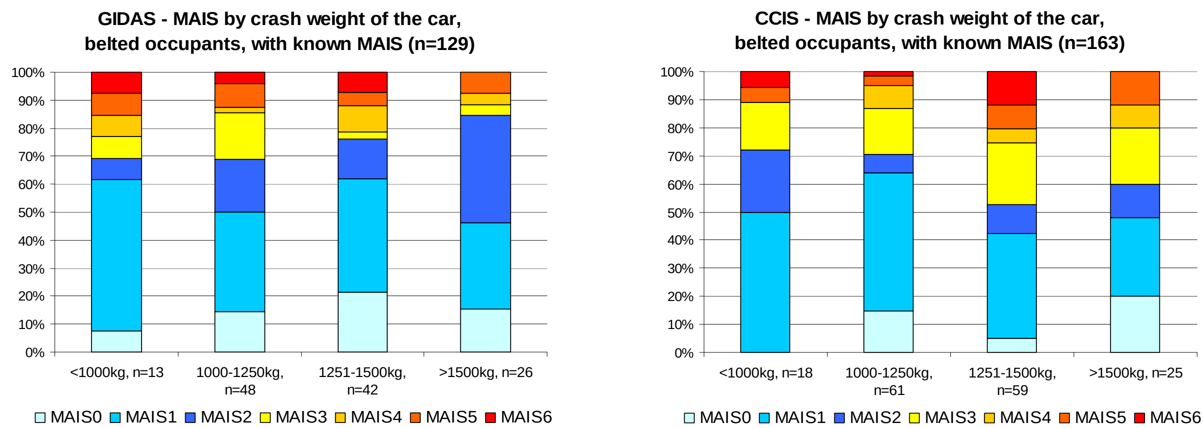

Figure 9 MAIS by Crash Weight of the Car

Pole Diameter

In the GIDAS database 60% of the impacted poles have a diameter less than 40 cm. In CCIS nearly one half of the single side to pole impacts happen to poles of this size.

GIDAS provides also more detailed information on the distribution of pole diameters. Biggest group with more than 25% are the poles with diameter between 21 and 30 cm.

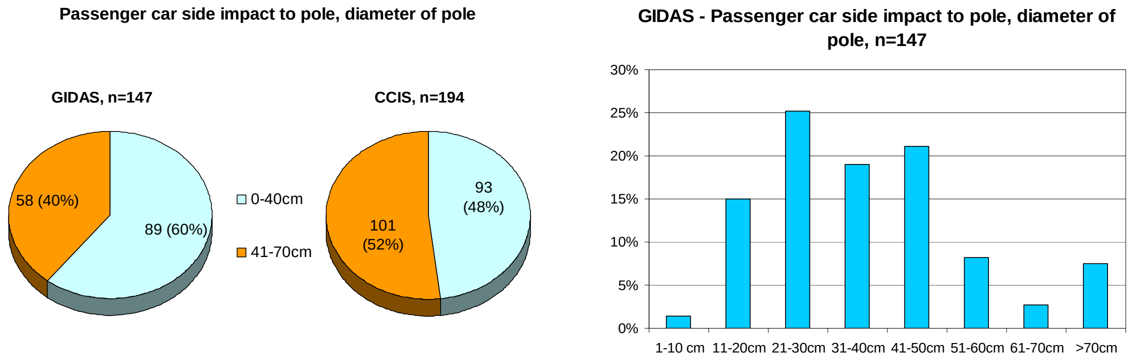

Figure 9 Diameter of Pole in Car to Pole Impacts

3.4 Occupant Parameters

Age

The share of young drivers is significantly higher in car to pole impacts compared to all other side impacts. Clearly more than 40% of all drivers in pole impacts are younger than 26 years. In other side impact configurations this share is around 25% (fig. 10). Side to pole impacts are generally single vehicle accidents. Other studies show that especially in this type of accident young drivers are overrepresented [6].

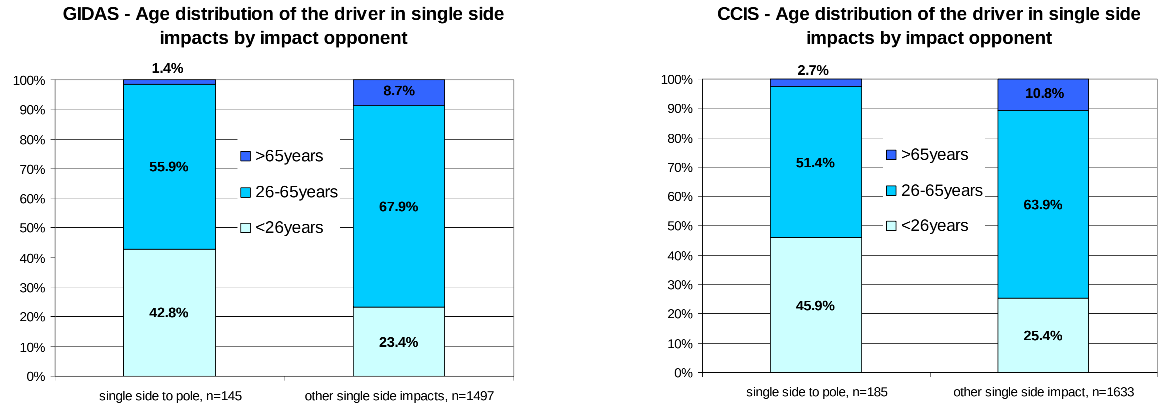

Figure 10 Driver Age Distribution in Side Impacts and Pole Impacts of Cars

Injuries per Body Region in Pole Impacts

Looking at all injuries, occupants received in car side to pole impacts the head, the thorax and the extremities account for more than 80% of the injuries (fig. 14). Slight injuries are dominated by the head and the extremities. The combined share is about 75%. For AIS3+ injuries the share of injuries to the thorax rises to 32% in GIDAS and 38% in CCIS.

The share of abdominal injuries is 4% in GIDAS for slight and severe injuries. In CCIS abdominal injuries have a share of 11% for AIS1&2 and 5% for AIS3+ injuries.

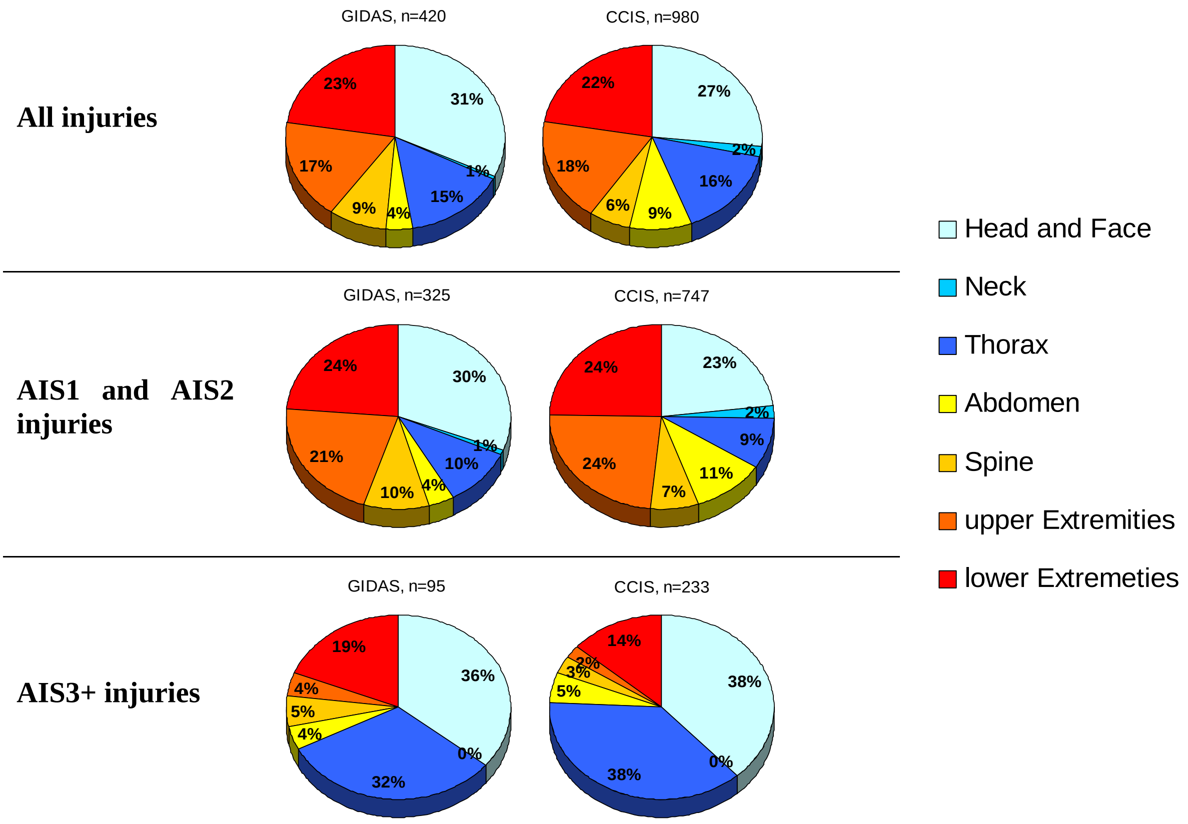

Figure 12 Injury Distribution per Body Region in Pole Impacts

4. CASE BY CASE ANALYSIS

Complementary to the statistical analysis on all car side to pole impacts a case-by-case analysis was carried out. It is focussed on a detailed in-depth-investigation by using the original accident files, the accident images, injuries and its causation factors and the vehicle deformation pattern.

Data sample for case by case analysis

The data sets on side to pole impacted cars is based on the data that was used for statistical analysis. In addition the case by case analysis is focussed on struck side occupants in cars registered 1998 onwards resulting in a sub sample with **n=26 cases out of the GIDAS data base and n=97 cases out of CCIS**.

Methodology of case by case analysis

For the analysis the car exterior is classified into a matrix system A, B, C, and D (fig. 13). The area A describes the area in front of the A-pillar, B describes the area between A- and B-pillar, C the area between B- and C-pillar and D the area in the rear of the car. The principle direction of force (fig. 13) was classified into rectangular (R) and oblique from the front (F) and oblique from the rear (B).

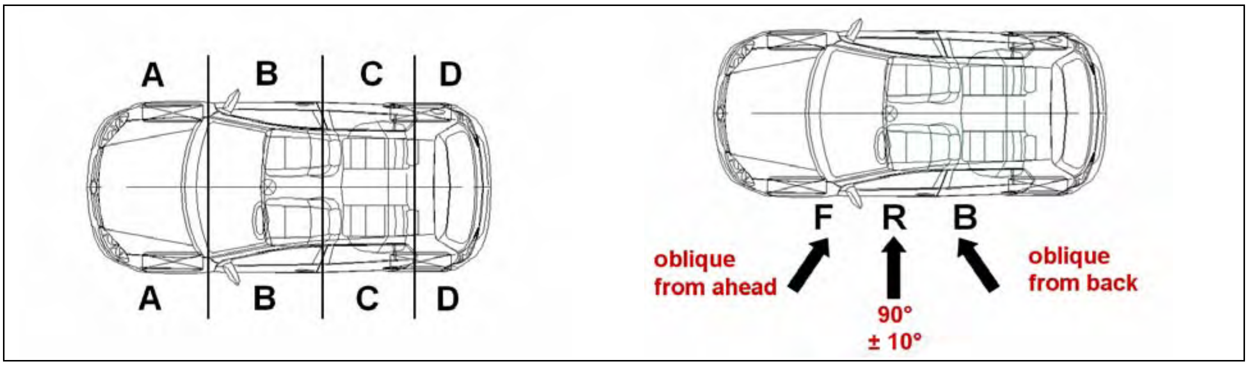

Figure 13: Definition of the 4 impact areas and principle direction of force

The frequency for these different classifications in side to pole impacts is given in the figures below (fig. 14). The most frequent impact area is the B-area with 44.5%. The most frequent impact direction is in oblique direction from the front in nearly the half of all cases (48.2%). A rectangular impact ±10 degree can be seen in 40.9%. Impacts from the rear direction occur rarely (10.9%).

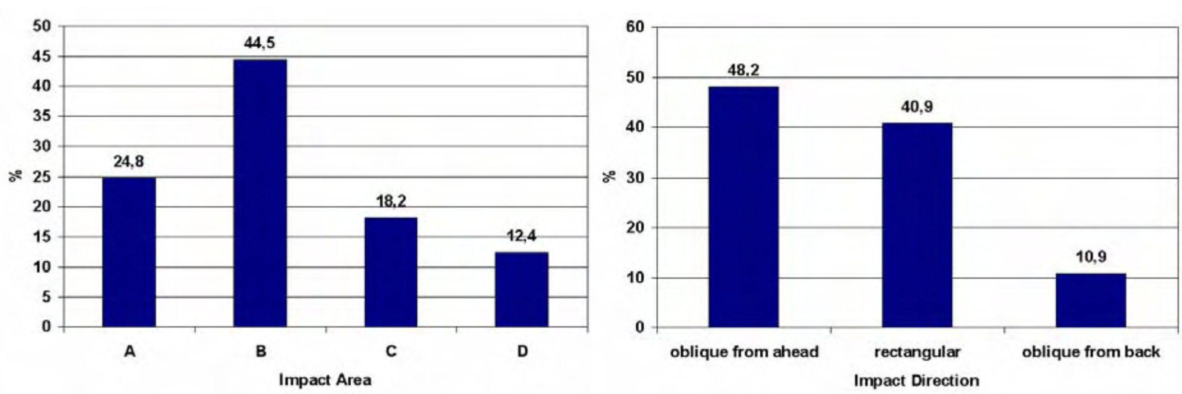

Figure 14: Frequencies of impact area and impact direction

The most frequent combinations of impacts area and direction are AF, BF, BR and CR (fig. 19), together they cover 68% of all situations. Around 19% of all impacts occur in the area between A- and B-pillar with force direction from front respectively perpendicular direction. Focussing on seriously injured struck side occupants (MAIS3+) more than the half had an impact from the frontal or perpendicular direction to the B area. Impacts to the front or the rear of the car occur rarely.

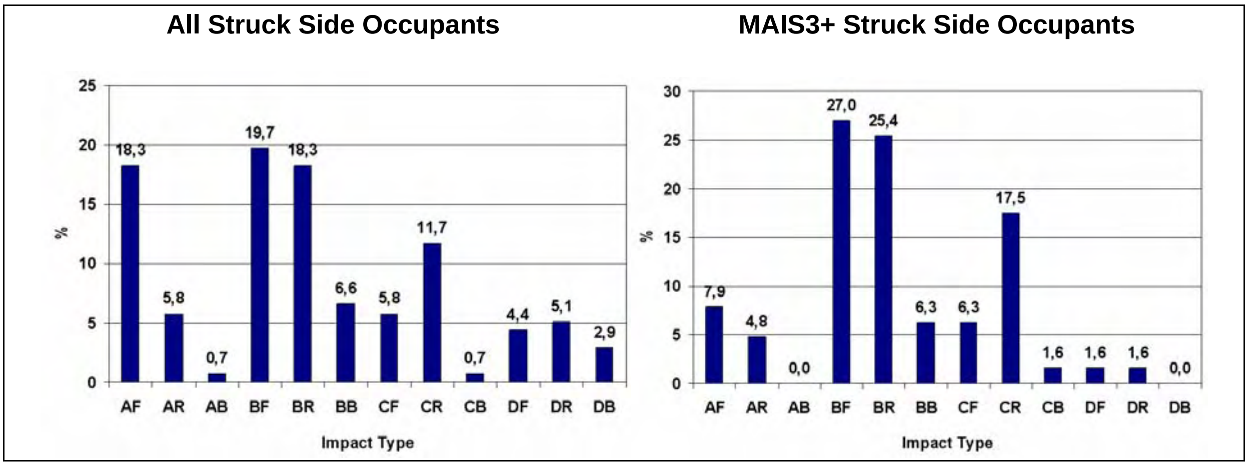

Figure 19: All Struck Side Occupants, Combinations of impact area and direction

Statistical Analysis of Car-Side-to-Pole-Impacts within the Case by Case Analysis

Ordinal logistic regression

To identify the relevant factors for the MAIS of the struck side occupants an ordinal logistic regression was carried out. As potential factors/variables the delta v, year of first registration, impulse angle, depth of deformation, country, diameter of pole and damage location were used.

In Table 2 the p-values for the Chi square test are given for the correlation of the variables and MAIS, respectively MAIS in individual body regions. According to this, delta v has significant influence on the overall MAIS, on the injury severity in head and abdomen. The depth of deformation has significant influence on the injury outcome of the extremities, and the damage area on MAIS and the injury severity in thorax and lower extremities. The impulse angle has only significant influence on MAIS, the pole diameter only to the head injury severity and country only to the injury severity of the lower extremities. Having only cars registered 1998 onwards presented in this sample the variable "year of first registration" has no significant influence on the injury severity levels.

Variable	Degree of Freedom	MAIS	Head MAIS	Thorax MAIS	Abdomen MAIS	Upper Extremi-ties MAIS	Lower Extremi-ties MAIS
Delta-v	1	0.0002	0.2836	0.0011	0.0022	0.0590	0.0547
Year of first Registration	1	0.2024	0.5139	0.3297	0.2341	0.5039	0.1382
Impulse Angle	1	0.0242	0.5742	0.2418	0.8825	0.0858	0.6958
Depth of Deformation	1	0.2716	0.5308	0.1071	0.5839	0.0462	0.0213
Country	2	0.3494	0.6573	0.8830	0.3151	0.1845	0.0122
Pole Diameter	1	0.9178	0.0286	0.6395	0.4471	0.6758	0.6684
Damage Area	4	0.0221	-	0.0341	0.1619	0.2379	0.0010

Table 2: p-values for the ordinal logistic regression analysis, correlation of given variables and injury severity of struck side occupants.

CART-analysis

To get more information on the influence of delta-v on the injury outcome a Tree- or CART-Analysis was carried out. It gives more information on the thresholds of a variable (delta v) where changes in the target parameter (MAIS) are visible.

First there is an upper change of significance at a statistically evaluated delta-v of 61.5 km/h describing an over proportional significance to high injury severity grades. Above this delta-v value the injury severity is increasing rapidly, explained by the severe deformation of the cars similar to catastrophic pattern. Next level of remarkable change can be found for a statistically evaluated delta-v of 27.5 km/h. The CART-analysis gives the indication that real world side to pole impacts have a significant level of accident severity at 27.5 km/h, where the injury severity is expected to increase over proportional (Figure 20).

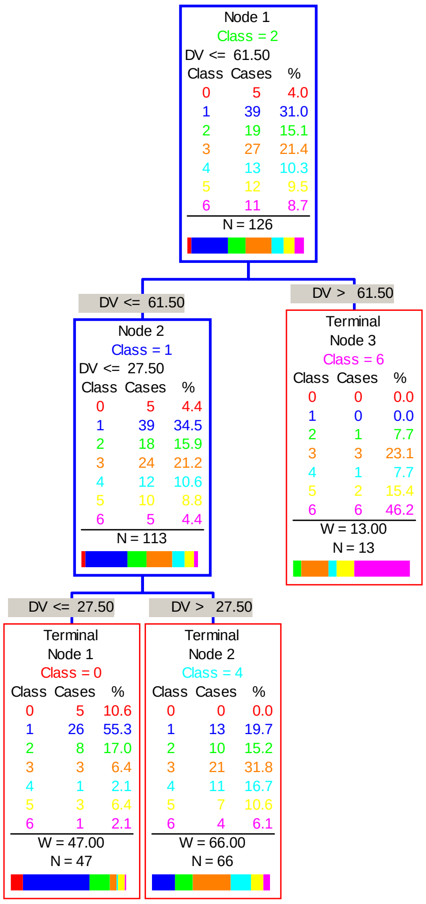

Figure 20: CART-analysis of car side impacts with poles

CONCLUSION AND DISCUSSION

From this study the following conclusion can be drawn:

- Pole impacts are relatively rare events compared to other impact types. But the importance of side to pole impacts increases by focussing on seriously injured occupants (MAIS3+).
- Cars equipped with ESC show a by far lower share of car side to pole impacts and in consequence have reduced numbers of injured car occupants. Currently 10% of the vehicles in the GIDAS dataset were equipped with ESC. In the future the higher market penetration of ESC will further reduce the number of car side to pole impacts.
- In GIDAS 50% of the occupants in single side to pole impacts receive a delta v less than 35 km/h, in CCIS this 50% rate is reached at 29 km/h. This is in contrast to the injury severity distribution in both studies. The share of MAIS3+ injured occupants in single side to pole impacts is in CCIS with 37.5% clearly higher than in GIDAS 26.4%.
- The most frequent direction of impact in car side to pole impacts is perpendicular (90° ±15°). Damaged passenger compartments causing the vast majority of severe and fatal injuries.
- The injury outcome does not correlate with the vehicle mass.
- The highest proportion with approximately 50% of all car side to pole impacts happen to poles with a diameter of less than 40 cm (CCIS 48% and GIDAS 60%).
- Head and thorax injuries of the occupants are of highest importance when looking at severe and fatal injuries. Their share is above 70% of all MAIS 3+ injuries.
- Delta-v can be identified as most significant influence factor for MAIS.
- At a delta-v value of 27.5 km/h the injury severity is expected to increase over proportional.

One of the critical points in the discussion of future side impact testing criteria is the test speed. In the present study the MAIS distribution and the delta v distribution give a different picture. The injury severity level in CCIS is much higher than in GIDAS, but the impact severity level, defined by delta v, is lower than in GIDAS. The given values of delta v should and could not be used as absolute figures. The origin of the delta v, full accident reconstruction in GIDAS and damage based calculation in CCIS, makes it difficult to compare this value directly with the measured delta v in crash tests.

However a comparison between individual cases and a categorisation of the cases into cases of comparable severity within the individual in-depth study is possible, but a direct comparison of the two in-depth databases on delta v level is not possible.

ACKNOWLEGEMENTS

For the present study accident data from GIDAS (German In-Depth Accident Study) was used. GIDAS is the largest in-depth accident study in Germany.

The data collected in the GIDAS project is very extensive, and serves as a basis of knowledge for different groups of interest. Due to a well defined sampling plan, representativeness compared to the federal statistics is also guaranteed. Since mid 1999, the GIDAS project has collected about 2000 cases on-scene of the accident per year in the areas of Hannover and Dresden. GIDAS collects data from accidents of all kinds and, due to the on-scene investigation and the full reconstruction of each accident, gives a comprehensive view on the individual accident sequences and its causation.

The project is funded by the Federal Highway Research Institute (BASt) and the German Association for Research in Automobile Technology (FAT), a department of the VDA (German Association of the Automotive Industry). Use of the data is restricted to the participants of the project. However, to allow interested parties the direct use of the GIDAS data, several models of participation exist. Further information can be found at http://www.gidas.org.

This paper uses accident data from the United Kingdom’s Co-operative Crash Injury Study (CCIS) collected during the period 1996 to 2006 (Phases 6z, 7o and 8c).

Currently CCIS is managed by the Transport Research Laboratory (TRL Limited), on behalf of the United Kingdom’s Department for Transport (DfT) (Transport Technology and Standards Division) who fund the project along with Autoliv, Ford Motor Company, Nissan Motor Company and Toyota Motor Europe. Previous sponsors include Daimler Chrysler, LAB, Rover Group Ltd, Visteon, Volvo Car Corporation, Daewoo Motor Company Ltd and Honda R&D Europe (UK) Ltd.

Data was collected by teams from the Birmingham Automotive Safety Centre of the University of Birmingham; the Vehicle Safety Research Centre at Loughborough University; TRL Limited and the Vehicle & Operator Services Agency (VOSA) of the DfT

Further information on CCIS can be found at http://www.ukccis.org.

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Lateral Impacts in Australia, Germany and the United States

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Abstract – Side impacts, both nearside and farside, have been indicated by research to be responsible for a large proportion of serious injuries from road crashes. This study aimed to compare and contrast the characteristics of nearside and farside crashes in Australia, Germany and the U.S., using the ANCIS, GIDAS and NASS/CDS in-depth-databases, in order to establish the impact and injury severity associated with these crashes, and the types of injuries sustained. The analyses revealed some interesting similarities, as well as differences, between both nearside and farside crashes, and the emergent trends between the three investigated countries. More specifically, it was indicated that whilst the severity of injury sustained in nearside crashes was slightly greater overall than that found for farside crashes, careful consideration of struck and non-struck side occupants must be made when considering aspects such as vehicle design and occupant protection.

NOTATION

AIS Abbreviated Injury Scale: An internationally-recognised scale for coding traumatic injuries, with AIS severities ranging from 1 (minor) to 6 (catastrophic).

CDC Collision Deformation Code: A coding system for vehicle collision damage, whereby the first two digits represent the principal direction of force (PDOF) on a clock face and the last digit the extent of damage (1 minor to 9 severe). The other digits indicate the location of damage on the vehicle.

Delta-V Vector difference between impact velocity and separation velocity.

EBS Equivalent Barrier Speed: This is the approximate Energy Equivalent Speed (EES) of a vehicle with respect to a 90° fixed, rigid and flat barrier. EES is the speed at which a vehicle would need to contact any fixed object in order to yield the same observed residual crush.

ISS Injury Severity Score: A measure of overall injury severity. Equal to the sum of squares of the highest AIS in each of the three most severely injured ISS body regions (head, face, chest, abdomen, extremities and external). Ranges from 1-75, with any AIS 6 injury automatically resulting in a score of 75.

MAIS Maximum AIS: The highest AIS score in any body region.

INTRODUCTION

Side impact collisions are a particularly severe and harmful type of crash for vehicle occupants. Depending on the severity of the crash, side impacts are involved in up to 35 percent of road trauma and are particularly noteworthy in fatal crashes [1,2]. Nearside impacts are commonly associated with side impact trauma, yet farside occupants can also be seriously injured in these crashes [1,3]. While some inroads have been made in improved frontal crash protection for occupants, the same cannot be said about side impacts and suitable countermeasures to address this trauma.

Furthermore, while there has been some research attention and government regulations addressing the protection of nearside (or struck side) occupants of the vehicle, there has been much less emphasis placed on farside (or non-struck side) occupants [3]. Farside occupants, for example, have been found to account for 43 percent of seriously injured persons and 30 percent of the Harm in U.S. side impact crashes, using NASS/CDS and FARS data from 1997 to 2002 [4]. In addition, Gabler and colleagues [5] also observed, using 1993 to 2002 Australian MUARC in-depth data (MIDS), that farside occupants accounted for 20 percent of the seriously injured persons and 24 percent of the Harm in Australian side impact crashes.

Aims of study

Given the level of road trauma associated with side impact crashes for occupants in both nearside and farside crashes, the aim of this study was to compare the characteristics of these two crash types, primarily in regards to their crash and injury severity, as well as the types of injuries that are sustained in these crashes and their sources. In addition, given the likely differences across continents, the study also set out to compare side impact in-depth crash data from Australia, Germany and the U.S. to examine trends of lateral impact between nations.

Database investigated

Three databases were available to investigate side impact crashes in this study – the Australian National Crash In-depth Study (ANCIS), the German In-Depth investigation Accident Study (GIDAS) and the U.S. National Automotive Sampling System Crashworthiness Data System (NASS/CDS). A brief description of these databases follows.

ANCIS has collected retrospective in-depth real-world crashes cases since 2000, with more than 500 cases collected to-date across Victoria and New South Wales in Australia. It is a collaborative research program involving the automotive manufacturing industry, State and Federal Government agencies, the insurance industry and Australian automobile organisations. The main entry criterion is severe crashes whereby at least one occupant has been hospitalised as a result of the crash. Participants in the study are administered a structured interview, their medical records examined, the crash vehicle inspected and photographed, and the crash site inspected in detail. This retrospective examination of the crash enables a '*best evidence*' approach to be taken in determining the crash circumstances and sources of occupant injury [6,7]. There were 111 nearside and 30 farside cases available for analysis in the ANCIS system from 2000 to 2007.

GIDAS is a joint initiative between FAT (Forschungsvereinigung Automobiltechnik or Automotive Industry Research Association) and BASt (Bundesanstalt für Straßenwesen, the Federal Road Research Institute), that began in July 1999. The Medical University of Hannover and the Technical University of Dresden have specialist teams that go directly to the crash scene to collect the necessary information for completing detailed accident reconstructions, and medical data about how the crash victims were injured and treated is also collected. A target of 1000 accidents per year has been set as the basis for performing future evaluations, with a statistical sample plan used for selecting crashes for investigation. Various aspects of the pre-crash, crash, and post-crash phases are collected and then compiled into the database which can be seen as representative for the situation of traffic accidents with injured persons in Germany [8]. There were 88 nearside and 51 farside cases available for analysis in the GIDAS system from 2000 to 2007.

NASS/CDS represents a sample of police-reported crashes that occur in the U.S. every year. It is a nationwide crash data collection program sponsored by the U.S. Department of Transportation, and is operated by the National Center for Statistics and Analysis (NCSA) of the National Highway Traffic Safety Administration (NHTSA). NASS/CDS provides an automated, comprehensive national traffic crash database. The data collected from each of the Primary Sampling Units (PSU's) across the U.S. are weighted to represent all police-reported motor vehicle crashes occurring during the year involving passenger cars, light trucks and vans that were towed due to damage. Detailed information regarding the crash, the vehicle(s) involved and its occupant(s) are collected from a variety of sources, including police and hospital reports [9]. There were 351 nearside and 159 farside cases available for analysis in the NASS/CDS system from 1997 to 2006.

Study challenges

Anyone who has ever attempted a comparative study of databases from different regions and from different data collection agencies will appreciate the challenges that lay in store for the analyst. First, entrance criteria for the study often varies, the level of detail collected by the various data collection agencies differs, the motivation for the study may be quite different and the representativeness of the data sample can be quite unique for the database under investigation.

Nevertheless, these data have the potential to highlight important details of crashes not available elsewhere and can provide additional information on crashes. Causal information is more likely from these samples as many mass databases lack sufficient detail to illustrate these important features for identifying new opportunities for injury intervention. Moreover, understanding the variations of crash types and injuries to occupants across regions is highly important for governments and the automotive industry in attempting to optimise road safety.

To overcome any sampling bias, data collection agencies often *weight* each of the cases they collect in terms of how representative they are across the whole system. However, even this attempt to make these sample data more representative of the whole system is complex and cannot always be taken to be an accurate reflection of the extent of crashes in their regions. One should question the merits of weighting small samples, as the resultant outcome can be quite misleading. In addition, weighting criteria, usually based on large state and national crash statistics, varies considerably across time and often involves various estimates, thereby potentially introducing another bias in interpretation.

Data from these three countries were chosen for the comparative study as they seemed to be reasonably consistent in their data systems and legitimate to compare. For reasons expressed above, it was decided to conduct the analysis using unweighted data. However, it must be stressed that many of the findings of difference could be explained by differences in the data collection procedure and care needs to be taken in interpreting these findings. Furthermore, not all of the reported variables were directly corresponding between all three datasets, although every effort was made to utilise the most similar variable available.

METHOD

Inclusion criteria

In each of the three databases, there was a number of selection criteria applied to these data, so that the key characteristics of the databases were as closely matched as possible for comparative purposes. These criteria were as follows:

- Side impacts only (identified using the CDC), with nearside or farside clearly stipulated depending on the seating position of the vehicle occupant;
- The case must have been hospitalized for at least one day;
- The case must have been wearing a seat belt at the time of the crash;
- The crash must have involved a passenger vehicle;
- The crash vehicle model year should be from approximately the mid-1980’s to the present

Procedure

Each of the three databases were analysed separately, following an agreed analysis strategy. The ANCIS and NASS/CDS databases were analysed by researchers from the Monash University Accident Research Centre while analysts from the Medical University of Hannover provided similar aggregate findings from the GIDAS database. In analysing these data, an emphasis was placed on identifying the crash and occupant injury severity of both nearside and farside impacts, including identifying the injury contact sources and the prevalence of injury for the various body regions. An attempt was also made to examine whether there were any significant statistical differences between the databases. These analyses are not presented in the Results section; however, key differences between the three databases are highlighted in the Discussion.

RESULTS

The findings from this analysis were separated into the following categories: occupant and vehicle characteristics; the crash environment; and injuries and source of injury, and are reported individually as follows.

Occupant & vehicle characteristics

Various results from the analysis of the occupant and vehicle characteristics of the three investigated databases are presented below in Tables 1 to 4.

Table 1: Occupant characteristics across the ANCIS, GIDAS & NASS/CDS databases

Vehicle Damage	Nearside Crashes			Farside Crashes		
	ANCIS	GIDAS	NASS	ANCIS	GIDAS	NASS
Drivers	79.3%	67.7%	73.5%	73.3%	59.5%	64.8%
Front passengers	18%	18.5%	22.5%	23.3%	28.7%	27.7%
Rear passengers	2.7%	13.8%	3.9%	3.3%	11.7%	7.5%
Age (years)	39.2	39.6	43.1	44.4	35.5	46.6
Height (cm)	171.3	172.3	168.8	170	170.7	164.4
Weight (kg)	73.5	75.1	73.5	69.4	76.9	69.2
Male gender	56.8%	54.6%	41.6%	60%	45.7%	69.8%

These data are remarkably similar across the three databases. Of particular note, there were many more rear passengers in the GIDAS database, possibly because of the On-The-Spot procedure used by them, compared with the retrospective nature of the other two databases. There was also more female drivers in the NASS/CDS data compared to the others.

Table 2: Extent of vehicle damage across the ANCIS, GIDAS & NASS/CDS databases

Vehicle Damage	Nearside Crashes			Farside Crashes		
	ANCIS	GIDAS	NASS	ANCIS	GIDAS	NASS
Driver-side damage	73.9%	71.9%	76.3%	33.3%	33.5%	28.6%
Passenger-side damage	26.1%	28.1%	23.7%	66.7%	66.5%	71.4%
Damage Location – P*	47.7%	40.8%	13.1%	40.0%	38.1%	14.5%
Damage Location – Y*	28.8%	24.7%	43.0%	33.3%	24.7%	42.1%
Damage Location – Z*	11.7%	11.1%	13.7%	10.0%	11.1%	14.5%
Damage Location – D*	6.3%	4.5%	12.8%	3.3%	8.6%	14.5%
PDOF - perpendicular	35.1%	32.0%	39.7%	33.3%	42.5%	13.3%
Maximum Crush (mm)	452	375	450	542	369	431

* As coded by the Collision Damage Classification (CDS) of the NASS/CDS coding system

The results of Table 2 show good similarity between these data across the 3 databases. Of particular note, NASS/CDS crashes involved fewer pure compartment impacts and more partial overlaps than either ANCIS or GIDAS. The substantial reduction in the number of perpendicular impacts highlights the importance of oblique impacts for injury to farside occupants in the U.S. database, over the others.

Table 3: Average crash severity and pre-crash speed across the 3-databases

Average Crash Severity & Pre-crash Speed	Nearside Crashes			Farside Crashes		
	ANCIS	GIDAS	NASS	ANCIS	GIDAS	NASS
EBS (km/h) – EES (GIDAS)	32.3	35.9	33.8	39.6	39.6	37.8
Delta-V (km/h)	31.2	35.2	31.1	30.3	37.1	33.2
Approx. pre-crash speed	37.9	60.2	40.2	39.2	62.0	44.5

Table 3 shows good similarity between all data on the crash severity measures, although estimates of pre-crash speed tended to be higher for GIDAS than either ANCIS or NASS/CDS.

Table 4: Collision partner across the ANCIS, GIDAS & NASS/CDS databases

Collision Partner	Nearside Crashes			Farside Crashes		
	ANCIS	GIDAS	NASS	ANCIS	GIDAS	NASS
Passenger car	27.0%	39.2%	95.9%*	43.3%	44.2%	97.2%*
Tree or pole	36.0%	38.8%	3.1%	40.0%	30.9%	2.1%
Other vehicle	21.6%	14.6%	-	13.3%	20.7%	-
Other	15.3%	7.4%	0.9%	3.3%	4.2%	0.7%

* NASS/CDS did not distinguish between vehicle types for this variable; hence, these figures represent all vehicle types

It was not possible to fully compare the data from the three databases on collision partners from these data. Of particular note, the lack of tree or pole collisions in NASS/CDS crashes is a bit surprising, given the frequency of these crash types in ANCIS and GIDAS.

Summary: these findings show remarkable similarity across most of the measures analysed. Of some concern was the apparent lack of pole collisions in the U.S. database, which might reveal a bias in the sample to these crash types. The increase in partial overlaps, combined with fewer perpendicular crashes in the NASS/CDS data highlights the importance of considering oblique side impact collisions in measures aimed at protecting farside occupants in these crashes.

The crash environment

The environmental conditions that existed at the time of these nearside and farside crashes in the three databases are analysed in Tables 5 through to 10 below.

Table 5: Crash location across the ANCIS, GIDAS & NASS/CDS databases

Crash Location	Nearside Crashes			Farside Crashes		
	ANCIS	GIDAS	NASS*	ANCIS	GIDAS	NASS*
Urban	66.7%	46.8%	-	63.6%	52.2%	-
Rural	22.8%	53.2%	-	36.4%	47.8%	-
Mixed	10.5%	0.0%	-	0.0%	0.0%	-

* NASS/CDS does not provide information regarding whether the crash occurred in an urban or rural area

The under-representation of rural crashes in ANCIS, compared to GIDAS reflects differences in the sample strategy behind these two data collection activities. This is likely to be the result of the on-the-spot nature of GIDAS, compared to the retrospective nature of ANCIS, as well as limits imposed on travel distance in the ANCIS study. Clearly, ANCIS needs to consider ways of increasing its rural crash population to ensure it is more representative of all Australian crashes.

Table 6: Road class of crashes across the ANCIS, GIDAS & NASS/CDS databases

Road Class	Nearside Crashes			Farside Crashes		
	ANCIS	GIDAS	NASS	ANCIS	GIDAS	NASS
Mid-block	50.9%	50.4%	-	54.5%	56.9%	-
Crossing	42.1%	27.0%	-	36.4%	28.1%	-
Junction	0.0%	18.9%	-	0.0%	15.0%	-
Roundabout	7.0%	2.8%		9.1%	0.0%	
Undivided road	-	-	74.6%	-	-	81.1%
Divided road	-	-	17.1%	-	-	11.9%
One-way road	-	-	8.3%	-	-	6.9%

It was not possible to obtain data on road class to compare NASS/CDS with the other two databases, given that this database only specifies whether the crash occurred on a divided or undivided road.

However, the other two databases appear to have similar distribution of mid-block and crossing crashes, although there were some variations for junction and roundabout collisions. It is also worthy of note, however, that this variable was coded slightly differently between the ANCIS and GIDAS databases (e.g. ANCIS does not specify junctions), making direct comparisons slightly difficult.

Table 7: Road topography of crash sites across the ANCIS, GIDAS & NASS/CDS databases

Road Topography	Nearside Crashes			Farside Crashes		
	ANCIS	GIDAS	NASS	ANCIS	GIDAS	NASS
Flat surface	60.5%	99.0%	79.2%	43.8%	100%	83.0%
Uphill grade	23.3%	1.0%	12.3%	25.0%	0.0%	8.8%
Downhill grade	12.8%	0.0%	8.0%	25.0%	0.0%	6.9%

There was little consistency in road topography across the three databases. GIDAS cases in particular predominantly involved flat roads, whereas the others (particularly ANCIS) had more uphill and downgrades. This may reflect differences in sampling strategies, especially across urban/rural crash locations.

Table 8: Road curvature at crashes across the ANCIS, GIDAS & NASS/CDS databases

Road Curvature	Nearside Crashes			Farside Crashes		
	ANCIS	GIDAS	NASS	ANCIS	GIDAS	NASS
Straight road	59.6%	79.9%	94.3%	54.5%	83.0%	96.9%
Curved bend	40.4%	20.1%	5.7%	45.5%	17.0%	3.1%

Straight roads were more predominant among GIDAS and NASS/CDS crashes, compared to the higher distribution of curved roads in the Australian sample.

Table 9: State of road surface across the ANCIS, GIDAS & NASS/CDS databases

Road Surface	Nearside Crashes			Farside Crashes		
	ANCIS	GIDAS	NASS	ANCIS	GIDAS	NASS
Wet road	40.4%	52.9%	12.5%	28.6%	52.4%	13.5%
Dry road	59.6%	47.1%	87.5%	71.4%	47.6%	86.5%

Of some surprise was the lack of wet roads involved in NASS/CDS cases, compared to the other two. As it is unlikely to reflect differences in weather patterns in this region, this could reflect a bias in the data collection activities in the U.S., and policies behind crash investigation activities between them.

Table 10: Light conditions for crashes across the ANCIS, GIDAS & NASS/CDS databases

Light Conditions	Nearside Crashes			Farside Crashes		
	ANCIS	GIDAS	NASS	ANCIS	GIDAS	NASS
Daytime	40.4%	68.7%	66.7%	42.9%	61.0%	62.3%
Night-time	31.8%	24.0%	30.5%	39.3%	29.9%	33.4%
Other/unknown	27.8%	7.3%	2.8%	17.8%	9.1%	4.3%

There tended to be a higher proportion of night-time crashes among the ANCIS data. As this is a retrospective study, it could also be explained by differences in procedures across the three studies.

Summary - This analysis has highlighted a number of differences in the crash environments between the ANCIS, GIDAS and NASS/CDS cases. For the most part, it seems that these reflect differences in data collection activities, rather than fundamental differences in side impact crashes in the different regions. The degree to which these differences might impact on the other analyses needs further consideration.

Injuries and source of injury

The third and final set of results relate to the injuries, their severity and the major causes of these injuries for occupants injured in nearside and farside crashes for the three databases (ANCIS, GIDAS and NASS/CDS) analysed, as shown in Tables 11 through to 15 below.

Table 11: Injury severity for occupants in Nearside and Farside crashes

Injury Severity	Nearside Crashes			Farside Crashes		
	ANCIS	GIDAS	NASS	ANCIS	GIDAS	NASS
Average ISS	18.7	10.2	15.3	13.7	7.3	9.5
Days spent in hospital	14.4	10.4	6.9	6.4	4.9	4.9

There were differences observed in the injury severity of the occupants involved in the nearside and farside collisions, with the severity of injury from nearside impacts tending to be higher than that for farside crashes. While the GIDAS cases tended to be less severe than the others in terms of the Injury Severity Score, of interest was the fact that most of these crashes had an ISS less than 20 and in many, less than 15, considered to be a critical threshold between minor and the more severe outcomes for patients. Differences in days spent in hospital, while somewhat correlated to threat-to-life, is also likely to reflect differences in hospital policies across the three countries.

Table 12: Total injuries of all severity* for occupants in Nearside and Farside crashes

Vehicle Damage	Nearside Crashes			Farside Crashes		
	ANCIS	GIDAS	NASS	ANCIS	GIDAS	NASS
Head	88.3%	97.7%	122.2%	103.3%	60.8%	99.4%
Face	107.2%	39.8%	99.1%	76.7%	37.3%	73.6%
Neck	12.6%	1.1%	7.1%	6.7%	0%	6.9%
Thorax	126.1%	115.9%	101.7%	66.7%	64.7%	73.6%
Abdomen	66.7%	27.3%	56.4%	70.0%	9.8%	56.0%
Spine	50.5%	79.5%	36.2%	30.0%	58.8%	39.6%
Upper extremity	131.5%	84.1%	97.7%	100.0%	35.3%	79.9%
Lower extremity	188.3%	131.8%	179.2%	110.0%	43.1%	103.1%

* Multiple injuries for each body region included in the analysis

The frequency of injury by body region shown in Table 12 reveal a high number of injuries to the head, face, thorax and extremities in both nearside and farside crashes. Notably though, the frequency of injury for farside crashes was generally less than nearside crashes, particularly for body regions such as the thorax and upper and lower extremities.

Table 13: AIS3+ injuries for occupants involved in Nearside and Farside crashes

Vehicle Damage	Nearside Crashes			Farside Crashes		
	ANCIS	GIDAS	NASS	ANCIS	GIDAS	NASS
Head	16.2%	17.0%	16.5%	20.0%	21.6%	15.1%
Face	3.6%	1.1%	1.1%	0%	0%	0.6%
Neck	1.8%	0%	1.0%	0%	0%	0%
Thorax	37.8%	26.1%	2.3%	16.7%	35.3%	18.9%
Abdomen	9.9%	3.4%	1.9%	3.3%	5.9%	3.8%
Spine	3.6%	2.3%	1.7%	6.7%	2.0%	2.5%
Upper extremity	3.6%	2.3%	1.3%	0%	2.0%	2.5%
Lower extremity	24.3%	17.0%	1.8%	33.3%	27.5%	5.7%

Table 13 shows the more severe (AIS3+) injury distribution of the three databases for both nearside and farside collisions. The pattern of severity is clearer in these data, revealing the predominance of head, chest (thorax) and lower extremity injuries in both nearside and farside crashes. Differences in the absolute numbers can be explained by the differences in crashes reported in the first two sections. However, the pattern of injuries across these databases is clear and illustrates why side impact collisions can be life-threatening and why injury prevention in side impacts should be prioritised.

Table 14: Mean AIS value for occupants injured in Nearside and Farside crashes

Vehicle Damage	Nearside Crashes			Farside Crashes		
	ANCIS	GIDAS	NASS	ANCIS	GIDAS	NASS
Head	2.6	2.2	2.4	2.8	2.3	2.3
Face	1.1	1.1	1.1	1.3	1.3	1.1
Neck	1.5	1.0	1.0	2.0	0	1.0
Thorax	2.5	2.5	2.3	2.4	2.0	1.9
Abdomen	2.1	2.3	1.9	1.7	1.4	1.5
Spine	2.1	1.5	1.7	2.3	1.5	1.7
Upper extremity	1.3	1.3	1.3	1.0	1.5	1.2
Lower extremity	1.9	1.8	1.8	1.2	1.3	1.4

Table 14 again reinforces the findings of the previous two tables. Head, chest, abdominal and spinal injuries had the highest average AIS values in these databases for both nearside and farside crashes.

Table 15: Major sources of injury for occupants injured in nearside and farside crashes across the ANCIS, GIDAS and NASS/CDS databases.

ANCIS – Nearside		GIDAS – Nearside		NASS/CDS - Nearside	
Windscreen	19.8%	Nearside interior	12.7%	Nearside interior	14.8%
Nearside interior	9.0%	Seatbelt system	11.0%	Door h'ware & armrest	14.0%
Nearside B-Pillar	6.3%	Nearside B-Pillar	10.5%	Nearside B-Pillar	10.0%
Front header	6.3%				
Seatbelt system	6.3%				
ANCIS – Farside		**GIDAS – Farside**		**NASS/CDS - Farside**	
Seatbelt system	30.0%	Body motion (whiplash)	18.5%	Seatbelt system	20.1%
Farside B-Pillar	6.7%	Seatbelt system	7.3%	Transmission lever	10.1%
				Farside interior	8.8%

The final analysis in Table 15 illustrates the most common sources of injury across the three databases. While there are some database differences in these major sources, the nearside of the car, the B-Pillar and seatbelt were consistent sources of injury to nearside occupants, while the seatbelt system and the farside of the car (the impacted surface) were the major causes of injury to farside occupants in these crashes.

Summary: The injury analysis showed considerable consistency in the types of injuries most common to nearside and farside occupants in lateral impacts, and clearly illustrates the priorities for injury prevention in side impacts for those seated on both sides of the vehicle. Earlier differences in occupant and vehicle characteristics and the crash environment do not seem to have unduly influenced the injury patterns observed in the three databases, apart from possible differences in absolute numbers.

DISCUSSION

Nearside and farside crashes in the ANCIS database

Overall, there were not many significant differences between nearside and farside crashes in relation to both crash and injury severity within the ANCIS database. More specifically, the conducted analyses indicated that there were no significant variations between the two crash types for variables such as the maximum crush depth, delta-V, the estimated speed prior to the crash, ISS, and the mean AIS for injuries sustained to the various body regions. Significant differences were found, however, for EBS, the number of days spent in hospital and AIS 3+ lower extremity injuries. Whilst the mean EBS was significantly higher for farside crashes, the number of days spent in hospital and the number of AIS 3+ lower extremity injuries were significantly higher for nearside crashes. One possible explanation for this result is that given that ANCIS only involves hospitalized cases, farside crashes may require a higher impact severity in order for hospitalization to occur.

Nearside and farside crashes in NASS/CDS and comparison to the ANCIS database

Within the NASS/CDS database there were several significant differences between nearside and farside crashes, particularly in regards to injury severity. More specifically, the conducted analyses indicated that were significant variations between the two crash types for mean ISS, number of days spent in hospital and MAIS, with near-side crashes obtaining higher scores on average than farside impacts. In addition, when individually investigating the various body regions, it was also found that the mean AIS was significantly higher in nearside crashes for the thorax, abdomen, upper extremity and lower extremity. Further analyses revealed that AIS 3+ (i.e. higher severity) injuries were also significantly more common for the thoracic, abdominal and lower extremity body regions in nearside crashes. In relation to crash severity, however, there were not as many significant differences between nearside and farside crashes, with the only significant difference being a higher mean EBS for farside crashes. Similarly to ANCIS, a possible explanation for this result is that given that only hospitalized cases were selected, farside crashes may require a higher impact severity in order for hospitalization to occur. These results for crash severity also indicate that the higher levels of injury severity that were associated with nearside crashes cannot be attributed to the severity of the crash, given that, if anything, the analysed farside crashes tended to be more severe than the nearside ones.

Overall, there were some similarities, as well as some interesting differences, between ANCIS and NASS/CDS. The two databases were relatively similar in regards to occupant characteristics (i.e. age, height and weight), although female occupants were more prevalent in NASS/CDS for both nearside and farside crashes. The crash vehicle characteristics were also relatively similar (i.e. passenger vehicles with closely corresponding model years), but frontal airbags were more common in the NASS/CDS database. In addition, nearside and farside crashes in NASS/CDS were more likely to occur on dry roads and in during the day-time, with the road also more likely to be level and straight than what was the case in ANCIS. It must also be noted that side impact crashes in NASS/CDS were more likely to involve multiple impacts, as opposed to ANCIS cases, which tended to only involve one impact. NASS/CDS crashes were less likely than ANCIS, however, to involve other objects aside from passenger vehicles as collision partners, such as poles and trees.

In regards to the crash severity of both nearside and farside impacts, there were no significant differences between ANCIS and NASS/CDS, with the investigated variables being crush depth, EBS, delta-V and the approximate speed before the crash. Furthermore, within each of these two databases, EBS was the only crash severity measure to significantly differ between nearside and farside crashes, with a higher mean found for farside impacts. Despite these similarities for crash severity, there were a number of key areas in which the databases differed in relation to injury severity. More specifically, in NASS/CDS, there was a larger discrepancy observed between nearside and farside crashes in terms of injury severity (i.e. with nearside crashes being higher in severity according to ISS, the number of days spent in hospital, MAIS, and the number of AIS 3+ injuries sustained to the thoracic, abdominal and lower extremity body regions) than what was the case in ANCIS. When directly comparing the injury severity levels between ANCIS and NASS/CDS, however, there was not a great deal of difference between the two databases for the mean levels of ISS, number of days spent in hospital and MAIS. For nearside crashes, ISS and number of days spent in hospital were significantly higher in

ANCIS than in NASS/CDS, but there were no significant differences in injury severity between the databases for farside crashes.

The final area of comparison between ANCIS and NASS/CDS was the injury contact sources for nearside and farside crashes. In nearside crashes, the interior surface (right side for ANCIS and left side for NASS/CDS, due to the driving sides being opposite in Australia and the U.S.) was a common contact source in both databases, but the windscreen was much more prevalent in ANCIS, whilst the (left side) hardware or armrest was more common in NASS/CDS. In farside crashes, the seat belt restraint webbing/buckle was the main injury contact source for both databases, although the (left side) B-pillar was more common in ANCIS and the floor or console-mounted transmission lever was more prevalent in NASS/CDS.

GIDAS compared with ANCIS and NASS/CDS

In the GIDAS dataset, it appeared that the crash severity tended to be slightly higher for farside crashes than for nearside crashes, in regards to delta-V, EBS (EES) and approximate speed before the crash. Alternatively, the injury severity was, on average, greater for nearside crashes than for farside crashes, with the mean levels of ISS and number of days spent in hospital (and to a lesser extent MAIS) being higher for nearside impacts. This was a trend which was also common to the other two databases (particularly in NASS/CDS, whereby there were greater discrepancies in injury severity between nearside and farside crashes than what were found in ANCIS). The possible explanation that was previously provided for this trend is that given that the databases only analysed hospitalized cases, it is likely that farside crashes require a higher impact severity in order for hospitalization to occur, even though the extent of injury tends to be greater in nearside impacts regarding the duration of hospitalisation and the patient's injury severity score.

Implications of results

This study has indicated that whilst nearside crashes on average, may be associated with higher levels of injury severity (although this did vary to some extent between the databases), the number and severity of injuries sustained in farside crashes is still worthy of concern. Furthermore, whilst the frequency and severity of injury tended to be greater for nearside side crashes in some body regions (particularly the lower extremity), this was not the case for important body regions such as the head.

It is apparent through the investigation of the injuries and contact sources that there is still scope for improvements in vehicle design to better protect vehicle occupants in both nearside and farside crashes. Specifically, in nearside crashes, the interior surface was a common injury source for each of the databases examined, suggesting possibilities for targeting this area. In addition, in farside impacts, the seat belt system was consistently noted as a major injury source within each database. It is envisaged that in the future, however, the number of injuries sustained due to contact with the seat belt could be reduced, providing that various restraint technologies, such as motorized seat belts, pretensioners and adaptive load limiters, continue to become increasingly fitted to newly manufactured passenger vehicles. To this effect, the increasing presence of various airbag types in vehicles, particularly side airbags (e.g. door and cant-rail mounted), are also likely to assist in reducing the frequency and severity of injuries sustained in side impact crashes. Furthermore, other airbags, such as foot well and knee bolster airbags, could also make a valuable contribution in mitigating lower extremity injuries, which were found to be particularly prevalent in nearside crashes, as well as quite prominent in farside crashes.

Limitations

A number of limitations in comparing in-depth data across different countries and differing data collection procedures were alluded to earlier in this paper. These three databases were chosen for analysis because they were considered to be roughly equivalent and within the scope of this study. It would be useful though to include other databases in this analysis, should there be interest in pursuing this comparative analysis further.

The use of unweighted data for these analyses is always subject to some criticism. It was decided to use these data given the relatively small numbers of the sample (a maximum of 350 nearside cases from NASS/CDS to a minimum of only 30 farside cases in ANCIS). The extent to which this may have influenced the analyses is unclear, although other comparisons of nearside and farside crashes between ANCIS and NASS/CDS failed to show any severe differences in the outcome [5]. Nevertheless, it would be useful to conduct a similar analysis using weighted data in future.

CONCLUSION

This study has revealed a number of interesting similarities and differences in crash and injury severity patterns between nearside and farside crashes, as well as between the emerging trends for the Australian, German and U.S. in-depth crash databases. Overall, it appears that in hospitalized cases, the crash severity of nearside and farside impacts were relatively close, with the EBS (EES) of farside crashes tending to be slightly higher. The injury severity of nearside crashes tended to be slightly higher than for farside crashes, particularly in body regions such as the lower extremity. The results further indicated that serious injuries are frequently sustained in both nearside and farside lateral impacts, and future vehicle design measures should therefore address this trend. Care must be taken in interpreting the results of this study, however, given that generally small sample sizes were involved and there were limitations on the range of statistical analyses that could be performed with the data. Nevertheless, the richness of the available in-depth data has enabled several valuable findings regarding lateral impacts to emerge. The study provided a useful overview about the injuries sustained in side impact crashes across different countries. on the basis of detailed descriptions by in-depth-investigation.

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Single Vehicle Accidents, Incidence and Avoidance

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Abstract
In a first step, we have examined approximately 23 000 single vehicle accidents within the Austrian National Statistics database. In a second step, we considered 15% of all fatal 'running off the road' accidents that occurred in Austria in 2003. As a result, two accident categories were specified; 'leaving the road without preceding manoeuvre' and 'leaving the road with preceding manoeuvre'. These two categories can be basically characterised by the vehicle's heading angle and its velocity angle. In this report, we further suggest theoretical approaches for the dimensioning of a safety zone, an area adjacent to the road free of fixed objects or dangerous slopes. We also show the link between the two accident categories mentioned above and the real world accidents analysed in detail. These observations also form the basis for the required length for safety devices. Finally, we summarise accident avoidance strategies.

NOTATION

α	exit angle
a	acceleration, deceleration
d	lateral distance to the roadside
g	acceleration due to gravity
η	driven slope angle
φ	slope angle
R	curve radius
s	braking distance
μ	coefficient of friction
v	velocity

INTRODUCTION

Injuries and fatalities due to single vehicle accidents (SVA) are a significant component of annual road casualties; in the European Union, one third of all fatalities result from SVA. The challenge for road safety professionals lies in finding methods and designing strategies to reduce these casualties.

The objective of this investigation was to analyse the incidence of single vehicle accidents and the corresponding infrastructural safety measures with a particular view to frequency and dangerousness of different accident types as well as the accident causation action.

On the basis of the detailed investigation of real world accident data, two major accident categories were specified, namely 'Leaving the road without preceding manoeuvre' and 'leaving the road with preceding manoeuvre'. The accidents in the first category represent the main part of the running off the road accidents on straight roads. These accidents are typically caused by inattentiveness, distraction, fatigue, alcohol, etc. Characteristic for these kinds of accidents is, the small running off angle on the one hand and the fact that the running off angle is equal to the velocity angle on the other. In contrast, the accidents in category two typically show a yaw angle, i.e. the running off angle and the velocity angle are not equal.

Trees were identified as the most dangerous collision objects involved. Their partially small lateral distance to the road - often in combination with a fill slope - represents an increased risk compared to other collision objects. Embankments are also a big problem for running off the road accidents as they often initiate a rollover. In addition, the transitions between different inclinations are a problem if they are not rounded. As for cut slopes, an impact against the embankment frequently occurs, and this impact is the initial cause for the subsequent rollover. The beginning and end ramps of guardrails represent further risk objects.

For the dimensioning of the safety zone, that shall provide an area for drivers to control or stop their vehicles if they have had an unplanned departure from the road, we point out appropriate theoretical observation and we further outline the link between the two accident categories mentioned above and the real world accidents analysed in detail. These observations also form also the basis for the required length for safety devices. In addition, accident avoidance strategies are summarised.

PROCEDURE

Statistical data provides the basis for determining the relevance of single vehicle accidents. At first, we examined Austrian National Statistics in order to receive an overview of SVA [1, 2]. National Statistics uses census templates with defined data fields, which are filled out by the police [3]. We used these data to analyze the distribution of the individual accident types with a particular view to their frequency and severity [5, 9].
This enabled the comparison with statistical data of other countries that we used to measure whether such accident scenarios can be considered as a purely local problem or if they show similarities even in different countries [5]. These evaluations formed the basis for the selection of the real world accidents, which we analyzed in further consequence to measure their causes and their avoidance potential.
To determine the accident inducing event, the performance of infrastructure and the avoidance strategies, detailed accident data is necessary. We selected the real world accidents according to the quality of the respective available data (documentation, photo, sketch, court records, medical reports, etc.) [4, 6], and according to the statistic distribution. Furthermore, the selected accidents were simulated with the accident reconstruction program PC-Crash [7, 8]to illustrate both the accident-inducing event and the possible avoidance scenarios. With the results of the analysis we defined two typical categories of SVA that show different characteristics. They represent the two main groups of running off the road accidents. Additionally, we analysed objects in the road side area and their hazardous potential. [9].
We derived and compared characterizing parameters for the two accident types and the different infrastructural objects and used these parameters to develop avoidance scenarios.

RESULTS

Austrian Statistics

We investigated approximately 23 000 single vehicle ‘running off the road’ accidents out of the National Statistics data with respect to KSI (killed and severe injured) participants. The Austrian accident types catalogue comprises ten main groups. Each main group is divided into distinct sub-groups which describe the accident configuration more or less exactly [10].
For the investigation of SVA, however, not all accident types are of interest. Secondary collisions, i.e. accidents in which the actual cause was an event that resulted in a running off the road and/or impact into a object in or near the road, are not considered in this study.

Accident type 0 „Single vehicle accident“		
UG 01	„Single vehicle accident due to leaving the road on the right side“	
UG 02	„Single vehicle accident due to leaving the road on the left side“	
UG 03	„Single vehicle accident due to leaving the road in the area of an exit or junction“	
UG 04	„Single vehicle accident due to leaving the road while reversing or turning around“	
UG 06	„Single vehicle accident due to driving into hindrances, securings; rear-end collision w/o another vehicle or animal“	
Accident type 1 „Collision between two vehicles driving in the same direction“		
UG 12	„Collision between two vehicles driving in the same direction due to changing into the lane “	
	UT 122	„Collision between two vehicles driving in the same direction due to changing into the right lane and leaving the road on the right side“
	UT 124	„Collision between two vehicles driving in the same direction due to changing into the left lane and leaving the road on the left side“
Accident type 2 „Collision between two vehicles proceeding in opposite directions“		
UG 22	„Leaving the road to the right/left due to a vehicle proceeding in the opposite direction, no collision “	

Table 1: Accident types and sub-groups

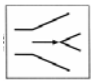
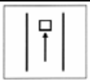
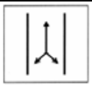
SVA - SUBGROUP	Fatal		Severe		Minor		Not Defined		Total	
LEAVING THE ROAD LEFT 		402		1 959		4 529		1 170		8 060
		5.0%		24.3%		56.2%		14.5%		100.0%
	38.0%		27.7%		27.5%		29.4%		28.2%	
LEAVING THE ROAD RIGHT 		563		3 160		7 413		1 939		13 075
		4.3%		24.2%		56.7%		14.8%		100.0%
	53.2%		44.7%		45.0%		48.7%		45.7%	
LEAVING THE ROAD AT JUNCTIONS... 		36		387		1 082		176		1 681
		2.1%		23.0%		64.4%		10.5%		100.0%
	3.4%		5.5%		6.6%		4.4%		5.9%	
DRIVING INTO HINDRANCES... 		11		70		231		36		348
		3.2%		20.1%		66.4%		10.3%		100.0%
	1.0%		1.0%		1.4%		0.9%		1.2%	
REVERSING OR TURNING AROUND 		4		27		55		7		93
		4.3%		29.0%		59.1%		7.5%		100.0%
	0.4%		0.4%		0.3%		0.2%		0.3%	
OTHER SINGLE VEHICLE ACCIDENTS		1		16		47		3		67
		1.5%		23.9%		70.1%		4.5%		100.0%
	0.1%		0.2%		0.3%		0.1%		0.2%	
FALL FROM AND IN THE VEHICLE		41		1 450		3 121		649		5 261
		0.8%		27.6%		59.3%		12.3%		100.0%
	3.9%		20.5%		18.9%		16.3%		18.4%	
TOTAL		3.7%		24.7%		57.6%		13.9%		100.0%
	100%	1 058	100%	7 069	100%	16 478	100%	3 980	100%	28 585

Figure 1: SVA in Austria between 2000 and 2002

Three accident types with the corresponding sub-groups are important for this investigation, namely accident type 0 ‘Single vehicle accident’, accident type 1 ‘Collision between two vehicles driving in the same direction’ and accident type 2 ‘Collision between two vehicles proceeding in opposite directions’. As described in this paper, the classification of the real world accidents with respect to the accident type catalogue is ambiguous, depending on the accident or the initiating event. Hence, accident type 0, defined as ‘Single vehicle accident’, is of main interest, but we also considered type 1 type 2 accidents as supplementing for detailed investigations.

For a general overview, the accidents in Austria were analyzed during a period of three years (2000 - 2002). In this period, 28 585 accidents with 37 730 injured people occurred in the category of ‘Single vehicle accidents’.

With approx. 46%, the accident subtype ‘Leaving the road on the right side’ holds the highest share within SVA, whereas the accident subtype ‘Leaving the road on the left side’ represents 28% of the overall sum of SVA. Further relevant accident subtypes in SVA are: ‘Fall from and in the vehicle‘ with 18% (this subtype is not relevant for this investigation), ‘Leaving the road in the area of an exit or junction, applied to all types of junctions’ with 6% and ‘Driving into hindrances, securings; rear-end collision w/o another vehicle or animal’ with a share of 1%. All other accident types are of minor relevance.

The occurrenace of the accident subtypes ‘Leaving the road on the right side’ and ‘Leaving the road on the left side’ increases if the frequency is compared to the severity of the accident subtypes (right: 46% of all SVA but 53% of all fatal SVA; left: 28% of all SVA, but 38% of all fatal SVA).

In the ‘Leaving the road on the right side’ and ‘Leaving the road on the left side’ accidents an increased risk for fatal accidents can be observed; it is interesting, however, that the subtypes ‘Leaving the road on the left side of a right-hand curve‘ and ‘Leaving the road on the right side of a left-hand curve’ show an increased risk for injuries. This circumstance can be explained by the fact that these are typical accidents where speed is not adjusted.

If the so called KSI accidents, i.e. accidents that usually result in severe or fatal injuries, are investigated, ‘Leaving the road on the right side of a left-hand curve’ and ‘Leaving the road on the left side of a right-hand curve’ show an increased risk. Compared with ‘Leaving the road on the left side of a right-hand curve’ (11%), the subtype ‘Leaving the road on the right side of a left-hand curve’ also shows an increased frequency (18%) . This circumstance can be explained by the fact that the

oncoming traffic lane is still available as additional area for correction manoeuvres for right hand traffic in the case of ‘Leaving the road on the left side of a right-hand curve’.
An increased risk for fatal injuries is shown for accidents on straight road, for severe injuries there is an increased risk for leaving the road accidents at the exterior side of the bend. For KSI, again an increased risk results for leaving the road accidents in the exterior side of the bend.
Within the analysis of KSI accidents regarding the type of road, ‘Leaving the road on the right side of a left-hand curve’ and ‘Leaving the road on the left side of a right-hand curve’ showed an increased risk. This increased risk can be particularly observed for B-roads. For fatal accidents, an increased risk for leaving the road on straight roads was determined.
In 68 % of all ‘leaving the road’ accidents in the years 2000 – 2002 with well-known accident severity, passenger cars were involved. Considerable rates were also recorded for motorcycles (11 %), mopeds (9 %), bicycles (5 %) and trucks up to 3.5t without trailers. The participation of all other vehicles was below 1 %. If a reference value from frequency (occurrence) and risk (accident severity) is built, then an increased risk for KSI accidents is reported for motorcycles.
Regarding the participation of vehicles in fatal leaving the road accidents during the year 2003, passenger car accidents dominated. Further considerable shares were observed for motorcycles (13%), mopeds (4%) and trucks up to 3.5t without trailers (3%).

Riser Statistics

Within the RISER project (Roadside Infrastructure for Safer European Roads; project funded by the European Commission under the ‘Competitive and Sustainable Growth’ Programme) a database for statistical and detailed data of single vehicle collisions in Europe was generated. In a first step, statistical data from Austria, Finland, France, Spain, Sweden, the Netherlands and United Kingdom were collected. These data were harmonised and a common form was defined to build a representative European database with the aim of comparing the large amount of data, to identifying the distribution of the different accident types and their causation and to provide data and guidelines for further investigations [11].
Most of the RISER SVA occur on straight roads, whereas nearside (nearside means to the right, offside to the left for right-hand traffic; vice versa in the UK) on straight roads is the most important accident type. In Finland and Austria, *nearside in a left curve* and *offside in a right curve* are dominating the accidents in curves. In Great Britain, the opposite distribution can be found due to left-hand traffic. In the category *objects hit*, the relatively high rates of none object hit in Spain (40 %) and the Netherlands (24 %) are remarkable. The *Safety Barrier impact* lies between 20 and 24 % in France, Spain and Great Britain and represents 13 % in Austria (for Austria, only this category is reported) and 14 % in Sweden, but only 2 % in Spain. *Ditch accidents* are relevant for France (29 %) and Spain (15 %); for the Netherlands no *ditch accidents* are reported.
In about 80 % of all RISER SVA a passenger car was involved, in 8 % motorcycles and heavy trucks; bus accidents are below 1 %. Notable is the high rate of *motorcycle accidents* in Austria (17 %) as well as in Spain (11 %), France (10 %) and Great Britain (8 %). In Sweden and the Netherlands the ratio of *motorcycle accidents* is around 4 %, in Finland it is only below 2 %.
Compared to the occurrence in other countries, the ratio of *heavy truck accidents* is high in Finland and Sweden (single unit in Sweden 7.8 %, other countries < 3.2 %; truck trailer combination in Finland 8.3 %, other below 3.1 %).
Regarding the accident type, there are comparable data from Finland, Austria and Great Britain. In general dominates the SVA on straight roads (maximum frequency) and with higher risk for Austria. In Great Britain, *offside in a left curve* and *nearside in a right curve* are important accident types with high risk. These accident types are the corresponding types to *nearside in a left curve* and *offside in a right curve* for right hand traffic (Austria, Finland, etc.), with high frequencies and risk. These accident types typically occur in situation where speeding and inattention are found.

Real Word Cases

In a second step, we examined 15% of all fatal ‘leaving the road’ accidents in Austria throughour the year 2003. Criterion for the accidents selected was the availability of an appropriate documentation, in

order to be able to accomplish a meaningful simulation and thus investigation of the real word accident circumstances.
The detailed investigation of the real word accidents resulted in an adjustment of the accident types compared with the accident types of the statistics. For this investigation we considered the entire operational sequence of the accident. To give an example: the critical situation was in a bend, but the vehicle left the road on the straight section. Or to give another example: Due to driving manoeuvres the vehicle could still be held on the road over a certain distance and so the respective accident was coded as *leaving the road in a bend*. Thus, there was an adjustment of *leaving the road on a straight road* and *junction accidents* to *accidents in a curve*.
On the basis of the analysis of the data from the detailed investigation we specified two main accident categories:

- Leaving the road without preceding manoeuvres
- Leaving the road with preceding actions

It has to be said, however, that a clear demarcation cannot be made as a certain share is flowing as an exact allocation is problematic in case of absence of traces, no appropriate documentation and no clear testimonies.
'Leaving the road without preceding manoeuvre' accidents represent the main part at the *running off the road accidents* on straight roads. These accidents are typically caused by inattentiveness, distraction, fatigue, alcohol, etc. Characteristic for these kinds of accidents is the small running off angle. The running off angle (i.e. the angle between the longitudinal axis of the vehicle and the edge of the road) is equal to the velocity angle (i.e. the angle between the velocity vector of the vehicle and the edge of the road)
In contrast, the 'leaving the road with preceding actions' accidents typically show a yaw angle, i.e. the running off angle and the velocity angle are not equal. In all cases, the velocity angle is less than 20° and shows a tendency to smaller angles at higher speeds with exception of the exterior side of the bend with approximately constant tendency. As for the running off angles, a reverse tendency can be observed; at higher running off velocities a tendency to greater running off angles can be seen.
When analysing the distance from the actuating manoeuvre to the running off the road for the 'leaving the road with preceding actions' accidents, we found that the higher the increasing initial velocity, the longer the distances on the road.
Regarding the time, the vehicle moves on the road until the running off occurs. Particularly for *leaving the road on straight roads accidents*, an, average time interval between two and three seconds is shown, that is independent from the initial velocity.
An interesting fact for the 'leaving the road with preceding actions' is the low deceleration level(mean deceleration of 1.8 m/s²) until the leaving the road sequence, although the majority of the accidents occurred on dry roads. This can be explained by the fact that the majority of the drivers tries to control their vehicle by steering manoeuvres and only moderate brake sequences. The full application of the brake is generally executed at the time when the vehicle leaves the road (e.g. average deceleration level from running off the road to the impact of 5.0 m/s²).
For the 'leaving the road without preceding manoeuvre' accidents, the mean deceleration level until the impact is 3.1 m/s². This is a lower level compared to the 'leaving the road with preceding actions' accidents with a mean deceleration level of 5.0 m/s². This can be argued by the fact that the reaction and the following brake sequence are executed after the vehicle runs off the road, and therefore the distance for deceleration is reduced.
The comparison of the two categories regarding running off velocity, shows that the mean running off velocity for both types of accidents is app. 85 kph. The mean initial velocity for the 'leaving the road with preceding actions' accidents is app. 100 kph.
The mean velocity angle for the 'leaving the road without preceding manoeuvre' accidents is app. 8° and the mean running off angle is app. 9°, compared to 16° of mean velocity angle and 31° of mean running off angle for 'leaving the road with preceding actions' accidents. Therefore, different requirements have to be claimed for roadside safety systems of the two categories. The 'leaving the road without preceding manoeuvre' accidents are on a lower level compared with the required test conditions from EN 1317 [13] regarding velocity and angles. With containment level N2 (car with 900

kg and 100 kph with an angle of 20°, car with 1500 kg and 110 kph with an angle of 20° against safety barrier), nearly all passenger car 'leaving the road' accidents on standard roads could be handled as only heavy vehicles and vehicles with exceeded travel speed exceed the requirements N2.
The 'leaving the road with preceding actions' accidents show higher demands for the safety systems regarding running off angles, and are also more problematic to be handled, since they occur with a yawing movement of the vehicle.
The mean impact velocity for both categories is app. 70 kph, with a large range from a minimum of 25 kph and a maximum of 113 kph for 'leaving the road with preceding actions' to a minimum of 20 kph and a maximum of 135 kph for 'leaving the road without preceding manoeuvre'. An accumulation can be seen between 60 and 70 kph impact velocity.
Regarding the crash causing collision partner, 11 different objects could be identified. The most frequent collision object was a tree (12 cases) followed by fill slopes (7 events), cut slopes (6 cases) and guardrail ramps (5 accidents).
Trees were identified as the most dangerous collision objects. The partial small lateral distance to the road often in combination with a fill slope represents an increased risk compared to other collision objects. Embankments also are a big problem for leaving the road accidents as they often initiate a rollover. These rollovers are often released by the fact that no uniform ground exists and thus it comes to hooking in the soil with simultaneous skidding movements of the vehicle. In addition, the transitions between different inclinations are a problem if they are not rounded. For cut slopes, an impact against the embankment frequently occurs which is the initial cause for the following rollover. The beginning and end ramps of guardrails represent a further risk object.
Concerning the lateral distance of the impact objects it can be stated that the mean lateral distance was 2.4 m, whereby the minimum was 0 m and the maximum was 9 m. The majority of the fatal accidents happened, however with an impact against an object whose lateral distance was smaller than 6 m.

THEORY

The path of the centre of mass of a vehicle leaving the road can be expressed as a function of the lateral distance to the roadside (d) and the speed (v), assuming that the steering system is the determining factor for the motion of the vehicle. For straight roads (Figure 2 right, Formula [2]) the maximum exit angle (α) can be derived over the centripetal acceleration and the maximum coefficient of friction (μ).
With similar considerations the exit angle (α) in curves can be derived (Figure 2 left, Formula [1]), whereby however, not the vehicle speed (v), but the lateral distance to the roadside (d) and the curve radius (R) are the determining factors, with the assumption that the vehicle is not steered in the curve (Figure 2 left).

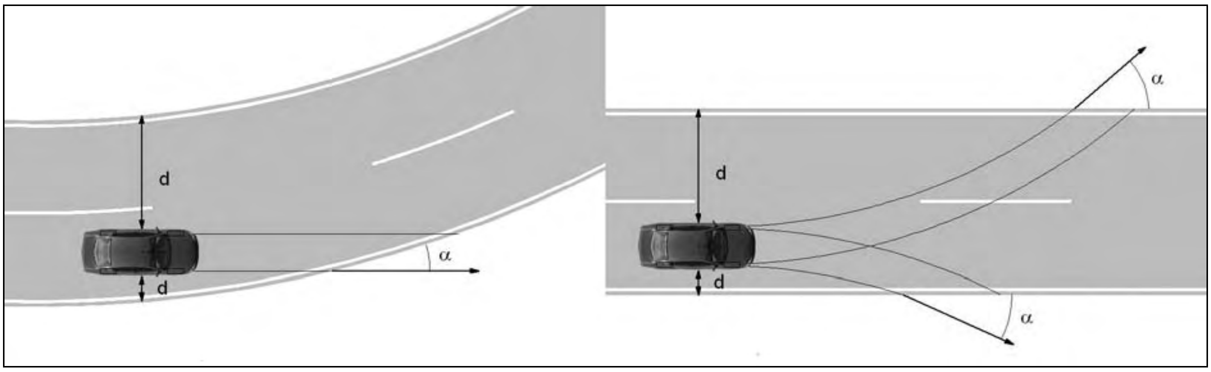


Figure 2: Exit angle for curves and on straight roads

$$\alpha = \arccos\left[1 - \left(\frac{d}{R}\right)\right] \qquad [1]$$

$$\alpha = \arccos\left[1 - \left(\frac{\mu \cdot g \cdot d}{v^2}\right)\right] \qquad [2]$$

From the formula for straight roads [2] it results that the exit angle (α) increases with the coefficient of friction (μ) and the lateral distance to the roadside (d) and decreases with the speed (v) of the vehicle. The tendency to smaller exit angles with higher speeds also is a result of the evaluation of the real world accidents. From the theoretical considerations it can be verified that for conventional roads with two lanes, dry pavement and a vehicle speed of 100 kph the accident results in a maximum exit angle smaller than 20°. This is in accordance with the EN 1317 [13] regulation tests for road restraint systems. For conventional curve radii, the maximum exit angle is also smaller than 20°.
For the theoretical considerations we assumed that the vehicle moved stable. Due to an abrupt steering manoeuvre, in real world accidents a rotation of vehicle around the vertical axis (yaw) can be observed. It must be differentiated between the trajectory of the vehicle's centre of gravity (speed angle) and the vehicle orientation (heading angle). If now yawing arises, both angles are identical.
If it is assumed that the human body cannot survive without additional protective mechanisms in collisions with impact speed above 40 kph, this value results for the definition of the maximum needed stopping distance and/or the lateral surface, which is needed to decelerate the vehicle to this value. During the impact, part of the energy is absorbed by the vehicle structure and by the occupant restraint system. The vehicle structures and the restraint systems are optimized for standard crash-tests, hence SVA accidents are not sufficiently considered within legal crash-test scenarios. Thus, an accumulation of impact speeds above 50 kph could be observed for the fatal real word accidents as well (in 87% of all evaluated cases the impact speed was higher than 50 kph and in 92% higher than 40 kph).

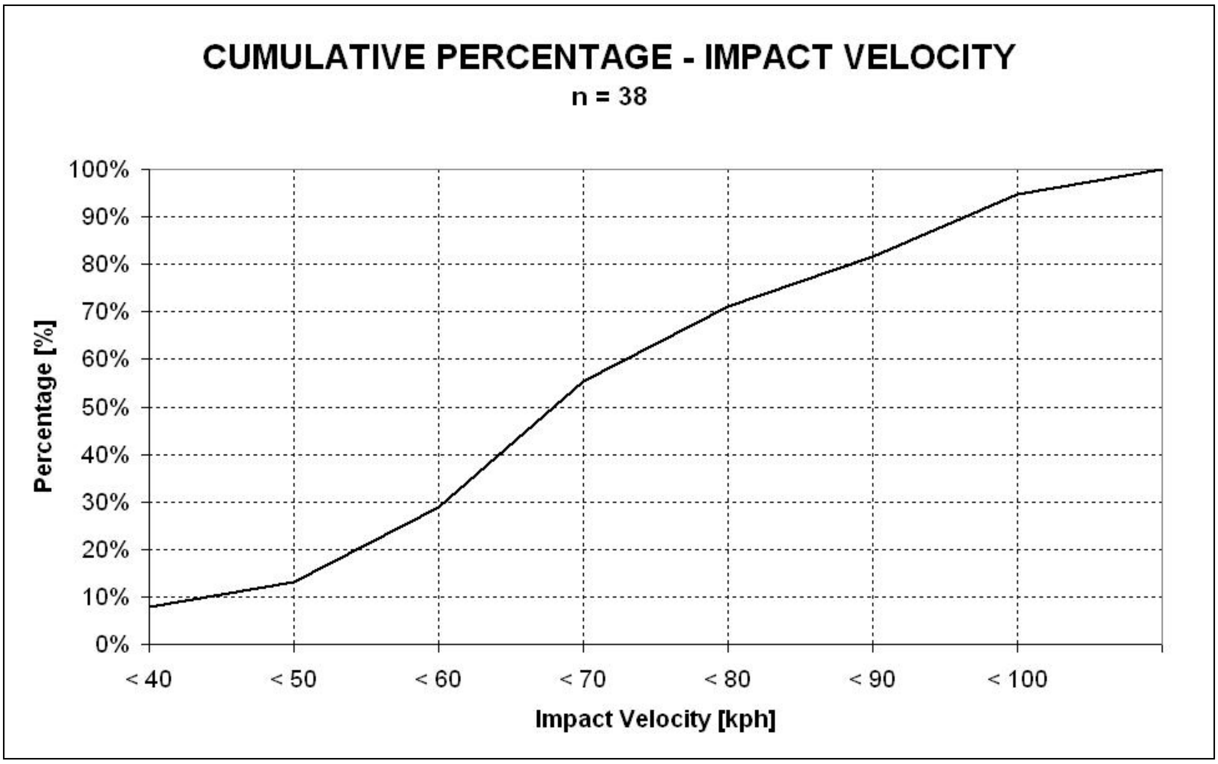


Figure 3: Cumulative Percentage of impact velocity for fatal real world accidents

If the safety zone is designed to eliminate impacts with objects for impact speeds higher than 40 kph, then the lateral distance of the safety zone must be designed in such a way that the vehicle can decelerate until this speed is reached. The approximate braking distance of a vehicle from the speed of the roadway to 40 kph (11.1 m/s) may be determined from the following equation:

$$s = \frac{v^2 - 11.1^2}{2 \cdot a} = \frac{v^2 - 11.1^2}{2 \cdot \mu \cdot g} \qquad [3]$$

Previous studies documented that most drivers decelerate at a rate greater than 4.5 m/s² during braking. Approximately 90 percent of all drivers decelerate at rates greater than 3.4 m/s². Such decelerations can be handled by most drivers [14]. The friction levels of the different roadside sections are often not consistent. In case of wet grass for a vehicle leaving the road the worst case is a friction coefficient of 0.3 (with exception of ice). This results in an available deceleration rate of 2.9 m/s².

Roadside geometry has a great influence on the frequency of serious injury and fatal crashes; especially the design of the side slopes has influence on the occurrence of rollovers, which is one of the most dangerous events in single vehicle accidents. The US Roadside Design Guide [15] defines recoverable, traversable and non-traversable slopes. A recoverable slope is a slope on which a motorist may, to a greater or lesser extent, retain or regain control of a vehicle by slowing or stopping. Slopes flatter than 1:4 are generally considered recoverable, where motorists can stop their vehicles or slow down enough to safely return to the roadway. A non-recoverable slope is a slope which is considered traversable but on which an errant vehicle will continue to the bottom. Embankment slopes between 1:3 and 1:4 may be considered traversable but non-recoverable if they are smooth and free of fixed objects. A clear run-out area is the area at the toe of a non-recoverable slope available for safe use by an errant vehicle.

For fill slopes, the approximate stopping distance of a vehicle may be determined from the following equation:

$$s = \frac{v^2 - 11.1^2}{2 \cdot a} = \frac{v^2 - 11.1^2}{2 \cdot g \cdot (\mu \cdot \cos(\varphi) - \sin(\varphi))} \qquad [4]$$

The formula above also contains the maximum slope angle for a given coefficient of friction. If the upward gradient of the slope is equal to the coefficient of friction, the limit for a safe deceleration is reached.

$$\tan(\varphi) = \mu \qquad [5]$$

Thus, for slopes 1:3 and coefficient of friction 0.3 there will be no safe stop possible (the border inclination for a coefficient of friction of 0.3 is 30%, which means no speed reduction despite full brake application).

The absolute inclination of the slope is not relevant for leaving the road situations, but the resulting inclination when driving under a certain course angle. The vehicle's heading angle changes while driving on the slope due to the driver input. The driven inclination can be determined by the side inclination and the speed direction using the following correlation:

$$\sin(\eta) = \sin(\varphi) \cdot \sin(\alpha) \qquad [6]$$

Using the information presented previously, the width of the safety zone can be defined as the width necessary to stop a vehicle to avoid serious impact. As an example, the following table lists the recommended safety zone widths if the road, speed, and slope conditions are:

- Coefficient of friction 0.3 (grass)
- Initial manoeuvre on the road was abrupt steering
- Vehicles decelerate on roadside without manoeuvre
- Impact velocity 40 kph after crossing the safety zone
- Flat Ground (ideal conditions)

Exit angle	Slope	µ	a	30	40	50	60	70	80	90	100	110	120
°			m/s²	Posted speed kph, Impact speed = 40 kph									
35	0	0.3	2.9	0	7	15	25	37	50	64	80	98	117
28	0	0.3	2.9	0	6	12	21	30	41	52	66	80	96
22	0	0.3	2.9	0	4	10	16	24	32	42	52	64	76
19	0	0.3	2.9	0	4	9	14	21	28	36	45	55	66
16	0	0.3	2.9	0	3	7	12	18	24	31	39	47	56
14	0	0.3	2.9	0	3	6	11	15	21	27	34	41	49
12	0	0.3	2.9	0	2	6	9	13	18	23	29	35	42
11	0	0.3	2.9	0	2	5	8	12	16	21	27	32	39
10	0	0.3	2.9	0	2	5	8	11	15	19	24	30	35
9	0	0.3	2.9	0	2	4	7	10	14	17	22	27	32
8	0	0.3	2.9	0	2	4	6	9	12	16	19	24	28

Table 2: Theoretical Safety Zone Widths

DISCUSSION

A comparison of the values in Table 2 with actual safety zone dimensions in current guidelines demonstrates that the theoretical values are much higher than in practice. This is a practical problem for the road owner/operator and local conditions must be considered. However, this approach can be useful for applying local modifications to the safety zone.

The dimensioning of a safety zone is a difficult process. A theoretical process using vehicle dynamics and human tolerance information provides rather large safety zone dimensions. An alternative is to use the struck object setback obtained from the accident data. In this approach, the data coming from Austria and the RISER real world cases appear to support information from France, the US, and the Netherlands which shows that the risk of contact with an obstacle drops dramatically after the first few meters and most impacts with roadside obstacles occur in the first 10 m.

Most safety zones in Europe are specified to be between 6 and 10 m for travel speeds around 100 kph. Safety zones are smaller for lower speeds and for 80 kph roads, investigated European countries use 4.5-7 m as a safety zone width.

There should be no dangerous objects within an area of 5 to 7 m to the roadside; if this is not possible, the objects should be removed or protected by safety barriers.

Dangerous objects are

- Trees with a defined diameter
- Poles and posts
- Slopes (fill and cut slopes have nearly the same risk potential)
- Noise protection walls (if they are within the working with of the barrier system)
- Barrier terminations are also of high relevance and have great design potential

Driving behind a safety barrier (moving back the start and end elements) and lacks within some meters of safety barrier systems should be avoided [16, 17].

CONCLUSION

On the basis of the detailed investigation of real world accident data in general, two accident categories could be specified. ‘Leaving the road without preceding manoeuvre’ accidents represent the main part of the leaving the road accidents on straight roads. These accidents are typically caused by inattentiveness, distraction, fatigue, alcohol, etc. Characteristic for these kinds of accidents are the small running off angle and the fact that the running off angle is equal to the velocity angle. In contrast, the ‘Leaving the road with preceding actions’ accidents show typically a yaw angle, i.e. the running off angle and the velocity angle are not equal.

Objects are collision-relevant if they are located within a distance between five to seven meters on the road side. For SVA leaving the road accidents the velocity angle generally is below 20 degrees. The typical leaving the road velocity is about 80 kph but however, can be strongly deviate. Nearly all vehicles get off the road within three seconds after the conflict situation.
Trees were identified as the most dangerous collision objects. The partial small lateral distance to the road - often in combination with a fill slope - represents an increased risk compared to other collision objects. Embankments are also a big problem for leaving the road accidents as they often initiate rollovers. In addition, the transitions between different inclinations are a problem if they are not rounded. For cut slopes often occurs an impact against the embankment which is the initial cause for the following rollover. The beginning and end ramps of safety barriers represent a further risk object.
Nearly twice as many vehicles get off the road on the exterior side of a bend compared to the interior side and in left bends the injury risk is twice as high as in right bends.
For the dimensioning of the safety zone, appropriate theoretical links are pointed out and the link with the detailed analysed real world accidents is shown. These observations also form the basis for the length of need for safety devices.
The requirements for the safety zone are that:

- the consequences of running of the road accidents are reduced
- the width is designed in such a way that most vehicles leaving the road do not leave the safety zone
- there are only slopes that do not cause rollovers
- the surface is homogenous and even to prevent rollovers
- there are no unprotected fixed objects located within the safety zone

The safety zone should only contain objects that will collapse or break away when impacted without significantly damaging an errant vehicle. Where allocation of an appropriate safety zone is not possible, appropriate barriers should be used to protect dangerous objects [16, 18].

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Comparative Assessment of the Passive Safety of Passenger Cars

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Abstract - One goal of the assessment of the crashworthiness of passenger cars is to characterize the potential of injury outcome to occupants of cars involved in an accident. This can be achieved by the help of an index that puts the number of injured occupants of passenger cars in relation to the number of cars involved in an accident. As a consequence, this index decreases with a lower potential of injury and rises with a higher number of injuries while assuming a fixed number of accidents. Another index is introduced that uses an economical weighting of each injury level. The consequential injury costs are calculated using the average economical costs for lightly, severely and fatally injured persons. The calculation of the safety indices is based on an anonymized sample of accident data provided by the Federal Statistical Office. An index of Mercedes passenger car drivers depending on the year of registration between 1991 and 2006 is compared to the index of drivers of cars of other makes within the same range of registration years.

NOTATION

ESiX	economic safety index
SiX	safety index
VL	number of seriously and fatally injured persons
VLFK	consequential injury costs
$VLFK_i$	consequential injury costs of slightly, seriously and fatally injured persons
GVWR	gross vehicle weight rating

ACCIDENT DATA

The basis of the assessment of crashworthiness is an analysis of an anonymized 50%-sample of accident data from the years 2002 to 2006 provided by the Federal Statistical Office. “Light”, “severe” and “fatal” injuries of the drivers of passenger cars which are registered in between 1991 and 2006 are selected. These injury numbers are separated into drivers of Mercedes passenger cars (in total 143,800) and drivers of passenger cars of other makes (in total 1,762,000). By using the indices SiX and ESiX that serve as an indicator of crashworthiness, trends are shown and comparisons between certain vehicle groups are made.

INDICES FOR ASSESSMENT OF PASSIVE SAFETY

Safety Index SiX

The Safety Index SiX is a measure for the passive safety of a vehicle in terms of protection of the occupants against consequential injuries in a road accident. SiX stands for “Safety Index” and denotes the number of at least severely injured drivers per 1,000 vehicles involved in an accident. If the following holds for severely and fatally injured persons

$$VL = \sum_{i=1}^{2} n_i \tag{1}$$

with i = 1: severely injured and
i = 2: fatally injured,

then

$$SiX = \frac{VL}{vehicles\ involved\ in\ accident} \cdot 1.000 \tag{2}$$

SiX is a value that measures solely the outcome of an accident. One main influence factor is the number of slightly injured and uninjured drivers, as the set of all vehicles involved in an accident can be divided into the four groups of slightly, severely, fatally injured, and uninjured drivers. If all drivers of a certain group of vehicles would only be slightly injured or not injured at all, SiX would have a value of zero, and the target of protecting the vehicle occupants (here the drivers), would essentially be achieved. Other occupants than the driver are not considered here because of the following reasons:

- The index is independent from the number of passengers in the vehicle.
- The occupant rate in passenger cars in Germany is approximately 1.4 occupants per vehicle. The main focus should therefore initially lie on the driver.
- The design of passive safety systems with respect to the driver (because of the steering column and pedals) is considered to be more challenging than protecting for example an adult front passenger.

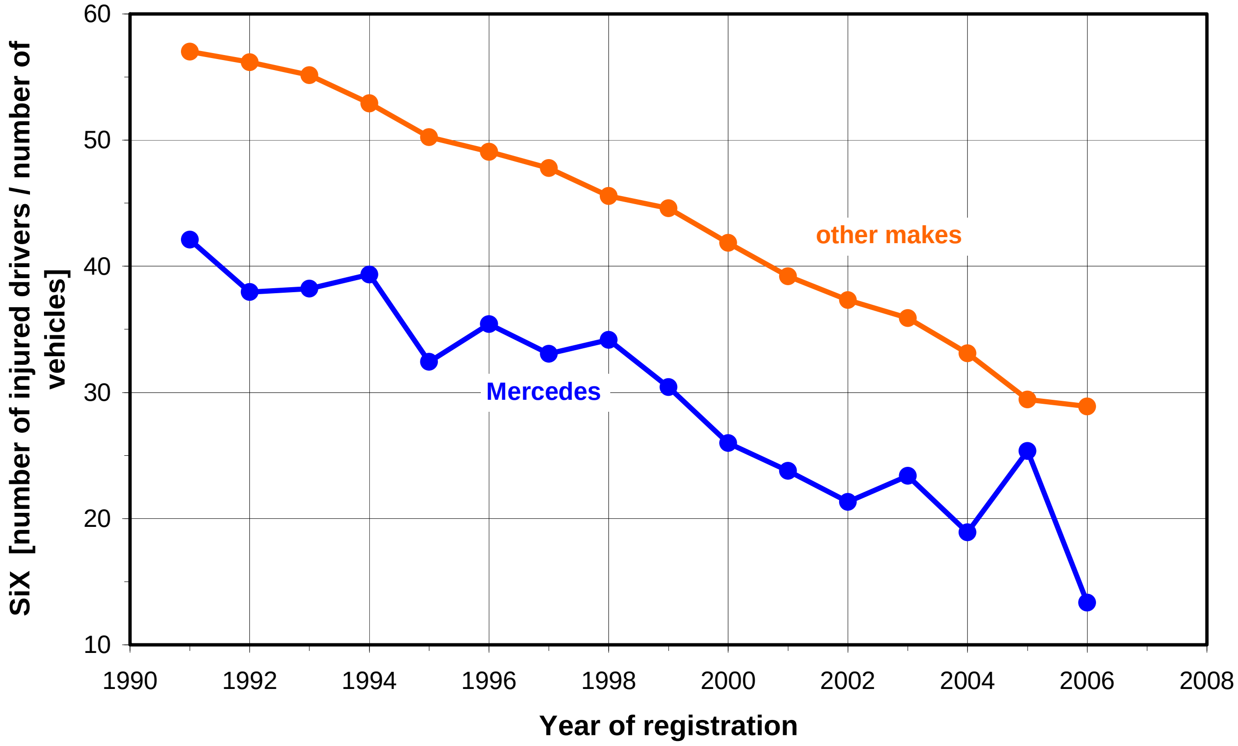

Figure 1: Safety index SiX for passenger cars from Mercedes and other makes depending on year of registration

By means of the safety index SiX we can compare the passive safety of different groups of vehicles. Based on the number of drivers of passenger cars from Mercedes and other makes that have a different injury severity, the SiX depending on the year of registration is shown in figure 1.

Consequential Injury Costs

The next step is to treat the different levels of injury severity differently by weighting each level with a factor and to include the lowest injury severity into the index. An economical assessment fits nicely in this approach by using consequential injury costs as weighting factors. Consequential injury costs denotes the average economical loss caused by slightly, severely, and fatally injured persons involved in a road accident. Using the instruments of consequential injury costs we gain the ability to assess the benefit of safety measures for example by setting up a cost/benefit analysis. By introducing new findings from an economical and medical point of view, calculations could be updated in the end of the 1980ies that lead to a consistent monetary assessment. More specifically, these improvements were:

- revision of the earning rate of children and young persons,
- introduction of a lethality rate,
- replacement of the initial value by the earning rate,
- integration of new economic developments: increasing unemployment and rising of the so called hidden economy [1].

In a first step, the resulting consequential injury costs (rounded to the nearest €) were defined for each level of injury severity [MAIS] and averaged over gender, constitution and age of all road users.

By means of the yearly growth rate of the net national product that is highly correlating to the medical care costs, the consequential injury costs are calculated for each year [2]. By leveraging a proper distribution model the costs were transformed into the injury scale “slight”, “severe”, “fatal” used in the federal statistics data.

Tab. 1: Consequential injury costs for the year 2005

Injury Severity	**Consequential Injury Costs VLFK [€]**
slight	20.000
severe	164.000
fatal	989.000

Now, consequential injury costs can be calculated for a given period of time:

$$VLFK = \sum_{i=1}^{3} n_i \cdot VLFK_i \qquad (3)$$

with i = 1: slightly injured,
i = 2: severely injured and
i = 3: fatally injured

In this study the consequential injury cost values shown in table 1 for the year 2005 are used for all calculations.

Safety Index ESiX

ESiX denotes the „Economic Safety Index“, and is calculated as follows:

$$ESiX = \frac{VLFK\ [Tsd.\ €]}{vehicles\ involved\ in\ accident} \qquad (4)$$

It corresponds to the consequential injury costs of the driver in thousand € per vehicle involved in an accident. Obviously, the ESiX increases with rising consequential injury costs or with a lower number of involved vehicles and therefore expresses a lower level of safety, while with a low number of injured or a higher number of involved vehicles it shows a higher safety potential.

Figure 2 shows the safety index ESiX for each year of registration in order to compare crashworthiness of two different groups of vehicles. It is based on the consequential injury costs for drivers of passenger cars from Mercedes and other makes related to the number of vehicles involved in an accident.

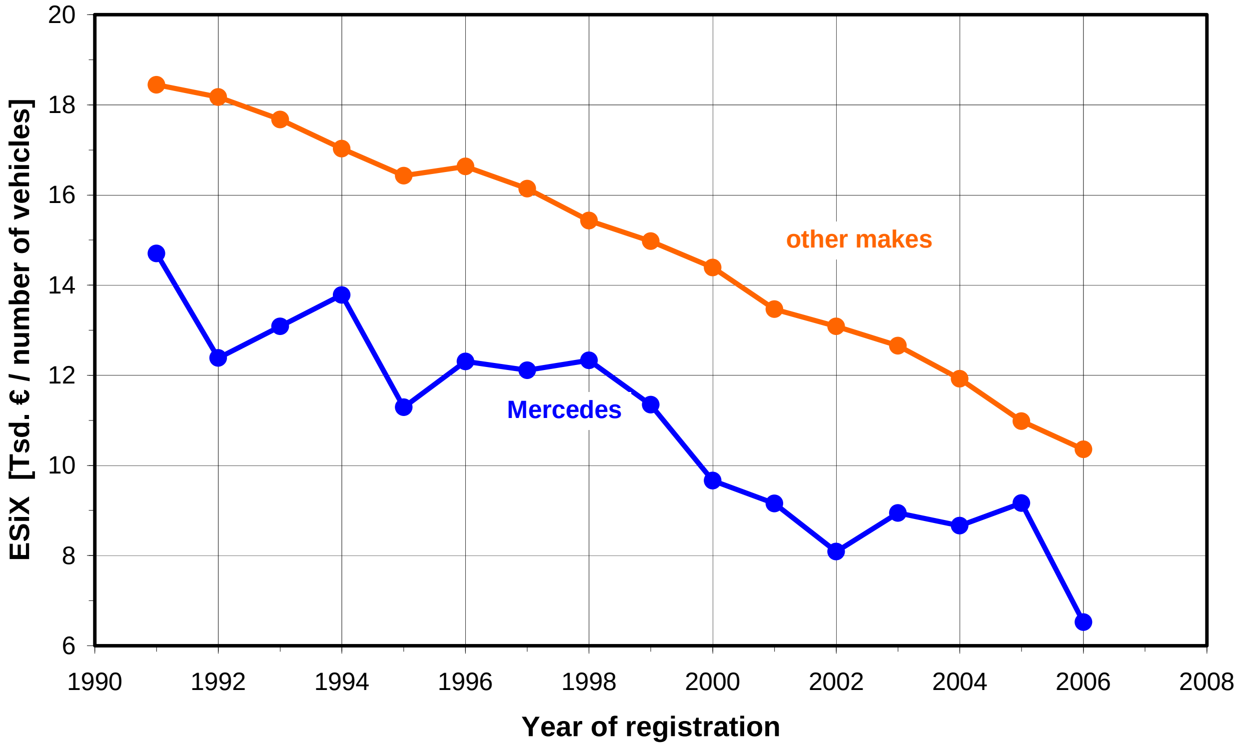

Figure 2: Safety index ESiX for passenger cars from Mercedes and other makes depending on year of registration.

Comparison and Discussion of the Safety Indices

Both Indices SiX and ESiX, shown in Figure 1 and 2, are based on a sample of data from the Federal Statistical Office. A clear trend can be derived: Both, Six and ESiX decrease continuously with growing year of registration. That means newer passenger cars have clearly a higher crashworthiness. Additionally, both safety indices show a noticeable gap between Mercedes passenger cars and other makes where Mercedes cars are below the others.

Both indices show a similar trend, so the question is which one is to be preferred. To find an answer, both indices are compared to each other, which is shown in figure 3 and we can also see that there is a high correlation between the two safety indices SiX and ESiX (see figure 4) which is expressed by the square of the correlation coefficient R^2 = 0,995.

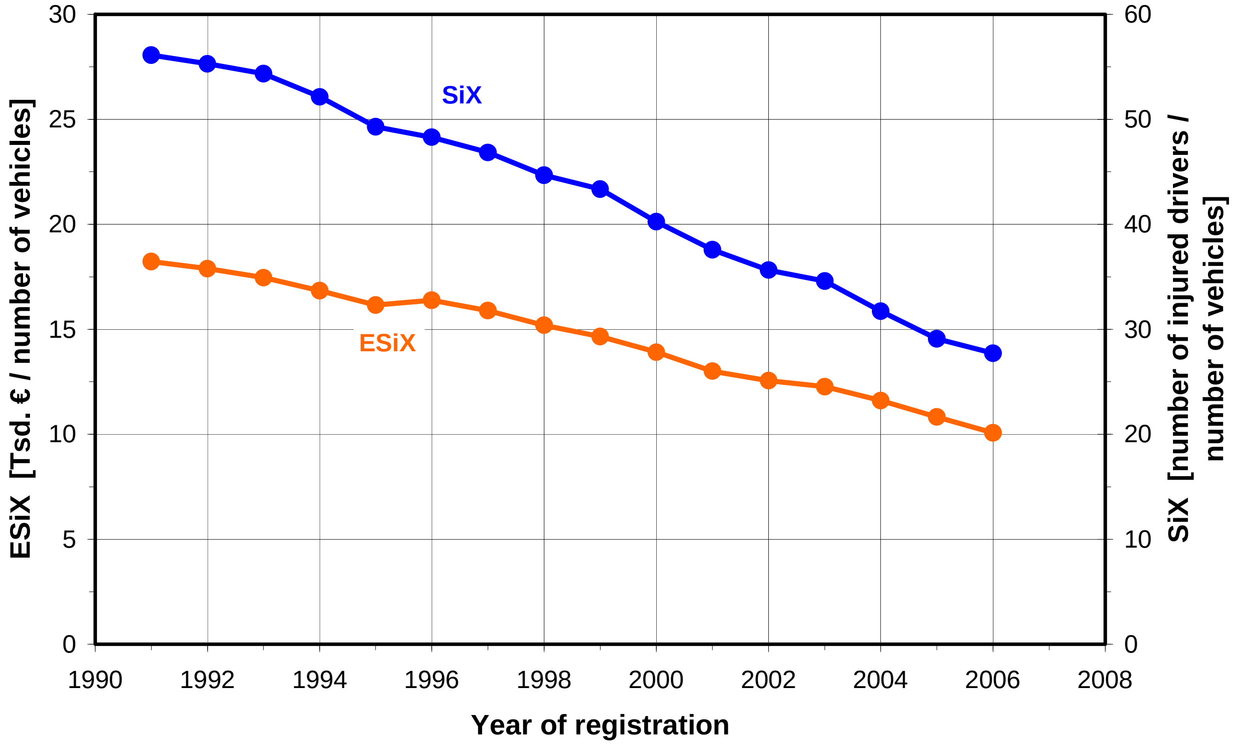

Figure 3: Safety indices SiX and ESiX for all passenger cars depending on year of registration

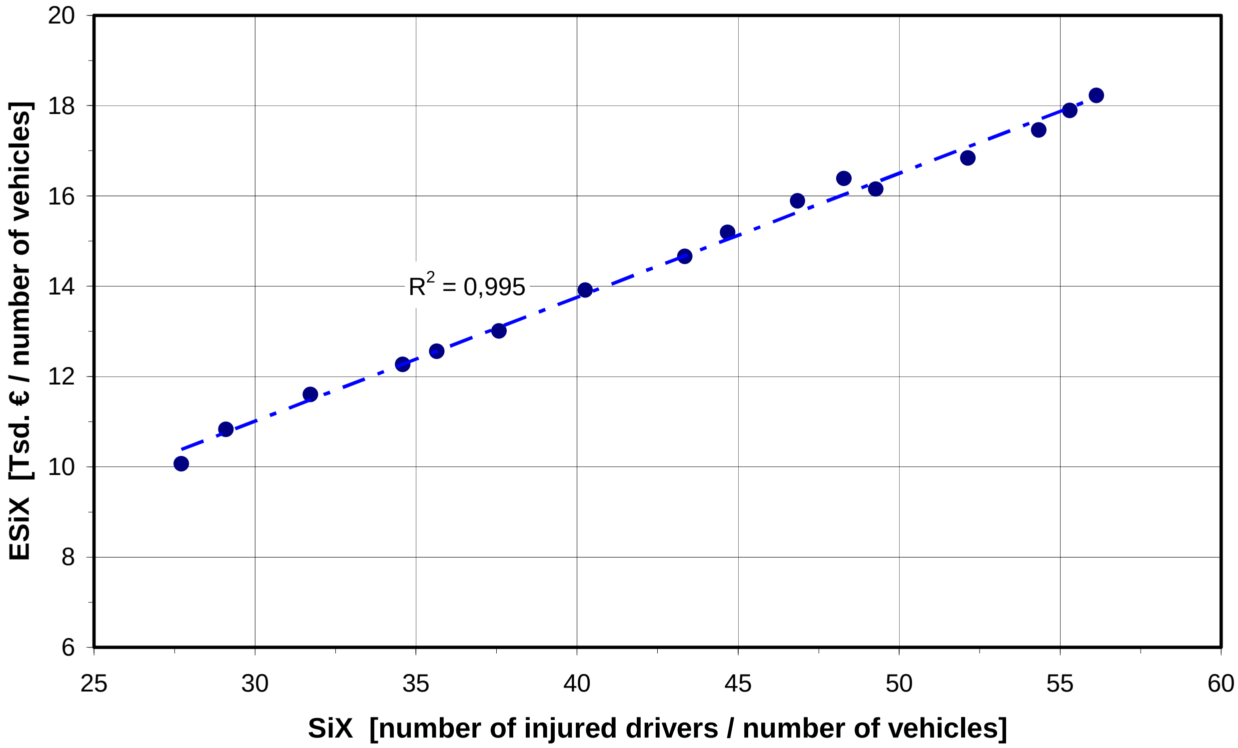

Figure 4: Correlation between the safety indices SiX and ESiX for all passenger cars

The safety indices SiX and ESiX differ in the weighting of the injury severity of vehicle's driver: The index SiX is calculated by the sum of severely and fatally injured casualties in the nominator while the ESiX is made up of slightly, severely, and fatally injured casualties that are weighted by the consequential injury costs. The number of severely and fatally injured casualties is provided by the federal statistics regularly. Additionally the proportion of the consequential injury costs of slightly injured casualties accounts for only 28.5% (for the year 2005), thus the safety index SiX is preferred in the following discussion. Besides, the slightly injured casualties only have a small influence on the outcome of the ESiX, so they can be neglected.

APPLICATION OF THE SAFETY INDEX SiX

To avoid a comparison of mid- and large-size Mercedes passenger cars with small size vehicles of other makes, only vehicles with a gross vehicle weight rating of 1,65t or above are selected in the following discussion. This guarantees that only vehicles in the same weight class are compared with each other. Due to a low number of cars for the vehicle years 2005 and 2006 in the accident data, this holds especially for cars with fatally injured drivers, these years are left out by now. The safety index SiX is shown for both groups of cars in figure 5. While the curve of the injured drivers in cars of other makes resemble closely a decreasing straight line, the SiX of injured drivers of Mercedes passenger cars shows some variability. The reason for this effect is the (by a factor of about 7) lower number of Mercedes cases per year of registration. Overall the Mercedes curve is considerably below the SiX curve of other makes.

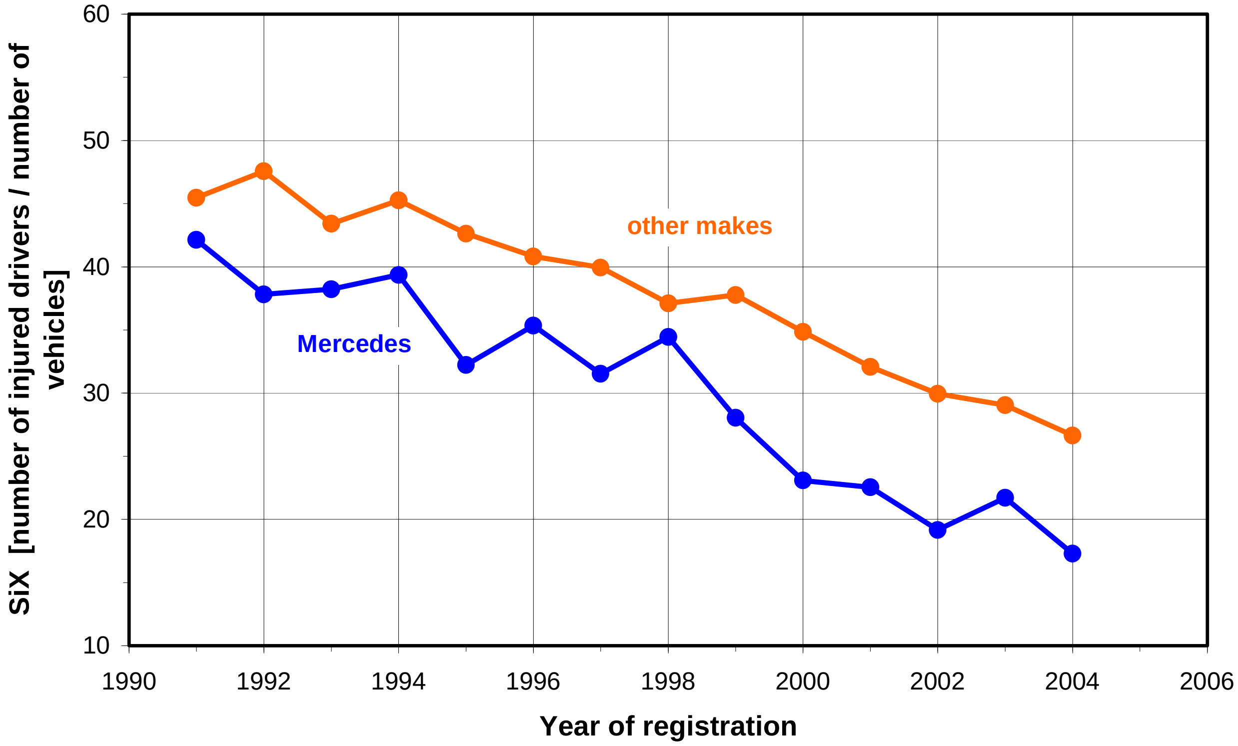

Figure 5: SiX in comparison for passenger cars from Mercedes and other makes with GVWR $\geq$ 1.65 t

Figure 6 shows the quotient of the safety indices of both groups. The average of the quotient has a value of about 1.3 which means that the safety index for the driver of a Mercedes passenger car is by this factor lower than for the drivers of other makes. Additionally, the quotient is above the average value from the year 1999 onwards while it is below the average before. That means the margin of the SiX between Mercedes passenger cars and other makes even broaden with newer vehicles.

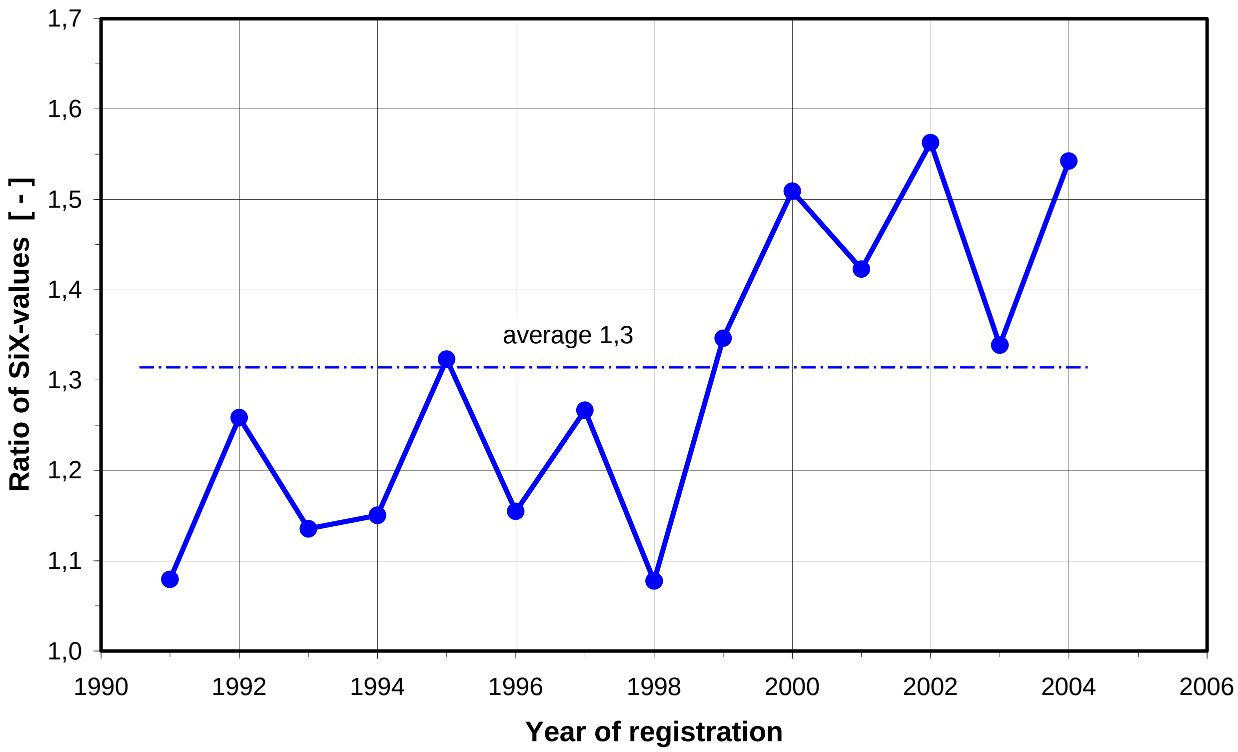

Figure 6: Quotient of SiX values of car drivers from other makes and Mercedes

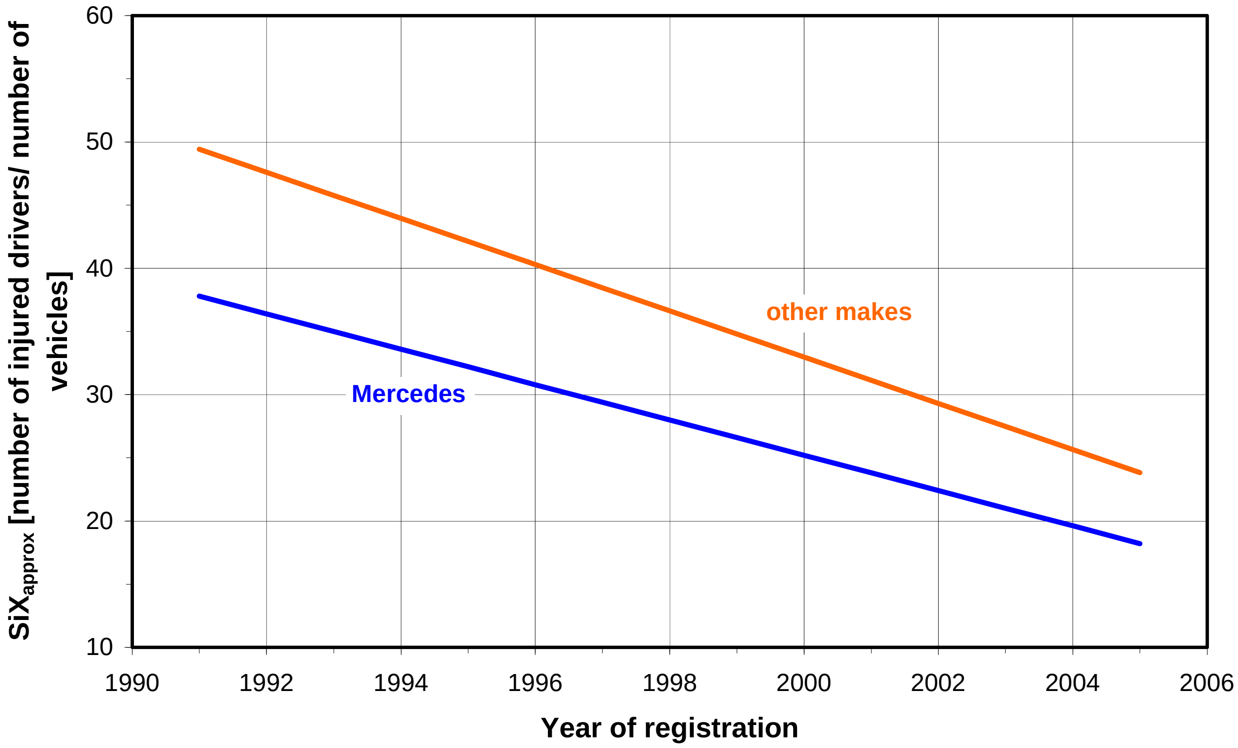

Figure 7: Approximate SiX values of passenger cars from Mercedes compared to other makes with a GVWR ≥ 1.65 t

Figure 7 shows the linear approximation of the SiX curves for passenger cars from Mercedes and other makes: The SiX curve for Mercedes passenger cars is considerably below the curve for other makes. We can conclude that the injury potential for drivers of Mercedes passenger cars is in average about 24% lower than for drivers of cars of other makes.

INTERPRETATION OF RESULTS

The decreasing safety index SiX proves that we have a considerable gain of crashworthiness in passenger cars. Surely, this is due to the continued development of safety measures in passenger cars for protection of the occupants. Especially Mercedes passenger cars show an advantage in this trend. One reason for this is the early introduction of innovations in the field of passive safety in the broad fleet of Mercedes cars. Real-life safety has always been the basis for introduction of these measures and specification of safety systems being built into new car models. For example, the side air bag has been introduced in all models and the window bag in E- and S-Class even before the year 2000. The efficiency of both systems has already been proven in [3].

Moreover, the early introduction of active safety systems in the Mercedes passenger car fleet, for example ESP since year 2000, has also a positive effect on the protection of occupants in a crash. This is because the type of collision is shifted from side collisions in accidents where the car is skidding into a more frontal type of collision and thus increasing the possible protection for the occupants against injuries caused by the crash. Additionally the whole kinetic energy of the collision is reduced by ESP right before the crash which also leads to a lower accident severity.

SUMMARY

The safety indices SiX and ESiX are very well suited for the assessment of crashworthiness of vehicles based on data from real life accidents. Choosing the SiX for the sake of simplicity, the index could deliver a clear first evidence that improvements in the crashworthiness of passenger cars have been made, both, measures improving passive safety as well as by introducing active safety, in the form of driver assistance systems, which have an effect in reducing the severity of accidents.

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Keynote lecture at the ESAR Symposium in Hanover on 5 September 2008

„Efficient Road Safety Policy needs In-Depth-Accident Data"

Ladies and Gentlemen,

I am delighted to welcome you today to the third ESAR Conference. I would like to start by conveying the regards and best wishes of the Federal Ministry of Transport, Building and Urban Affairs, in particular of State Secretary von Randow, and wishing the conference every success.

This two-day conference pursues an ambitious goal - that is to contribute to minimizing the number of traffic fatalities worldwide. It provides representatives from the political circus, the industry and academia with a great opportunity for a comprehensive exchange of ideas.

I am glad that Germany can provide a powerful impetus for vehicle safety with its "In-Depth"-Database which already exists for many years and the GIDAS project– the German In-Depth Accident Study – a joint project of the Federal Highway Research Institute and the Research Association for Automotive Technology. GIDAS offers the famous opportunity to draw conclusions regarding the accident sequence and injury mechanisms on the basis of detailed accident data. By carrying out efficient sampling procedures GIDAS also lends itself to projections at national level and therefore makes it possible to issue statements beyond the areas of investigation Hanover and Dresden.

Ladies and Gentlemen,

Efficient transport policy is well advised to use the full existing accident reduction potential by well planed and implemented measures.

Efficient transport policy, therefore, is not geared to phantasmal requirements or goals but for the good of society uses a pragmatic approach to achieve the best results possible.

From the point of view of transport policy, improving road safety is one of the main challenges. Our paramount goal in this respect is to reduce the number of traffic fatalities. If you consider this goal taking into account a steadily increasing traffic volume, policymakers seem to face an unsolvable task.

The last years have shown, however, that it is possible to square the circle. Let's have a look at the development in Germany:

The number of registered vehicles in the Federal Republic of Germany has risen by 10 per cent since the turn of the millennium. In the same period the number of fatalities in road traffic has decreased by more than 30 per cent. Among other things, this success is due to the Traffic Safety Programme of the Federal Ministry of Transport, Building and Urban Affairs which is based on the principles of efficient transport policy already mentioned. In detail, the priorities of the programme are the following:

- improving the highway culture in Germany
- protecting more vulnerable road users
- reducing the likelihood of novice drivers of becoming involved in an accident
- minimizing the risk potential of heavy goods vehicles and
- enhancing road safety on rural roads

The progress achieved so far is an incentive to continue this positive development also in the future.

Situated at the centre of Europe, Germany is the transit country number one. For this reason, in an expanding Europe, German road safety efforts do not end at the borders. Together with its European friends, Germany works hard on improving road safety in the respective bodies. More than ever, the motto is the following: We have to take concerted action. This is the only way we can bring the high-flying goals of the European Union within reach, that is: to reduce the number of traffic fatalities by 2010 to half the number of the year 2000.

This ambitious task can also only be fulfilled if all opportunities connected with the complex human-being, vehicle and infrastructure are taken consistently.

An important example in this respect is the eSafety initiative launched by the European Commission and the industry within the framework of eEurope. The Federal Government supports the eSafety initiative and held a conference on this issue in June 2007 within the framework of the German EU Presidency. The European Commission has appreciated the conclusions of the conference as decisive.

The eSafety initiative will help to get innovations in the fields of road traffic, telematics and driver assistance systems accepted in Europe.

Timely and more targeted information enables road users to better adapt to upcoming traffic situations. Additional assistance systems installed in the vehicle support the driver in especially critical situations. The consequences of human fatal behaviour are thereby minimized.

I am thankful that the automotive industry, too, makes a considerable contribution to the introduction and development of such systems. Thus, for instance, partners from the automotive industry, from electronics, telecommunications, and software companies, from research institutes and from the road and traffic administration work together in the AKTIV research initiative founded in Germany in 2006 in order to develop innovative driver assistance systems.

AKTIV means: Adaptive and Co-operative Technologies for the Intelligent Transport.

In particular, I would also like to mention the SIM-TD project (safe intelligent mobility - test field Germany) because also in this project the industry, research, and administration will develop and test modern information and communication technologies aimed at enhancing road safety further. The catchwords in this context are “intelligent vehicle“ and “intelligent road“ which in future will communicate car to car (C2C) and car to infrastructure (C2I).

Experience shows that technical innovations must reach every price segment and have to remain affordable for everyone in the end. The example ESP has shown how an effective assistance system found its way from the luxury class into now more than 80 per cent of all newly registered vehicles in Germany.

A look at the presentations to be given at this conference tells me that you, too, are thoroughly addressing the benefit of new drivers’ assistance systems. The results of such studies will subsequently be the basis for our political decisions. For example, we support the plans of the European Commission for a regulation on the mandatory fitting of new commercial vehicles with ESP, emergency brake and lane keeping assistants from 2012. According to estimates, about 2,500 lives can be saved every year in the EU by these measures.

By adopting the D - Minimis programme the Federal Government has laid the foundations for additional promotional measures of freight transport in Germany in the fields of environment and safety, inter alia. The volume of the D - Minimis programme will be 600 million Euros every year. The programme will presumably be launched in January 2009.

The safety of freight transport is especially close to my heart for the following reason: The future shape of freight transport will decide what the transport system as a whole in Europe will look like. At the same time, it will also be crucial in deciding whether, in twenty years’ time, we have a transport system that ensures mobility, prosperity and jobs while reflecting environmental concerns. In this respect, Germany has presented a Freight Transport and Logistics Masterplan which contains numerous measures aimed at making optimum use of transport infrastructure, making transport more efficient, ensuring mobility and shifting higher shares of traffic to the railway and the waterway.

Also transport arteries and hubs are to be upgraded and the transport is to become more environmentally friendly, quieter, safer and more secure. In this context, vehicle safety plays an important role.

Ladies and Gentlemen,

At the end of my welcome address, I would like to explicitly encourage you once again in your work for road safety:

Keep on working with great commitment and joy. So that we will be able to continue to set the right transport policy priorities in the future. Against the background of globalisation, a Europe that is growing closer and has to face demographic change, the goal to enhance vehicle safety in a sustainable way needs further requirements.

By all means, road safety policy will remain a first-rate task for the whole society.

Your conference gives an important contribution to this issue.

Thank you very much for your attention.

Implementation of ACASS - Accident Causation Analysis with Seven Steps – in In-Depth Accident Study GIDAS

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Abstract
As the official German catalogue of accident causes has difficulty in matching the increasing demands for detailed psychologically relevant accident causation information, a new system, based on a "7 Steps" model, so called ACASS, for analyzing and collecting causation factors of traffic accidents, was implemented in GIDAS in the year 2008. A hierarchical system was developed, which describes the human causation factors in a chronological sequence (from the perception to concrete action errors), considering the logical sequence of basic human functions when reacting to a request for reaction. With the help of this system the human errors of accident participants can be adequately described, as the causes of each range of basic human functions may be divided into their characteristics (influence criteria) and further into specific indicators of these characteristics (e.g. *distraction from inside the vehicle* as a characteristic of an *observation-error* and *the operation of devices* as an indication for *distraction from inside the vehicle.* The causation factors accordingly classified can be recorded in an economic way as a number is assigned to each basic function, to each characteristic of that basic function and to each indicator of that characteristic. Thus each causation factor can be explicitly described by means of a code of numbers. In a similar way the causation factors based on the technology of the vehicle and the driving environment, which are also subdivided in an equally hierarchical system, can be tagged with a code. Since the causes of traffic accidents can consist of a variety of factors from different ranges and categories, it is possible to tag each accident participant with several causation factors. This also opens the possibility to not only assign causation factors to the accident causer in the sense of the law, but also to other participants involved in the accident, who may have contributed to the development of the accident. The hierarchical layout of the system and the collection of the causation factors with numerical codes allow for the possibility to code information on accident causes even if the causation factor is not known to its full extent or in full detail, given the possibility to code only those cause factors, which are known. Derived from the systematic of the analysis of human accident causes ("7 steps") and from the practical experiences of on-scene interviews of accident participants, a system was set in place, which offers the possibility to extensively record not only human causation factors in a structured form. Furthermore, the analysis of the human causation factors in such a structured way provides a tool, especially for on-scene accident investigations, to conduct the interview of accident participants effectively and in a structured way.

Introduction and objective

Accidents happen as consequence of disregarding traffic rules and a conflict situation between the road users, whose temporal movement leaves no room for avoiding a collision. The police accident documentation contains a kind of determination of accident causes, which is oriented however at criminal offences and irregularities committed. These causes of accidents are part of the official accident statistics for Germany and are also being used in a similar form in national accident statistics of other countries, amongst others in IRTAD und CARE. The **I**nternational **R**oad **T**raffic and **A**ccident **D**atabase IRTAD is an international database that gathers data on traffic and road accidents from 28 of the 30 OECD Member countries, the European database CARE (**C**ommunity database on **A**ccidents on the **R**oads in **E**urope) is a Community database on road accidents in European member states, collecting data on accidents resulting in death or injury (no statistics on damage - only accidents). The major difference between CARE and most other existing international databases is the high level of disaggregation, for both, however, the data collected by the police are used exclusively for the description of the accident and they contain no statements on the cause of the accident. Nevertheless, the official national accident statistics also contain a characteristic marked as cause of accident, which is determined primarily by the police immediately after the acquisition of accident data from the apparent circumstances. These causes of accident specified by the police do not contain a reconstruction of the accident event, based on which an excessive driving speed, for example, or the actual visibility conditions at the site of the accident would be considered in the cause evaluation. Also the frequently given cause "alcohol" is stated exclusively as a fact, based on finding blood alcohol levels, the actual effect of the alcohol on the accident emergence is not proven. For many years there have been efforts to conduct an adequate evaluation of the causes of accidents, usually in scientific studies of psychologically oriented scientists, who analyzed interviews of persons having been involved in an accident, compared to those of control groups without accident. Into the 70s so-called

In-Depth-data collections were used, where a team at the site of an accident questioned persons involved in accidents and thus collected information on failure and behavior patterns (Wanderer et al. 1974). In-Depth-collections open the possibility to understand not only the kinematic and biomechanical operational sequence of the accident, but also of creating the human system-component from his reported or observed behavior, from his memory and his evaluation of the course of the accident and thus access an analysis of accident causes. In a study conducted for the Federal Highway Research Institute, Germany (Pund et al. 1994), suggestions were made, based on a bibliographical evaluation and different method variations, which accommodate both research based on an analysis of the accident participant as well as the conditions of an accident research working on-scene.
In the past years many of the conducted safety measures concentrated on the avoidance and reduction of injuries and injury severity in case of an accident (measures of passive safety). Measures for the avoidance of accidents (measures of active safety) were so far conducted usually sporadically and were advanced individually by transport authorities and road and town planning. They were based on police collections and the official system of accident causes. Only recently analyses of causes of accidents also put emphasis on optimized safety strategies in automotive engineering and research on accidents. In that way the relatively increasing numbers of accidents due to the increase of the vehicle population and the mileage can be encountered with decreasing numbers of fatalities and severely injured persons. In particular the use of intelligent technical aids like vehicle assistant systems, currently being intensified, such as navigation systems, brake assistants, lane departure warning, adaptive Cruise control, it becomes more and more difficult to evaluate the contributions of these electronic systems implemented in the vehicle on accident influence and accident avoidance. Thus active safety and above all the knowledge of the causes of traffic accidents seem to play an ever-increasing role.

The objective thus has to be to compile an evaluation-neutral coding system of causes of accidents and/or accident influence parameters on the accidents, which can be used within the procedures of accident research. This system has to contain the individual components "human-vehicle-environment" and has to supply a methodology for the collection of important information, it also has to make the causes and/or influence parameters available for computer-based evaluation. To this end at first a suitable system has to be developed and the relevant parameters have to be defined. In a second step these can be coded and a technical and practical coding structure can be developed. For In-Depth data collections on scene it would be particularly helpful, if the developed system could not exclusively be applied by psychological specialists, but also by other researchers after a psychological and system-oriented training. Beyond that it is well known from past on scene accident research and other in-Depth-collections that not always all information concerning the accident is available and that the persons involved or injured in an accident are not always available for questioning. Even in these cases without direct interview of the involved parties the causes of the accident and/or the influencing parameters should still be analyzable.

From these multivariate requirements it was possible to develop a methodology (ACASS – Accident Causation Analysis with Seven Steps), which is to aid the on-scene accident research GIDAS (German in-Depth-Accident Study) and which is in use since the beginning of 2008. GIDAS' special feature is a statistically representative sample appropriate for all types of accidents with personal injury collected by an on scene investigation team consisting of physicians and engineers and a very comprehensive, detailed compilation of the accident data by means of more than 2000 items of information for every accident, concerning injury and deformation patterns, driving and collision speeds as well as other accident characteristics, and, in addition, information from questioning persons involved in the accident (Otte et al. 2003 and Bruehning et al. 2005). In the context of this study the newly developed methodology and structure of the causation coding in GIDAS by means of ACASS and the first results of the application in GIDAS, implemented at the beginning of 2008, are illustrated.

Psychological basis of methodology

Apart from the collection of technical and infrastructural characteristics the analysis of the human "variance " during the accident development contributes to the explanation of causes (cf. PUND & OTTE, 2005). Therefore the influence of the situationally effective behavior is recorded in the context of an analysis of the persons involved as soon as as possible after the accident and if possible at the site of the accident (for the reasons, cf. PUND & NICKEL, 1994). The explorative analysis of accident causes in seven steps ("Seven steps" method) based on traffic-psychology considers the dynamic process character of human functions, which play a role in the avoidance of collisions when coping with a traffic conflict.

The analysis of causes of accidents starting with the event (in contrast for instance to the traffic conflict research) the conditions effective at the time of the critical event are examined as extensively and exactly as possible, on the other hand looking backwards on a time axis conditions, which were the cause of the accident are tracked. The latter applies particularly to the human contribution: Conditions like fog or icy roads as such relatively rarely represent causes of a certain accident (otherwise all road users would have been involved in an accident at the observed accident site under these conditions), but only become an identifiable cause in connection with human processes. Human conditions unfold interactively-dynamically, occur iteratively-process-like and are subject to a high variance. Perception, evaluation and decision procedures, for instance, depend to a high degree on basic functions, which humans bring into the accident situation and which also change and adapt in the course of events, e.g. a "switching" from a more distributed attention attitude to a focused one.

If one considers the structure of an accident causation analysis, one arrives at the rather complex representation of the possible influence parameters relevant in this context (figure 1). From this the approach of a system-oriented recording of accident influence parameters and the ACASS-methodology were developed.

The systematics used for ACASS in the context of the GIDAS accident research contain an explorative classification of characteristics affecting accidents, which occur during the analysis of accidents. Causation factors are relevant single characteristics or combinations of characteristics, which were causal for the development of a traffic accident, or which contributed to the development of the accident. For traffic accidents these factors can be expected to originate from the areas "human", "machine" and "environment".

"Human“ → Group 1, human cause factors (Seven Steps)
„Machine“ → Group 2, factors from the technical nature of the vehicle
"Environment“ → Group 3, factors from the range of the infrastructure and nature

Group 1 with its 7 subcategories is the seven-steps method and thus the core of this system for collecting causes of accidents, which can be attributed to human behavior.

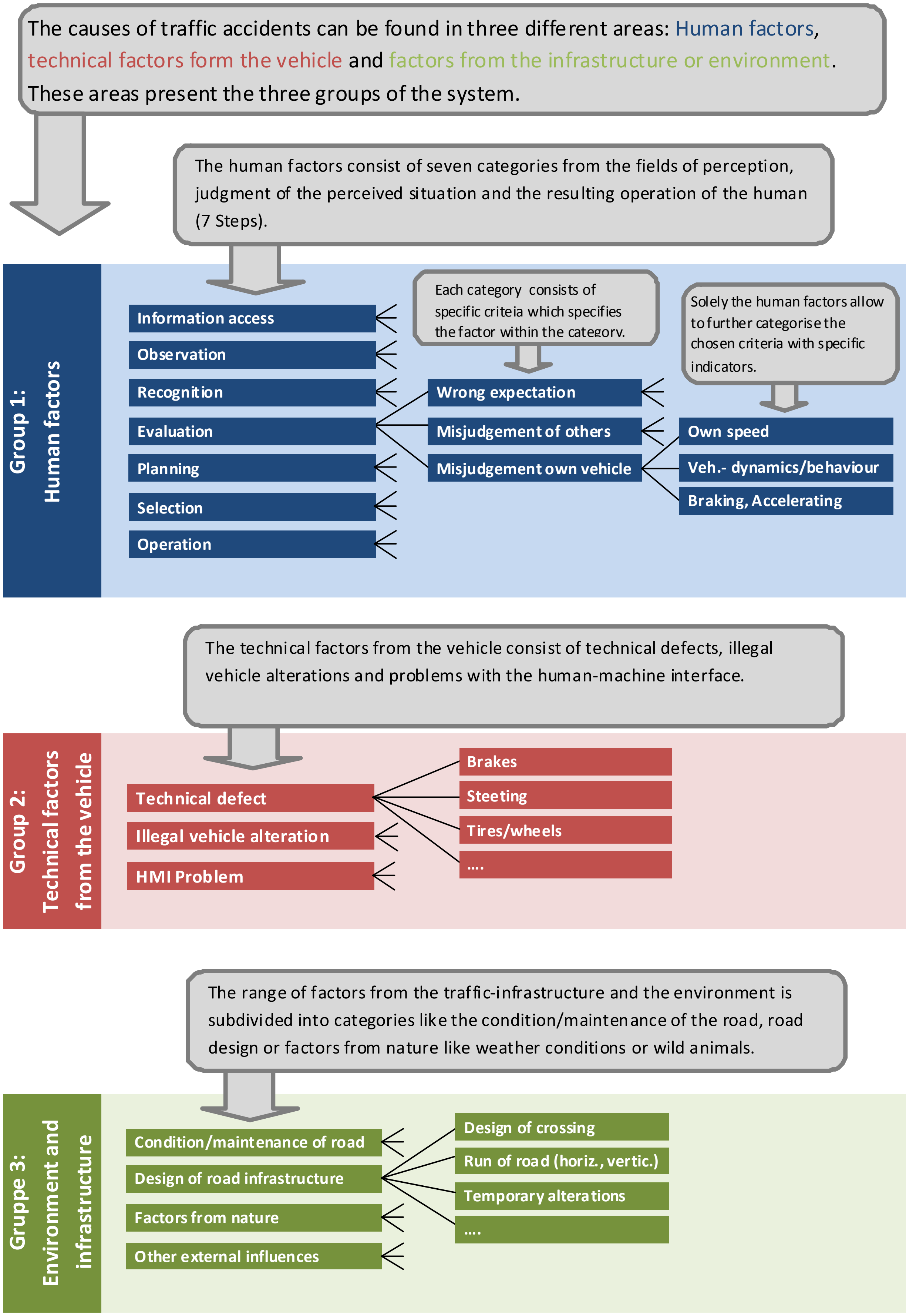

Figure 1: Structural-analytical view of causes of accidents in the human-vehicle-environment-model

ACASS not only is a system for recognizing and describing causation information but also for collecting them in a data base, by categorizing them using a system of numeric codes. Such a system requires additional information apart from the concrete influence parameters of the cause of the accident, in order to be able to deliver as complete a picture of the accident as possible. As can be seen in figure 2, for each accident participant a set of codes is collected, which contain information on the causes of the accident and the source of the corresponding information as well as their reliability. Besides for each causation code an explanatory text is given in a text field.

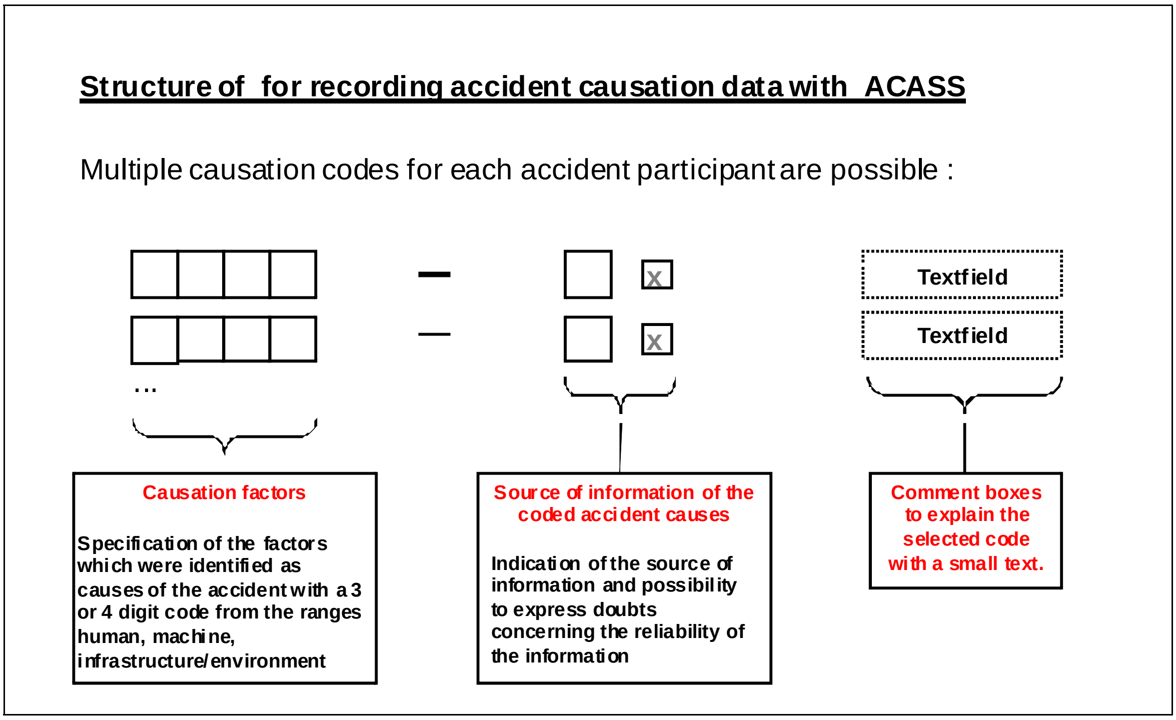

Figure 2: Overview over the data to be encoded for ACASS.

Cause factors

The cause factors constitute the core of the system for the collection of accident causes. The cause factors specific to traffic accidents are summarized in a catalog, which covers the ranges human, machine and environment. Each recognized cause, which has been considered relevant for the respective traffic accident, can be assigned a code, consisting of 3 or 4 numbers. Frequently a combination of several cause factors is responsible for the development of a traffic accident, thus the indication of only one cause of accident would not be sufficient. For this reason there is the option of assigning several cause factors to each person involved in an accident.

Source of information of the coded causes

Here the source of information of a factor can be indicated for each coded cause factor. During the accident investigation and the collection of the causes of the accident frequently possible causation factors are found, which may or may not have contributed to the development of the accident. Often even people involved in the accident also indicate or assume causes, whose relevance may be doubted. For this reason the source of the information of the respective causation factor can be number coded: *(1) questioning of the involved person at the site of the accident; (2) questioning of the involved person in hospital; (3) retrospective interview of the involved person by telephone; (4) retrospective questioning of the involved person in person; (5) questioning of another involved person; (6) questioning of eye-witnesses; (7) information by the police; (8) information from accident reports/official records; (9) estimate of the accident research team.*

To have the opportunity of expressing doubts about a cause of the accident expressed by third parties, there is the possibility, apart from the indication of the source of information, of marking a check box expressing the doubt of the accident researcher, while the cause factor is being recorded in the data base.

Further relevant information

To be able to piece together a complete picture of the development of the traffic accident at a later point in time, it is sensible to collect descriptive information of the constellation of the accident in addition to the cause factors.

For this purpose a text describing the accident is suitable as well as recording the type of the accident in accordance with the GDV (General Association of German Insurance Companies - Gesamtverband Deutscher Versicherer)/ISK (Institute for Traffic Cologne - Institut für Straßenverkehr Köln). This is another 3-digit code, based on the classification in 7 main classes and subsequently in several subclasses of the respective main classes.

Causation factors of traffic accidents

A number of investigations on causes with traffic accidents, already conducted, showed that most causation factors are to be found within the range "human". Due to this relevance the Seven step system was developed, which divides the human factors in 7 categories within group 1. Together with the factors from the range of the technology of the vehicle and the factors from the ranges "nature/infrastructure" three different groups emerge, in which causation factors for traffic accidents can be found. These 3 groups constitute the first digit of the cause code.

Illustration 3 shows that the causation factors of the three mentioned groups are divided in each case into up to seven subcategories within the groups.

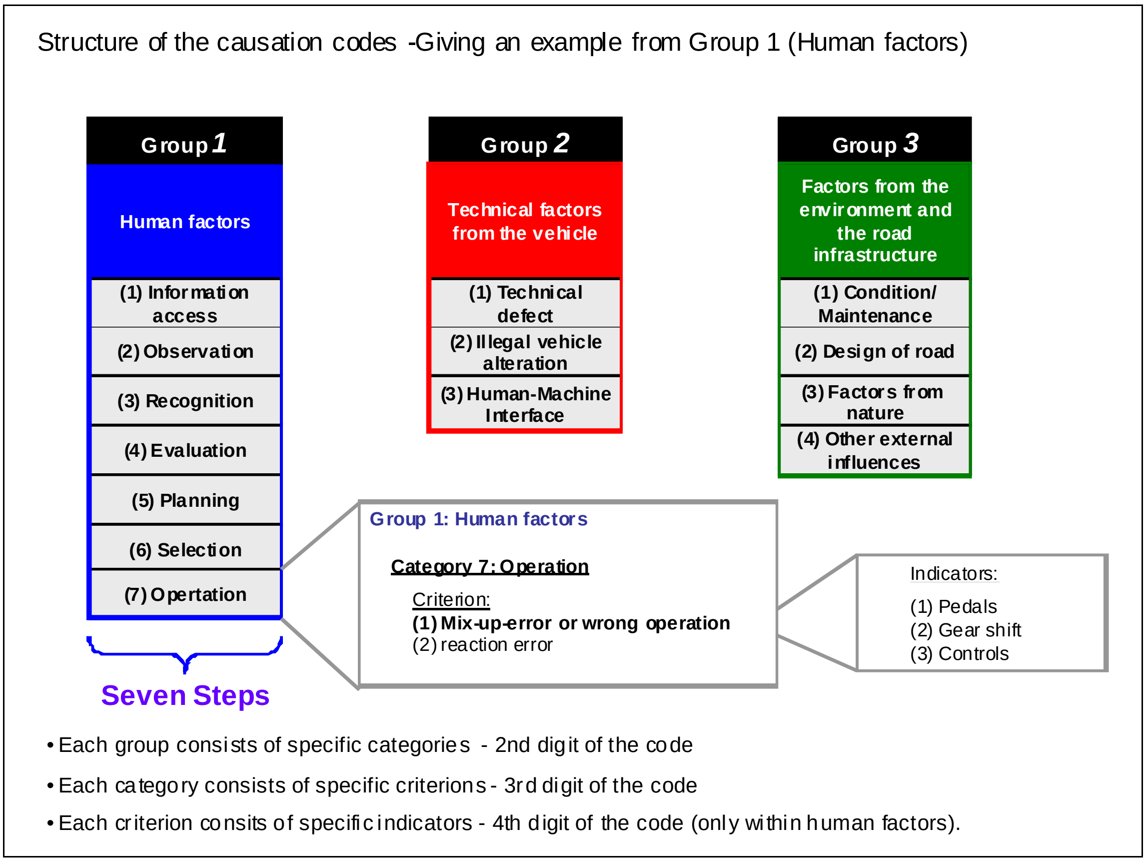

Figure 3: Structure of the causation code.

The respective categories constitute the second digit of the causation code. The third number of the causation code is determined by the concrete causes or by the influence criteria within the respective categories. This has been represented as an example of subcategory (7) "Opertation" within Group 1 (human factors). For human cause factors, however, there is an additional fourth number (indicator). Each influence criterion has a set of indicators, which indicate frequent occurrences of these influence criteria. Using the example (1) of "mix-up and operating error" from group 1, category 7, the most frequent occurrences were (1) pedals; (2) gear shift; (3) control elements. The fourth digit of the code is used to specify the appropriate indicator applicable here. If a mix-up of gas and brake pedal were a cause for a traffic accident, the appropriate cause code for that constellation would be 1711, for instance.

Explorative analysis of causes of accidents due to human factors in seven steps (Seven steps)

The 7 categories (seven steps) of the human cause factors in group 1 are an analysis and order system, which describes the possible human causation factors at the moment of the accident development in chronological order (from perceptibility to action errors). These seven steps are first based on error tracing in the top category of the "information access" and subsequently on the basic 6 human functions (from "observing" to "operating"), which run in chronological order from recognizing the danger up to the reaction to a cause, e.g. a traffic situation evaluated as critical. Based on this structure, the human cause factors can be divided not only into meaningful categories, but can be recognized and collected more easily because of a structured questioning method.

As process model Seven steps takes into account the dynamic sequences, which develop, if a human with his characteristics, abilities and restrictions intervenes in a system. The core method of interviewing the persons involved created a structure of the procedure of data acquisition. The identification of causes of accidents in human behavior should consider the process character of human observation, thinking and acting, in order to arrive at manageable analysis units, which permit clear statements as to the respective human sources of error on distinguishable "function levels". A procedure based on hypotheses lends itself for this purpose, where for every step within the processing concept of the seven steps a core hypothesis is presented, which can be disproved using certain criteria. The respective criterion again experiences its validity of the allocation by different indicators, which are collected at the site of the accident in a predominantly explorative manner.

Result of an application orientated study

The methodology of the collection of accident causes was presented for the first time at the first international conference "Expert symposium on Accident Research" (ESAR) in September 2004. After a testing phase it has been used in this shape by GIDAS in the course of the ongoing analyses of accidents at the medical university Hanover. The model it is based on has been theoretically justified and its implications for application on the special conditions of an "In-Depth/On-the Spot" analysis were derived (PUND and OTTE, 2005). Within two years of developing work, the model underwent a definition and an adjustment taking into account the feasibility and restrictions of the research at the sites of accidents, where the aspect of the "feasibility" and the realistically executable time and effort for data acquisition and coding was focused on (PUND, OTTE and JAENSCH, 2007). A further objective was as high an agreement of the model structure with the collection instruments derived from it as possible and their adjustment to the half-standardized interview form used up to that time (cf. PUND and OTTE, 1999).

The analysis of the human causation factors of accidents in seven steps is now a variable set of group 1 of the causation codes, besides the "factors of influence from the range of the vehicle technology" of group 2 and the "factors of influence from the range of the infrastructure and environment" of group 3 (cf. diagram 3).
On the basis of interactive models of the traffic participation and accident development, the model of the Seven Steps is based on an information-theoretical access; it considers action theoretical explanation approaches and covers components of the error analysis. Models of the procedural data processing generally assume step procedure "perception - interpretation - decision - action" and also consider the interfaces of the "human factor" with other system components (in summary e.g. HEINRICH and PORSCHEN, 1989; WILLUMEIT and JUERGENSOHN, 1997; WICKENS, 2000). The approach of process description of the information acquisition, its cognitive processing, the intention and goal formation, which are based on the above, as well as their conversion into actions have been integrated into the model, just like the observation of human processes as sequential

functions from the perception of a critical attraction to the execution of the action. The "disturbance" identified in the respective step of the hierarchically structured flow chart, describing the human basic function in detail is perceived as an error during the process of the information processing and action conversion (e.g. REASON, 1994; RASMUSSEN, 1986, 1995; KUETING, 1990), the failure of a basic human function is explained due to effective physiological or psychological factors, e.g. perception errors due to distraction; decision errors due to unsolvable conflicting objectives or action errors due to coordination errors (see tri level study; TREAT et al., 1977). The role of the motivation of the drivers concerns above all the risk evaluation of a situation and the driver's behavior, thus questions concerning the motivational conditions, particularly in the steps "estimate" (interpretation of the recognized characteristics) and "planning" (action draft due to intention formation) are asked (see NAEAETANEN and SUMMALA, 1974).

The first question, which the accident analyst puts to the person involved in the accident and his "view" of the accident (in both senses of the expression), is the one concerning the existing access to information on all sensory levels. As the solution of traffic conflicts in the predominant number of the cases is dependant on a visual perceptual input and less on an auditory or kinesthetic-tactile access, the visual conditions on individual, vehicle-lateral and environmental basis have the highest priority (in the course of the interview different perception restrictions can turn out to be important, for instance if acoustic warning signals were not noticed).

Group 1 of the human cause factors (Seven step) subsequently shown as a hypothesis list conveys only exemplarily and as abstracts some of the criteria associated with the hypothesis.

In agreement with a hypothesis-based procedure with the identification of relevant human causes of accident the first hypothesis reads (if this cause is true, it has to be negated):

<u>1. The information necessary for the possible solution of the traffic conflict was objectively available and the person involved in the accident was able to perceive it without obstruction.</u>

- The presence of an "unobstructed perception" is examined exemplarily on the basis of the following criteria: the involved person did not exhibit functional limitations of his eyesight and his central daily visual acuity as well as the other vision functions (e.g. color vision, twilight vision, stereoscopic vision) generally enabled him to use the field of view for the acquisition of information (also taking into account corrective lenses).
- The perception field necessary for the observation of the relevant traffic conditions was not obscured by vehicle-specific perception barriers (characteristics of the vehicle construction, passengers, additional load, changes to the vehicle, wrong or insufficient use of perception assisting devices, condition of the windscreen and other windows, retro-fitted devices).

The first of the seven steps thus refers only indirectly to human characteristics in the sense of an individual reception possibility of sensorily transmitted information. This step designates something like a "gate" for the use of the information. The access opened by this "gate" represents the pre-condition for the second step:

<u>2. The involved person was able and motivated to direct his perception by attentive observation to the relevant/critical situation characteristics based on sufficient perception conditions.</u>

The existence of an "attentive observation" (distributed attention, observation of details) is examined exemplarily on the basis the following criteria:

- The observation accuracy of the person involved was not subject to a diverting influence due to outside stimuli from the driving environment, which limited the distributive attention or which impaired channeling the attention on relevant details.
- The degree of physiological activation of the person involved was not reduced; in particular there were no negative influences on the vigilance (fatigue, exhaustion, drowsiness, microsleep, effects of monotonous driving conditions, influences of the circadian rhythm,

disease symptoms with reduction of the level of activity, (side-) effects of medication, influence of other substances).

The criteria the examination of the second hypothesis was based on comprise features effective in certain situations, which negatively affect the attention attitude of the person involved: external and internal distractors, deactivating factors and influences restricting vigilance restrictive due to substance consumption (alcohol, drugs, medication). The influence of the substances also impairs the cognitive and coordination conditions in the next steps, but it is postulated that a substance consumption particularly and primarily affects the observation ability and attention attitude as a malfunction, thus it is explicitly inquired as specific effect factor in the second step of the Seven steps and is also coded there, if necessary.

If the second hypothesis cannot be negated due to the absence of negative attention-related influences, the next step of the correct identification of the relevant situation characteristics is entered:

<u>3. The person involved recognized the major elements of the situation and completely understood their impact on the further development. With several elements observed simultaneously he kept the track of all of them and identified the major features that were relevant to his actions.</u>

Identifying / recognizing the complete situation and the identification of the major action-relevant characteristics from an event stream is determined exemplarily by the following criteria:

- With available information density, complex perception conditions and/or requirements of the substantial/solid information admission (incessant flood of irritations/sensory overload) the person involved was nevertheless able to understand the substantial features and their meaning.
- During the observation of the traffic the person concerned has filtered the action-relevant information from the information on offer and neglected irrelevant features.

A further criterion in the third step refers to identification problems such as similarity mistakes, mistake or fusion of an object with the background ("Camouflage").
In the consequence the situation is misjudged, which negatively affects the next step of a reliable "risk evaluation". The question concerning the evaluation of a situation regarding its decision relevance (e.g. a palpable threat) follows upon the fourth hypothesis:

<u>4. The person involved was able to evaluate the danger on the basis of the recognized features, by correctly judging the situation and its development concerning its instability and/or its risk content in time.</u>

A timely evaluation and a correct interpretation is examined exemplarily on the basis of the following criteria:

- The person involved correctly estimated speeds and distances of other road users and/or distances of objects or topographic features.
- The person involved combined and correctly interpreted information concerning the driving environment or the behavior of other road users (no "hasty conclusions"; no incorrect assumptions, e.g. due to communication error, confidence error, transfer of responsibility).

In this step all causes of misinterpretations are of interest due to lack of experience, erroneous assessment of physical dimensions (distances, speeds, dimensions, spacial location, length of time), misinterpretations of indications and warning signals and communication errors between road users. Also erroneous evaluations due to "experience problems" (neglecting a risk due to wrong expectations and habits: "nobody ever comes out of this road") are covered by this analysis step. If the situation was judged correctly, however, and understood as a request for action, the next step of action planning follows:

5. The person involved made at least a rudimentary action draft with correct objective and has considered alternative possibilities when planning. He has not also understood what needs to be done, but also how to implement it (correct method).

An indication for the presence of a plan that is as complete and correct as possible can be exemplarily derived from the following criteria:

- The person involved decided on the correct alternative course of action with sufficient time for the selection of the action strategy.
- The person involved did not consciously decide in his planning to violate well-known traffic rules.
- The person involved did not include any "ulterior motives" in his decision-making, which have no recognizable connection to the traffic conditions (counter-productive goals and problematic driving motives, such as superiority, competition, demanding privileges etc.).
- The person involved considered the possible side effects of his planning in the decision-making process and made changes to the plan if necessary and/or considered corrective measures.

For the analysis of the fifth step it has to be considered that for a rational behavior planning and control the time available permits at most a preconscious planning due to quickly recalled "internal sequence models", which developed with the experience of the driver. Questions about decision errors due to incorrect assumptions of the development of the situation thus play a role for the analysis just like skipping the planning phase in favor of a reflex action.

In the context of the explorative accident research persons concerned occasionally report the execution of an action, yet the execution of the intended action was omitted or delayed. In order to be able to analyze this phenomenon more in detail, the sixth step of the pertinent hypothesis is formulated as follows:

6. With the intention of realizing a decision that had been made, no psychologically or physiologically disturbing influences arose, which prevented the implementation of the decision or which prolonged the time required for decision.

The question of a correct and punctual conversion of the principally promising decision can be determined by the criterion of "performance obstacles during the conversion". This can be described based on the following examples:

- The person involved was not subject to a reaction inhibition due to shock phenomena, fright or fear and/or escape reactions.
- During the implementation of the planned action no reaction errors in the sense of inappropriate force, delayed introduction of the reaction or wrong sequence occurred.

The causes of a delayed reaction or of a complete suppression of a reaction are often "shock and block phenomena", confusion due to panic, "hyperactivity / uncontrolled reaction", "a feeling of being overwhelmed" or unsolvable conflicting aims with several equivalent options to react (“to brake or to accelerate”). Also the necessary intensity of the reaction implementation may be negatively influenced herewith (e.g. too weak braking).
In case of unobstructed implementation of the planned decision, possible execution errors move into the focus of the analysis. General action errors and specific control errors prevent the correct execution of a preventive action or emergency and/or avoidance reaction:

7. The person involved did objectively have the chance of intervening in the system by acting and no qualitative or quantitative procedural errors occurred. The person involved implemented the selected mode of operation as intended.

As criteria for a correct und complete action or for an error-free operation the following indicators may be drawn on:

- The action of the person involved was not subject to mix-ups or operating errors.

- The person involved was able to operate the control element without interruption

In the seventh step the question of the concrete execution of the action, after a reaction has occurred, is discussed. Possible action and control errors are explored in the interview. If errors in the execution of the action were not identifiable, however, technical and/or structural system errors in group 2 (e.g. vehicle changes, malfunctions, interface problems) have to be searched for or the respondent has not contributed to the causation of the accident.

In the context of implementing ACASS into GIDAS it appeared to be sensible to simplify the seven Categories of human causation factors, to improve the practicability of this system during on scene investigations for team members without a fundamental psychological background. Thus two changes were performed: First the categories “(2) Observation” and “(3) Recognition” were merged to one category “Information access” und secondly the category “(6) Selection” was merged into the category “(7) Operation”. These remaining five categories may easily be converted back into a seven step system with the knowledge of the specific influence criteria of the categories.

In the following the seven-step system for the collection of causes of accidents is to be clarified by an example. This example is based on a real-life traffic accident, which was collected in the context of the GIDAS accident research project.

Example of use of ACASS in GIDAS

Description of an accident:
The 46-year-old driver of an AUDI A6 (built in 2005) drove along a single-lane highway on the ramp leading to a bridge. At the end of a right hand bend, immediately before he came to the bridge he lost control of his vehicle, ran off the road to the left and collided with the left hand guard rail behind the bridge. The driver was questioned in hospital. He stated that he drove around the right hand bend, when suddenly there was quite a large animal on the bridge. Then he oversteered to the left and lost control.

In the context of the investigations of the GIDAS research team, it turned out however that the driver possibly briefly used the telephone function of his navigation system before the accident. When the research team arrived at the scene of the accident the system was still in the telephone mode ready to dial a number (cf. figure 4). Thus it seems also possible that the driver was distracted from his driving task and this distraction caused the accident. The fact that he wanted to avoid hitting an animal could also be a protection statement of the driver, particularly as it appears improbable that larger animals stay on bridges.
Using the causation codes as shown in illustration 4, three causes of accident factors were recorded. First the information from the interview with the driver was coded. The driver stated to have suddenly seen an animal on the road and steered, possibly due to fright, too far to the left. Here an overreaction due to fright was coded from the human factors.

Code 1612
Group 1 (human factors), category 6 (selection of the action), influence criterion 1 (performance of obstacles), indicator 2 (fright/shock).

On the other hand as another factor of influence the animal on the road is coded from the group 'environment'

Code 341
Group 3 (factors from the environment), category 4 (additional external influences), influence criterion 1 (animals).

As these causes of the accident were stated by the driver during questioning in the hospital, the source of information was coded here as 2. If the statement made by the driver was possibly only a defensive maneuver, doubt concerning the reliability of the code could be expressed by marking the following check boxes.

Then the assumption of the accident investigation team that operating the telephone possibly distracted the driver was coded. This is a cause factor from the group of the human factors

<u>Code 1211</u>
Group 1 (human factors), category 2 (observation), influence criterion 1 (distraction from inside the vehicle); Indicator 1 (operation of devices)

As this cause factor is an assessment of the accident investigation team, the source of information 9 was encoded here.

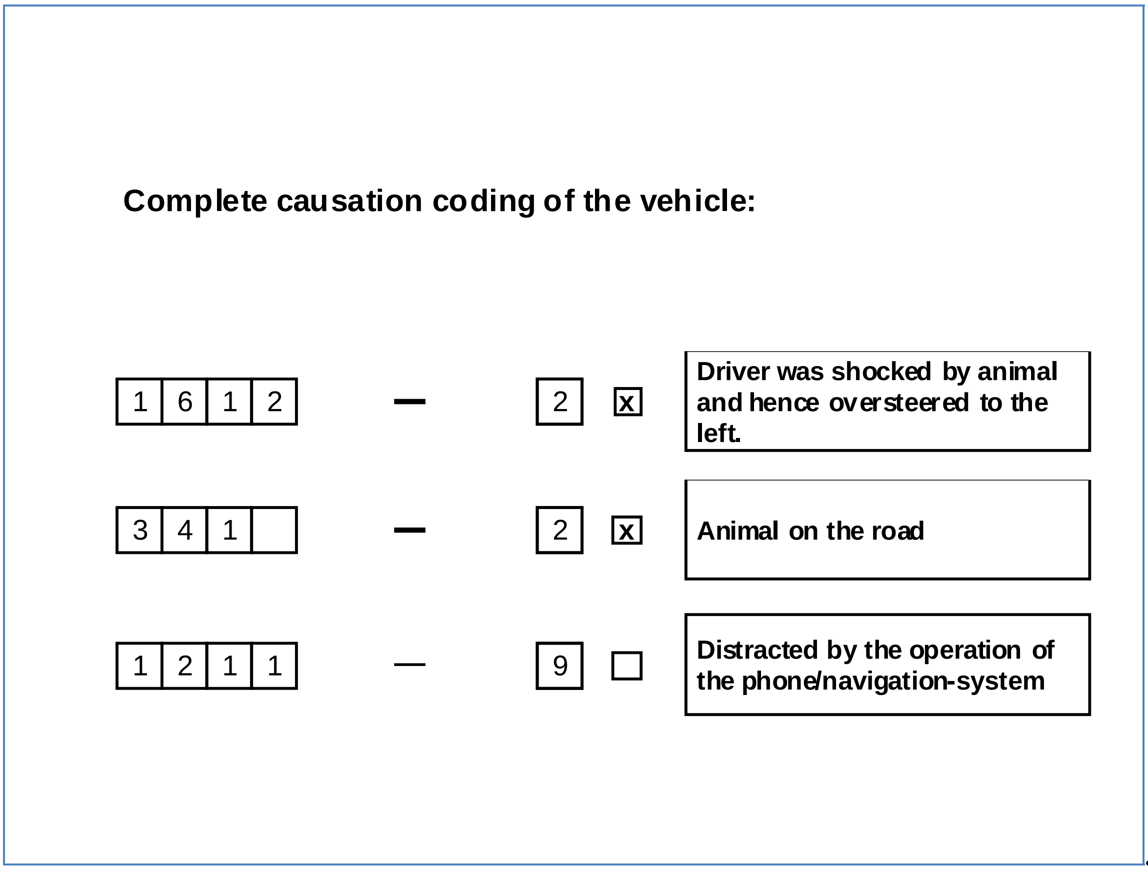

Figure 4: ACASS coding of the example.

Figure 5: Direction and path of the Audi.

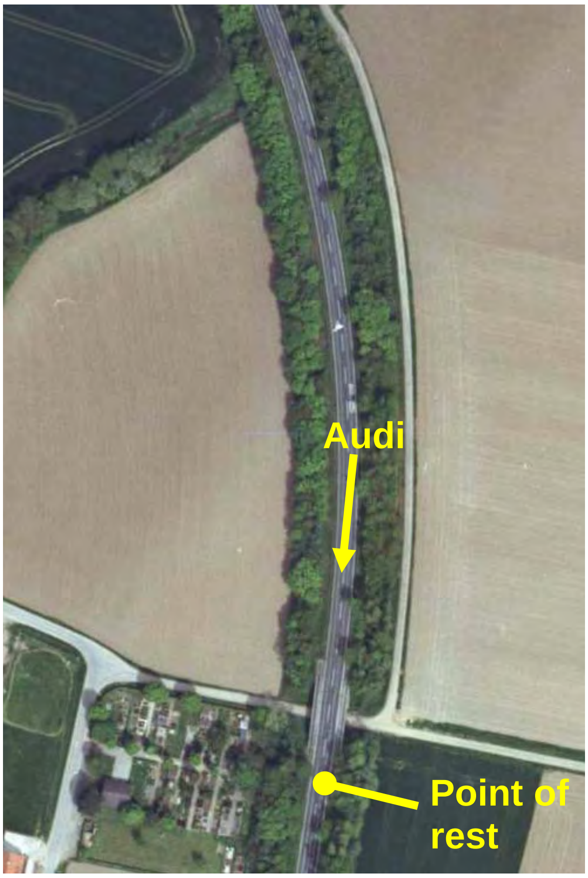

Figure 6: Aerial picture of the site of the accident.

Figure 7: Point of rest of the vehicle.

Figure 8: Interior of the vehicle.

Results of the implementation in GIDAS

561 accidents collected within GIDAS by June 2008 were evaluated, of these 412 cases (73%) contained causation codes. Thus 687 involved persons were available for analysis, of which 457 persons contributed to the emergence of the accident and had a causation code. A population of cases resulted with a distribution similar to all accidents in GIDAS, for instance based on the proportion of traffic participants, cars 54%, trucks 6%, bicycles 21%, 8% pedestrians, 9% motorcycles. Human causes were determined for all road users in over 92% of the cases, with the exception of accidents involving busses and streetcars (figure 9). Environmental factors obviously have less effect on the development of accidents involving passenger cars and trucks than on accidents involving pedestrians and motorcyclists as traffic participants.

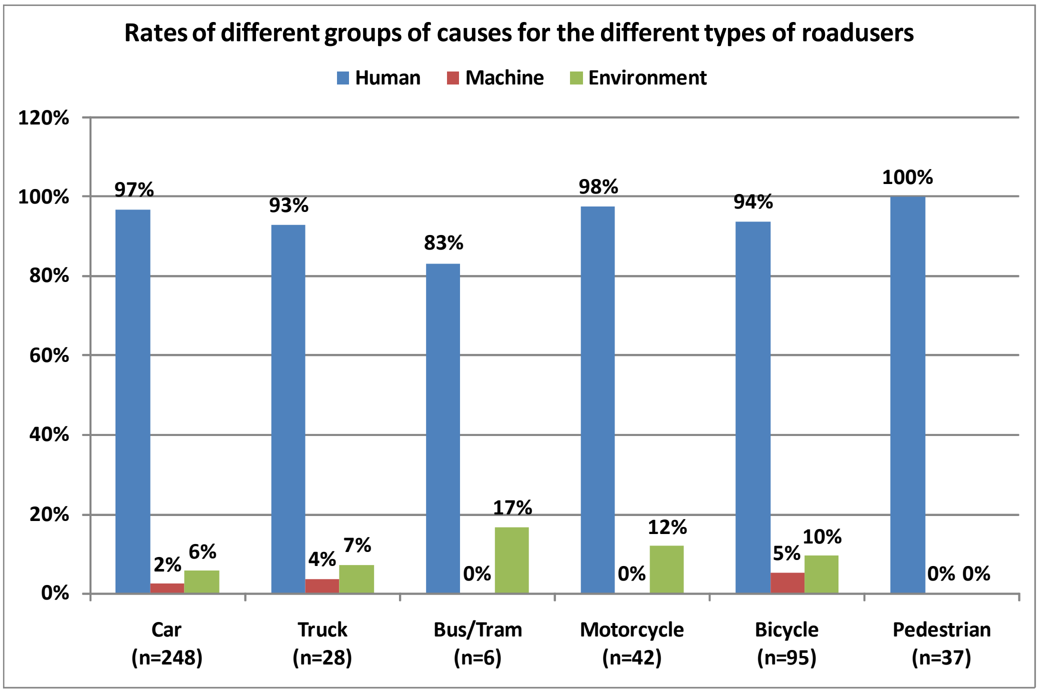

Figure 9: Frequency of the indicated causation factors in the accident documentation of GIDAS

A coding of the human cause factors was done as a complete code in 91,2% of the cases, in 6,8% of the cases without an indicator and in 2% of the cases only the group could be specified (figure 10).

The group of the human cause factors consists of categories of the ranges of the perception of humans, the evaluation of the perception and the resulting action, which is called 7 Steps because of the possible 7 categories.
In 20% of the cases no complete access of the participant to all information was possible. Furthermore 18% of the participants that contributed to the emergence of the accident did not observe the Situation with full attention. 31% of the human factors relate to failures with the recognition of the traffic situation and respectively about 25% relate to errors when evaluating the situation and when planning an action to handle the situation. Only 10% of the participants had problems with the selection and initiation of an action and only about 1% had an action error like mixing up the brake-pedal with the accelerator (figure 11)

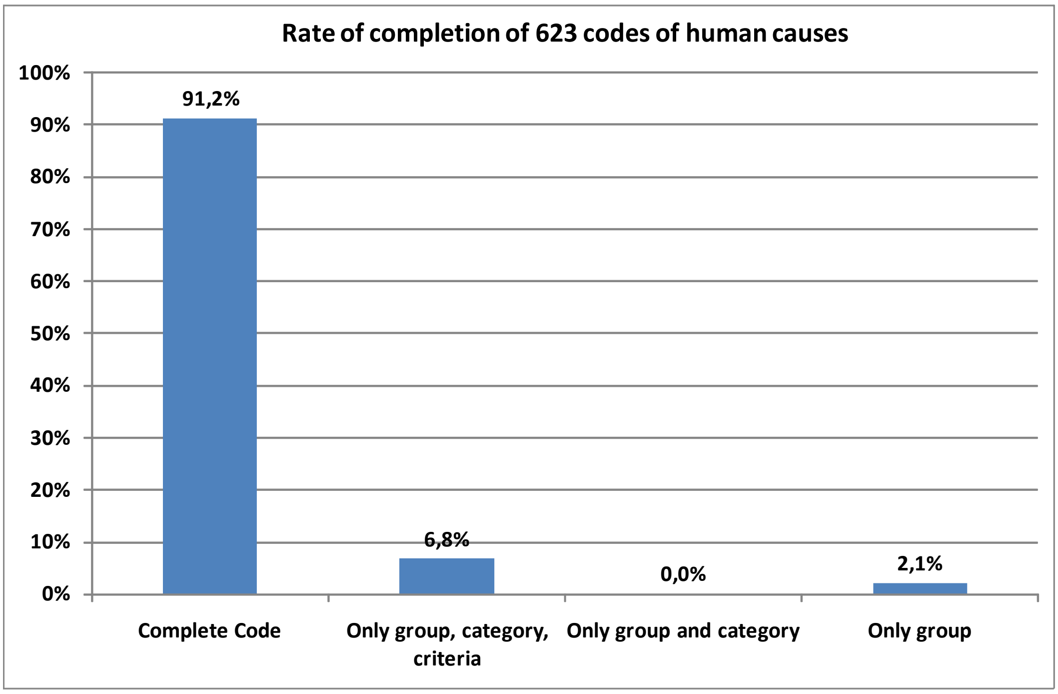

Figure 10: Completion of human factors.

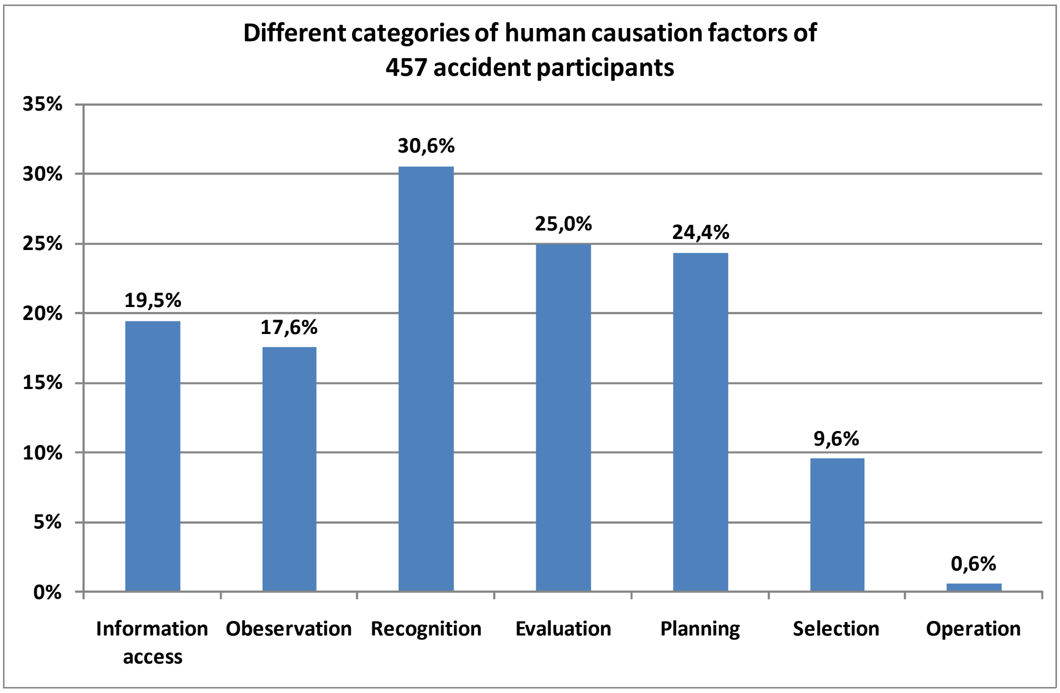

Figure 11: Frequencies of the categories of the human causation factors.

With the more differentiated evaluation of the categories, using the criteria, a wrong focus of attention of the driver appears with an incidence of 29 % (figure 12). This can be regarded as a substantial influence parameter for accident causation. But also the intentional breach of rules with an incidence of 14 % proves to be a frequent accident causation factor.

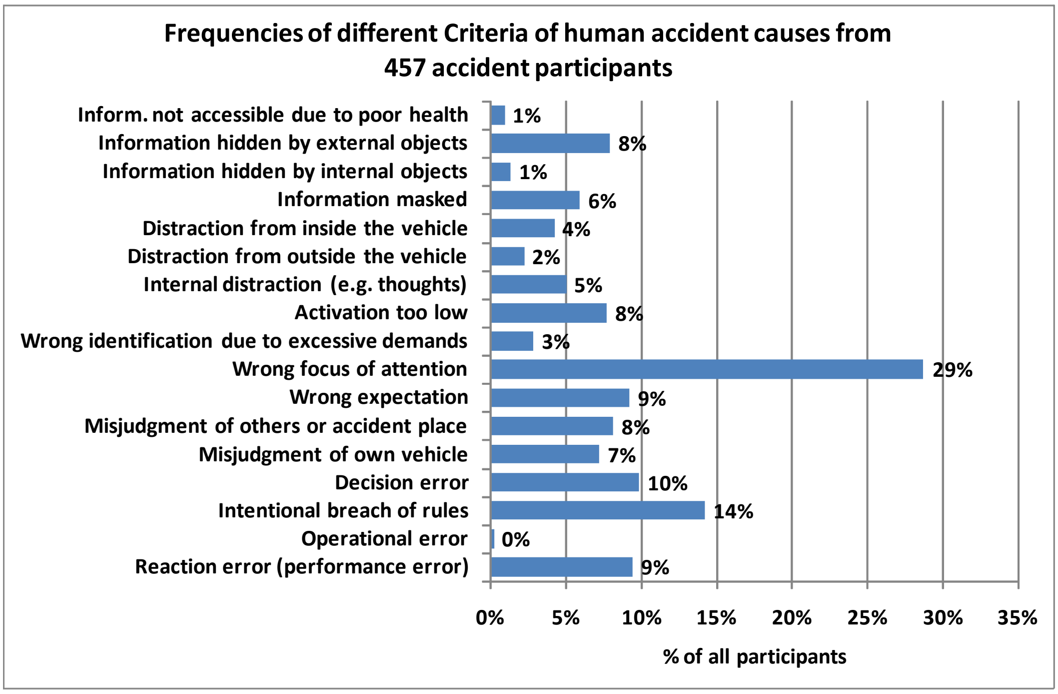

Figure 12: Frequencies of the criteria within the different categories of the human causation factors.

When evaluating the most frequent indicators of the different criteria, the “wrong observation strategy” and also the “wrong assumption concerning the outcome of a situation“ appear most frequently from altogether 669 mentions. But also “excessive speed” and the “focus towards the wrong road user”, the “wrong estimation of distance of other road users” as well as “driving under influence of alcohol” appears as frequent indicators of human causes:

12063	Wrong observation strategy	n=87
14012	Wrong assumption concerning the outcome of a situation	n=36
14022	Excessive speed	n=27
12061	Focus of attention towards the wrong road user	n=25
13022	Wrong estimation of distance of other road users	n=20
12042	Driving under influence of alcohol	n=18

Conclusions

In particular due to the increasing use of intelligent technical aids of the vehicle assistant systems, it becomes more and more difficult to evaluate the contributions of these electronic systems built in the vehicles concerning their influence on accident causation and accident avoidance. Active safety and above all the knowledge of the causes of traffic accidents gain at present an ever-increasing importance for the development of safety measures. The objective was the creation of a coding system of causes of accidents and/or influencing parameters on the accidents, which can be used in the framework of accident research. This system should contain the individual components "human - vehicle - environment" and a methodology for the collection of the important information, beyond that it should also make the causes and/or influence parameters available for evaluation/processing on computers.

The objective of finding a suitable system to supply the relevant parameters for the GIDAS on scene investigations and also other in-Depth-investigations was achieved and the system has been judged as suitable after it underwent a practice test.

The practice test resulted in a satisfactory usage rate of coding application for the accident documentation. The team members had undergone psychological training and the codes selected by the team were correctly chosen in the majority of the cases. Next to three days of traffic psychological training, the quality control arrangements also included case reviews with plausibility validation of the codes as well as a random operation of the traffic psychologist in the accident research team.

The coding should be a component of an on scene accident data collection system. Thus information collected from persons and vehicles involved in an accident can be recognized as parameters influencing the accident development and processed for use on computers based on the coding system.

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Hypothesis-based explorative analysis of causes of accidents due to human factors in seven steps (ACASS)

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For the multivariate requirements of In-Depth-studies on accident-causes a methodology (ACASS – Accident Causation Analysis with Seven Steps) was developed, which is to aid the on-scene accident research GIDAS (German in-Depth-Accident Study) and which is in use since the beginning of 2008. In a study conducted for the Federal Highway Research Institute, Germany (PUND & NICKEL, 1994), suggestions were made, based on a bibliographical evaluation and different method variations, which accommodate both research based on an analysis of the accident participant as well as the conditions of an accident research working on-scene.

Apart from the collection of technical and infrastructural characteristics the analysis of the human influences during the accident development contributes to the explanation of causes (cf. PUND & OTTE, 2005). Therefore the influence of the situational effective behavior is recorded in the context of an analysis of the persons involved as soon as possible after the accident and if possible at the site of the accident. The explorative analysis of accident causes in seven steps based on traffic-psychology considers the dynamic process character of human functions, which play a role in the avoidance of collisions when coping with a traffic conflict.

The 7 categories (seven steps) of the human cause factors are an analysis and order system, which describes the possible human causation factors at the moment of the accident development in chronological order (from perceptibility to action errors). These seven steps are first based on error tracing in the top category of the "information access" and subsequently on the basic 6 human functions (from "observing" to "operating"), which run in chronological order from recognizing the danger up to the reaction to a cause, e.g. a traffic situation evaluated as critical. Based on this structure, the human cause factors can be divided not only into meaningful categories, but can be recognized and collected more easily because of a structured questioning method.

As process model “Seven steps” takes into account the dynamic sequences, which develop, if a human with his characteristics, abilities and restrictions intervenes in a system. The core method of interviewing the persons involved created a structure of the procedure of data acquisition. The identification of causes of accidents in human behavior should consider the process character of human observation, thinking and acting, in order to arrive at manageable analysis units, which permit clear statements as to the respective human sources of error on distinguishable "function levels". A procedure based on hypotheses lends itself for this purpose, where for every step within the processing concept of the seven steps a core hypothesis is presented, which can be disproved using certain criteria. The respective criterion again experiences its validity of the allocation by different indicators, which are collected at the site of the accident in a predominantly explorative manner.

The methodology of the collection of accident causes was presented for the first time at the first international conference "Expert symposium on Accident Research" (ESAR) in September 2004. After a testing phase it has been used in this shape by GIDAS in the course of the ongoing analyses of accidents at the medical university Hanover. The model it is based on has been theoretically justified and its implications for application on the special conditions of an "In-Depth/On-the Spot" analysis were derived (PUND and OTTE, 2005). Within two years of developing work, the model underwent a definition and an adjustment taking into account the feasibility and restrictions of the research at the sites of accidents, where the aspect of the "feasibility" and the realistically executable time and effort for data acquisition and coding was focused on (PUND, OTTE and JAENSCH, 2007). A further objective was as high an agreement of the model structure with the collection instruments derived from it as possible and their adjustment to the half-standardized interview form used up to that time (cf. PUND and OTTE, 1999).

Following the “Seven-Steps-Model” (focused on the pre-crash-phase) the sequence of accident-related human functions can be described in following terms:

-no problem-solving (concerning immediate accident-danger) without **information access**
-without sufficient information access no **indication for observation**
-without attentive observation no **identification** and recognition
-without correct recognition no **interpretation** and evaluation
-without rational and critical evaluation no planning and **intention forming**
-without (at least rudimentary) planning no selective **implementation of action**
-without unhampered implementation no correct **interference** and operation.

In agreement with a hypothesis-based procedure with the identification of relevant human causes of accident the first hypothesis reads:

1. **The information necessary for the possible solution of the traffic conflict was objectively available and the person involved in the accident was able to perceive it without obstruction.**

The presence of an "unobstructed perception" is examined exemplarily on the basis of the criterion, that the involved person did not exhibit functional limitations of his eyesight. Another criterion is, that the perception field necessary for the observation of the relevant traffic conditions was not obscured by vehicle-specific or infrastructural perception barriers.
This step designates something like a "gate" for the use of the information. The access opened by this "gate" represents the pre-condition for the second step:

2. **The involved person was able and motivated to direct his perception by attentive observation to the relevant/critical situation characteristics based on sufficient perception conditions.**

The criteria the examination of the second hypothesis was based on comprise features effective in certain situations, which negatively affect the attention attitude of the person involved: external and internal “distractors”, deactivating factors and influences restricting vigilance restrictive due to substance consumption (alcohol, drugs, medication).
If the second hypothesis cannot be negated due to the absence of negative attention-related influences, the next step of the correct identification of the relevant situation characteristics is entered:

3. **The person involved recognized the major elements of the situation and completely understood their impact on the further development. With several elements observed simultaneously he kept the track of all of them and identified the major features that were relevant to his actions.**

Identifying / recognizing the complete situation and the identification of the major action-relevant characteristics from an event stream are determined exemplarily by the criteria of information density, complex perception conditions and/or information overload.
A further criterion in the third step refers to identification problems such as similarity mistakes, mistake or fusion of an object with the background ("Camouflage").
In the consequence the situation is misjudged, which negatively affects the next step of a reliable "risk evaluation". The question concerning the evaluation of a situation regarding its decision relevance (e.g. a palpable threat) follows upon the fourth hypothesis:

4. The person involved was able to evaluate the danger on the basis of the recognized features, by correctly judging the situation and its development concerning its instability and/or its risk content in time.

In this step all causes of misinterpretations are of interest due to wrong expectations, lack of experience or erroneous assessment of physical dimensions.
If the situation was judged correctly, however, and understood as a request for action, the next step of action planning follows:

5. The person involved made at least a rudimentary action draft with correct objective and has considered alternative possibilities when planning. He has not also understood what needs to be done, but also how to implement it (correct method).

An indication for the presence of a plan that is as complete and correct as possible can be exemplarily derived from the criterion, that the person involved decided on the correct alternative course of action with sufficient time for the selection of the action strategy, or he did not consciously decide in his planning to violate well-known traffic rules.
For the analysis of the fifth step it has to be considered that for a rational behavior planning and control the time available permits at most a preconscious planning due to quickly recalled "internal sequence models", which developed with the experience of the driver. Questions about decision errors due to incorrect assumptions of the development of the situation thus play a role for the analysis just like skipping the planning phase in favor of a reflex action.

In the context of the explorative accident research persons concerned occasionally report the execution of an action, yet the execution of the intended action was omitted or delayed. In order to be able to analyze this phenomenon more in detail, the sixth step of the pertinent hypothesis is formulated as follows:

6. With the intention of realizing a decision that had been made, no psychologically or physiologically disturbing influences arose, which prevented the implementation of the decision or which prolonged the time required for decision.

The question of a correct and punctual conversion of the principally promising decision can be determined by the criterion of "performance obstacles during the conversion".
E.g., the effect of "shock and block phenomena" is a delay or a suppression of the intended reaction. In this step paralyzing emotional reactions like "a feeling of being overwhelmed" (e.g. the participant shuts his eyes because he is horrified) or the opposite, a "hyperactivity / uncontrolled reaction" as stress reaction are queried, which altogether prevent a coordinated setting of priorities and implementation of actions.
In case of unobstructed implementation of the planned decision, possible execution errors move into the focus of the analysis. General action errors and specific control errors prevent the correct execution of a preventive action or emergency and/or avoidance reaction:

7. The occupant did objectively have the chance of intervening in the system by acting and no qualitative or quantitative procedural errors occurred. The person involved implemented the selected mode of operation as intended and the interference was carried out completely..

The indicators that lead to criteria for a correct and unhindered transformation of the decision into action and for an operation without error are, that the action of the person involved was not subject to mix-ups or operating errors.

In the context of implementing ACASS into GIDAS it appeared to be sensible to simplify the seven Categories of human causation factors, to improve the practicability of this system during on scene investigations for team members without a fundamental psychological background. Thus two changes were performed: First the categories “(2) Observation” and “(3) Recognition” were merged to one category “Information access” und secondly the category “(6) Selection/Implementation” was merged into the category “(7) Operation”. These remaining five categories may easily be converted back into a seven step system with the knowledge of the specific influence criteria of the categories.

With the “Seven-steps model” as a theoretical approach to describe and explain the human causes of accidents efforts were made to develop an economic tool suitable for the practical use “on scene.” Furthermore, the hypothesis-based procedure ensures reliable linking of the found topics with possible human causes and transforming them into a code-system also derived from the model.
Training and supervision of the research-team (interview-techniques, use of the codebook, use of the semi-structured questionnaire) are as much essential as plausibility-checks of the coding in the sense of inter-rater-reliability.

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Development of an In-depth European Accident Causation Database and the Driving Reliability and Error Analysis Method, DREAM 3.0

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Abstract - The SafetyNet project was formulated in part to address the need for safety oriented European road accident data. One of the main tasks included within the project was the development of a methodology for better understanding of accident causation together with the development of an associated database involving data obtained from on-scene or "nearly on-scene" accident investigations. Information from these investigations was complemented by data from follow-up interviews with crash participants to determine critical events and contributory factors to the accident occurrence. A method for classification of accident contributing factors, known as DREAM 3.0, was developed and tested in conjunction with the SafetyNet activities. Collection of data and case analysis for some 1 000 individual crashes have recently been completed and inserted into the database and therefore aggregation analyses of the data are now being undertaken. This paper describes the methodology development, an overview of the database and the initial aggregation analyses.

INTRODUCTION

The SafetyNet project is an Integrated Project (IP) which was developed as part of the European Commission's 6th Framework programme. SafetyNet has built the foundations of a European Road Safety Observatory (ERSO) which can be used by the European Commission for the purposes of policy review and development. The SafetyNet project is divided into seven main Work Packages each of which deal with specific aspects of road safety research [1]. This paper describes the second task of Work Package 5 of SafetyNet which involves the development of a method for assessment of contributing factors and an accident causation database including some 1 000 individual cases. The accidents were investigated using an analysis approach known as the SafetyNet Accident Causation System (SNACS) [2] to classify the contributing factors that lead to the crash, SNACS is a slight modification of Driving Reliability and Error Analysis Method (DREAM 2.1) [3].

A persistent lack of data pertaining to accident causation is a major obstacle in the development and refinement of in-vehicle technological systems aimed at accident mitigation but also in the understanding of driver behaviour in different road environments. Data are needed to both assess the performance of existing systems and furthermore the development of systems of the future. Therefore, a harmonised, prospective "on-scene" method for recording the critical events and the contributing factors of road crashes was developed. Where appropriate, this includes interviewing road users in collaboration with more routine accident investigation techniques. The database enables multi-disciplinary information on the circumstances of crashes to be interpreted to provide information on the contributing factors. The development of the data-recording method is now described.

DEVELOPMENT OF DREAM 3.0

Since the middle of the 20th century the number of human-machine-systems has grown enormously. Unfortunately, these systems sometimes fail, resulting in more or less severe consequences. To prevent future failures it is important to understand why human-machine systems have failed in the past. A tool which was developed for analysis of past accidents as well as prediction of future ones within the process control domain (i.e. nuclear power plants, train operation, etc) is the Cognitive Reliability and Error Analysis Method (CREAM) [4]. CREAM was later adapted to suit the road traffic domain and the resulting tools were called the Driving Reliability and Error Analysis Method (DREAM) [5] and the SafetyNet Accident Causation System (SNACS) [2]. The DREAM and SNACS methods have a Human-Technology-Organisation perspective. Their basic philosophy is that accidents happen when the dynamic interactions between people, technologies and organisations fail to meet the demands of the current situation in one way or another and that such failures are due to a combination of contributing factors which together generate the accident.

Methodology development process

DREAM 2.1 [3] was first used in the Swedish project Factors Influencing the Causation of Accidents and Incidents (FICA) [6]. When it was established that DREAM 2.1 would be used in work package 5 of the European co-operation road safety project SafetyNet [1], DREAM 2.1 was translated into English and adapted to suit the traffic environment in the participating countries. The adapted version was called SNACS [2]. It uses the same method, accident model and main structure of the classification system as DREAM 2.1, but some individual contributing factors and their links have been altered.

Both DREAM 2.1 [3] and SNACS 1.2 [2] have been successfully used as tools for accident analysis in Sweden and other European countries, including extensive application throughout the SafetyNet WP5 accident investigations. During this practical work some suggestions for improvements have been put forward. Both DREAM 2.1 and SNACS 1.2 were therefore revised by a reference group including researchers in psychology, human factors, accident analysis and driver behaviour.

The revision resulted in DREAM 3.0 [7] which is modified to meet the needs of practitioners all over Europe (DREAM 3.0 can of course also be used in other parts of the world but due to country specific differences further adjustments might be needed). DREAM 3.0 uses the same accident model as the earlier versions while the classification scheme and the method have been somewhat adjusted.

With regards to the classification scheme in DREAM 3.0 [7], the majority of contributing factors are left in their original form. Where needed, definitions have been improved to resolve potential ambiguities. A few new contributing factors have been added and some have also been removed due to merging or exclusion. In conjunction with the revision a literature review [8] was conducted in order to investigate empirical support for the links between contributing factors in the classification system. A reliability test was also conducted to examine the intercoder agreement for DREAM 3.0 [9]. Both studies are briefly described later in this paper.

Theoretical Background

DREAM 3.0 [7] includes three main elements: an accident model, a classification scheme and a method.

The accident model

The accident model uses the human-technology-organisation (HTO) triad as a reference - represented by the driver (human), the vehicle and traffic environment (technology) and the organisation (see Table 1).

A key assumption is that driving can be viewed as a control task which involves the continuous adaptation to a changing environment, in a way which promotes goal fulfilment. The Contextual Control Model (COCOM) [4, 10] is used to describe the nature of the basic cognitive processes which support drivers' control. COCOM recognises that cognition includes processing observations and producing reactions, as well as continuously revising goals and intentions which creates a "loop" on the level of interpretation and planning. This is assumed to occur in parallel with ongoing events, at the same time as it is also being determined by those events. In later work, COCOM has been extended into the Extended Control Model (ECOM) [10]. ECOM offers a control theoretic account for how goals on different levels interact dynamically, recognising that control includes working towards multiple parallel goals on different time scales, so in reality a number of parallel control processes are at play. Cognition in the context of human-machine system performance should therefore not be described as a sequence of steps, and classification schemes based on this model must represent a network rather than a hierarchy. This theoretical standpoint is reflected in how the contributing factors in the classification scheme are defined as well as related to each other.

The accident model of DREAM 3.0 [7] combines the driving-as-control concept with the wide HTO perspective on where contributing factors can be found. Figure 1 illustrates the model, showing how accidents are seen as a loss of control due to an unsuccessful interplay between driver, vehicle and traffic environment, as well as the organisation(s) responsible for shaping the conditions under which driving takes place. Failures at the sharp end as well as at the blunt end are taken into consideration. Sharp end failures happen in close proximity to the accident (e.g. the driver fails to see a red traffic light which contributes to two cars colliding), while blunt end failures occur at other times and/or at other locations (e.g. a mechanic fails to maintain the brakes properly which later contributes to two cars colliding).

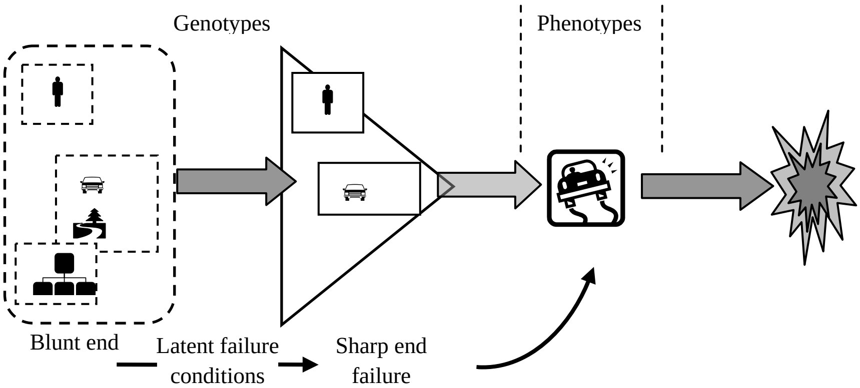


Figure 1. Blunt end and sharp end failures (after [5])

The classification scheme

The classification scheme of DREAM 3.0 [7] comprises a number of observable effects in the form of human actions and system events called critical events, or phenotypes. It also contains a number of possible contributing factors which may have brought about these observable effects. The contributing factors are called genotypes and are organised according to the driver-vehicle/traffic environment-organisation triad mentioned above. The driver category contains genotypes related to possible cognitive function problems such as observation, interpretation and planning failures (in accordance with COCOM [4, 10]). It also includes more general driver states of temporary and permanent person related character that can contribute to an accident (e.g. distraction, fatigue, etc). The vehicle/traffic environment category consists of vehicle and traffic environment related genotypes, while the organisation category consists of genotypes related to organisation, maintenance and design. See Table 1 for a schematic presentation of different categories. Besides the phenotypes and genotypes mentioned above, the classification scheme in DREAM 3.0 [7] also includes links between phenotypes and genotypes, as well as between different genotypes.

Table 1. Overall grouping of the genotypes and phenotypes in DREAM 3.0 [7]

		GENOTYPES		PHENOTYPES
HUMAN		TECHNOLOGY	ORGANISATION	
Driver		**Vehicle**	**Organisation**	
Observation	} in accordance	Temporary HMI problems	Organisation	Timing
Interpretation	with	Permanent HMI problems	Maintenance	Speed
Planning	COCOM	Vehicle equipment failure	Vehicle design	Distance
Temporary Personal Factors			Road design	Direction
Permanent Personal Factors		**Traffic environment**		Force
		Weather conditions		Object
		Obstruction of view due to object		
		State of road		
		Communication		

The method

The method in DREAM3.0 [7] is fully bi-directional which means that the same principles can be used for analysing past accidents as for predicting future ones. However, with regards to DREAM 3.0, the focus is on retrospective analysis of accidents that have already occurred. The classification scheme is therefore organised to make this as easy as possible. Furthermore, the method contains several stop rules, e.g. well defined conditions that determine when the analysis should come to an end. These stop rules are necessary as the classification scheme represents a network (rather than a hierarchy) and the analysis or prediction could continue without end. Otherwise there is the risk that an analysis is terminated by subjective rather than objective criteria in the absence of these rules.

JUSTIFICATION OF THE CLASSIFICATION SCHEME

Literature review

The human-technology-organisation in CREAM [4] as well as the driver-vehicle/traffic environment-organisation triad in DREAM [3, 5] and SNACS [2] are used as frames of reference for the main categories of genotypes and COCOM [4, 10] to organise human cognition. For the links between the genotypes there are, however, no documented references to literature. The aim of the literature review was therefore to investigate the empirical support for the links between the genotypes in DREAM 3.0 [7]. It is however important to remember that, for the individual accident, even links with documented references in literature represents possible rather than necessary connections. The use of a link always has to be justified by available empirical data.

The literature review was based on the genotypes in DREAM 3.0 [7]. The databases used were PsychInfo and Science Direct. Depending on the number of hits, the genotypes were combined with other words (e.g. genotype, genotype + driv*, genotype + driv* performance, genotype + accident*, genotype + traffic*).

A first selection of texts was based on titles while a second selection was based on abstracts. This resulted in approximately 185 texts which were more thoroughly read and among them 76 texts could be referred to one or more links between the genotypes in DREAM 3.0. Most of the remaining texts could be referred to links between genotypes and accident involvement. Only texts relevant for links between genotypes are presented in the literature review report [8].

Reliability test – the intercoder agreement

Many different classification schemes have been used in the analysis of road traffic accidents but the agreement between coders using a scheme is rarely tested and/or reported. As a high intercoder agreement is a prerequisite for a study's validity, this is a serious shortcoming. The aim of the present study was, therefore, to test the intercoder agreement of the DREAM 3.0 [7] by letting seven coders from different European countries analyse and classify the contributing factors of the same four accident scenarios. The results showed that the intercoder agreement for genotypes (contributing factors) range from 68% to 94% with an average of 84%, while for phenotypes (observable effects) it ranges from 57% to 100% with an average of 78%. This high level of agreement between coders from different countries shows that the DREAM 3.0 classification scheme is clear and explicit enough to be used all over Europe. The results also showed that testing intercoder agreement can play an important role in identifying weaknesses in the classification scheme, in the training of coders as well as in how accident information is presented. The result of the study will be published in a paper submitted for publication [9]

SAFETYNET ACCIDENT CAUSATION DATABASE

The aim of the SafetyNet work package 5, task 2 was to develop an in-depth European accident causation database to identify the risk factors that contributes to road accident occurrence. The main outcome was to investigate some 1 000 accidents from six EU member states (including; Germany, Italy, The Netherlands, Finland, Sweden and the United Kingdom) according to a harmonised methodology. Three tools were developed to guide the investigation teams in the data collection process and in the individual case analysis.

An independent accident investigation protocol (general variables) includes information from the accident site, the road environment, the vehicle(s) and the road user(s) involved. Since the investigations were focused at accident prevention rather that injury prevention the vehicle damages and the injury outcome were described in less detail.

A method to classify contributing factors was adapted to suit the traffic environment in the participating countries, known as SNACS [2] and DREAM 3.0 [7]. Where possible, interviews with drivers and other road users have been carried out according to an interview guide.

For input and storage of the data collected and the individual case analysis performed, a database was developed. The system was based on the general variables, the critical events and contributing factors in SNACS. It was especially suited to help the investigators in the SNACS analysis of each vehicle involved in an accident.

The database developed includes 1 006 accident cases, 1 833 vehicles and 2 428 road users. An on-scene approach for collecting the data has mainly been used where investigation teams has visit the accident scene shortly after occurrence.

Data analysis

The data analysis of the SafetyNet Accident Causation Database can be divided into two parts; analysis of individual cases and analysis of aggregated cases. The analysis of an individual case is performed on vehicle level (including pedestrians) and is based on the information collected from the accident scene and the interviews. The SafetyNet Accidents Causation System (SNACS 1.2) [2], which is one of the precursor methods to DREAM 3.0 [7], was used to analyse the individual cases stored in the database.

An example of an individual case analysis based on DREAM 3.0 is illustrated in Figure 2. The corresponding accident scenario is as follows: Driver A is driving above the 70 km/h speed limit on a road. When A enters a sharp curve, which is incorrectly cambered and the surface is covered in gravel, the vehicle starts skidding. A tries to control the skid but fails and the vehicle comes to rest upside down in a ditch. Driver A is a 19-year old man (has had a driving licence for 1 year), was not tired or distracted, was not under the influence of alcohol, drugs or medication. He drove an older Volvo in good condition.

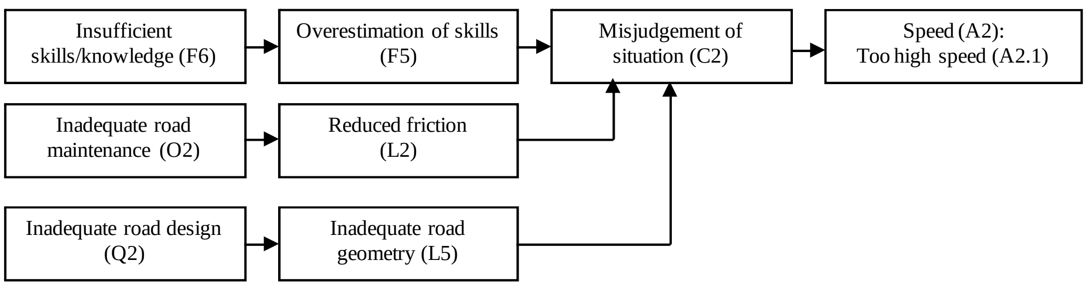


Figure 2. Example of an individual case analysis of a run off the road accident in a sharp curve (based on DREAM 3.0)

While the analysis of an individual case results in a chart of interlinked contributing factors, the analysis of aggregated cases is performed by superimposing individual charts in order to find common causation patterns for a selected group of cases. The selection of cases can be performed in a number of different ways depending on the research question. The analysis of aggregated cases in the

SafetyNet Accident Causation Database is in progress and the initial data analysis is described below. An example of superimposing of cases (analysed with SNACS 1.2 [2]) from the analysis group vehicle-leaving-lane trajectories (further described below) is illustrated in Figure 3.

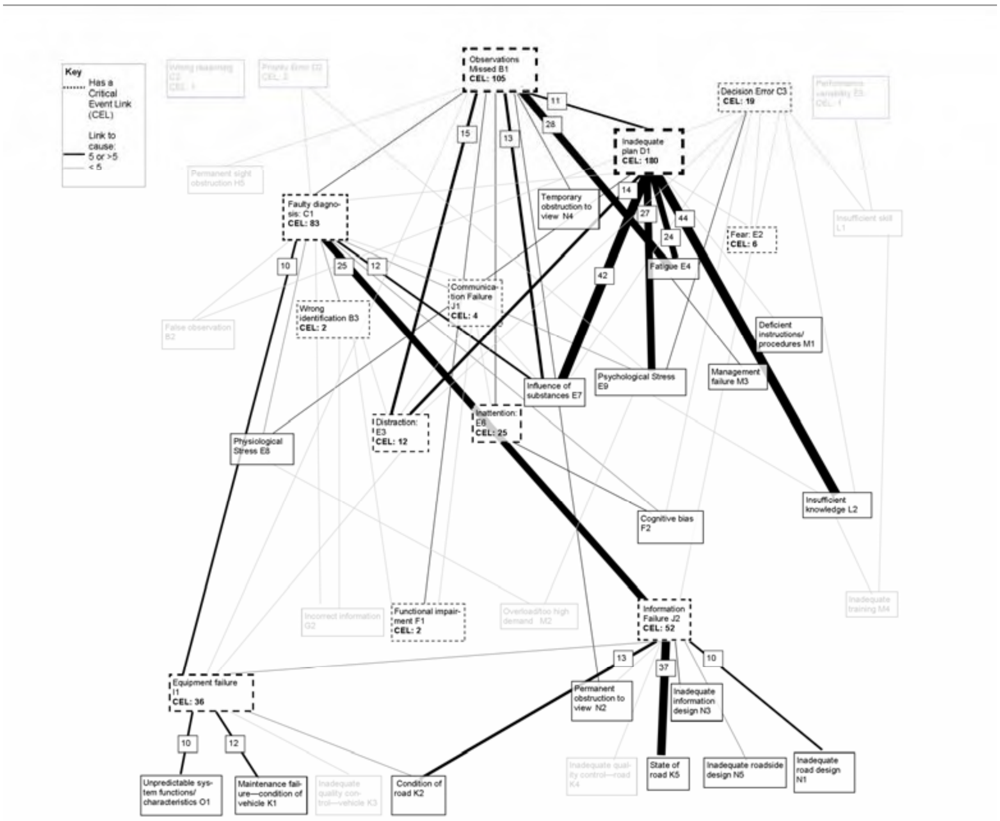


Figure 3. Example of a causation pattern for vehicle-leaving-lane trajectories (based on SNACS 1.2)

Initial data analysis - taxonomy

Since the analysis is causation focused rather than outcome focused, accident data was sorted into other groups than suggested by the traditional accident outcome based taxonomies. The main approach chosen was therefore to base the analysis on a combination of accident context and vehicle trajectory. Since an accident can contain more than one trajectory, (i.e. there will be one trajectory per involved vehicle), the sorting was performed on a vehicle level.

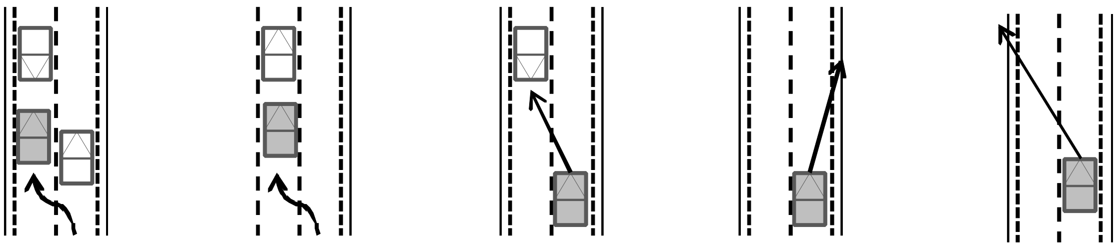
Prior to sorting the vehicles according to trajectory, all accidents involving Slower moving Vulnerable Road Users (SVRU), i.e. pedestrians and bicyclists, were sorted into a separate group because accidents involving SVRU is believed to have different causation patterns and characteristics, compared to single or multiple motorised vehicle crashes.

Except the SVRU group, the sorting resulted in three main accident context and vehicle trajectory based groups. Each main group was divided into subgroups relating to conflict scenario, participant or counterpart, for further analysis. The subgroups for each main group are described in more detail under each heading.

Vehicle leaving its lane

A vehicle-leaving-lane trajectory represents driving situations where the vehicle leaves its lane by crossing the lane boundary either to the left or the right. There are two subgroups, depending on whether the manoeuvre was intentional (e.g. driver actively changing lane or initiating an overtaking of another vehicle) or unintentional (driver drifting out of lane or losing control).

Figure 4 illustrates typical outcome scenarios initiated by vehicle-leaving-lane trajectories which can lead to a conflict with another vehicle or the vehicle running off the road. In scenario 1a the vehicle leaves its lane by crossing the median line intentionally (i.e. starts to overtake another vehicle) and collides with a vehicle travelling in the opposite direction. In scenario 1b the vehicle leaves its lane by intentionally crossing a lane marker (i.e. initiating a lane change manoeuvre) and collides with a vehicle travelling in the same direction. Lane departures where the initial crossing of a lane marker or median line is unintentional include the vehicle colliding with a vehicle travelling in the opposite direction (scenario 2a) and running off the road to the nearside or offside (scenarios 2b and 2c).



1a 1b 2a 2b 2c

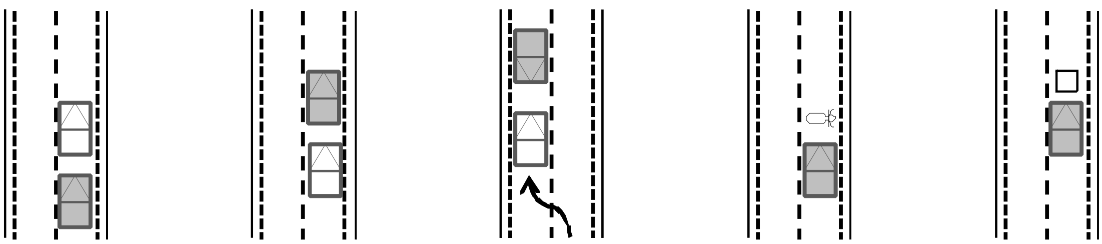
Figure 4. Typical outcomes scenarios following vehicle-leaving-lane trajectories. Conflicts between vehicles following an intentionally leaving lane trajectory either to overtake another vehicle (1a) or due to a lane change (1b). Conflict between vehicles (2a) or road departures (2b-2c) following an unintentionally leaving lane trajectory by drifting out of lane or loss of control, (subject vehicle is grey).

Vehicles are not included in vehicle-leaving-lane category if they first collide with a vehicle or an object in its own lane and then exit the lane – these vehicles will be included either in the 'vehicle encountering something while remaining in its lane' or 'vehicle encountering another vehicle on crossing paths' groups (see below).

Vehicle encountering something while remaining in its lane

This trajectory group represent vehicles encountering something in its own lane which typically result in a front or rear end collision for the subject vehicle. The main group is divided into four subgroups, depending on whether the conflict is with another vehicle, an animal or an object.

Figure 5 illustrates typical outcome scenarios following a trajectory where a vehicle encounters something in its own lane. In scenario 1 the subject vehicle is striking a lead vehicle, in scenario 2 the subject vehicle is rear ended by another vehicle. In Scenario 3 the subject vehicle is struck by a vehicle which has left its lane and in scenario 4a and 4b the subject vehicle is frontally striking object other than a vehicle.



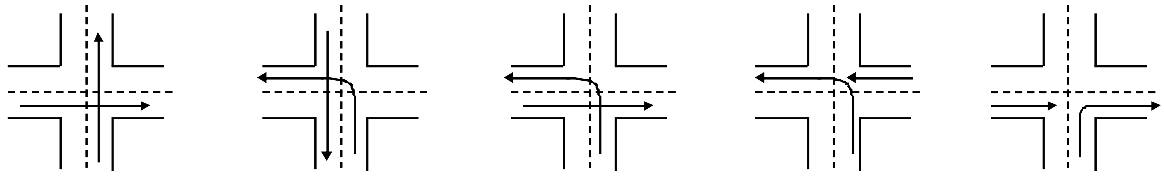
1 2 3 4a 4b

Figure 5. Typical outcome scenarios for vehicle encountering something while remaining in its lane. 1; striking lead vehicle, 2; being rear ended by another vehicle 3; being struck by a vehicle which has left its lane, 4a-4b; frontally striking object other than vehicle (subject vehicle is grey).

Vehicle encountering another vehicle on crossing paths

A crossing path crash is defined as a traffic conflict where one moving vehicle cuts across the path of another, when they were initially approaching from either lateral or opposite directions in such a way that they collided at or near a junction [11]. The typical outcome is an intersection crash, but reversing from a driveway type crashes are also included.

Figure 6 illustrates the four subgroups which are divided into; Straight Crossing Paths (1. SCP), Left Turn Across Path-Opposite Direction (2. LTAP-OD), Left Turn Across Path-Lateral Direction (3. LTAP-LD) and Merge conflicts, (Left Turn Into Path (4a. LTIP) and Right Turn Into Path (4b. RTIP)).



1. SCP **2. LTAP-OD** **3. LTAP-LD** **4a. LTIP** **4b. RTIP**

Figure 6. Typical outcome scenarios for vehicle encountering another vehicle on crossing paths. Straight Crossing Paths (1. SCP), Left Turn Across Path-Opposite Direction (2. LTAP-OD), Left Turn Across Path-Lateral Direction (3. LTAP-LD), Merge conflicts, Left Turn Into Path (4a. LTIP) and Right Turn Into Path (4b. RTIP)

Initial data analysis - summary of vehicle grouping

Since the analysis of aggregated cases is in progress the causation patterns can not be presented for each group. According to the grouping of vehicles presented above the vehicles included in each group is distributed as shown in Table 2.

Table 2. Number of vehicles for each group selected for analysis of aggregated cases. *9 vehicles are excluded from the selection.

	SVRU	Leaving lane	Remaining in own lane	Crossing paths	Total
Agricultural vehicle	-	-	4	1	5
Bicycle	96	-	-	-	96
Bus / Minibus	11	4	10	10	35
Car / MPV	134	277	396	357	1164
Motorcycle / Moped	11	27	36	105	179
Other	2	2	8	6	18
Pedestrian	91	-	-	-	91
Train / Tram	2	-	-	8	10
Truck	11	37	59	28	135
Unknown	-	-	1	-	1
Van	11	14	43	22	90
Total	369	361	557	537	1824*

DISCUSSION

The aim of the SafetyNet work package 5.2 was to develop an in-depth European accident causation database to find the risk factors that contributes to road accident occurrence. The work performed was closely related to already existing accident investigation activities within the partnership including multidisciplinary teams with many years of experience within the field. The main outcome was to investigate some 1 000 accidents from six EU member states according to a harmonised methodology discussed previously.

Despite the high level of expertise within the investigation teams it was discovered that cultural differences and differences in the road traffic system and definitions resulted in some challenges. The general variables had to be clearly defined and revised several times to discard any confusions and differences in interpretations among the investigators. Concerning the analysis of individual cases with SNACS [2] several quality review meeting was conducted to ensure that the classification scheme was clear and explicit enough to be used all over Europe. During the work suggestions on clarifications and additions/removal of contributing factors were made resulting in an updated version of the method (SNACS 1.2) [2] that was used throughout the project. However, further development was needed and the final version DREAM 3.0 [7] has gone through an extensive literature review [8] and a reliability test [9].

Trying to understand the contributing factors to accident occurrence throughout Europe has shown being a complex task. The new way of thinking in accident prevention compared to injury prevention demand understanding of cognitive processes and driver behaviour. Nevertheless, it has been shown in the project that when sufficient training has been undertaken and the threshold for the understanding of the classification scheme is reached by the investigators the intercoder agreement can be considered acceptable.

The initial aggregation analysis is performed on a vehicle level rather than on accident level. The subgroups under each heading may not be completely intuitive, since they do not follow the traditional outcome based categorisation in passive safety. However, the taxonomy is hypothesised to present the clearest differences in causation patterns between each of its three main groups as well as their subgroups. Also, sorting on trajectories facilitates comparison with existing, outcome oriented crash databases, since they usually contain detailed vehicle trajectory information. It is believed that the aggregation of each analysis by describing the frequency of accident contributing factors and their relationship as shown on the example identifies the main determiners how and why accident occurs in sufficient detail to be used for further traffic safety development.

CONCLUSION

The data from the accident causation study are required for a variety of reasons. For example, the data are needed to provide policy-makers and regulators with data that can be used in decision making for road safety policy and regulation. It is intended that the data can also be used in the development of new in-vehicle technology e.g. accident avoidance systems and road design.

The next step in the development of DREAM 3.0 could be to use the method in a wider range of countries and eventually adjust the classification scheme to fit to non-European countries. Even when DREAM 3.0 is used within Europe it is important to remember that the classification scheme should not be seen as fixed or static. Instead it should be adjusted in order to fit the needs of different projects as well as the future needs required by the road traffic development.

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DETERMINATION OF ACCIDENT CAUSATION AND RISK FACTORS IN TRAFFIC ACCIDENTS FROM THE POINT OF VIEW OF MOTORCYCLIST USERS

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Abstract - The Powered Two Wheelers (PTWs) accidents constitute one of the road safety targets in Europe. PTWs users' fatalities represent 15% of EU road fatalities [1], having increased the last few years, which is quite opposite than other road users casualties.

To reduce PTW accidents is necessary to know which the accident causations are from different points of view (human factor, vehicle characteristics, environment, type of accident, situation, etc.). In TRACE project ('*Tr*affic *A*ccident *C*ausation in *E*urope', under the European Commission 6th Framework Program, 2006-2008, [2]) a specific task was focused on PTW users point of view, analyzing extensive databases to locate the main accident configurations (type of accident, severity, frequency…), and an in-depth database to obtain the causation factors, the risk factors for each configuration founded in the extensive databases analysis and the variables associated to each causation factor in the PTW configurations.

NOTATION

EU	European Union
EC	European Commission
OR	Odds Ratio
PTW	Powered Two Wheeler
WP	Work Package

INTRODUCTION

The European Commission set the ambitious objective of halving the number of road traffic fatalities by 2010 in its White Paper [3]. Since this paper was published, much progress has been achieved. According to the ERSO's evolution report [4] fatalities in the EU-25 have been reduced by 18,1% between 2001 and 2005.

In line with the objective of improving the road safety, TRACE project (**TR**affic **A**ccident **C**ausation in **E**urope), under the European Commission 6th Framework Program, is to provide an overview of the road accident causation topics in Europe**.** TRACE proposes three different research angles to cover accident causation issues:

- The Road User approach (WP1): it allows detecting the main causation and risk factors for specific road users.
- The Types of Situation approach (WP2): the road user can be confronted with different driving situations that can develop into different emergency situations that deserve specific analysis regardless the road user type.
- The Types of Factors approach (WP3): the factors can be identified and observed according to an innovative split: the social and cultural factors, the factors related to the trip itself and the factors related to the driving task.

Within the first angle ('Road user approach'), PTW users were one of the five user groups analysed. Nowadays, this road users group is especially important because whereas the number of European road deaths has declined considerably in the last years, the number of killed PTW users has risen in 13 out of 27 EU countries [5]. It is well known that, for the same distance travelled, a motorcyclist has on average 18 times the risk of being killed in a road accident that a car driver has.

METHODOLOGY AND RESULTS

The first step carried out in TRACE related to accident causation and risk analysis in PTW accidents was to detect the main configurations where PTW accidents occurred, considering area (urban/rural), road layout (junction or out of junction), severity, accident type (run off, rear end…) and, of course, taking into account the PTW category (moped or motorcycle). To perform these analyses literature review and seven extensive databases available to TRACE were used. The outcome of this procedure was the selection of the most common PTW accident configurations and their main characteristics.

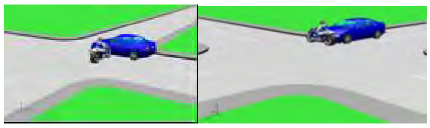
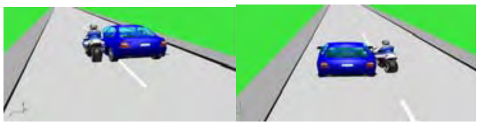
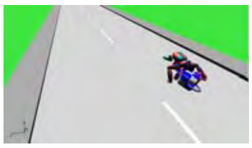
Distribution of the most common PTW accidents configurations			
Type of PTW involved	**Accident Configuration**	**% Fatal & Serious Accidents**	**Illustration**
MOTORCYCLES ACCIDENTS	**1. Motorcycle single accidents:** accidents which involved just one motorcycle on a rural road: run-offs, rollover on the carriageway and collisions with road restraint systems.	27%[1]	
	2. Front-side accidents in rural and urban junctions between motorcycles and passenger cars.	13%	
	3. Side-side accidents in rural and urban non junctions between motorcycles and passenger cars.	5%	
	4. Rear-end accidents in rural and urban non junctions between motorcycles and passenger cars.	5%	
MOPEDS ACCIDENTS	**5. Moped single accidents:** Accidents which involved just one moped on a rural or urban road: run-offs, rollover on the carriageway and collisions with road restraint systems.	21%[2]	
	6. Front-side accidents in rural and urban areas (junction and non junction) between mopeds and passenger cars.	30%	
	7. Head-on accidents in rural and urban areas (junction and non junction) between mopeds and passenger cars.	8%	

Table 1.- Distribution of the main PTW accident configurations (National databases).

[1] This percentage is over the motorcycles accidents, not over all PTWs accidents.
[2] This percentage is over the mopeds accidents, not over all PTWs accidents.

These seven configurations were the starting point to analyze PTW accidents causation issues. After selecting these configurations, a detailed analysis was done over these configurations gathered in one of the most important intensive accident databases in Europe related to PTWs accidents. This in-depth database analyzed was the one generated in 'MAIDS' project ('In-depth investigations of accidents involving powered two wheelers'), from the European Commission 5th Framework Program [6]. 'MAIDS' gathers information from 921 motorcycle accidents (cases) and 923 sample of non-accident motorcycle riders (controls) through interviews which allow study not only the collisions but the risk and the variables which could have an influence since exposure data are available.

The above accident configurations were selected over MAIDS database with the aim of analyzing the following three aspects:

- **Accident causation analyses**: With the purpose of knowing the mechanism of the accident, and therefore, the accident causation, analyses over this information were done in each one out of the seven configurations.

- **Risk analyses**:

    - **Risk factors related to each accident causation** (**Test $\chi 2$ and Odds ratio analyses)**: Once the main accident causes were detected in each scenario, statistical analyses were done with the aim of knowing which factors are related to each accident cause in each scenario. Of course, only accidents from each scenario were used, so the conclusions obtained from these analyses will be focused to know which factors increase the risk for a cause of being the cause of the accident. Cross-tables have been used. When the factor had only two categories 'Odds ratio' (OR) analyses, while test $\chi 2$ have been used for all the cases.

      Unfortunately, in configurations 3, 4 and 7 is difficult to reach any statistically significant conclusion because there are not enough cases. This makes unfeasible to establish any kind of relationship between contributing factors and variables.

    - **Risk factors of being involved in a PTW accident** (**Case-control analyses)**: For each accident configuration, information from accidents (cases) and information from non-accidents (controls) were used to calculate 'Odds Ratios'. This means, the risk for a PTW user of being involved in each accident scenario was calculated related to different factors.

      The outcome was a p-value based on chi-square distribution, an OR estimation (when the variable had only two categories) and their confidence intervals.

      It is very important to notice that without exposure data is not possible to talk about risk. Exposure data are represented by 'controls' in MAIDS database. These are the motorcyclists interviewed that did not have an accident but were supposed to be exposed to the potential risk factors. Over than 60 variables were studied related to environmental factors, mechanical factors and human factors.

      A further step was to perform a multinomial logistic regression[3] model to consider not just the variables individually but the categories of this variable(s) and also the interactions between variables.

[3] Due to low frequencies of some configurations, it was not suitable to perform this analysis in all of them.

Accident causation analyses

In the Table 2, results from the accident causation analysis over MAIDS database (in-depth database) and the seven main scenarios are shown. Accident causations factors are coded within the databases as **Primary** (*Primary contributing factor: The contributing factor which the investigator considers to have contributed the most to the overall outcome of the accident*) or **Contributing** factors (*Contributing factors: Any human, vehicle or environmental factor which the investigator considers to have contributed to the overall outcome of the accident. The precipitating event may or may not be considered to be a contributing factor*). In some cases some contributing factors cannot be coded as primary factors but might be usually correlated to specific primary factors. For instance, the factor 'motorcycle rider drug and/or alcohol involvement' cannot be coded as primary factor within this database but in some configurations is usually present linked to 'Motorcycle reaction failure'.

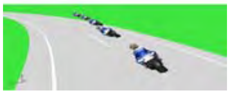
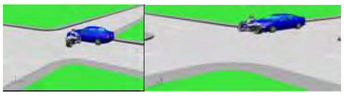
		Distribution of the contributing factors in the most common seven PTW accidents configurations		
		Accident Configuration	**Primary factors**	**Contributing factors (including primary)**
MOTORCYCLE ACCIDENTS	1		-Motorcycle rider decision failure (31%) -Motorcycle rider failure, unknown type (18%)	-Motorcycle rider decision failure (37%) -Motorcycle rider failure, unknown type (32%) -Others (16%): Too fast speed, motorcycle rider unsafe acts, inadequate speed.
	2		-Passenger car driver perception failure (60%) -Passenger car driver decision failure (12%)	-Passenger car driver perception failure (70%) -Passenger car driver unsafe acts or risk taking behaviour (31%) -Motorcycle rider unsafe acts or risk taking behaviour (38%)
	3		-Passenger car driver perception failure (47%)	-Passenger car driver perception failure (53%) -Motorcycle rider unsafe acts or risk taking behaviour (53%)
	4		-Motorcycle rider perception failure (58%) -Passenger car driver perception failure (25%)	-Passenger car driver perception failure (33%) -Motorcycle rider perception failure (58%)
MOPED ACCIDENTS	5		-Moped rider perception failure (41%) -Moped rider reaction failure (19%)	-Motorcycle rider perception failure (63%) -Motorcycle rider drug and/or alcohol involvement (33%)
	6		-Passenger car perception failure (51%) -Motorcycle rider perception failure (14%) -Motorcycle rider decision failure (12%)	-Passenger car perception failure (68%) -Rider unsafe acts or risk taking (49%) -Passenger car unsafe acts or risk taking (36%)
	7		-Moped rider perception failure (41%) -Moped rider reaction failure (19%)	-Passenger car perception failure (38%) -Moped rider decision failure (38%) -Moped rider unsafe acts or risk taking behaviour (62%)

Table 2 .-Contributing factors in the most common seven scenarios in PTWs accidents.

As it can be shown, 'Passenger car driver perception failure' could be considered as the main primary causation factor in front-side accidents between PTWs and passenger cars. In motorcycle single accidents 'Rider decision failure' appears as primary causation factor with 'Inadequate speed' and

‘Rider unsafe acts’ as contributing factors associated. In moped single accidents, the contributing factors present were ‘Rider perception failure’ and ‘Alcohol and/or drugs consumption’.

Risk factors related to each accident causation (Test χ2 and Odds ratio analyses)

Once the contributing factors were pointed for each one out of seven configurations, the following step was to identify possible associations between the most important causation factors detected in each configuration and any possible variable related to vehicle, human and environmental aspects.

Configuration 1: Single motorcycles run-off accidents

Contributing factor	Risk factor	p-value	Odds ratio
1 Motorcycle rider decision failure	Odometer (new motorcycle)	0.046	2.92
	Rider age (< 25 years)	0.016	3.44
	Traffic violation in the last 5 years	<0.001	9.33
2 Motorcycle rider unsafe acts	Lack of cargo rack	0.016	4.40
	Rider age (< 25 years)	0.022	2.48
	Traffic violation last 5 years	0.036	2.25

Table 3.- Risk factors related to each contributing factor - Configuration 1.

In this configuration ‘Rider decision failure’ and ‘Rider unsafe acts’ were the most common contributing factors, but also, it was important the presence of inadequate speed or too high speed. According to the results, both contributing factors were associated to rider age (younger than 25 years of age) and to had committed at least one traffic violation in the last five years. An example of the interpretation of these results should be ‘in case there was an accident belonging this configuration, if the rider ages is higher 25 years old the risk of being ‘Motorcycle rider decision failure’ the accident causation is 3.44 times higher.

Only statistically significant variables are included in the tables, this means that it was taken as reference p-values greater than 0.05 and all the confidence intervals of the odds ratios did not contain the reference value 1.

Configuration 2: Front-side accidents in rural and urban junctions between motorcycles and passenger cars

Contributing factor	Risk factor	p-value	Odds ratio
1 Passenger car perception failure	Motor displacement (>125 cc)	0.040	2.51
	Lack of front position lamp	0.026	3.62
	Front tyre: not wheel original equipment	0.023	3.46
2 Motorcycle rider unsafe acts	Rider age (25-40 years)	0.048	2.19

Table 4.- Risk factors related to each contributing factor - Configuration 2.

According to the contributing factor ‘Passenger car perception failure’, the variables associated to it were: ‘Motor displacement’, ‘Front position lamp equipped?’ and ‘Front tyre, wheel original equipment?’. This result confirmed the conspicuity problem associated to perception failures (found in the literature review).

The variable associated to contributing factor ‘Motorcycle unsafe acts or risk taking’ was ‘Rider age’ being the category between 25-40 years old overrepresented.

Configuration 3 4 and 7: As it has said, in configurations 3, 4 and 7 is difficult to reach any statistically significant conclusion because there are not enough cases. This makes unfeasible to establish any kind of relationship between contributing factors and variables.

Configuration 5: Single moped accidents run off accidents

Contributing factor	Risk factor	p-value	Odds ratio
1 Alcohol and/or drugs use	Under secondary school qualification	0.032	8.67

Table 5.- Risk factors related to each contributing factor - Configuration 5.

In this configuration contributing factor ‘Alcohol and/or drugs use’ was associated to ‘Educational status’ and obviously to ‘Alcohol or drugs’ as a risk factor. So the typical moped single run off or roll over accident where ‘Motorcyclist alcohol and/or drug use’ was contributing factor seems to occur in urban areas to people who had ‘no formal schooling or formal education prior to college’

Configuration 6: Front-side accidents in rural and urban areas (junction and non junction) between mopeds and passenger cars

Contributing factor	Risk factor	p-value	Odds ratio
1 Passenger car perception failure	Lack of front turn signals	0.049	2.07
	Lack of driving license (no license held)	0.030	1.74
	Not resident citizens	0.025	4.51
	Not frequent use of the road	0.015	3.96
2 Motorcycle rider unsafe acts	Front suspension in bad condition	0.044	2.62
	Headlamp assembly type (double)	0.046	1.74
	Modified / Enhanced motor power	0.008	3.42
	Gender (male)	<0.001	3.86
	Motorcycle training (no)	0.035	2.61
	Traffic violations in the last 5 years (yes)	0.002	2.89
	Previous motorcycle traffic accident (yes)	0.002	3.05

Table 6.- Risk factors related to each contributing factor - Configuration 6.

The analysis of the contributing factor ‘passenger car perception failure’ revealed that the variables associated to it were: ‘Front turn signals equipped?’, ‘Driver license qualification’, ‘No resident, citizenship’ and ‘Frequency of this road use’.

The second contributing factor analyzed within this configuration was ‘Motorcycle rider unsafe acts or risk taking’ and the variables which had an association with it were: ‘Front suspension condition’, ‘Headlamp assembly type’, ‘Motor power enhancement equipped?’, ‘Gender’, ‘Motorcycle training’, ‘Any traffic violations in the last 5 years?’ and ‘Any motorcycle traffic accident?’.

Risk factors of being involved in a PTW accident (Case-control analyses)

Once the main configurations where PTW accidents occurred were detected, a case-control analysis was performed to determine which variables (risk factors) are associated with the accidents in each configuration. Two steps were followed in order to carry out this case – control analysis:

- Cross tabulations procedure: First, all the variables were studied independently, without taking into consideration its likely correlation with the other factors. This was performed for each selected configuration. The result provides the variables that can be potentially considered as risk factor. To perform this study it was used a cross tabs analysis procedure which outcome was a p-value based on chi-square distribution, ‘Odds Ratio’ estimation when the variable had only two categories and their confidence intervals. Exposure data with this methodology is represented by ‘controls’ from MAIDS.

- Multinomial logistic regression: In a second step, a multinomial logistic regression model (where it was possible) was performed. After detecting which variable(s) is risk factor for each contributing factor, a multinomial logistic regression was done to study the ‘propensity toward’ the categories of this variable(s) for each contributing factor within each configuration.

Configuration 1: Single motorcycles run-off accidents

Risk factor	p-value	Odds ratio
Vehicle year of production (5-10 years)	0.002	2.29
Rider age (<25 years)	0.040	2.09
Lack of driving license	0.002	4.01
Not resident citizens	<0.001	5.87
Under secondary school qualification	0.001	4.05
Not frequent use of the road	0.001	3.53

Table 7.- Risk factors of being involved in a PTW accident - Configuration 1.

Several risk factors have been detected as significant from a statistic point of view. For a better understanding of these results, the following interpretation shows how these factors affect motorcycle user related to the probability of suffering an accident:

- For instance, a rider younger than 25 years of age has an Odds Ratio equal to 2.29, this means that this type of motorcycle riders are 2.29 times more likely (or (129% higher) to be involved in an accident corresponding to configuration 1 than a rider from another age group.
- Single run off motorcycle accidents occurred mostly to riders who did not have experience driving along that road or that area. The lack of driving license increased notably the risk of being involved in an accident of these characteristics.
- It has been seen how no resident motorcyclist or riders who do not know the road had a higher probability to be involved in single motorcycle accidents.

Configuration 2: Front-side accidents in rural and urban junctions between motorcycles and passenger cars

Risk factor	p-value	Odds ratio
Vehicle year of production (>2 years)	<0.001	5.25
Motor displacement (>125cc)	0.011	1.78
Front tread type (all weather, angle groove)	0.035	1.55
Driveline type (sprockets, enclose chain)	<0.001	1.97
Lack of windscreen	0.001	1.89
Lack of right side rear view mirrors, posts equipped	0.033	2.01
Rider age (<25 years)	0.001	2.07
Under secondary school qualification	0.037	1.55
Short length of the trip (<10 Km)	0.001	2.55

Table 8.- Risk factors of being involved in a PTW accident - Configuration 2.

After modelling with logistic regression models procedure, there were new findings: motorcycles with more than 125cc motor displacement, front tyre wheel no original equipment and without front position lamp had a propensity toward to be involved in motorcycles front side accidents. Again motorcycle riders younger than 25 years of age and riders under secondary school qualification appeared as risk groups.

Configuration 3: Side-side accidents in rural and urban non junctions between motorcycles and passenger car

In this configuration it was difficult to reach any significant conclusion because there were not many cases (only 13 cases), which means that any kind of relationship appeared is conditioned by low frequencies. Nevertheless, the main results obtained from comparing exposure data to side to side collisions between motorcycles and passenger cars cases are:

- Motorcycles with front suspension in bad conditions are overrepresented.
- Motorcycles without left side mirrors view posts are overrepresented.

Configuration 4: Rear-end accidents in rural and urban non junctions between motorcycles and passenger cars

Case-control study revealed some associations between this configuration and the variables ‘Front crash bars equipped?’ and ‘Windscreen equipped?’

This type of collisions had a low frequency within database, only 12 cases were registered; consequently a risk analysis could not be performed. However, there was an interesting trend with the variable ‘Does the license held qualify the rider for driving the accident vehicle?’ because two out of three riders without a qualifying license had a collision. Due to low frequencies is not possible to conclude anything related to causation factor or risk factor.

Configuration 5: Single moped accidents run off accidents

The analysis of this configuration showed the following association:

Risk factor	p-value	Odds ratio
Lack of front position lamp	0.009	2.90
Alcohol and/or drug use	<0.001	8.03
Not permanent physical impairment (tiredness, …)	<0.001	4.59
Previous motorcycle traffic accident	0.049	2.31

Table 9.- Risk factors of being involved in a PTW accident - Configuration 5.

The risk factors ‘Alcohol and/or drug use’ and ‘Not permanent physical impairment’ increased notably the propensity toward being involved in a single moped accident. In addition, these two factors are clearly correlated, meaning that most of the times when one of them is present the other one is present too, i.e.: alcohol and drowsiness.

Configuration 6: Front-side accidents in rural and urban areas (junction and non junction) between mopeds and passenger cars

Data from these accidents show association between this configuration and the next variables:

Risk factor	p-value	Odds ratio
Vehicle year of production (>2 years)	0.001	5.95
Front suspension type (no telescopic tube)	0.028	1.68
Front suspension in bad conditions	0.009	2.26
Head assembly type (double)	0.013	1.58
Fuel tank type (saddle)	0.046	2.84
Rear tread type (all weather, angle groove)	0.014	1.81
Modified / Enhanced motor power	0.001	2.79
Lack of driving license (no license held)	<0.001	4.04
Not regulated training	0.026	2.03
Not permanent physical impairment (tiredness, …)	0.002	3.73
Not frequent use of the road	<0.001	5.71

Table 10.- R Risk factors of being involved in a PTW accident - Configuration 6.

The variables ‘Vehicle year of production’, ‘Lack of driving license (no license held) and ‘no frequent use of the road’ were the ones which increased the risk the most.

Once again the variables ‘Lack of driving license (no license held) and ‘No frequent use of the road’ appeared as risk factors. Logistic regression procedure performed to this configuration showed that no resident drivers, without license held, driving a moped equipped with motor power enhancement and without right side posts rear view mirrors had a propensity toward to be involved in front side mopeds accidents.

Configuration 7: Head-on accidents in rural and urban areas (junction and non junction) between mopeds and passenger cars

Finally, case-control analysis revealed some associations between this configuration and the variables ‘Right side rear view mirrors, posts equipped?’ (Category ‘Yes’) and ‘Motor power enhancement equipped?’ (Category ‘Yes’).

There was a tendency in the variable ‘time travelling’ because three out of five moped riders who were driving more than an hour had an accident.

Unfortunately, in this configuration it is difficult to reach any statistically significant conclusion because, as happened with other configurations, due to there are only 12 cases.

CONCLUSIONS

PTW accidents are an important road safety problem nowadays. As it has been said, this road user group is one of the few user groups whose fatalities have been increasing in the last few years (together with pedestrians). This implies that all road safety community (Governments, Associations, Manufactures, Foundations…) should enlarge its effort to stop this trend.

The main objectives of this study was to identify accident causation factors and accident risk factors related to the road users group of powered two wheelers riders.

As it has been explained, for the realization of these analyses, the most relevant seven main scenarios have been detected (from National accident databases available to TRACE project and Literature review) and through one of the biggest PTW In-depth database (MAIDS), the accident causation and risk analyses have been done for each configuration.

After finishing this task, it could be said that the work done over this project related PTW accidents have allowed gathering the following items:

- The causes of PTW accidents (according to MAIDS in-depth database) have been analysed.
    - The main cause of the collisions was a human failure.
    - In the case of accidents between a PTW and a passenger car, the most frequent human error was a failure in perceiving the PTW by the car driver (associated to the traffic environment, traffic scanning error, lack of other vehicle driver attention, faulty traffic strategy or low conspicuity of the PTW).
    - Other variables as ‘Year of production’, ‘Citizenship’, ‘Rider age’ and ‘Frequency of this road use’ are present in most of the configurations.

- Risk factors for each scenario and for each contribution factor have been identified. Some of them are:
    - Variables ‘Year of production’, ‘Not frequent use of the road’ and ‘Not resident drivers’ are risk factors in the main configurations.
    - ‘Motor power enhancement’, ‘Driver license qualification’ and ‘Alcohol and/or drugs use’ are variables linked to accidents involving mopeds.
    - Usually, contributing factor ‘Motorcycle rider unsafe acts or risk taking’ has associated the variables ‘Any traffic violation committed in the last five years’ and ‘Rider age’.
    - ‘Traffic violation in the last five years’ always appeared associated to the contributing factor ‘Motorcycle rider unsafe acts’.
    - No resident motorcyclist or riders who do not know the road had a higher probability to be involved in single motorcycle accidents.

DISCUSSION

During this paper, several important aspects related to PTW accidents have been studied. Nevertheless, neither possible counter-measures to avoid the accidents nor injury mitigating actions have been defined. Although the scientific world have already thought about several actions to avoid or to minimize PTW accidents, this paper can help to understand answers to specific questions like how?, why?, who?.. riders are involved or are likely to be involved in PTW accidents, and therefore it could help to define specific actions for PTW safety improvement.

ACKNOWLEDGEMENT

1) To the TRACE consortium and specially to the information from the following accident databases:
- Descriptive National (extensive) databases: STATS19 (Great Britain), SISS (Italy), OGPAS (Germany), GREEK N.D. (Greece), EDN (Czech Republic), BAAC (France) and DGT (Spain).
- In-depth 'MAIDS' database and ACEM ('Association des Constructeurs Européens de Motocyles').

2) To the European Commission co-funding under the 6th Framework Programme.

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Methods for analyzing the efficiency of primary safety measures based on real life accident data

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KEYWORDS – effectiveness of primary safety measure, collision avoidance, brake assist, advanced cruise control, rear-end crash, active safety, safety benefit, real world accident data

ABSTRACT

Primary safety measures are designed to help to avoid accidents or, if this is not possible, to stabilize respectively reduce the dynamics of the vehicle to such an extent that the secondary safety measures are able to act as good as possible. The efficiency of a primary safety measure is a criterion for the effectiveness, with which a system of primary safety succeeds in avoiding or mitigation the severity of accidents within its range of operation and in interaction with driver and vehicle. Based on Daimler´s philosophy of the "Real Life Safety" the reflection of the real world accidents in the systems range of operation is both starting point as well as benchmark for its optimization.

This paper deals with the methodology to perform assessments of statistical representative efficiency of primary safety measures. To be able to carry out an investigation concerning the efficiency of a primary safety measure in a transparent and comparable way basic definitions and systematics were introduced. Based on these definitions different systematic methods for estimating efficiency were discussed and related to each other. The paper is completed by presenting an example for estimating the efficiency of actual "single" and "multi" connected primary safety systems.

INTRODUCTION

For Mercedes-Benz, automotive safety is not just a question of fulfilling crash tests. Mercedes´s innovations in the area of primary and secondary safety have been based successfully on findings of accident research for 39 years. Reality still is and continues to be the benchmark of the development of effective primary and secondary safety measures. The development of modern safety measures is a holistic process (figure 1) which is based on accident research, basic research on driver behaviour (situation based human or operating error), development and integration of new sensor, perception and actuator technologies. During the development process ample simulation series [6], system tests at test areas [5] and driving simulator tests are used to design and optimize the assistance systems [3]. During the final step customer-orientated testing of the system is organized. However, after the system is introduced it takes several additional years for it to penetrate the market. Only then it is possible to gain information on its efficiency based on real world accident statistics. Many of these systems take more than a decade of years to achieve a sufficient penetration rate. This immense lag of time is not acceptable for the development of safety measures that had to be efficient on the base of reality like it is required by Mercedes-Benz.

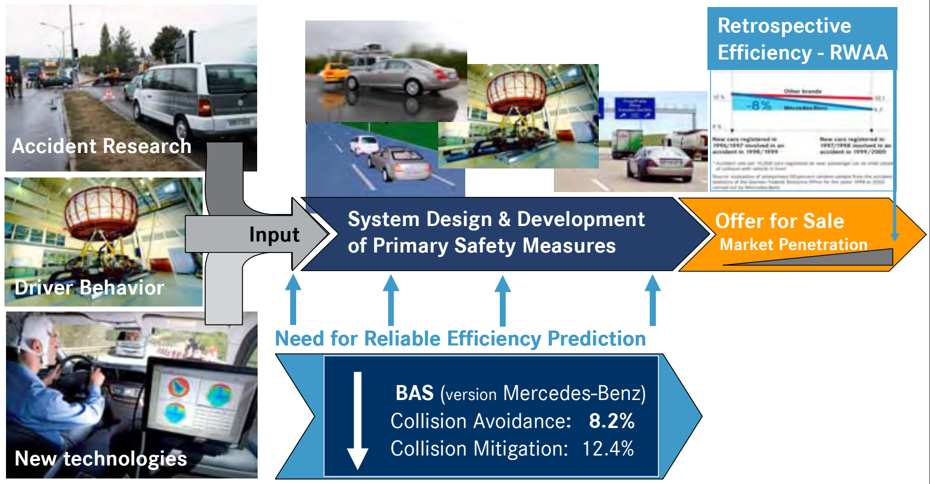

Figure 1: The need for statistically significant efficiency prediction during the development of safety measures and beyond

For the optimization of the development process described above it is essential to have statistically reliable predictions for the expected efficiency available continuously from the choice of a promising idea for the design of a new safety measure to the starting point of its development and through the whole process. So it becomes possible

- to focus on those primary safety measure that addresses most efficient relevant accidents and conflict situations resulting from human errors,
- to configure an efficient set of optimal balanced sensors, actuators and algorithms,
- to optimize the efficiency of the function by preliminary design using simulation methods,
- to obtain reliable information that the customer can expect from the system as benefit.

Efficiency analysis is the key technology to achieve such an improved development process.

DEFINITIONS

For analyzing the effect of primary safety measures it is useful to define terms that describe abstract characteristics of an accident or concrete accidents of a given characteristic e.g. in an existing data base. A characteristic could be e.g. a parameter that produces an accident like the conflict, an environmental parameter like ice or a property like skidding. Another useful distinguishing feature is that between the relative and the absolute effect. To be able to do so the definitions from [9, 20] were adopted.
The **area of conflict** [**AoC**] of a primary safety measure is defined as the pooling of abstract standardized conflict situations, in which the primary safety measure should be operating, avoiding or reducing accident severity due to its specifications. Use-cases which can be categorized as accidents are an example that makes up an "area of conflict". A(n) (representative) accident data base is the origin for the following explanations. It contains all kinds of accidents. Often it is useful to restrict the analysis to accidents which confirm to certain requirements – e.g. accidents with a certain severity.
The **area of reference** [**AoR**] is the set of cases that form the basis for the analysis. Depending on the type of question that has to be answered, a different set of accidents for the area of reference is selected, for example only fatal accidents or accidents with severely injured casualties.
The **area of action** [**AoA**] is defined as the mapping of the area of conflict in representative real life accident data contained in the data base respectively the **AoR**. It is the totality of accidents contained in **AoR** which correspond to the conflict situations in the area of conflict.
The **area of efficiency** [**AoE**] is defined as the subset of the area of action, in which the primary safety measure is able to avoid or mitigate the severity of accidents. For this subset of **AoA** the design specifications satisfy the physical parameters of the accidents.

The **degree of efficiency** [**DoE**] is defined as the quotient of the number of accidents in the area of efficiency and in the area of action.

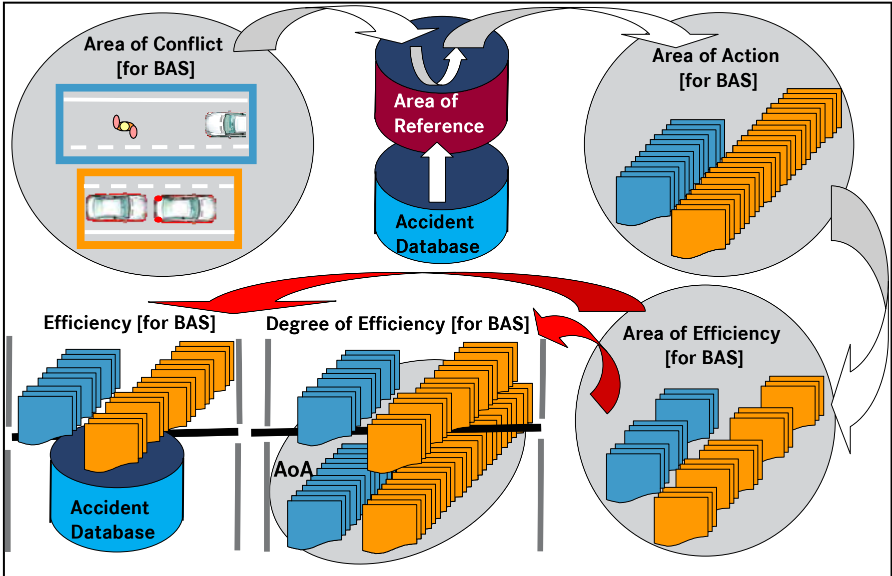

Figure 2: Visualization of the definitions around efficiency

The **efficiency** is defined as the quotient of the number of accidents in the area of efficiency and the number of accidents in the area of reference.

The **absolute efficiency** is given by the efficiency when AoR and AoA are equal to the accident data base.

The adjunct **"representative"** is used to clarify that the allocation accident data base was representative.

EXAMPLES

By definition **AoR** is a subset of the (representative) accident data base, **AoE** is a subset of **AoA** and **AoA** itself is a subset of **AoR**. An illustration of the terms defined above and their dependencies is shown in Figure 2 using the primary safety measure "Brake Assist (BAS)" as an example. Here the **AoC** consists of the accident types "collision with traffic moving ahead, waiting or starting", "collision with a pedestrian crossing the street".

For illustration we choose GIDAS for the accident data base in this example. For exemplification **AoR** is chosen to be the set of all accidents (and their documentation) in GIDAS with injury MAIS 3+ (seriously injured). **AoA** then is a subset of all accidents contained in GIDAS with injury MAIS 3+ which were of the kind "collision with traffic moving ahead, waiting or starting" or "collision with a pedestrian crossing the street". **AoE** is the subset of these cases where the brake assist (BAS) had / would have had an effect on the outcome / severity of this particular accident.

EFFICIENCY

So far efficiency quantifies the number of accidents which are likely to be influenced by the analyzed primary safety measure. So the efficiency is a proportion respectively a number. For the design or the assessment of a primary safety measure it is more important to get the two summands producing efficiency than the value for efficiency itself:

$$\textit{efficiency} = \textit{proportion of avoided accidents} + \textit{proportion of accidents with mitigated severity}$$

The aim of primary safety measures is to prevent accidents. Thus the "proportion of avoided accidents" or the "efficiency in avoiding accidents" is the most important characteristic of a primary safety measure.

The “proportion of accidents with mitigated severity” or the “efficiency in mitigating accidents” is hardly interdependent by classification measure that describes the performance of the mitigated severity over **AoE**.

SCORE CARD “Efficiency of a primary safety measure”

Often it is more appropriate to characterize efficiency by more than one figure. To be able to do so in [9] the concept of a “Score Card Efficiency” was introduced. The “efficiency“ of a primary safety measure is described with six characteristics and a distribution. The first characteristics are the proportions where the measure has / has no benefit. The amount of benefit is subdivided in the proportion of “avoidance” and “mitigation”. The effect of mitigating accident severity is characterized by a mean value and a distribution of an appropriate physical measure – here reduced collision speed. Other measures like reduced EES, injury severity (MAIS) etc. could be used as well. The mean value could be substituted by other statistical rations like the median, min-max, average and so on. The idea is illustrated in figure 3 for an academically emergency braking system: the system is able to detect a conflict with a vehicle moving ahead, waiting or starting. When a crash is imminent, the system automatically performs a full braking 0.3 seconds before the collision. This reaction of the system is independent from driver reactions. The area of conflict which is analyzed is rear-end collision.

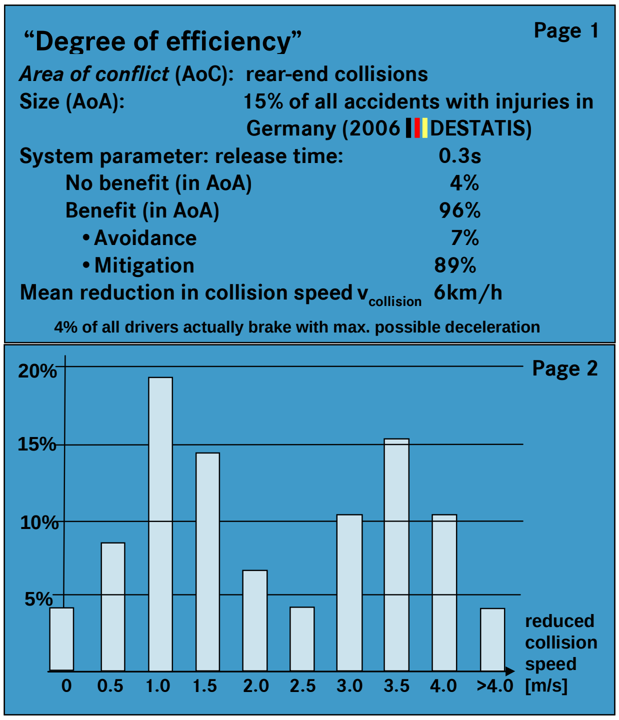

Figure 3: Score Card “Efficiency”

METHODS FOR DETERMINING EFFICIENCY

Initial findings about the methodology of retrospective and prospective analysis of secondary safety systems can be found in [18]. Secondary safety measures start working after the first contact resulting from a collision. Their aim is to reduce the consequences of an accident. In contrast primary safety measures are developed to reduce as much energy / velocity as possible in a fixed period of time before the first contact to avoid the collision. Hence an additional methodology is used for primary safety measures [20]. First of all methods for determining the efficiency of primary safety systems can initially be classified according to their ability to provide results for efficiency in a retrospective or prospective view.
Methods for a retrospect assessment of efficiency have established themselves by proving the evidence of ESP. Studies conducted by Mercedes-Benz [1], NHTSA and others show that in a representative sample of accidents a significant reduction in the number or the severity of special types of accidents between a group of cars equipped with ESP and a group of cars without ESP could be observed. One of these special types is for example the type of “driver related accidents”. Mercedes-Benz showed a reduction of 42% in this type of accident. This

result is confirmed by other studies and already existing meta-studies [2]. In contrast to [13] not a type of an accident but the conflict of a skidding car before the crash is analyzed.

The principle disadvantage of retrospect methods is that they base on the fact that there is a significant amount of cars equipped with the system in the market and that they are differentiable from those without the system. This penetration normally needs years after the point of sale. Hence a retrospective method is unacceptable in the development of effective safety systems.

The prospective methods can be distinguished by their ability to supply statistically reliable representative results. The following requirements had to be fulfilled to obtain such results:

[1] representative accident database and AoA used as a basis for the method / analysis
This means in particular a great number of total and considered accidents, surveyed coincidentally are containing all required information by the primary safety system.

[2] reproducibility of the results and the determination of AoA and AoE respectively
This means especially a strict rule-based or automated approach has to be used.

[3] integration of most / all parts of the primary safety system in the estimation of AoE
This means integrating descriptions or models for most or all parts of the system in the loop with car, driver and the complex accident situations in their holistic interactive dependencies (for the prevention of drastic simplifications) have to be made.

An assessment of common used method for predicting efficiency in the two dimensions “representative database” and “level of details of integrated parts” is shown in figure 4.

The “method” driving simulator has the unique advantage that it makes it possible to vary the driver and its behaviour in a fixed accident situation remaining the same for all different drivers. In [19] the use of a driving simulator in the development process of assisting systems is described. To cover the wide spread of conflicts that lead to a rear-end accident the efficiency is calculated as a mean of several typical rear-end accidents [3, 4, 14, 16]. A lot of sensitivity and experience is needed to gain reliable figures that describe the real life efficiency.

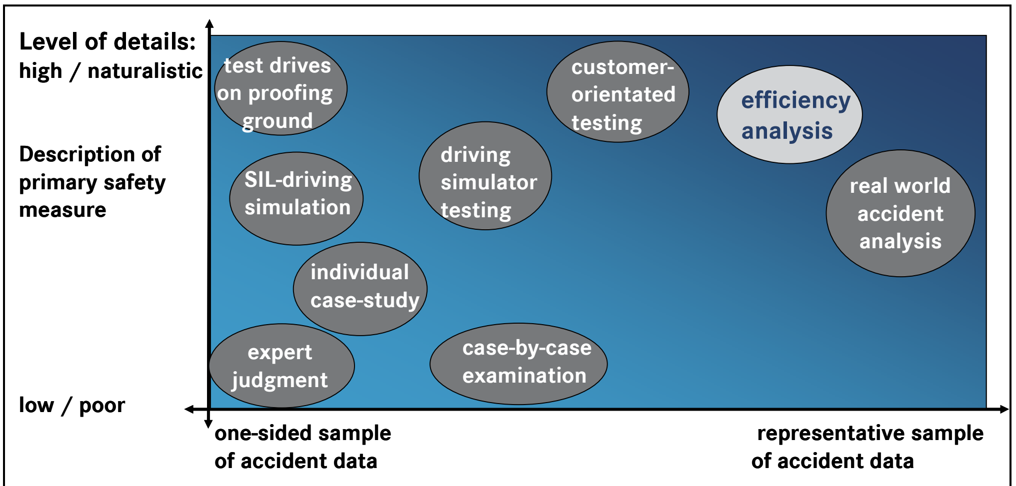

Figure 4: Efficiency assessment methods and their characteristics

For getting representative results the integration in other methods is necessary. The determination of **AoE** which is necessary to calculate **DoE** can be done in two ways. The simple way is to integrate parts of the primary safety system in the specification of **AoE**.

If **AoA** and **AoE** are determined from in-depth accident data, this could be done. An example is described in [7, 8]. A weakness of this approach is the not neglectable variance in the results. A more complex and expensive way is to determine **AoE** by an automatically performed analysis of all accidents contained in the **AoA** [8, 9]. This approach ends in a trustier **AoE** and **DoE** than the one resulting from the simplified approach described before.

Generally, **AoA** and **AoE** give an upper and lower estimation for the exact set of accidents that are addressed by a system and where a system has definitely an influence. AoA can also be considered as the upper boundary or the optimistic approach, while AoE is the lower boundary or pessimistic / conservative approach in estimating the system's impact on the accident cases. As always, the truth lies somewhere in between, and all the more the closer those two sets are approaching each other, the more precisely the result of the efficiency analysis will be. Usually, this accuracy comes at the cost of putting more effort into the analysis and by conducting for example a case-by-case assessment of the system, which can be done manually by an expert or automated.
Another issue arises by attempting to perform an overall assessment of more than one safety system. It is clear that different systems can have areas (sets of accidents), where more than one system can have an impact on the outcome of a single accident. A simple method has to be developed to deal with this issue. This method should also fit easily into the current framework for efficiency analysis of a single system. One solution is shown in figure 5.

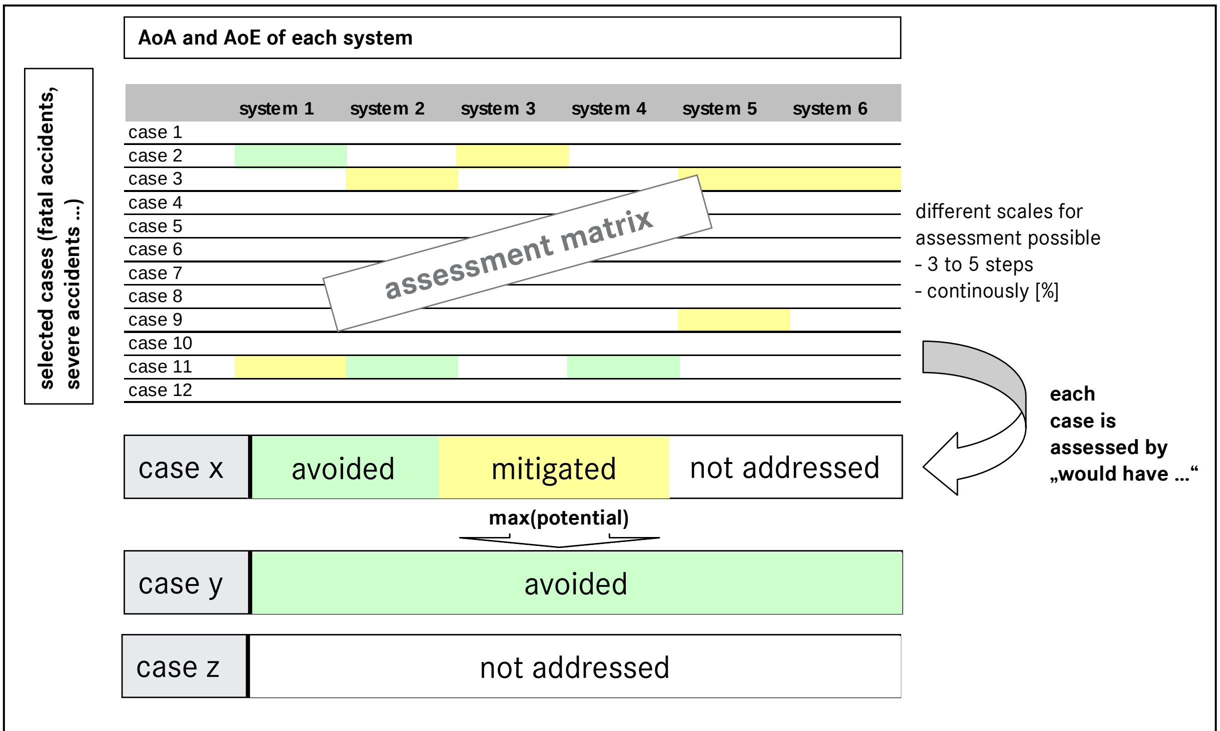

Figure 5: Assessment of more than one system at once

The columns of the assessment matrix are spanned by the list of systems that should be assessed. Each row represents an accident in the area of reference. In the process of assessment, each system in each accident has to be assigned a value of effectiveness of the system. This value is within a pre-defined scale which consists in its simplest form of the three values: "avoided", "mitigated", and "not addressed". The assignment can be accomplished by three different methods or by a combination of them:

1. Selection of cases in the database according to system correlated restraints: This is the easiest method and only works, if the parameters, that specify the constraints to make a valid decision, if the system is activated or not, can be mapped properly to values in the underlying accident database.

2. Case reconstruction:

Very often, a simple mapping to values in the database is not sufficient for a valid assessment of the situation with respect to a specific safety system. One needs to do a reconstruction of the case to see its outcome.

3. Case-by-case analysis based on expert assessment:

If no formal rules can be established to make a decision of the efficiency of a system in an accident, an overall assessment of the case needs to be done by judging from an expert's point of view or by discussing in a group of experts. However, this is the most time-consuming method and needs to the expertise and background of experts although it somehow has lack of reproducibility.

After having assigned a "multi-system" assessment of the potential to avoid or mitigate each single accident in the database, an overall value for both, conservative and optimistic efficiency can be determined in the already described way above. As a bonus, all cases with no potential effect of any of the systems are returned in this process. These cases can be seen as the blank spots on the map of accidents and can form a good starting point for future developments in traffic safety.

DATABASES

The choice of the accident data base used for an efficiency analysis for a primary safety measure determines whether the results can be applied to official accident statistics or not.

For Mercedes-Benz the reflection of these figures by real world accident statistics is an essential benchmark for judging the system's efficiency. A multiplicity of different accident data collections are used for analyzing the potential benefit of a primary safety measure. Common used collections came from police departments, insurance companies, unions of forensic accident assessors or accident research department of automotive manufacturers. All of these samples result from a special focus of their acquisition respectively the aim of the underlying survey. To perform a survey representatively (from their focus) for e.g. all accidents in Germany is not a requirement for all mentioned investigations.

Representativity of an accident data base means that its composition and characteristics resemble (of a defined severity) with the composition and characteristics of the allocation base – here the entirety of all accidents e.g. in Germany. In other words a smaller sample set (accident data base) is a consistent image of the big allocation base. It is a popular fallacy that representativeness of an accident data base correlates respectively growths with its size. This is only true for a data base that consists of an undistorted sample of accidents. Here a minimum number of samples that could be analyzed are needed to become statistical significant. For a distorted respectively focused selection increasing samples size tightened its missing representativeness.

Representativity of an accident data base is the basis to be able to educe universally valid evidences for the entirety of all accidents from analyzing a smaller (but representative) image established in the accident data base. The GIDAS data base is proved to be representative for accidents with injuries (and fatalities) in Germany. This is why GIDAS is used in this paper.

GIDAS DATABASE - A STATISTICAL REPRESENTATIVE SAMPLE OF ACCIDENTS

The analysis in this paper is based on accident data provided by the GIDAS project. GIDAS is an abbreviation for "German In-Depth Accident Study". GIDAS is a cooperative project between the German Association for Automotive Technology Research (Forschungsvereinigung Automobiltechnik e.V., FAT) and the German Federal Highway Research Institute (Bundesanstalt für Straßenwesen, BASt) (see [11] for more details). In its current form it was founded in 1999. Since this time the data for in-depth documentations of more than 2000 accidents per year is collected in two research areas – the metropolitan areas around Hanover and Dresden – see figure 6.

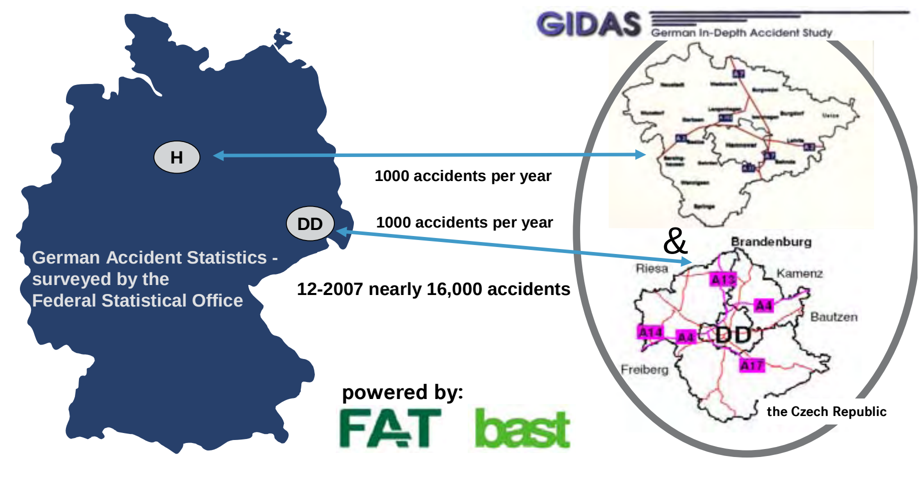

Figure 6: GIDAS database - the research areas around Hanover and Dresden

The criterions for choice and collection are: (1) road accident, (2) accident in one of the research areas, (3) accident occurs when a team is on duty in a defined timeframe, and (4) at least one person in the accident is injured, regardless of severity. For each accident a digital folder is delivered according to carefully defined guidelines and coded in a database. Depending on the type of accident, each case is described by a total of 500 to 3,000 variables, containing e.g. accident type and environmental conditions (the type of road, number of lanes, width, surface, weather conditions, time of the day,…) surroundings of the accident scene, vehicle-type, vehicle specifications (mass, power, tires, …) and configurations (e.g. with safety measures), documentation of damage of the vehicles and injury data for all persons involved and their medical care. Investigation of all cases is "on the spot" to ensure best visibility of traces for a best possible reconstruction. Each accident is reconstructed in detail including the pre-collision-phase. Available information includes initial vehicle and collision impact speed, deceleration as well as the speed sequence of the collision.
Half the battle of the pro of this database is that: (1) for standard AoA´s (needed for the assessment of actual safety measures) the number of cases is high enough to provide statistically significant results, and (2) each accident is documented in great detail, including in-depth-analyses and reconstructions of the course of the accidents including the pre-crash phase, and (3) most of all this database is proven to be representative to German national accident statistics.

EFFICIENCY OF SERIES "SINGLE" AND "MULTI" PRIMARY-SAFETY-SYSTEMS

Development objective for primary safety measure is the avoidance of accidents. But avoided accidents are not contained in an accident data base. Thus the efficiency of a primary safety measure in contrast to a secondary safety measure can not be determined directly from accident data. By construction **AoE = AoA** gives an upper limit for the efficiency with the assumption that the **DoE** equals 100%. A better estimation can be obtained by integrating the range of operation or system boundaries of the primary safety measure in the determination of **AoE**. This gives a better upper bound for **DoE** than **AoA** itself.
("Single") Primary safety measures could be categorized by "always-on" respectively "manual-on" systems. A special case is established by "operated-on" systems. Examples for "always-on" primary safety measures are ABS, ESP, and BAS, an example for a "manual-on" measure are daylight running lights. Series vehicles did not have one system of primary safety but a combination of systems referred to as "multi" measures. Particularly with regard to

determining efficiency in avoiding or mitigating the severity of accidents, it is useful to distinguish between cooperative, competing and non-effecting primary safety measures. In the case of rear-end accidents an example for cooperating systems is the combination of (switched-on) ACC and an emergency brake or a Brake Assist (BAS), an example for competing systems is ESP and ABS or BAS in the case of skidding, an example of non-effecting measures is the combination of daylight running lamps and flashing brake lights in the first car. In the first example the efficiency in avoiding accidents is greater than the sum of the single values, in the second it is less then the sum and in the last case it is the maximum of the single values.
By so far driver behavior is not consequently modeled. This is why assumptions about this had to be made, e.g. reactions on warnings, behavior in critical situations, switching on systems and so on. This leads to different scenarios, which can be optimistic or conservative.

EXAMPLE – EFFICIENCY FOR AN ACTUAL MULTI PRIMARY SAFETY MEASURE

To make the definitions and methods presented before more clearly an example is discussed next. The combination of DISTRONIC PLUS and Brake Assist PLUS has been chosen for this example. It is adopted from [20] where it is explained in more detail. This combination or "multi" primary safety measure addresses rear-end collisions. A collision with a vehicle moving ahead, waiting or starting is very common. In Germany each sixth accident with injuries and each sixteenth accident with fatalities is a rear-end collision see figure 7. What is the expected efficiency from the combination of DISTRONIC PLUS and Brake Assist PLUS in these kinds of accidents?

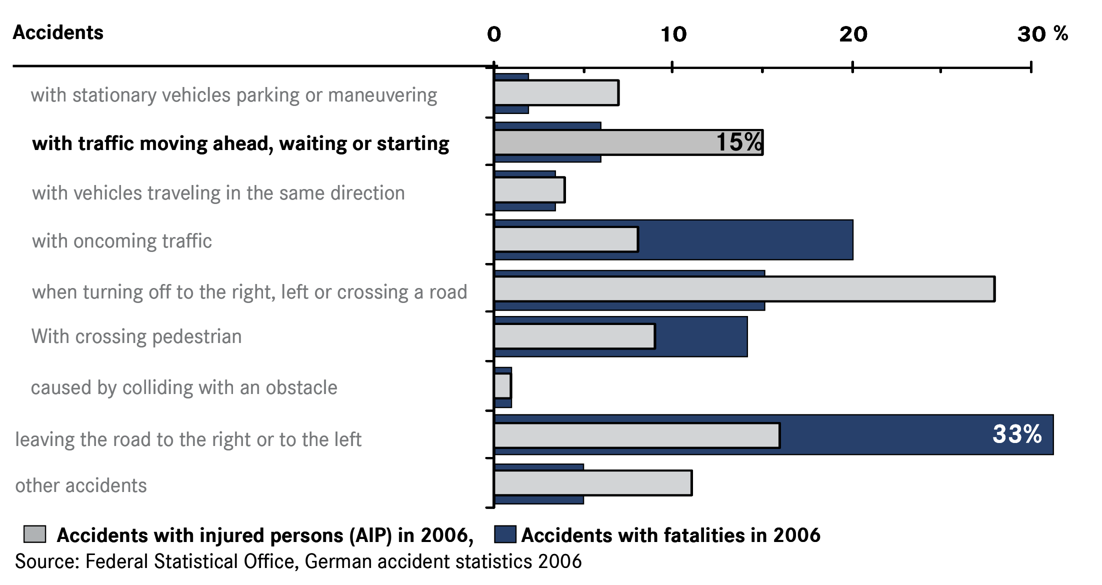

Figure 7: Distribution of different accident types with injured persons or fatalities in Germany 2006
(Source: Statistisches Bundesamt, Fachserie 8, Reihe 7, 2007)

Selective further developments of the advanced cruise control system (ACC) of Mercedes-Benz called DISTRONIC lead to the new system DISTRONIC PLUS in 2005. A relevant improvement was the integration of two radar sensors systems to monitor and evaluate the traffic situation in front of the car. The 77 GHz DISTRONIC radar was combined with two 24 GHz short range radar sensors. The 77-GHz long-range radar is able to scan three lanes over a distance up to 150 meters with an angle of nine degrees. Two 24-GHz radar sensors monitor the immediate area in front of the vehicle from 0.2 up to 30 meter with an angle of 80 degrees. The algorithms for situation perception and assessment were enhanced. This leads to an increased operating range from 0 km/h to 200 km/h, an extension of the area of operation of the distance control from 0.2 m up to 150 m and an advanced dynamic range for deceleration from 4m/s² to 2m/s². DISTRONIC PLUS is supplemented by an increasing number of primary safety measures that share the sensors with DISTRONIC PLUS and implement an additional safety feature. Brake Assist PLUS (BAS PLUS) is one of them. The BAS PLUS system is an additional option efficient especially in the case of rear-end collisions; naturally the (classic) BAS remains available. With this radar-based environmental perception the situation evaluation algorithm of BAS PLUS can detect imminent rear-end collisions with identified obstacles. If there is currently one detected:

(1) BAS PLUS calculates continuously the actual braking assistance required to avoid the collision by target braking (not necessarily a full braking).

(2) BAS PLUS warns the driver with an audible signal, prompting him to take action.

Brake Assist PLUS is an “always-on” system while DISTRONIC PLUS is a “manual-on” system. Both complement each other if DISTRONIC PLUS is switched-on. The combination of both systems is not a single but a “cooperating” multi system. Its efficiency is more than the sum of both efficiencies.

The assumptions on which the following efficiency analysis is based are very important, they are chosen to be very conservative: Selecting accidents from GIDAS **database** (2006) that belong to “Area of Action – all rear end collisions with injuries, in which a passenger car collides with another vehicle in front” as defined before. Then **AoA**:

- consists of 839 in-depth evaluated accidents, especially containing reconstruction data
- constitutes a representative sample of rear-end accidents with injured persons in Germany

The systems DISTRONIC PLUS and BAS PLUS were tested virtually in a conservative scenario assuming:

- Equipment rate is 0% or 100%.
- BAS PLUS is activated permanently (rate of switching-on is 100%).
- DISTRONIC PLUS - is activated for 100% extra urban driving on freeways (BAB – for “Autobahnen”) and highways (B – for “Bundesstraßen”).
- Conservative assumptions with respect to the behaviour of the driver during the accident:
  - Driver behaviour remains UNCHANGED during the accident (equal to reconstruction).
  - A possible reaction of the driver to all kinds of collision warnings is NOT MODELED.
  - A simple driver model for activating BAS is used.

To clarify the definitions introduced before examples for their usage are given here. The result of the “testing” is the “area of efficiency - **AoE**”. The “degree of efficiency” **DoE** is what is depicted in figure 7. Additionally **DoE** is subdivided in the proportion of mitigated (**DoM**) and avoided (**DoA**) accidents. Three single cases were analysed. These cases arise from three different “Areas of References - **AoR**”. In the first case **AoR** is equivalent to all accidents with injuries. In the second case **AoR** is equivalent to all accidents with injuries extra urban on freeways and motorways, in the last case the restriction is on all accidents with injuries extra urban on freeways only.

With this conservatively defined scenario a lower limit for the efficiency of the combination of DISTRONIC PLUS and Break Assist PLUS in the case of rear-end accidents in Germany assuming a penetration rate of 100% is gained. The results were taken from [20].

The results show that DISTRONIC PLUS and Brake Assist PLUS complement one another in a perfect way, provided that DISTRONIC PLUS is switched on.

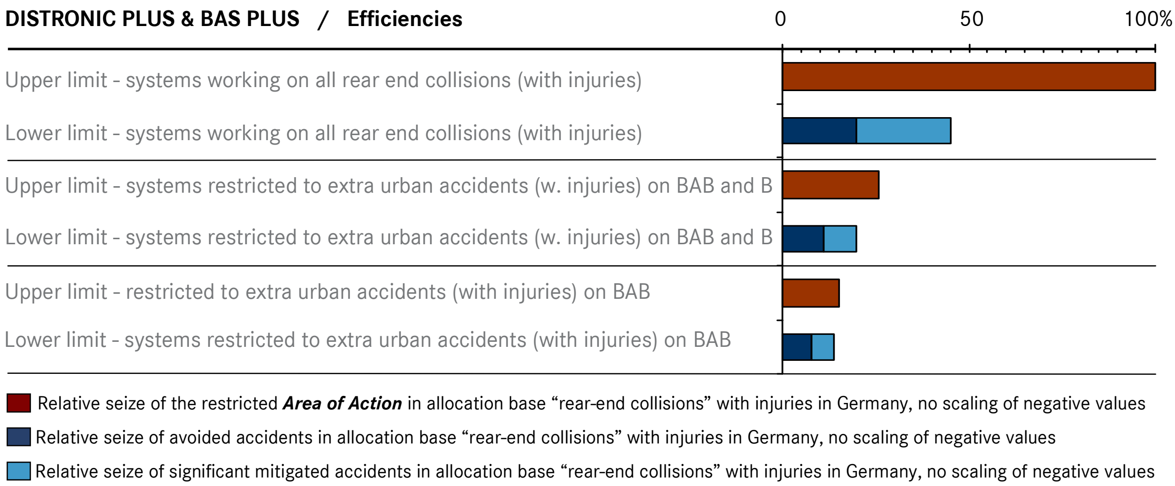

Figure 8: Limits fort he efficiency of the „multi" measures DISTRONIC PLUS and Brake Assist PLUS in German rear-end collisions with injured persons.

DISTRONIC is designed for keeping a chosen distance to a vehicle in front – if possible, with the desired speed, - if not possible, with a speed resulting from keeping the distance having higher priority. The recommended field of application for DISTRONIC is extra urban on freeways and highways. That is why these cases were regarded here explicitly. The results show that the combination of both systems is highly efficient in extra urban while using DISTRONIC PLUS. The value of the efficiency in all rear-end crashes in figure 8 is recognisable influenced by the amount of completed cases with fragmentary data.

CONCLUDING REMARKS

The range of methods used to estimate "efficiencies" for primary safety measures is wide. It varies from "crystal ball" expert judgement to technically high sophisticated simulation techniques. The aim of this paper is to introduce and harmonize definitions for common used notations to get an abstract concept for the "efficiency" of a primary safety measure. The resulting benefit of these measures in real world accidents has a high relevance in different topics and is used by miscellaneous stakeholders. To increase automotive safety actually it is important that the predicted efficiency can be assigned to the real life accident world mapped itself to national accident statistics. It is shown that representativeness of the (predicted) efficiency is the key request to get statistically reliable results as stipulated before. This requirement puts high demands on the used method. Necessary constraints for a potential method like using a representative accident data base, reproducibility of the results, integratability of detailed components of the primary safety measure were discussed. The paper ends by applying a presented method to determine the efficiency of a "multi" measure consisting of DISTRONIC PLUS and Brake Assist PLUS, two realistic assisting systems purchasable for Mercedes-Benz S- and (soon coming new) E-class. High demands should be taken on the accurateness of a detailed modelling of components of a primary safety measure like environment perception, sensors and functionality but also on vehicle dynamics and the situation itself. A holistic approach and a close multidisciplinary collaboration of different specialisms are needed. An accident researcher as well as an expert on assisting systems, simulation, ergonomics or vehicle dynamics working on their own will produce insufficient results. Therefore Mercedes-Benz established an interdisciplinary team of experts to manage this demand. The requirement for a representative prospective "efficiency" of a primary safety measure sets the standard up another notch. From an automotive manufacturers point of view this request is necessary to obtain the reliability needed for its far reaching consequences.

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The EU action for Road Safety and the Role of In-Depth Investigation of Road Accidents

Jean-Paul Repussard
Directorate General Energy and Transport, European Commission, Brussels

(extract from the keynote speech)

The EU road safety policy

- White Paper on Transport (2001)
- European Road Safety Action Programme (2003)
  - *Halving the number of victims by 2010*
  - *A shared responsibility*

The "-50%" objective

- A political & global commitment
- Individual responsibility of Member States
- Each Member State should strive to perform at least as well as the best-performing ones

"A shared responsibility"

- Numerous stakeholders
- Public: EU level + Central Governments + Local Authorities
- Private: Car industry + Transport companies …
- Everybody: all users !

Action by ALL stakeholders is needed.
The EU level acts wherever it provides an added value.

"An integrated approach"

- User behaviour
  Campaigns Enforcement
  Education Driving licences
- Vehicle safety
  Passive and active safety
  Technical inspection
- Road Infrastructure safety
- European Road Safety Charter
- Observatory (incl. accident data)

The EU instruments

- Road accident data and information
- Financial support to projects
- Research and studies

- Best practice guidelines
- Legislation (only when necessary)
- The Road Safety Charter

Next step: the EU road safety action programme (2010-2020)
- Soon in the make
- Step1: Public consultation to be launched in 2009

Focus on some topics

1. Infrastructure
2. Enforcement
3. Professional driving
4. Vehicle safety
5. Driving licence
6. Alcohol, drugs & medicines
7. the Charter
8. Road Safety day
9. Best practices
10. Campaigns

1. Road Infrastructure Safety management

Objectives
- To ensure that safety is integrated in all phases of planning, design, construction and operation of road infrastructure
- To bring about a common high level of safety of roads in all EU Member States
- To use the limited funds for more efficient construction and maintenance of roads.

Directive adopted by the European Parliament and by the Council in June 2008 (to be published in October)

2. Enforcement of road safety rules

Basic facts

- A top priority for almost immediate results
- Enforcement varies considerably between Member States
- Traffic offences by non residents (a significant proportion of offences in many Countries) are rarely sanctioned, as appropriate, legal and technical instruments are lacking

Step 1: Commission recommendation (2003)
- Best practices for enforcement of speeding, drink driving and non-use of seat belts

Step 2: Directive on cross border enforcement (proposal adopted on 19 March 2008)
- Type of offences : speeding, drink-driving, non-use of seat belts & red-light running
- Information exchange
- Notification of offences

3. Professional driving: legislation in force

- ✓ Initial qualification and periodic training *(35 hours every 5 years)* of truck & coach drivers *(road safety is one of the topics for both qualification and training)*
- ✓ Digital tachograph
- ✓ Driving (working) time and rest periods

4. Vehicle safety

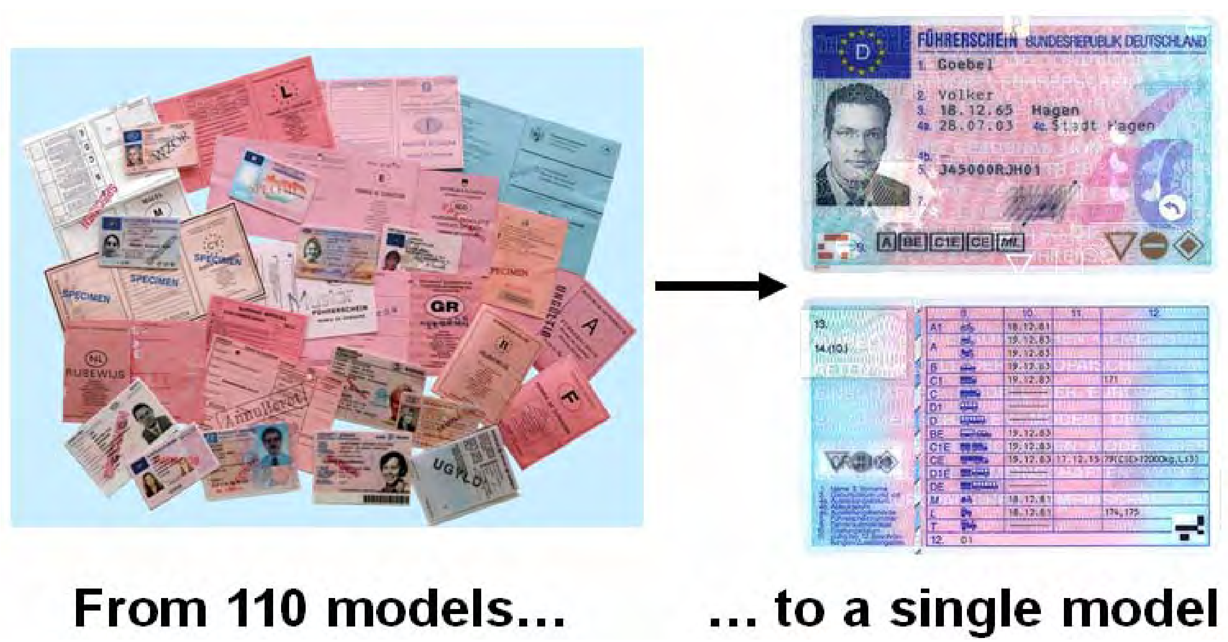
- ✓ Front protection of vulnerable users (Dir.2005/66) - *2nd proposal now in discussion*
- ✓ Blind spot mirrors: for new trucks (Dir. 2003/97) & existing trucks (Dir. 2007/38)
- ✓ Generalisation of the use of seat belts (incl. in coaches) & of child restraint systems (Dir. 2003/20)
- Day time Running lights (DRL): dedicated lights to become mandatory for all new vehicles – after completion of the UN-ECE decision process
- Electronic Stability Control (ESC): to become mandatory for new trucks & coaches, later for new passenger cars – after completion of the UN-ECE decision process
- Tyres: minimum requirements for rolling resistance, noise, <u>grip</u> & <u>pressure monitoring*</u> – new legislative proposal COM(2008)316, 23.5.2008

  * passenger cars only

[✓]''CARS 21'' - dialog with the automotive industry (a 'road map', no directives)

5. Driving Licence: what's new?

Legislation adopted on 20 December 2006, in force by 19 January 2013



From 110 Models .... to a single model

- Anti fraud measures : credit card size, administrative validity 10 years only (up to 15 years possible), one licence only for each driver, optional microchip

- Harmonization of the periodicity of medical checks for professional drivers (5 years)
- Minimum training requirements for driving examiners
- Further harmonization of categories

progressive access to the powered-2 wheels

- new AM (max. 50 cm³ & 45 Km/h): age 16, possible 14, theoretical exam
- A1 (max. 125 cm³, 11 kW & 0.1 kW/kg), age 16
- new A2 (max. 35 kW & 0.2 kW/kg) *[indicative 125-500 cm³],* age 18
- after 2 years experience A1:
    - 7 hours training or practical exam (annex VI*)
- otherwise (direct access) theoretical & practical exam (annex II*)
- A (all other motorbikes)
- after 2 years experience A2, age 20
    - 7 hours training or practical exam (annex VI*)
- otherwise (direct access) age 24, theoretical & practical exam (annex II*)

** annexes of Directive 2006/126/EC of 20 December 2006 (OJEU L403/18)*

6. Blood alcohol limit (BAC): no European harmonisation

Failure of a proposal for a directive (13 years in discussion…)

BAC (mg / ml) - current situation
- 0.0 Czech Rep., Hungary, Slovakia, Romania
- 0.2 Estonia, Poland, Sweden
- 0.4 Lithuania
- 0.5 16 Countries
- 0.8 Ireland, Malta, United Kingdom

In several Countries, restrictions for some categories: novice / professional drivers, bus & coach drivers

A higher BAC well enforced is better than a lower BAC with poor enforcement

Alcohol, Drugs & Medicines: Commission's initiatives

- Drink-driving: Commission Recommendation (2001)
- Alcohol Interlock (alcolock) – feasibility study & pilot project
- Drugs: Council Resolution (2003)
- Immortal (2002-2005): study
- Rosita 2 (2002-2005): RTD
- ''DRUID'' (www.druid-project.com)

7. The European Road Safety Charter

- The extension of the "shared responsibility" concept to civil society
- 1000 signatories so far
- Signatories commit themselves to concrete and measurable actions
- Commission creates awareness and makes commitments public

- Logo
- Awards
- Presentations
- Reports and newsletters

http://www.europa.eu.int/comm/transport/roadsafety/charter_en.htm

8. European Road Safety Days

Coordination with the 1st global road safety week (UN)
Focus on Young drivers

2nd European Road Safety Day:
Paris, 13 Oct. 2008
- Focus on safety in urban transport

9. Catalogue of best / good / promising practices

Methodology
List of measures collected and analysed
Handbook for measures at the Country level
Handbook for measures at the European level
Review of the implementation at the Country level
Thematic reports

Campaigns
Driver education training licensing
Rehabilitation and diagnostics
Vehicles
Infrastructure
Enforcement
Statistics and in-depth analysis
Institutional organisation
Post accident care

Summary and publication of best practices in road safety in the Member States (+ Norway & Switzerland) http://ec.europa.eu/transport/roadsafety/publications/projectfiles/supreme_en.htm

10. Some EU-wide Road Safety Campaigns

www.chooseesc.eu/

(Red Cross)
www.1-life.info/

Helmet wearing (no EU funding)

acem

European Night without Accident

And also… (not campaigns, but …)

EURO NCAP

www.euroncap.com

Information of consumers (stimulating demand for safer cars)

(in discussion) towards a labelling scheme for tyres: rolling resistance, noise & grip (stimulating demand for more efficient tyres)

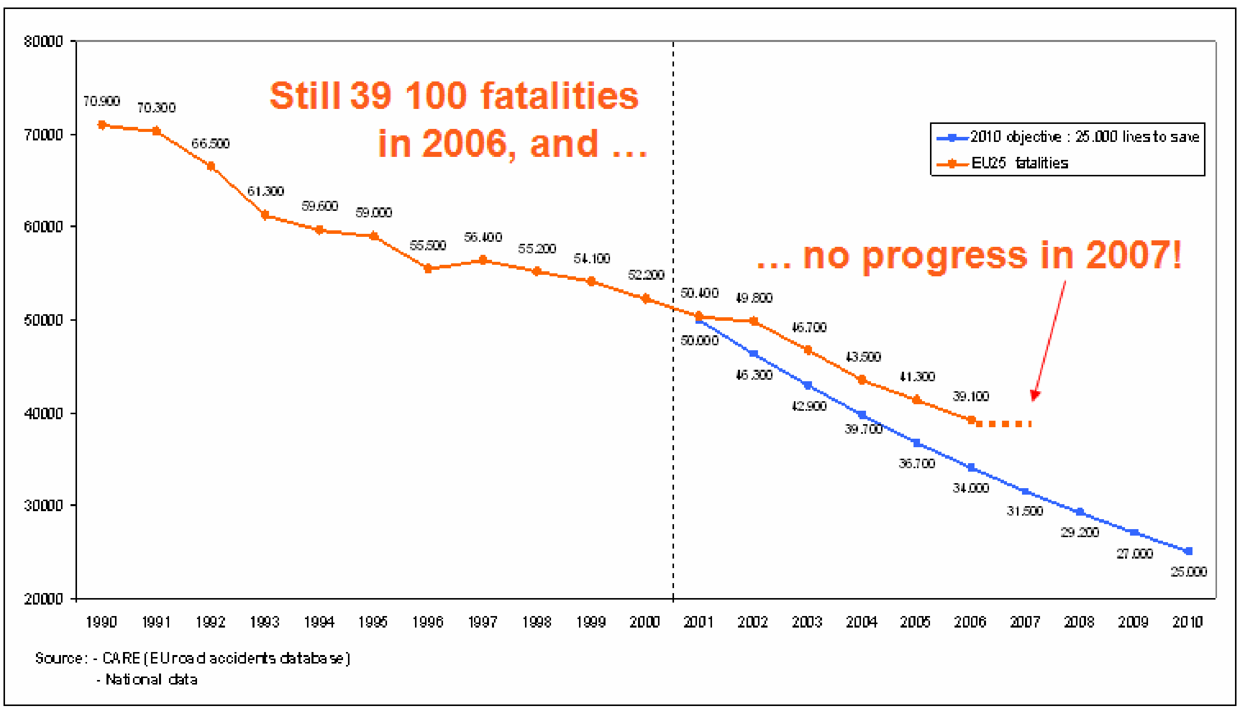
Data & Statistics (help for targeting action)

European level Data & Statistics on road accidents:
where to find them?

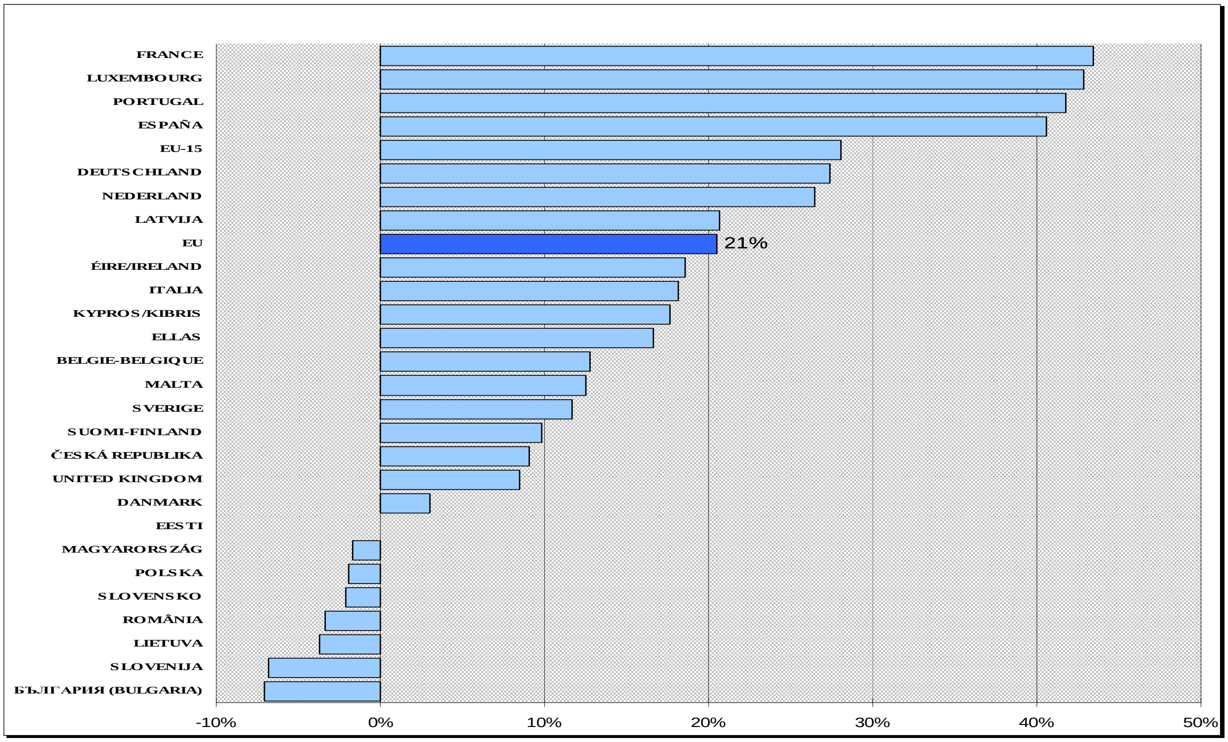
European Road Safety Observatory

www.erso.eu

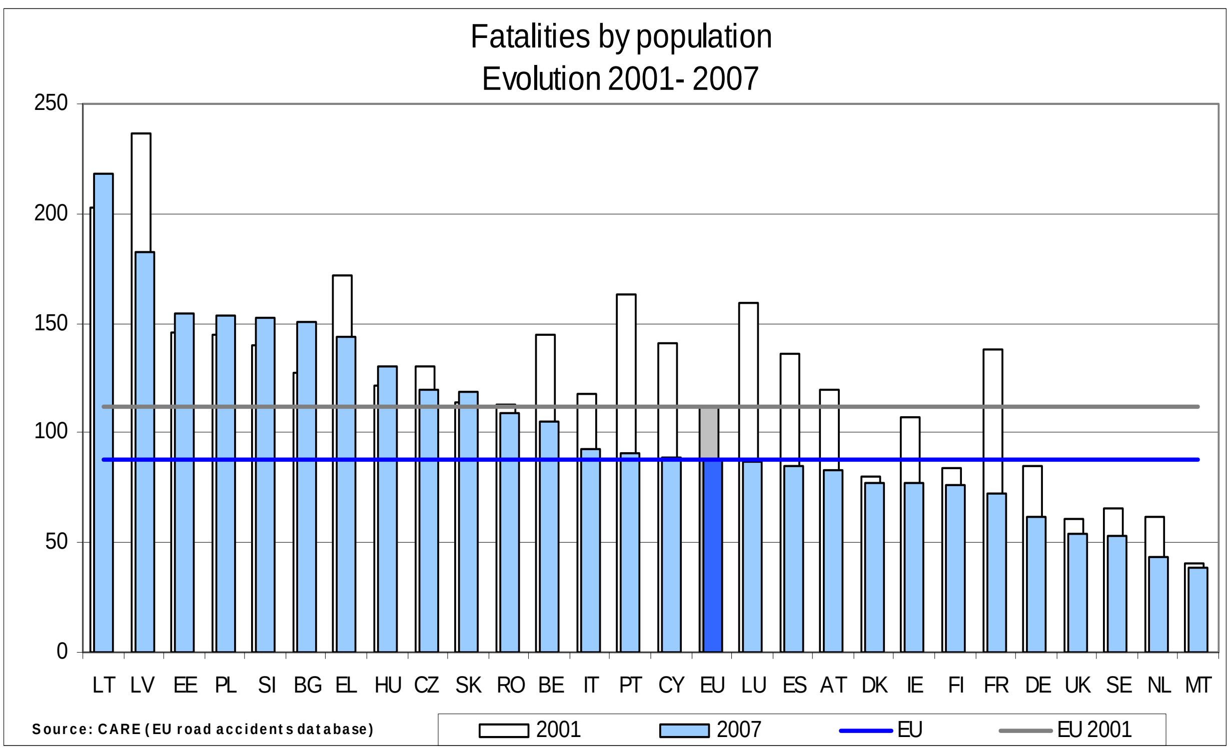
Fatalities – evolution 1990-2010



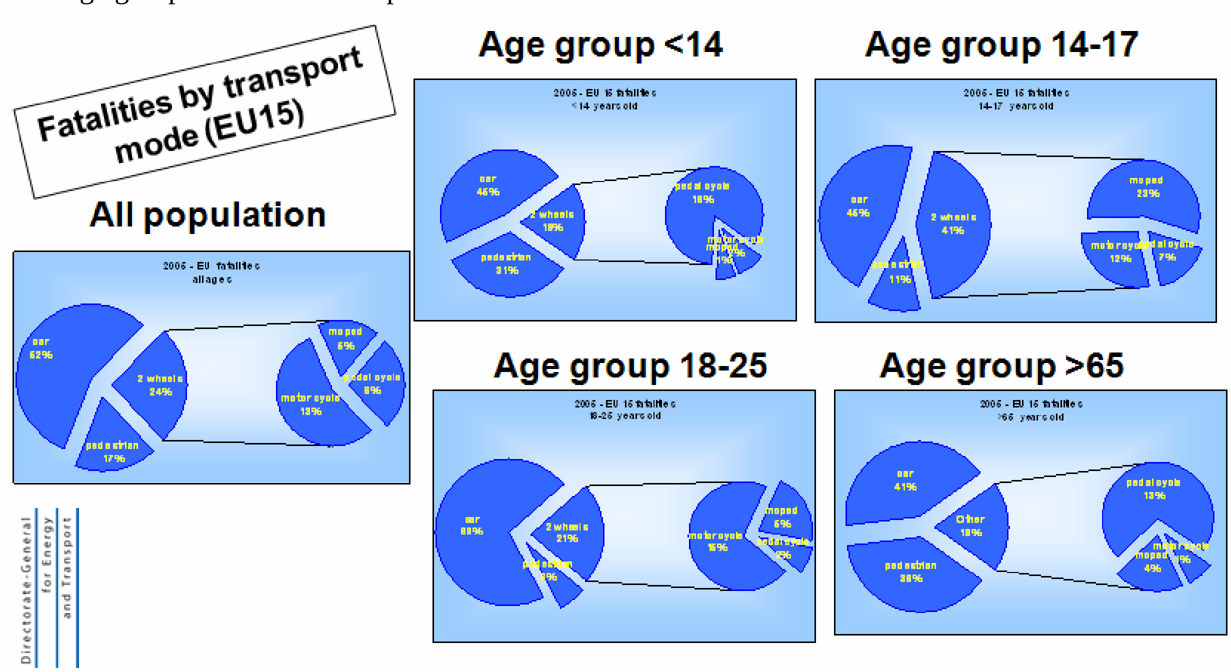
Progress by Country (2007 vs 2001): contrasted results



Fatalities / population: great contrasts

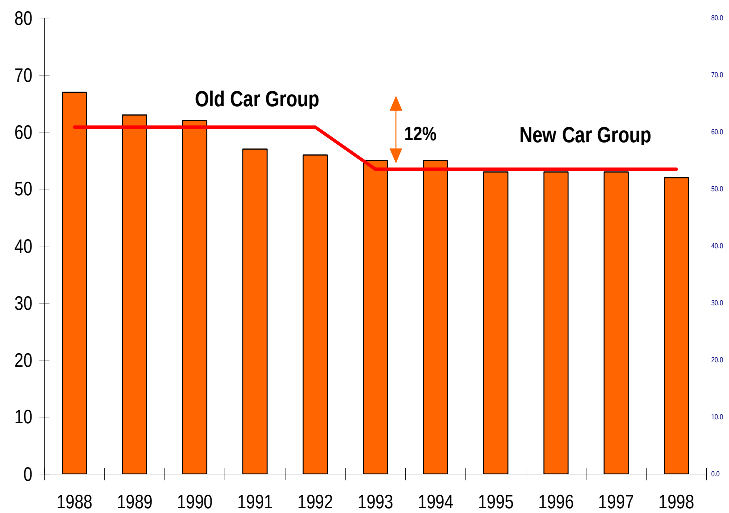


Each age group has a distinctive pattern



EU & national levels need more detailed data for better data-driven policies …

… Policy Priorities



- Counting crashes, fatalities and casualties
- Monitoring the progress of casualty reduction actions
- Identifying overall priorities for safety countermeasures
- Allocation of resources

… Vehicle Safety Priorities

- Effectiveness of existing regulations
- Technical development of new requirements
- New priorities in regulation
- Assessment of non-regulatory activities e.g. Euro-NCAP
- Support for Industry – new products and technologies

… Infrastructure Safety Priorities

- Highway design requirements
- System interactions e.g. vehicle and barrier
- Requirements for Intelligent Transport Systems

…Road Users Behaviour Priorities

- Effectiveness of enforcement measures
- Understanding driver decision making
- New priorities in accident prevention

Towards a comprehensive set of road accident data at European level

complementary sets of data for macroscopic and in-depth analyses:

- Reliable
- Detailed
- Comparable

… Therefore, a mix of:

- Millions of data with dozen of parameters

and,

- Thousands of data with hundreds/thousands of parameters

Both groups are developed in parallel

Macroscopic level:

- CARE (the basic data base since 1991)
    - now absorbing data from "EU newcomers" + NO, CH & ISL
    - close to routine, but data on injuries not yet comparable
- Exposure data (still at pilot stage)
- Performance indicators (idem)
- Other analyses: SARTRE & SUNflower

In-depth level: what did the EU White Paper on Transport say in 2001

- "… The need for independent investigations which follow accidents … towards revealing [their] causes …" [*i.e. not for determining the liability*]
- "Independent investigations … need to be conducted at national level but following a European methodology. The results should be [pooled as to] improve the existing legislation …"

Building European in-depth data bases: a long process…

The past:

- STAIRS (RTD-FP4)
- PENDANT (RTD-FP5)
- SARAC
- MAIDS
- ETAC
- RO-SAT
- SafetyNet (RTD-FP6)

What's available at the end of 2008?

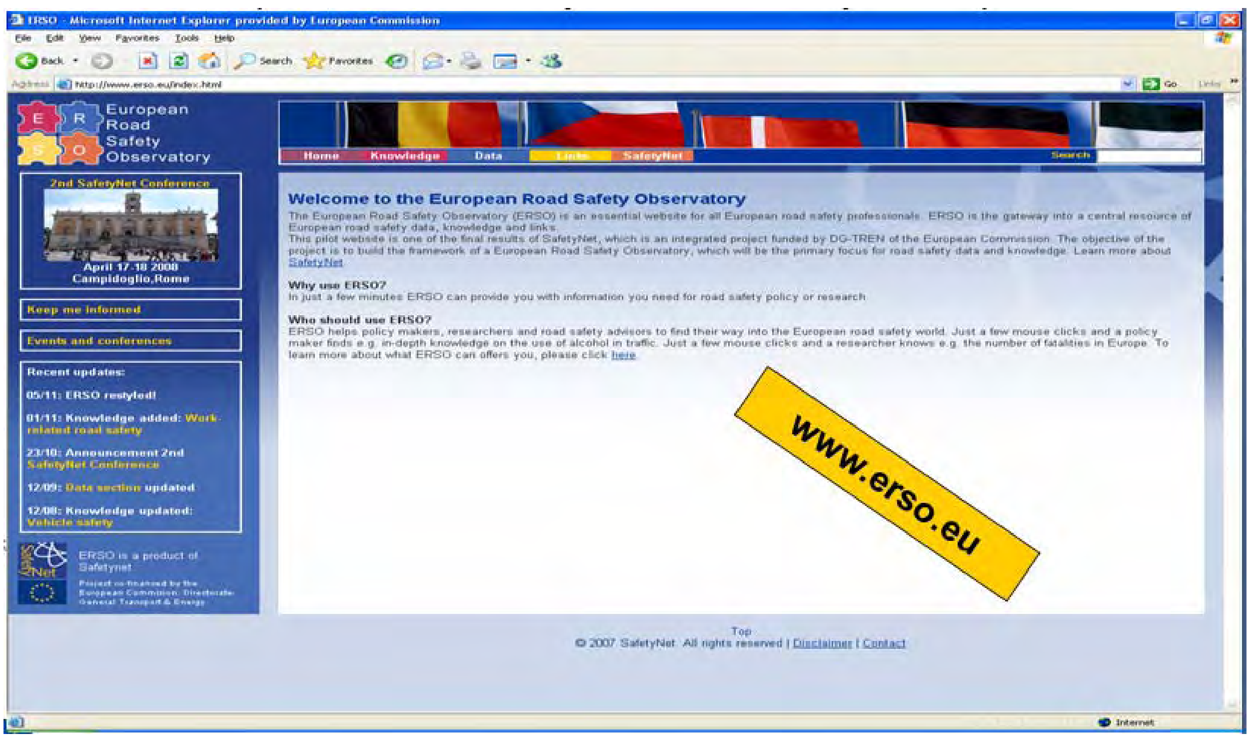
- Recommendations for transparent / independent investigations
- European methods for
  - data collection and storage
  - data analyses

    validated within SafetyNet)

Next steps (as of 2009)

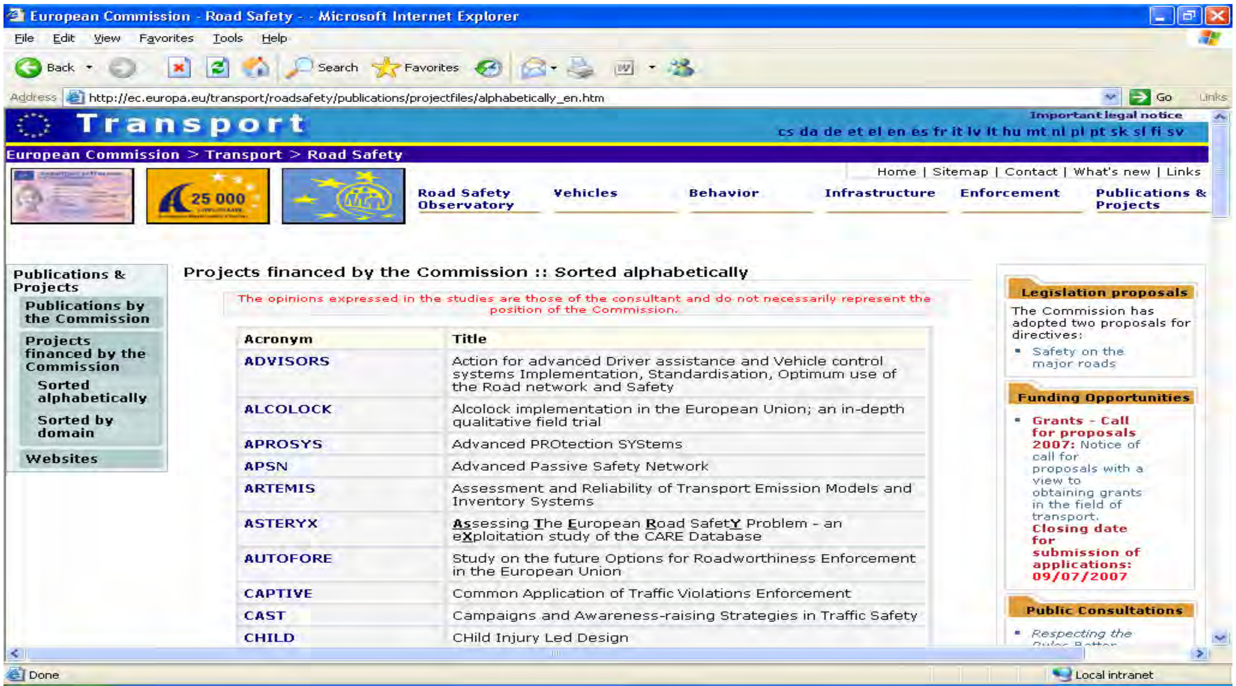
- Further work towards a full scale pilot (i.e. getting a critical mass of data from a significant batch of Countries) before it becomes a routine activity
- "Data Collection, Transfer & Analysis ("DaCoTA", RTD FP7 call, May 2008 – selection process still ongoing)

More statistics & accident data analyses (both at macroscopic level & in-depth data)



Information on all EU-funded projects

http://ec.europa.eu/transport/roadsafety/publications/projectfiles/alphabetically_en.htm



Conclusion

- Globally, the EU was almost on track (until 2006) towards road safety, but not all Member States
- Political willingness (highest possible level) and users' awareness are necessary
- Integrated approach & shared responsibility:
  - Good co-operation of various Gov^t Dep^ts (Justice, Transport, Police, Health) is necessary
  - More commitment from the "civil society" (Charter...)

Web sites

- **Commission transport website**
  http://ec.europa.eu/transport/index_fr.html

- **Road safety section**
  http://ec.europa.eu/transport/roadsafety/index_en.htm

- **CARE database**
  http://ec.europa.eu/transport/care/index_en.htm

- **Driving licences**
- http://ec.europa.eu/transport/home/drivinglicense/index_en.htm

MULTIVARIATE BENEFIT ESTIMATION OF FUTURE VEHICLE SAFETY SYSTEMS

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ABSTRACT
Over the last decades the number of traffic accident fatalities on German roads decreased by 77% down to 4968 in the year 2007. This positive development is due to optimisations of vehicle safety, roads and infrastructure and medical rescue issues.

Up to now mostly the optimisations of secondary safety measures lead to this effect on vehicle safety. Since some years more and more driver assistance systems are available and lead to a further reduction of all accidents. These new systems are often comfort systems and have not primarily been developed to increase vehicle safety. In contrast to secondary safety systems primary safety systems are able to mitigate and avoid accidents. So in the future it is important to estimate the benefit of these systems in reducing accident numbers as well.

Current benefit estimation methods mostly focus on a single system only and not on the combination of systems. In this paper a new method for a multivariate benefit estimation based on real accident data is developed. The paper describes the basic method to estimate the benefit of primary and secondary safety systems in combination. With the presented method the benefit will not be overestimated as it would be by a simple addition of the benefits of single systems. The model will be validated by a multivariate prospective benefit estimation of different vehicle safety systems in comparison to single benefit estimations of the same systems. For this the German In-Depth Accident Database is used. The results show the importance to implement the interactions of safety systems in the estimation process and rate the overestimation by a simple addition of the single system benefits. The validation includes primary and secondary safety systems in combination. The validation is done using more than 3500 real accidents which were initiated by cars. This sample out of the GIDAS database is representative for the current accident situation in Germany.

The paper shows the necessity of a multivariate estimation of the benefit for existing and future safety systems.

MOTIVATION

The number of traffic fatalities decreased by 77% to a minimum in 2007. In comparison to that the number of persons who have been injured in traffic accidents in Germany decreased by only 25% and the number of accidents has increased by 53% to about 2,3 Mio accidents with personal injuries. Therefore an optimization of traffic and vehicle safety is still a very important matter. (1)

New vehicle systems are often comfort systems and have not been developed to increase vehicle safety only, while secondary safety systems only operate during a collision. In contrast to secondary safety systems primary safety systems are able to both mitigate and avoid accidents.

Current benefit estimation methods mostly focus on a single system only and not on the combination of systems.

In the following example of a real world accident, the motivation of this study will be further explained.

The following accident happened:
On November 10 at 5:50 p.m. the driver of vehicle 1 drove on a rural road. In a left curve the driver left the lane to the right unintentionally. After an over-reaction of the driver, the vehicle swerved into the oncoming traffic and collided with the right side of the car with vehicle 2. In the collision the unbelted driver of vehicle 1 suffered serious injuries due to an impact on the right A-pillar. (figure 2 and 3)
The driver of vehicle 1 had a blood alcohol concentration of 2.4 ‰. (4).

The accident site was measured on the spot by the traffic investigation team (figure 1).

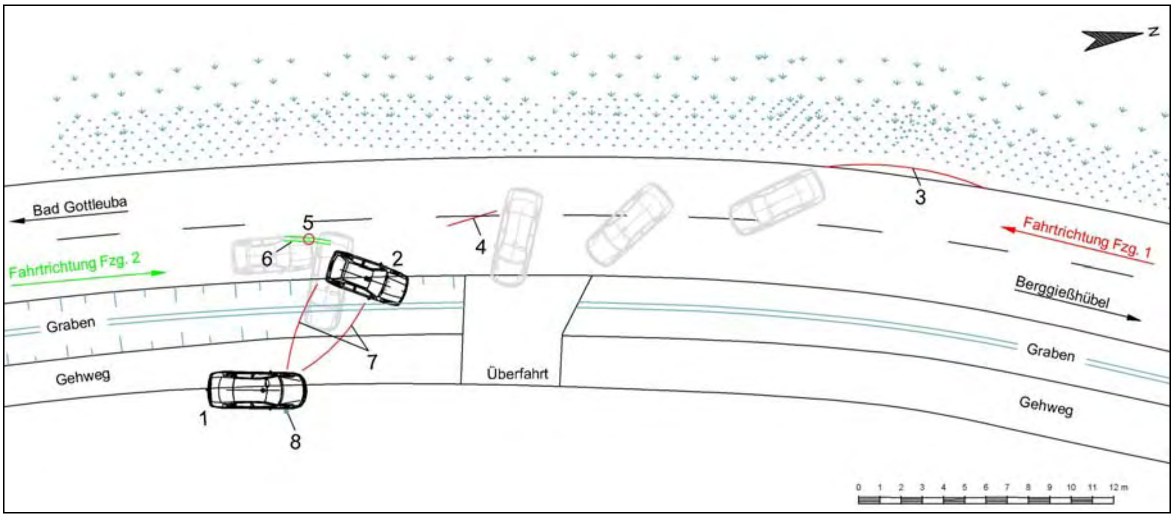

Figure 1: Accident sketch of a real world accident of GIDAS (4)

The serious injuries of the driver of vehicle 1 are shown in figure 2.

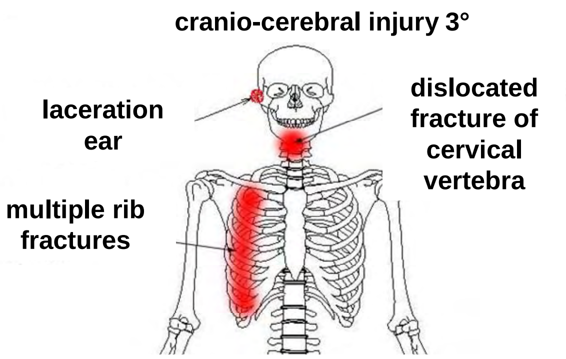

Figure 2: Injuries of the driver of vehicle 1 (4)

In correlation to these injuries the injury causing part could be identified (figure 3). The driver was thrown through his car and hit the right A-pillar.


Figure 3: Injury causing part for the injuries of the driver of vehicle 1 (4)

In the single case analysis of this accident the following systems were found to possibly avoid or mitigate this accident:
- a breathalyzer system (AAT), that does not allow an engine start if the driver has an alcohol concentration in breath
- a lane departure warning system (SVW), that gives a warning to the driver if an unintended lane departure is likely
- an electronic stability control (ESP), that could avoid or mitigate the swerving sequence into the oncoming traffic
- a seat belt reminder system (GURTW), that could help to remind the driver to use the seat belt and therefore mitigate the serious injuries caused by the movement inside his car

For all of these systems a mitigation or complete avoidance of the accident could have been possible. Yet it has to be considered that each accident can only be avoided once and a simple addition of all single system efficiencies will lead to an overestimation of the benefit for all systems.

DEVELOPMENT OF THE MULTIVARIATE ESTIMATION MODEL

Benefit estimations for safety systems can be done in a retrospective analysis, if the system is already in the market and the number of systems in the accident database is high enough. Otherwise it is only possible to appraise the benefit of a system in a prospective analysis. (Figure 4)

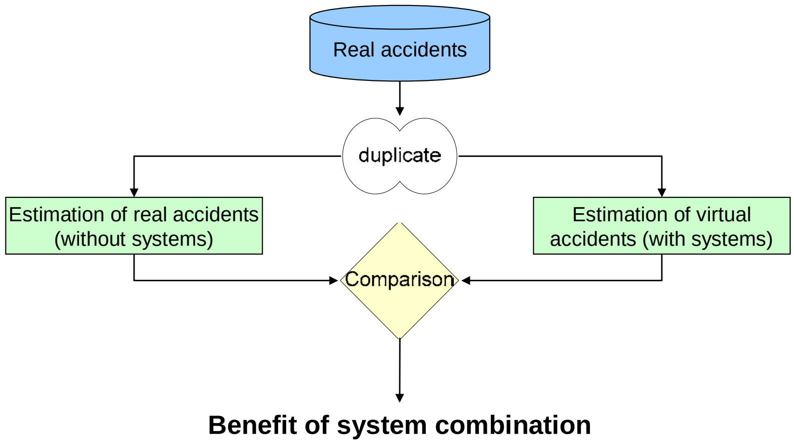

Figure 4: Prospective estimation of benefit of safety system (2)

In this prospective analysis the real accident will be compared with a virtual accident, simulated with the expected benefit of the safety system or system idea. The calculation of the difference between the real accident scenario and the virtual accident scenario is one possibility to estimate the benefit of the safety system. That way the global benefit of the single system can be estimated for all cases in the dataset using an automated case by case analysis.

Benefit estimation for single safety system

In the following figure 5 the estimation of real accidents without a safety system is shown.

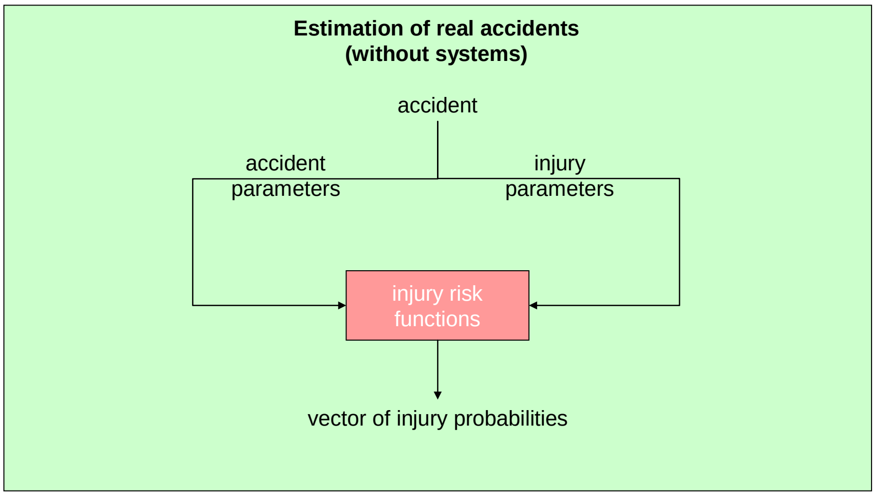

Figure 5: Development of the estimation model – real accidents

In this estimation process an injury risk function is used to calculate averaging probabilities of binary injury severity of the persons. The calculation process of the injury risk functions is shown in figure 6.

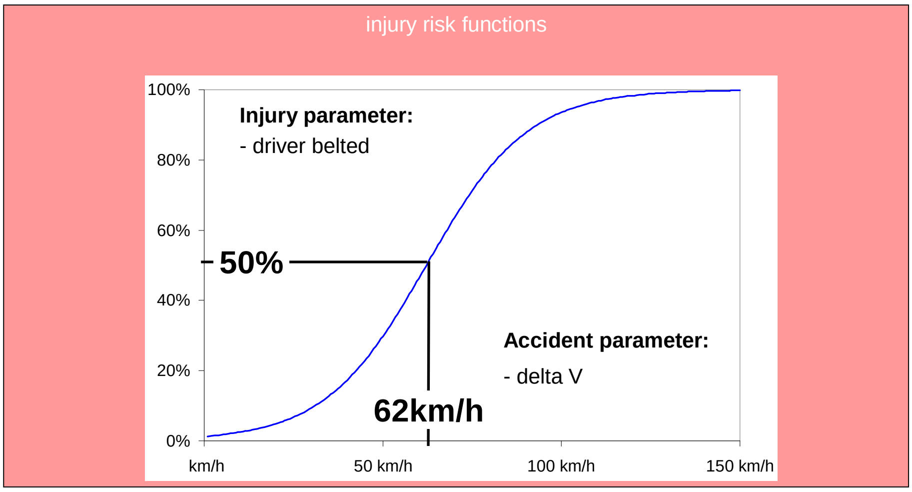

Figure 6: Development of the estimation model – injury risk function

In this estimation step the accident parameter (e.g. delta v of the car) is used to estimate the probability of a given binary injury severity (e.g. probability to be MAIS2+ injured)

After the estimation of real accidents, all accidents have to be analysed again in the estimation of virtual accidents. Therefore a simulation of the accident and injury initiation is done (figure 8).

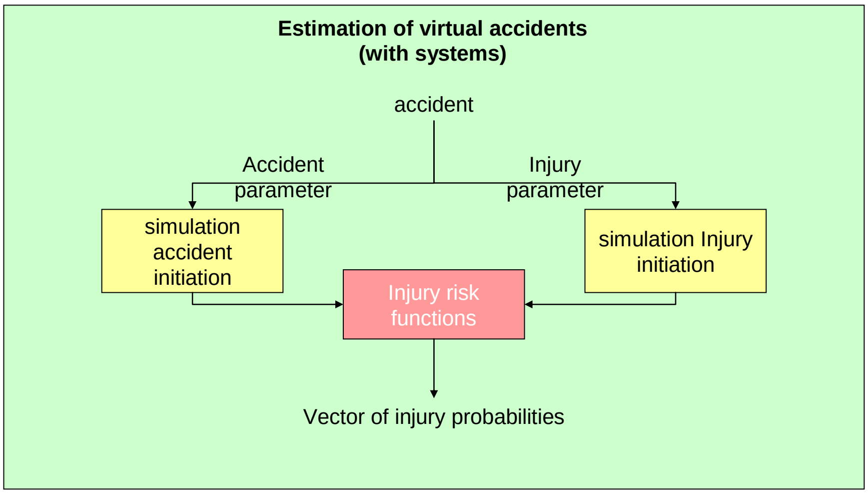

Figure 7: Development of the estimation model – virtual accidents

In the simulation process the accident and injury initiation are analysed independently. This gives the possibility to estimate a common benefit of primary and secondary safety systems.

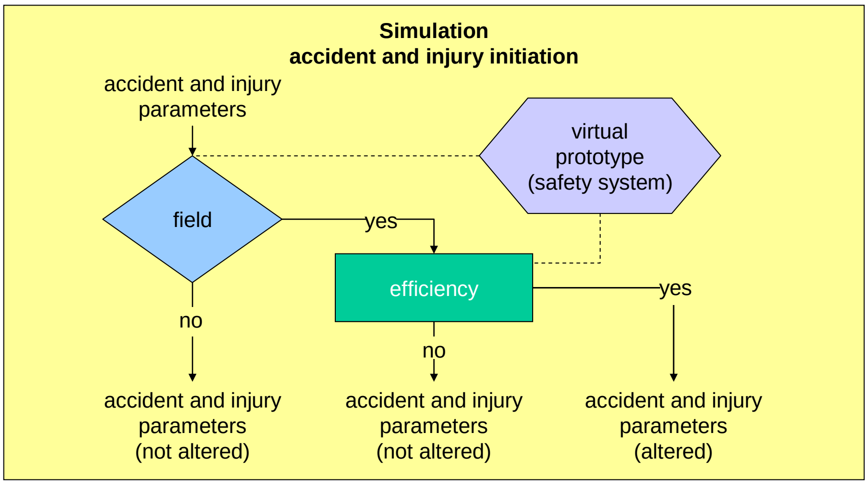

Figure 8: Development of the estimation model – simulation

For this simulation step a virtual prototype of the safety system is necessary. At first the accident is checked to be in field of the safety system. As an example, an accident is in field of the breathalyzer system if the driver had a higher alcohol concentration in breath than the defined threshold (e.g. 0,5‰). If there is no field for this system, all accident and injury parameters will not be altered.
If the accident is principally addressed by the system, the efficiency of the system will be checked. For example, a sober passenger could be used to disable the effect of a breathalyzer system. In that case the breathalyzer system will have no effect. These circumstances can usually only be appraised. If there is no efficiency assessed for this accident scenario, all accident and injury parameters will not be altered, otherwise they will be altered.

In figure 9 the complete estimation model for a single primary safety system is shown.

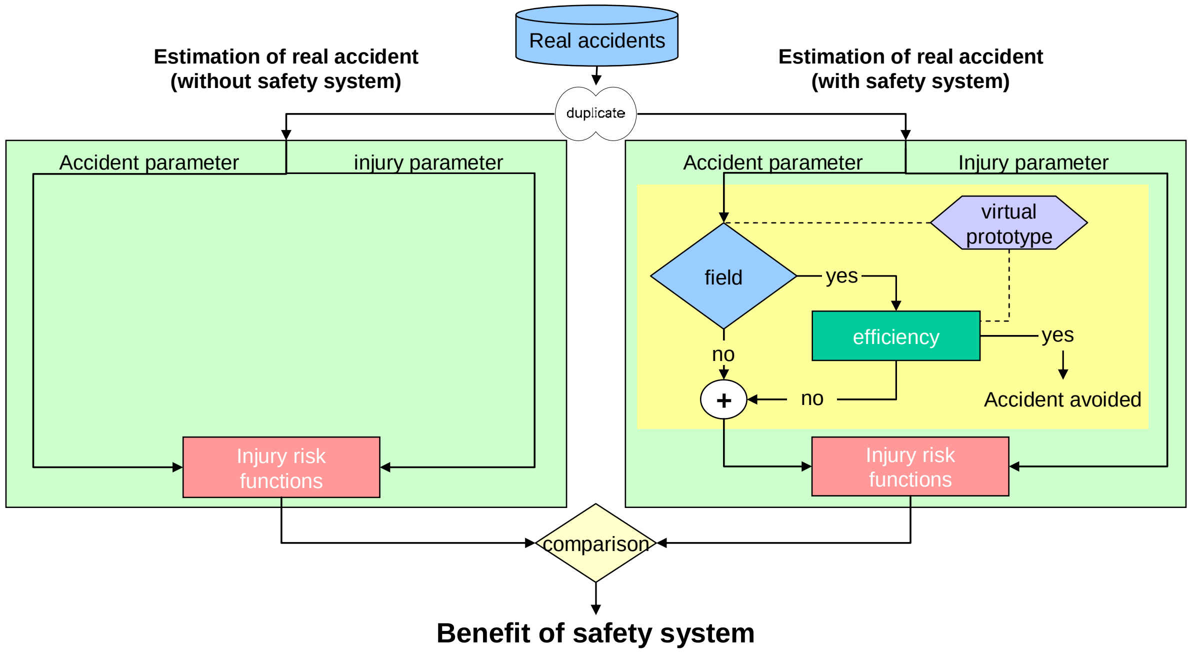

Figure 9: Development of the estimation model – single estimation of primary safety system

In figure 10 the complete estimation model for a single secondary safety system is shown.

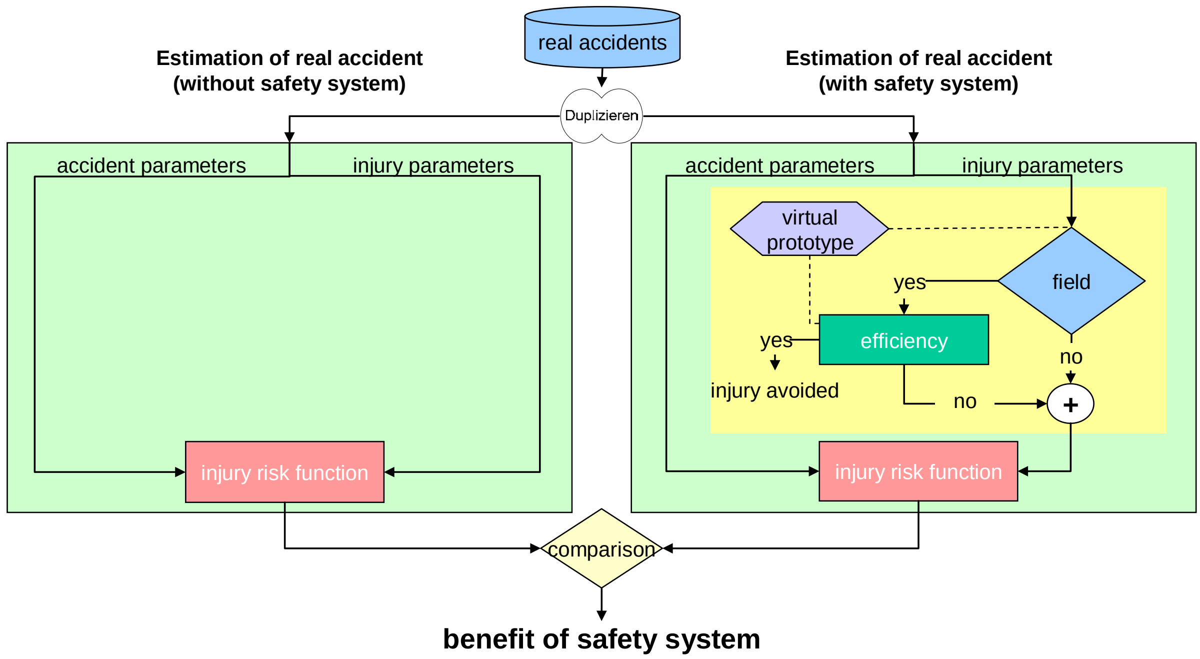

Figure 10: Development of the estimation model – single estimation of a secondary safety system

The given comparison of the estimation of real accidents and the estimation of virtual accidents delivers the benefit of this safety system.

Benefit estimation for combinations of primary and secondary safety systems

Based on the example of a real world accident (figures 1 to 3) the following safety systems or system ideas will be considered in the multivariate benefit estimation model:

- Breathalyzer system (AAT)
- Lane departure warning system (SVW)
- Electronic stability control (ESP)
- Seat belt reminder system (GURTW)

The breathalyzer does not allow starting the engine, if the driver exceeds the threshold of a maximum legal alcohol concentration in breath of 0,5‰. This system therefore operates at the beginning of the trip.

The lane departure warning system gives a warning to the driver, if the vehicle does leave the lane unintentionally. The system operates at the time of the critical situation.

The electronic stability control operates in the danger phase, when the vehicle does have a discrepancy between the trajectories of the driver's intention and the vehicle movement.

The seat belt reminder is defined as a primary safety system that reminds all occupants at the beginning of the trip to use the seat belt. The system's intention is to optimize the rate of belted occupants. A mitigation of injuries can only happen during the collision.

Safety systems operate at different times to collision. Therefore it is necessary to consider the chronological order of operation of all systems in the combination regarding the accident initiation sequence.

In figure 11 the ACEA Safety Model and the times of operation for all systems is shown.

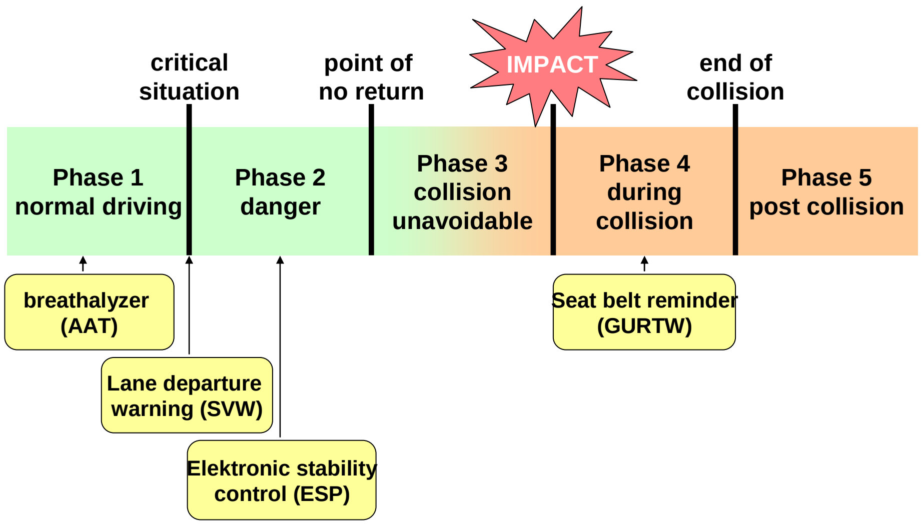

Figure 11: Development of the estimation model – ACEA Safety Model and time of operation of systems

As shown in figure 11, the first system that operates in the chronological sequence of each accident is the breathalyzer. If there is a critical situation of an unintended lane departure, the lane departure warning system gives a warning to the driver. The electronic stability control operates during phase 2 as the third system in the chronological order. Finally, a seat belt reminder will lead to the mitigation of the injury severity.

For the consideration of system combinations it is important that accidents, which are avoided by earlier systems in the simulation, are not further available for systems which operate later. Using this approach it is possible to estimate the global benefit of all systems realistically.

In figure 12 the complete estimation model for combined safety systems is shown.

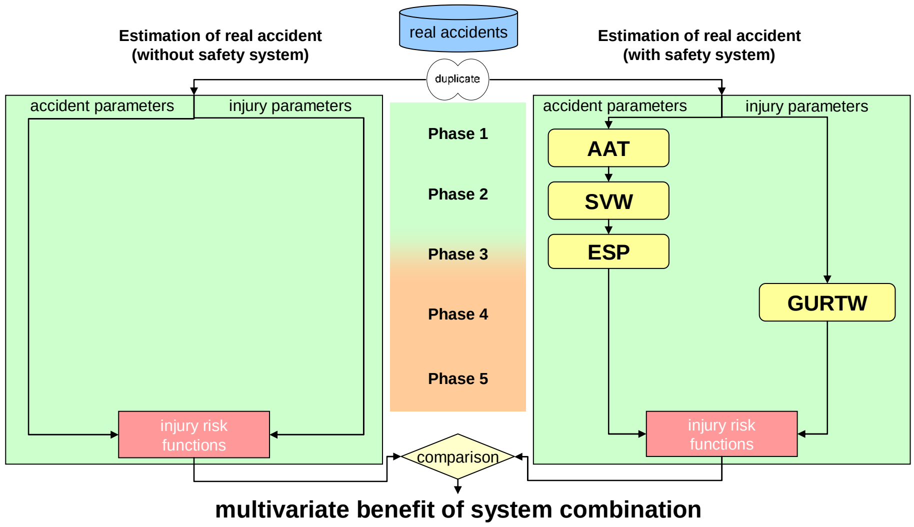

Figure 12: Development of the estimation model – multivariate benefit estimation for systems combination

The comparison of the estimation of real accidents and the estimation of virtual accidents gives the global benefit for the system combination. The correlations between these systems regarding the time of operation are considered.

The estimation model can be used for both primary and secondary safety systems. The model will estimate the benefit at the specific time of operation of each safety system. Due to the chronological order each accident can only be avoided once and the benefit of the single system therefore depends on other systems in the combination.

The overall benefit will not be systematically overestimated, as it would be by a simple addition of the single benefits of these systems.

COMPARISON OF UNIVARIATE AND MULTIVARIATE BENEFIT ESTIMATION

For all systems in the multivariate model an automated case by case analysis is performed using the dataset of GIDAS (July 2007). The dataset consists of 3789 accidents caused by cars. For all of these accident causing cars a 100% equipment rate of all four systems is assumed. In the dataset a total of 9821 involved persons are available.

At first the benefit for each single system was estimated separately (figure 13, yellow fields). The results are based on the reduction rate of the number of involved persons in all accidents. The difference is additionally divided in the groups “uninjured”, “slightly injured”, “seriously injured” and “fatalities”.

After the univariate summation of the benefit for all groups (orange fields), the results of the multivariate benefit estimation are shown (red fields).

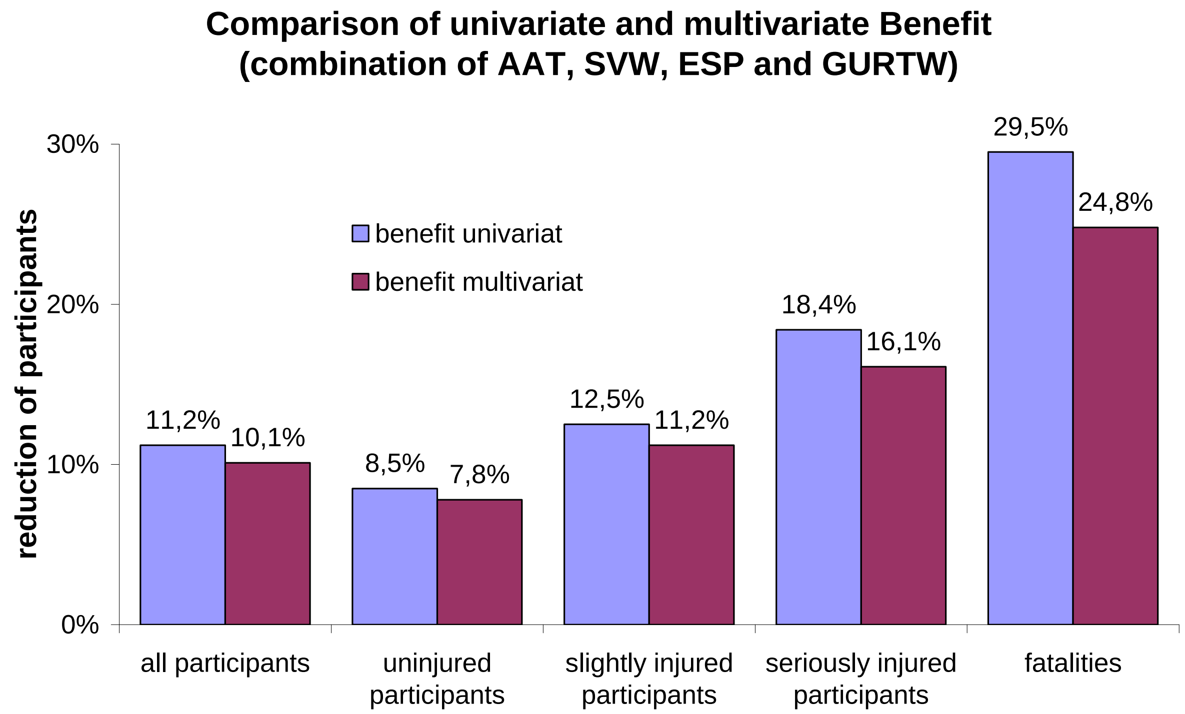

Figure 13: Comparison of univariate and multivariate benefit estimation

The univariate and multivariate analyses are based on the same assumptions for all systems. Therefore the results are directly comparable.

The overestimation of the benefit of system combinations based on the double counting of avoided and mitigated accidents can completely be prevented with this multivariate model. The overestimation of the benefit of a univariate analysis in comparison to a multivariate analysis can be as large as approximately 5% for fatalities.

SUMMARY

Safety systems are operating at different times to collision.

Each accident can only be avoided once. Thus, a multiple consideration of the avoidance of an accident will lead to an overestimation of the benefit for all systems.

With the developed model the chronological order of the systems and the correlations between the systems are considered.

The comparison of univariate and multivariate estimations of the benefit shows an overestimation of the global benefit up to 5% for the univariate estimation.

The overestimation of the global benefit will increase with the number of considered systems.

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In-vehicle Multi-channel Signal Processing and Analysis in UTDrive Project: Driver Behavior Modeling and Active Safety Systems Development

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Abstract

It has been pointed that most of the accidents on the roads are caused by driver faults, inattention and low performance. Therefore, future active safety systems are required to be aware of the driver status to be able to have preventative features. This probe study gives a system structure depending on multi-channel signal processing for three modules: Driver Identification, Route Recognition and Distraction Detection. The novelty lies in personalizing the route recognition and distraction detection systems according to particular driver with the help of driver identification system. The driver ID system also uses multiple modalities to verify the identity of the driver; therefore it can be applied to future smart cars working as car-keys. All the modules are tested using a separate data batch from the training sets using eight drivers' multi-channel driving signals, video and audio. The system was able to identify the driver with 100% accuracy using speech signals of length 30 sec or more and a frontal face image. After identifying the driver, the maneuver/ route recognition was achieved with 100% accuracy and the distraction detection had 72% accuracy in worst case. In overall, system is able to identify the driver, recognize the maneuver being performed at a particular time and able to detect driver distraction with reasonable accuracy.

INTRODUCTION

In order to increase the safety on the roads, current research efforts in in-vehicle systems have three main focus areas: in-vehicle controllers, driver assistance/monitoring systems and environmental risk assessment systems. Ideally, in the near future, these seemingly separate efforts are expected to come together under a decision making hierarchical system structure to reduce accidents caused by dynamical factors related to: vehicle, driver and traffic/infrastructure. The configuration of the integration of these sub-systems may vary from a fully automatic smart car to a semi-autonomous, driver-centered approach. To find the optimal solution for this problem with the least intrusion to the driver, driver behavior models will have crucial importance in developing driver-adaptive, context-aware active safety systems.

Under support from an international NEDO funded consortium, UTDrive project began two years ago, with the formulation of a data collection vehicle, Toyota RAV4, customized with a variety of sensors and transducers for multi-modal data acquisition. The data include audio, video, gas/brake pedal pressures, following distance, CAN-Bus information and GPS information. Signals are synchronously recorded with the help of a commercial data acquisition unit. In the first phase of the project (P1), 100 sessions of multi-channel driving data has been collected from a demographically wide range across 53 participants. Two driving routes in the neighborhood areas of Richardson, TX are chosen; the first route represents a residential scenario and the second represents a business-district scenario. Fundamentally, these two scenarios are quite different in terms of traffic density, infrastructure and attention sources required from the driver. Data collection from both routes includes neutral driving and driving under task distraction. For driving sessions with distraction, manual secondary tasks (adjusting radio, AC/heater, etc.), cognitive tasks (reading road signs, cell-phone dialing Airline flight speech prompted system and discussing with the research team member) and driving maneuvers (lane change, left/right hand turn) were requested from the driver. This extensive database is carefully transcribed to distinguish the time windows of interest (i.e. each particular maneuver, the section including the speech with Airline dialog, etc.) and log this data under a developed protocol. The transcribed multi-sensor data are then analyzed using different state-of-the-art techniques in speech signal processing, such as Hidden Markov Models (HMM) and Gaussian

Mixture Models (GMM) for the purpose of distraction detection. The results obtained so far have led contributions in three book publications [1, 2, 3] compiling the papers in international workshops under the name of DSP for In-Vehicle Systems.

In this paper, the second phase (P2) of the research will be detailed. In P2, three main areas related to driver behavior signal processing and analysis is explored in further depth: multi-sensor driver identification, route recognition and reliable driver distraction detection. First, the formulated driver identification system is explained in detail. It utilizes video (facial features), audio (speaker-dependent features) and CAN-Bus cues (driving performance metrics) of the individual drivers. This system can be classified as a multi-modal biometric identification system aimed at recognizing the driver with the ultimate goal of adapting the car set points and future controllers to the characteristics of the driver for safe operation of the vehicle. The second system is based on a novel idea of building a route model formed by maneuvers and sub-maneuvers in the analogy to speech recognizers working on phonemes (sub-maneuvers), words (maneuvers) and sentence (route) models having a semantic/syntactic language model (context of driving and sequence of driving) . The third system attempts to detect the distraction of the drivers from the multi-sensor data stream using HMMs.

This paper is organized in the following way: First the background on face recognition, speaker identification and CAN-Bus signal processing are mentioned with an emphasis on need for multi-modal systems for in-vehicle driver identification. Second, data collection vehicle, experimental procedure and corpus are mentioned. Next, integration of these three systems is explained in section 'System Integration and Overview' and then three modules are explained in greater detail in 'Driver Identification', 'Route Recognition' and 'Distraction Detection' sections. Finally, further work is recommended for this very promising in-vehicle safety system to be improved. The contribution of the study lies in combining the existing ideas on improving the safety using in-vehicle electronic devices in a system integration and mechatronics approach.

BACKGROUND

The research area this paper addresses is interdisciplinary and builds on multi-modal biometric identification systems employing mainly face and speaker recognition and driver characteristics from CAN-Bus. Recognizing the driver robustly despite of the adverse conditions of in-vehicle environment such as changing illumination and engine noise is very important in adapting the driver assistance and monitoring modules to driver characteristics. Here, brief background is given on face and speaker recognition, multi-modal bio-metric systems, route recognition and distraction detection to understand how these systems can be combined to increase the safety of vehicles.

Face recognition is a mature technology in itself and has been used in commercial systems in authenticity and security applications. A comprehensive literature survey on face recognition algorithms can be found in (4). The in-vehicle application poses extra challenges for face recognition as follows:

- The illumination changes are dramatic and at significant levels
- Drivers cannot be expected to stand still for image acquisition therefore system should use video sequences for recognition
- Video sequences contain face images with varying scale, orientation and non-rigid motion
- Driver appearance may change over time

Most of these issues are addressed in a probabilistic scheme in (5). They applied still-to-video and video-to-video recognition algorithms incorporating the temporal information from the videos in a probabilistic framework. In this paper, our focus is not developing the most capable face recognition system for in-vehicle application; rather we try to include face recognition cues in a multi-modal driver recognition system. In fact, we will be only using principal component analysis (PCA) method for now as it was applied in (6), since our main focus is to develop a multi-modal system for recognition with simplistic modules. Incorporating more robust 3-D, temporal and probabilistic approaches for in-vehicle use deserves a separate investigation in its own right.

The second modality of our system is based on speaker identification cues. For a comprehensive overview on speaker identification (7) is recommended. Here, most widely used MFCC will be employed for feature extraction and GMM will be used to assess the performance of this simplistic speaker identification system.

In our system, the third modality comprises several metrics derived from CAN-Bus signals comprising mainly vehicle speed, steering wheel angle and brake/pedal signals. Use of multi-modal systems for person identification is not a complete novel idea and kinematics of gait; key stroke in typing and several other dynamics of motion have been used for recognition. Although CAN-Bus signals can be used to derive more detailed models of driving models employing control theory, here they will be taken as time series representing a particular motion sequence (i.e. right turn, left turn and lane change). Using Can-BUS information and fusion with two previously mentioned modules is an in-vehicle focused and novel approach to multi-modal person recognition in car driving context. There is very little study on CAN-Bus signal modeling, however, some promising results can be found in (8).

CAN-Bus signals are not forming only the dynamic modality of our recognition system, but they are also the information source for diagnosis system comprising route recognition and distraction detection. We will be employing Hidden Markov Models (HMM) for modeling the maneuvers and detecting the distraction. There is substantial successful work on application of HMM in driver modeling (9, 10). Although these previous studies unleashed the potential of HMM in driver behavior modeling there is still need for extensive studies including larger databases and more real-world driving situations in models in a hierarchical approach.

It should be also noted that multi-modal person recognition with an in-vehicle application has been studied before (11), however, the recognition system has not been connected to maneuver recognition and distraction detection modules to improve their performances. Therefore, in this paper, we are offering an improvement in the performance of maneuver recognition and distraction detection algorithms by recognizing the driver in the beginning of the driving session as well as suggesting an authorization system as the other researchers suggested.

Data collection vehicle, experimental procedure and corpus

The vehicle (Figure 1) is equipped to perform multi-modal data collection with signal channels including:

- Videos: driver cabin and the road scene
- Microphone array and close microphone to record driver's speech
- Distance sensor using laser to measure the distance between ego vehicle and leading vehicle
- GPS for position measurement
- CAN-Bus: vehicle speed, steering wheel angle, brake/gas
- Gas/Brake pedal pressure sensors

These sensors allow collecting dynamic driving data and some physiological cues on driver status in a non-intrusive manner. Since the equipment is visible to the participant and there is an experimenter in the car, the collected data cannot be classified as pure naturalistic driving data; however, the routes, secondary sub-tasks and the scenarios are in good agreement with real driving experience.

Figure 1. Data collection vehicle and incorporated sensors

The driving scenarios include two different routes: residential and commercial areas including right turn, left turn, lane change, cruise and car following segments. Each route is driven by each driver twice: neutral and distracted. These routes can be seen in Figure 2.

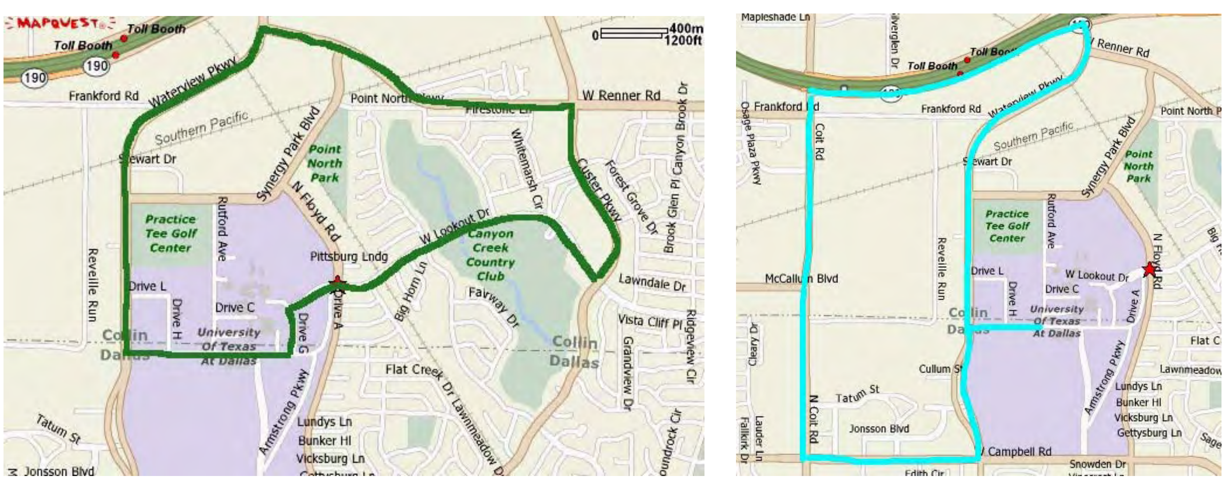

Figure 2. Route 1 (Left) and Route 2 (Right)

UTDrive Corpus includes 40 male 37 female drivers' multi-sensor driving data (each person has three sessions repeated twice giving six sessions in total) and the experiments are in continuation to extend the database. It is close to naturalistic driving data since the routes and the scenarios are from real roads. However, it should be noted as well that it is not completely naturalistic since the driver is aware that he/she is being recorded and there is often nervousness due to using the data collection vehicle which is completely new to participants. In this investigation a narrow data base containing only three drivers will be examined since it reflects the real situation that a vehicle may be used by 3-4 drivers but not more. While this restriction makes it easy for recognition, it comes with a drawback as well: there is limited data or limited number of observations of a maneuver from the same person in our database. Nevertheless, despite this limitation with very limited data we will demonstrate that the recognition system can help other two diagnosis modules increase the overall performance of the safety system. Next session gives the overview of the system integration between multi-modal biometric driver identification, route recognition and distraction detection modules.

System integration and overview

One important concept in mechatronics approach in active safety system design is to have the system integration for boosting the over-all system performance simplifying the structures. Applying this principle we combine the multi-modal biometric driver identification system with route/maneuver recognition and distraction detection systems. Individual systems combined here can work; however, the performances of the systems decrease due to dynamics of driving and personal differences among the drivers. Although systems are trained on a larger database including several drivers, the user might have different driving characteristics which would directly affect the performances of maneuver recognition and distraction modules. These problems can be alleviated by employing a driver identification system and personalization of the system, multi-modal driver identification system authorizes the driver as well as loading driver-characteristic properties. The flow-diagram of the system is shown in Figure 3.

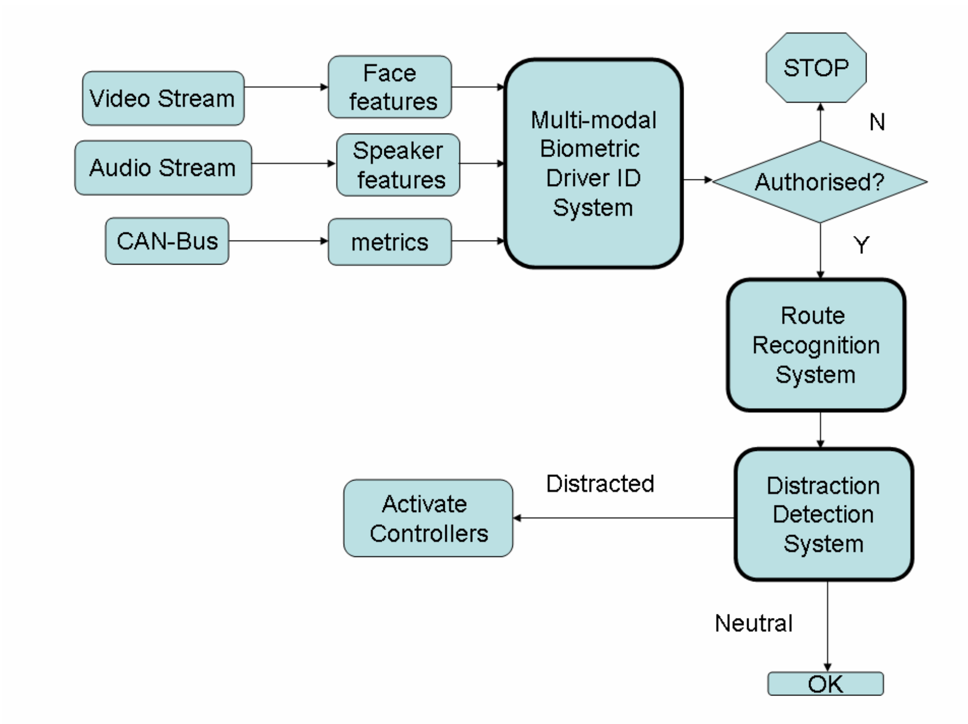

Figure 3. System Integration and flow diagram

In the following sub-sections the individual module development and performances are mentioned.

Driver identification

Face Recognition Modality

Driver identification module uses multi-modal information from the driver: face-recognition and speaker identification cues are used as primary modality while they are connected with and backed up by driving characteristics derived from CAN-Bus. The final identification result is a fusion of decision from these three modalities, however; first the identification results from individual modalities are given here.
First modality uses *eigen-faces* approach employing PCA. Ten images from each of three drivers (total 30) are included for training and 5 images are used for testing. In the resulting PCA analysis first 19 eigen-values and associated eigen-vectors are selected. Results are given for Driver 1 in Figure 4, indicating the reliable weights which give the shortest Euclidean distance between the weights obtained from the test and those obtained from test signals.

Figure 4. Test images weights with 19 eigen-vector subspace, reliable weights for driver I: 2,4,5,6,7,8,11,12,16,17,18,19

Cumulative PCA results can be seen in Table I, there are two failed test images from driver which are the cases when driver had a slight tilt or rotation. These failures can be easily fixed with a more advanced face feature extraction and classification scheme. However, in this application 13 cases of 15 test images were correctly classified, which is satisfactory performance for only one modality. The failures can be corrected by other modalities easily without applying a more advanced method on this modality.

Table I. Cumulative PCA results for face recognition module using 3 driver-database

Driver 1 Test image 1 (ground truth: 1)			Driver 2 Test image 1 (ground truth: 2)			Driver 3 Test image 1 (ground truth: 3)		
Class 1	1.308		Class 1	2.8714		Class 1	3.9308	
Class 2	4.0576		Class 2	0.8057		Class 2	4.5672	
Class3	4.2706		Class3	4.7348		Class3	0.524	
Class4	5.969	OK	Class4	4.4371	OK	Class4	4.9626	OK
Driver 1 Test image 2 (ground truth: 1)			Driver 2 Test image 2 (ground truth: 2)			Driver 3 Test image 2 (ground truth: 3)		
Class 1	1.309		Class 1	3.1135		Class 1	2.3383	
Class 2	3.9824		Class 2	0.778		Class 2	3.8475	
Class3	4.2566		Class3	4.4914		Class3	2.1232	
Class4	5.9447	OK	Class4	4.3241	OK	Class4	5.2668	OK
Driver 1 Test image 3 (ground truth: 1)			Driver 2 Test image 3 (ground truth: 2)			Driver 3 Test image 3 (ground truth: 3)		
Class 1	1.2337		Class 1	3.0956		Class 1	2.2045	
Class 2	4.0102		Class 2	1.2475		Class 2	3.7372	
Class3	4.3019		Class3	4.4251		Class3	2.3235	
Class4	5.9428	OK	Class4	4.0836	OK	Class4	5.1811	fails
Driver 1 Test image 4 (ground truth: 1)			Driver 2 Test image 4 (ground truth: 2)			Driver 3 Test image 4 (ground truth: 3)		
Class 1	1.1886		Class 1	3.2933		Class 1	2.2606	
Class 2	3.9427		Class 2	1.4564		Class 2	3.7417	
Class3	4.2865		Class3	4.9023		Class3	2.2739	
Class4	5.9099	OK	Class4	4.2657	OK	Class4	5.0772	fails
Driver 1 Test image 5 (ground truth: 1)			Driver 2 Test image 5 (ground truth: 2)			Driver 3 Test image 5 (ground truth: 3)		
Class 1	1.2915		Class 1	3.4055		Class 1	2.3884	
Class 2	3.8257		Class 2	1.5501		Class 2	3.8041	
Class3	4.2282		Class3	4.8726		Class3	2.1363	
Class4	5.8824	OK	Class4	3.8343	OK	Class4	4.9167	OK

Speaker Recognition Modality

For developing the speaker recognition module, 8 drivers' speech signals are included in training and testing. The Speaker/driver recognition system consists of three main blocks namely feature extraction, universal background model generation and the speaker/driver dependent model adaptation apart from testing. Feature extraction is front-end processing were distinguishable features of the speech signal are extracted and stored in a feature vector. Mel-frequency cepstral coefficients are very widely used features in speaker recognition domain. We used 19 dimension MFCC feature vectors. The universal background model (UBM) is trained using a large number of drivers' speech data (over 20 hrs of speech data) preferably other than the train and test set of drivers. The driver dependent Gaussian mixture (GMM) model is obtained by MAP adapting the UBM using driver specific feature vector files. An average of around 8 mins worth of speech data is used per driver to MAP adapt the UBM to train the driver dependent GMM. The driver dependent model will then contain only the distribution of a particular driver's speech. 3-6 mins of every driver's speech data (feature vector files) is used for testing. The data is windowed into various lengths for testing to know the best performance of the system with minimal data. Using the log-likelihood scoring these speech signals are scored against all GMM models and UBM. The

highest scores in each row in Table II give the classification result. As can be seen from Table II for full length of test data, the highlighted scores represent the highest scores for the drivers giving a correct classification rate of 100%.
The experiments were repeated for variable length of test data to obtain the minimum length of test utterance required to recognize the driver. Models were scored with 2 min, 1 min, 30sec, 10 sec, 5sec and 2 sec data. The drivers could be recognized using the speech signal with 100% accuracy for 30 sec or longer data lengths. Reducing the test data further to 10 sec, 5 sec and 2 sec length information leads the worst case accuracy dropping to 91%, 86% and 68% respectively. From these results we can draw the conclusion that 30secs of speech data is enough to recognize the driver with very good accuracy.

Table II. Speaker ID recognition test scores using full-length signals (3-6 mins)

FULL	MODELS									
		M1	M2	M6	M8	M10	M11	M17	M18	UBM
LLR score for raw spkr/driver files	1	-110.646	-128.013	-151.448	-131.678	-134.252	-138.781	-123.783	-128.72	-133.702
	2	-109.907	-96.3208	-131.896	-114.587	-114.537	-104.037	-110.249	-112.455	-108.181
	6	-148.673	-151.674	-109.55	-130.734	-146.519	-151.21	-145.097	-143.381	-140.103
	8	-121.752	-119.508	-115.728	-103.815	-112.888	-118.85	-113.64	-112.24	-115.213
	10	-161.914	-156.105	-166.587	-154.393	-124.645	-151.392	-155.965	-143.089	-149.036
	11	-174.27	-154.657	-196.47	-180.338	-167.637	-128.519	-173.834	-167.165	-161.067
	17	-136.965	-139.704	-158.256	-144.038	-140.699	-141.398	-120.451	-134.858	-139.078
	18	-194.236	-197.659	-196.553	-181.062	-182.105	-192.124	-192.782	-155.483	-186.165

CAN-Bus Based Driver Identification

Different from face recognition module, CAN-Bus includes time-varying characteristics of the driver therefore can be considered as less reliable. However, this modality is crucial for finding the nominal behavior of the particular driver and using this baseline to detect the distractions. Here, HMMs are used to model drivers right turn maneuvers. For each driver, a separate HMM is trained using only RT signals collected from that driver, however, the resultant HMMs are tested with RT maneuvers from all the drivers. The maximum log-likelihood of the results are found and correspondent HMM is tracked back to find out the identity of the driver. The cumulative results of this procedure are given in Table III.

Table III. Driver Identification Correct Classification Rates using HMMs trained by only CAN-Bus signals

	Driver 1 HMMs	Driver 2 HMMs	Driver 3 HMMs
Driver 1 RT test signals	--	83 %	69 %
Driver 2 RT test signals	30 %	--	22.2 %
Driver 3 RT test signals	89 %	100 %	--

The results from Table III should be interpreted carefully. For example when HMMs for Driver 1 are tested using Driver 2's signals only 30% of the cases were correctly identified as 'different from Driver 1', so the rejection rate was very low. On the other hand, when the same models are tested with Driver 3's signals 89% of them were correctly rejected. From this table we can see the best performance is observed when Driver 2 HMMs are tested with Driver 3 signals; 100% of them were rejected. This result is showing that drivers might have different characteristics and this can be modeled stochastically, however, they are not necessarily distinguishable in all cases. This makes CAN-Bus based module weaker than vision and audio biometrics. However, as can be seen in route maneuver recognition and distraction sections, the stochastic driver models can be used in those areas with better performance.

Fusion of Audio-Visual-CAN Bus Modalities

The fusion of the modalities can be achieved at different stages. One option is to include the feature vectors from all modalities as a single combined feature vector for that driver and then apply a classification algorithm for identification. The other more common way is to have the modalities completely separate and combine the classification results by using weight factors and belief networks. This process requires careful selection of the weights to have the leverage in overall performance of the identification system. From the individual performances of the modalities, we can say that face recognition and speaker ID systems are the best ones. Since we were not able to have satisfactory classification results from CAN-Bus modality, it is not included in the identification part.

Route/ Maneuver recognition

In order to develop the maneuver recognition system we use the same HMMs trained for each driver individually and test them with different type of maneuvers (lane change (LC) in this investigation). We observed that for Driver 1 and 3 a 100% correct classification was possible whereas for Driver 2 the HMM was not able to distinguish between the maneuvers. The results can be seen in Table IV; when the lane change maneuvers are used to test right turn HMMs, the likelihoods decreased which means system was able to reject lane changes to be classified as right turns. We demonstrate only this example between two maneuvers; however, a more extensive analysis is necessary to include more maneuvers here.

Table IV. Maneuver Recognition Sample Results for Driver 1 and 3

Driver 1 (LC maneuvers used to test RT HMMs)

-34665.8673	-35331.38023
-34834.2951	-35662.83673
-34831.945	-35524.56934
-35032.99553	-35753.50861
-34693.09733	-35433.78337
-34987.87301	-35589.16114

RT ground truth: -33396.7252, 100% recognition,

Driver 3 (LC maneuvers used to test RT HMMs)

-22846.8283	-22633.07504	-22591.839
-22888.5122	-22603.62654	-22603.627
-22884.9639	-22601.89573	-22601.896
-22953.3498	-22646.22121	-22646.221
-22919.6953	-22570.17769	-22570.178
-23033.2274	-22633.07504	-22633.075

RT ground truth: -21513.2232, 100% recognition

Distraction detection

As the maneuver recognition system, distraction detection uses the HMMs trained by neutral RT signals. Distracted RT maneuver signals (21 of them) are used to test these HMMs to see if they are able to distinguish between the neutral and distracted signals. The cumulative results are 72%, 100% and 83% correct classification of distracted signals for three drivers.

CONCLUSIONS and DISCUSSION

This probe study uses a database of eight drivers' audio, video and CAN-Bus signals to develop a preliminary driver identification and monitoring system emphasizing the need to make any driver assistance/ monitoring system driver-adaptive. Video and audio modalities are used to identify the drivers and the individual-specific HMMs are used to recognize the maneuver and detect the distraction of the driver. It is strongly believed that by using individual-based HMMs, the models of the driing behaviour can be more reliable and accurate.

Driver identification part can be used as verification if the smart keys are deployed for security purposes. Identification module is highly static in this sense, however, route recognition and distraction detection monitors the driver dynamically during the driving session and can help to reduce the accidents if it can be connected to preventive active safety systems or warning systems.

Acknowledgement

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Information theoretical methods dedicated to accidents analysis for GIDAS database.

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ABSTRACT

Nowadays, traffic accidents are recorded in historical databases. Regarding the huge quantity of data, the use of data mining tools is essential to help Experts, for automatically extracting relevant information in order to establish and quantify relations between severity and potential factors of accidents. An innovative approach is here proposed for an in depth investigation of real world accidents data base. Mutual information ratio based on conditional entropies is used to quantity the association strength between an accident outcome descriptor (injury severity) and other potential association factors. Information theoretic methods help to select automatically groups of factors mostly responsible of the severity of accident.

This work was conducted in the framework of the European project TRACE (Traffic ACcidents in Europe)[I]

Keywords: mutual information, conditional entropy, risk analysis.

NOTATION

MIR: Mutual Information Ratio

INTRODUCTION

Nowadays, traffic accidents are progressively reported and stored, through many fields, in historical database. In the GIDAS database devoted to German traffic accidents, more than 800 fields are potentially defined to describe an accident and more than 2000 new accidents are stored each year. Investigating relevant accident causations hidden in huge databases is an important goal for improving our knowledge on traffic accident and traffic safety. New preventive actions can also emerged from in depth investigations of real world accidents, with one objective, to reduce, in the future, rate and severity of accidents. This study focuses on injury severities. One of the main objective is here to find the main accident causes impacting the severity of the accidents.
The relation strength between injury severity and other variables can be quantified or modelled statistically. Depending on the nature of the variables, the association strength is measured differently. For continuous variables, the correlation coefficient, ρ, is a long-standing measure to evaluate the statistical dependence between variables and this coefficient is quite used in accidentology ([Huang et al., 2007]). For categorical data, the Cramer's V based on the X^2 statistics is mostly used to quantify the association between two variables. Both association coefficients are driven by some specific underlying hypothesis. Correlation coefficients are known to measure only linear dependence between variables. If the relation is not linear, then the use of this type of coefficient is definitely not the most efficient. For qualitative variables, in case of sparse contingency tables, the Cramer's V indicator, based on X^2 test, can also be inappropriate. When investigating large data bases, prior knowledge of functional relationships between variables is never directly available and consequently, the use of correlation coefficients, based on linear assumptions, can be totally inappropriate to measure statistical dependencies.

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Mutual information (MI), introduced by Shannon (1949) is a measure of statistical dependence which is able to catch complex relation between variables, even in cases of non linear dependence [Billingsley, 1965; Cover et al., 1991]. Mutual information ratio can be computed within discrete, continuous and discrete-continuous variables [Brillinger 2004], and provides also a powerful extension to the classical correlation and Cramer's V measures.

GIDAS DATA BASE

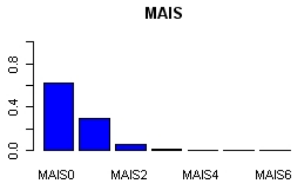
In Germany, since 1999, a consortium of two institutes (BAST, Federal Highway Research Institute and FAT, German Association for Research on Automobile-Technique) drives an important project of German In-Depth Accident Study [GIDAS]. For this purpose, teams of physicians and technicians collect information on personal injury accidents. In the area of Hanover and Dresden, all personal injury traffic accidents occurring are reported continuously by the police and the fire department stations. Accidents are selected according to a defined random procedure and then are carefully described following a given protocol. A detailed description of the investigation methodology can be found in [GIDAS]. Annually, approximately 2,000 traffic accidents are recorded in this way and the information is stored in an historical database. The "GIDAS" database is now the biggest and most complete In-Depth accident survey and data collection in Europe. In order to avoid distortions in the data structure of accidents recordings by different teams, the data are weighed annually through comparison with the officially recorded accident structure. This ensures that the present accident data are regarded as representative for the investigation area of the cities and administrative districts of Hanover and Dresden. The number of available observations in GIDAS database was at the end of year 2006 around 14 000 with the following per year repartition: 1999 (1018); 2000 (1987); 2001 (1906); 2002 (1643); 2003 (1806); 2004 (1849); 2005 (2007); 2006 (1737).

Accident outcome descriptor

For the current analysis, two accident outcome descriptors have been chosen: the maximum accident severity, (MAIS) and the accident Injury Severity of the head region (HWS).

Maximum Injuries Severity (MAIS)

In GIDAS database, MAIS original distribution is defined over 7 categories {0,1,2,3,4,5,6} which correspond to different injury severities: 0 corresponds to non injury, and 1 to 6 to more and more severe injuries (Figure 1).



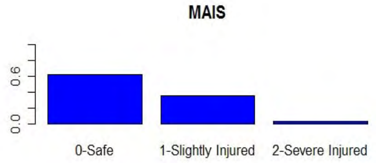


Figure 1 : MAIS distribution for GIDAS data. Original and agregated distribution of data.

The original MAIS distribution is agregated into three categories in order to analyze accidents leading to "not injured", "slightly injured" and "severe and fatal injured". The "Safe" label corresponds to observations with no injury (label 0), the "slightly Injured" label corresponds to observations with some injuries (labels 1 and 2), the "severe injured" corresponds to labels higher than 3. Most of the accidents stored in the database lead to no injury (rate 60%) or to minor injuries (rate 74%, for 0 and 1 labels).

Head injuries (HWS)

In GIDAS database, Head injuries are stored in the output variable "HWS", defined over 7 categories as for MAIS.

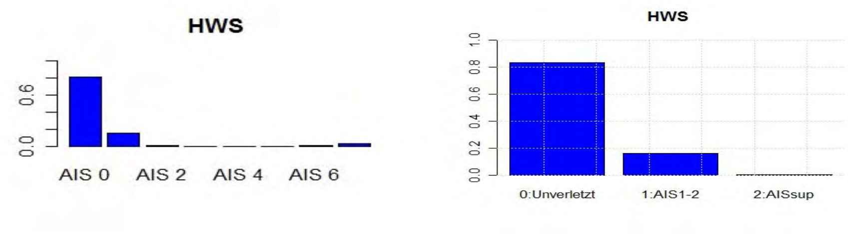


Figure 2: Head injuries distribution for GIDAS data. Original and agregated distribution of data.

Figure 2 shows that a large majority of accidents (80%) led to no injury for the head. HWS variable is aggregated into three categories to study safe, slightly or severe injured people relatively to the head. Histograms are built with 11586 observations.

Potential association factors

The choice of factors, used for this study, has been selected in collaboration with the German BAST institute. One of the objectives of this application is to focus on specific factors, to measure and compare the association strengths between factor and outcome, and then to determine which combination of factors is most influent on the outcome. For MAIS and HWS, the goal is especially to determine statistically the impact of each pre selected factors on the severity of the injuries, and which smallest group of factors can explain the injuries severity distribution given GIDAS data. Factors are listed in Table 1 for the analysis of accident injury severity (MAIS, HWS).

Variable (tag name)	**Description**	**Number of modalities and brief description**
GENDER	Gender	(2) male/ female.
PLACE	Place of the accident (urban/rural)	(2) urban/ rural.
TIME	Time of the day	(3) day/night/dawn
COLLSPEED	Initial speed of collision	Continuous
SEATBELT	Seat belt usage	(2) belted/ unbelted
ACCTYPE	Type of accident	(7) F/AB/EK/UES/RV/LV/SO
ACCKIND	Kind of accident	(10) unfall/ anfährt/…
LIMITSPEED	Speed limit at the accident scene	(17) 5 km/h/…/ 140 km/h
GUILTY	Responsible or not for the accident	(2) yes/no
OPPONENT	Opponent	(7) others Car HGV Bike Cyclist Pedest. Object
AGE	Age of the driver	(8) (0,18] , (25,30] (30,35] … (65,75] , (75,100]
AIRBAG	Use of the airbag	(2) AIRBAG /no AIRBAG
CARAGE	Age of the car at the date of the accident	continuous
DAMAGE	Main damage to the car (front, size, rear))	(7) Front Right Side … Bottom
ROLLOVER	Rollover (yes/no)	(2) yes/no

Table 1: Association factors used for MAIS or HWS outcome descriptor.

The following graph (figure 3) shows the empirical histogram computed for the different factors.

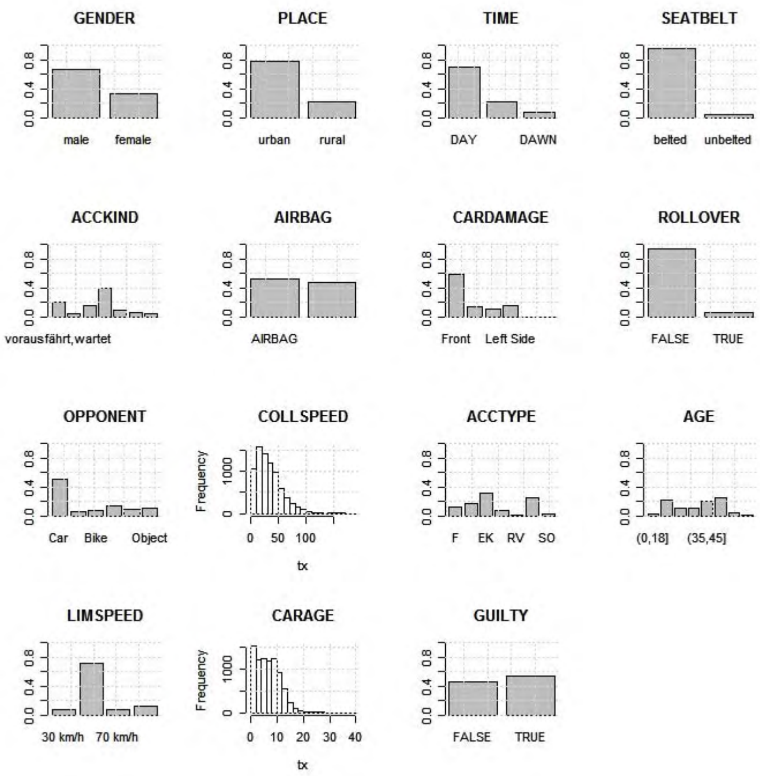


Figure 3: Histogram of potential association factors for MAIS descriptor.

MUTUAL INFORMATION

Mutual information, based on conditional entropy, quantifies the relation between two random variables X and Y. For example, Y can describe an accident gravity descriptor and X an accident causation factor.

The **Entropy** measures the average of information provided by the knowledge of a variable. For an X variable defined over a set of α_i modalities each of them with an occurrence probability p_i=Probability(X= α_i), $1 \le i \le m$, the entropy, H_X, is defined by:

$$H_X = -\sum_{i=1}^{m} p_i \log(p_i) \qquad [1]$$

By convention, $0\log(0) = 0$

If X is deterministic, the entropy is minimal, and H_X=0. The occurrence of any extra value of X brings no complementary information for the knowledge of X, which is, in this case, constant. On the opposite, for a uniform distribution, the entropy is maximal: H_X=m. All modalities of X, which have the same probability to occur, bring new information.

For two discrete variables X and Y, defined over a set of α_i and β_j modalities, with joint probability p_{ij}=Probability(X= $\alpha_{i,}$ X= $\beta_{j,}$) , $1 \le i \le m$, $1 \le j \le p$, the **joint entropy,** $H_{X,Y}$ is defined by:

$$H_{X,Y} = -\sum_{j=1}^{p} \sum_{i=1}^{m} p_{ij} \log(p_{ij}) \qquad [2]$$

Conditional entropy

$H_{Y/X}$ measures the average of information brought by variable X for the knowledge of Y and is defined by:

$$H_{Y/X} = -\sum_{j=1}^{p} \sum_{i=1}^{m} p_{ij} \log(p_{j/i}) \qquad [3]$$

pj/i denotes the conditional probability of Y= β_j given X= α_i. If X and Y are independent, then $H_{Y/X}$= H_Y: knowledge of X doesn't' bring any help nor information for the knowledge of Y.

Mutual information

Based on conditional entropy, Mutual information is a measure of statistical dependence between two variables X and Y. $I_{X,Y}$ quantifies the amount of information provided by the knowledge of variable X for the complementary knowledge of variable Y.

$$I_{X,Y} = H_x - H_{X,Y} \qquad [4]$$

Normalized by the entropy of variable Y, the **mutual information ratio (MIR)**, $R_{X,Y}$, is a zero to one range measure of the dependence of X and Y.

$$R_{X,Y} = \frac{I_{X,Y}}{H_Y} \qquad [5]$$

For two independent variables X and Y, prior knowledge of X doesn't provide any information for the knowledge of Y: $R_{X,Y}$=0. On the opposite, if a deterministic relation exists between X and Y then prior knowledge of X implies a specific value of Y, the mutual information ratio is also maximal: $R_{X,Y}$=1.

Estimation of Mutual Information Ratio

In most operational cases, theoretical distributions of jointly variables are not known and MIR should be estimated.

Considering, N independent realizations of (X, Y) available in an accident database, $v_{ij}(k)$ denotes the potential occurrence of (X, Y) for both modalities α_i and β_j and for realization k. if $v_{ij}(k)$ =1, it means that (α_i, β_j) occurs at k, $v_{ij}(k)$ =0 otherwise. The probability p_{ij} can be estimated by the maximum likelihood as follow:

$$\hat{p}_{ij} = \frac{1}{N} \sum_k v_{ij}^k \qquad [6]$$

The plug-in estimate of the mutual information ratio is then with

$$\hat{H}_{X,Y} = -\sum_{j=1}^{p} \sum_{i=1}^{m} \hat{p}_{ij} \log(\hat{p}_{ij}) \qquad [7]$$

$$\hat{R}_{X,Y} = \frac{\hat{I}_{X,Y}}{\hat{H}_Y} \qquad [8]$$

Consistent estimation of $R_{X,Y}$ is computed by a bootstrap aggregating procedure [Efron & Tibshirani 1993]. The Mutual information ratio is computed using B replications of the same unit procedure. For each b replication, an estimation of $R_{X,Y}(b)$ is performed, for a subset of observations chosen at random from the original data set. $R_{X,Y}$ is estimated by averaging all unit estimations of $R_{X,Y}$ (b) over the B replications.

$$\hat{R}_{X,Y} = \frac{1}{B}\sum_{b}\hat{R}^{b}_{X,Y} \qquad [9]$$

A similar bootstrap procedure is used to compute confidence intervals.

Selection of factors using mutual information ratio

Given a specific injury severity outcome (Y) and p potential accident factors (X_1,…Xp), mutual information is used to estimate statistically the relation strength between Y and the factors.
Considering the p factors, mutual information ratios are computed, in a first step independently, for each single variable using equation (7). To compare the respectively influence of the different variables on the Y outcome, the coefficients, $R_{X1,Y}$, …$R_{Xp,Y}$ are sorted in decreasing order of magnitude. We note $X_{(1)}$, the variable associated with the largest MIR, which has the highest predictive power on Y.

$$R_{X(1),Y} = \max_j \left\{R_{X_j,Y}\right\} \qquad [10]$$

Each coefficient lies between 0 and 100%, and measures the percentage of mutual information brought by X on Y entropy.

Mutual information can also be computed for multivariate factors [Joe 1989].
Let note X=(X_{i1},…X_{ik}), a multivariate variable of k factors (k≤ p). Mutual information ratio is computed, in a similar way, using equations (6) & (7). It is also possible to compute mutual information ratio considering a fixed number of factors: k=1 or k= 2 or k=p. In order to select a subset of k factors, which, in combination with each other, have the highest predictive power for Y, the same procedure as the one described above for single factors is applied to select the group of k variables with the highest MIR. This sub-group of k factors best explains the Y outcome distribution.
This method provides also an efficient and rigorous way of constructing hierarchies of causality factors on a given variable Y. The selected causality factors also computed have a strong prediction power on the outcome descriptor Y, and can be used as input to a model.

APPLICATIONS FOR RISK FACTORS QUANTIFICATION

In the German GIDAS database, most of the variables are qualitative, we hence have a natural situation where classical correlation analysis may be of limited use, and information theoretic methods based on entropy computation offer a more rigorous exploration tool for association or causal relations. The previously methodology has been applied on GIDAS database, with, at the end of 2006, 14000 observations, described over more than 800 fields [Mougeot & Azencott 2007]. A first pretreatment has been applied on the whole database to eliminate inappropriate values. All the studies have been carried on using the statistical programming software R [R development Core Team]. All the codes have been developed using the R standard language.
Mutual information is used to estimate the relation strength between each outcome descriptor (MAIS, HWS) and the corresponding potential factors presented in the previous tables. The observations of GIDAS data base are used to estimate the relation strength. Each estimated coefficient is computed using more than 8000 observations, depending on the proportion of missing values. For this specific

study, given one MIR ratio, all missing values have been eliminated for the involved variables. In a first step, the MIR coefficients are estimated independently for each single factor, and ordered. Groups of multivariate factors which best explain the accident outcome is computed afterwards.

MAIS

The MIR coefficients are first estimated using all original categories of MAIS (7 modalities) , and then estimated again using aggregated factors of MAIS (“Safe”, “slightly” or “severe” Injured categories). MIR coefficients, which evaluate the association link between MAIS outcome descriptor and each one of the accident causation factors selected by BAST, are computed and sorted by decreasing order of magnitude (Figure 4).

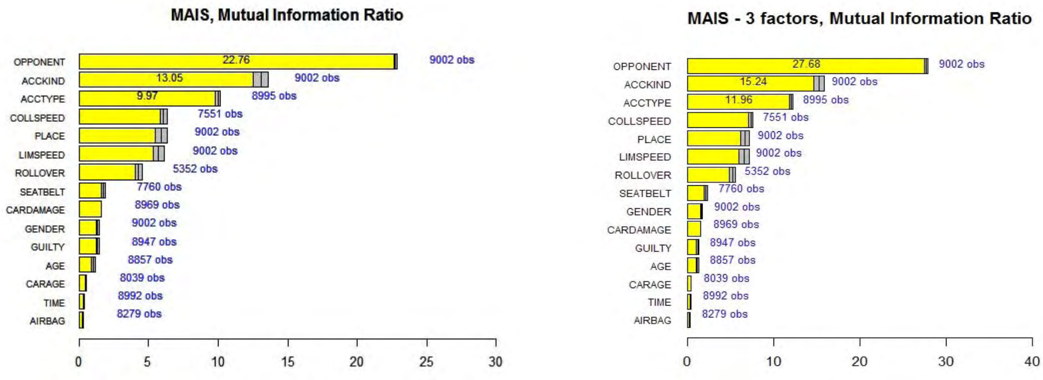


Figure 4 MIR for MAIS. Left: initial distribution. Right: aggregated distribution.

The presentation of the results is the following (Figure 4): considering an outcome descriptor (here MAIS), each MIR coefficient computed for one single factor is represented by a horizontally bar. The strength of the association, given by the MIR coefficient, is represented by the length of the horizontal bar (depending on the graph scale). The name of the tag of the corresponding factor is written on the left and Table 1 gives the description of corresponding tag names. The number of joint observations used for computing the coefficient is written on the right, and corresponds to the non missing values used to estimate each coefficient. On the right end of each bar, a confidence interval, computed by bootstrap, is represented for a 95% risk level. All MIR coefficients lie theoretically between 0 and 100%.

Considering, MAIS outcome descriptor, it appears that the type of OPPONENT during the accident is the most influent facto, with a MIR around 23%. As the number of initial modalities is reduced to aggregated classes (“safe”, “slightly” or “severe” injuries severity), this feature is even sharper and MIR value increases up to 28%. The Accident KIND appears in second position (13%; 16% for aggregated modalities), and the Accident TYPE in third position (10% or 12%). The association strength of all coefficients increases when computed from the original to the aggregated distribution.
The SPEED of collision, the PLACE and the limitation of speed obtain similar MIR coefficients. Although ROLLOVER accidents are quite rare, their impact on MAIS seems quite severe (MIR 5.8%).
The SEATBELT factor appears in the middle of the list and obtains a small coefficient (1.95%). SEATBELT usage is usually considered to be an important factor affecting the injuries severity of vehicle traffic accidents and, on a first view, this result seems to be contradictory with all knowledge about accidents causes and severity. Today, drivers and passengers are required by law to use their seat belt and the rule seems to be followed by most drivers: 97% of the available observations of GIDAS correspond to the use of seat-belt. So, statistically speaking, there is, today, no statistical variations for SEATBELT usage (or not), and this is confirm by the investigation of the real world accidents recorded in GIDAS (Figure 5).
In order to point out and to focus on, the severity of accidents due non seatbelt usage, we have artificially selected a subset of data in GIDAS with an equal proportion of observations corresponding to the usage (or not) of seatbelt . All observations corresponding to the non usage of seatbelt have

been taken (minor proportion), and have been completed with an equal proportion of observations, taken at random, corresponding to seatbelt usage. In order, to obtain, a robust estimation of the MIR coefficient, this procedure has been replicated 20 times, and the MIR coefficient has been averaged over all replications. For this artificial mixture of observations, the impact of the SEATBELT factor increases from 1.95% to 14%, which is quiet a high value (a 14% MIR corresponds to a second position in the ranking list). SEATBELT usage stays an important factor which is directly linked to injury severity. As today, a large majority of drivers wear their seatbelt; this factor appears to be less important in the real world accidents population.

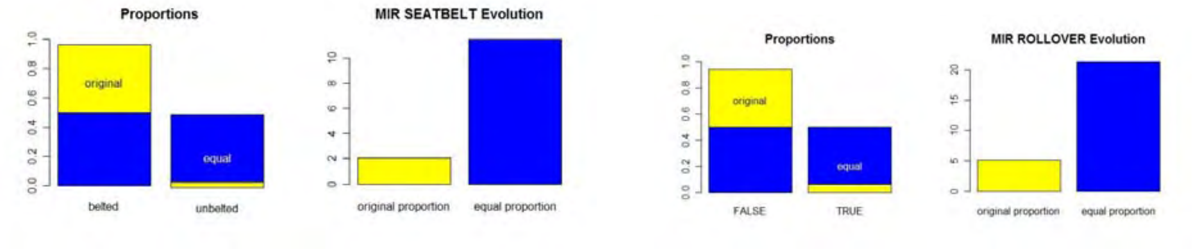


Figure 5: Seatbelt usage and Rollover accidents for original data (yellow) and artificially equaled proportion (blue). Impact on MIR.

If we compute the impact of rollover accident, using the same procedure as used before for the seatbelt factor, we observe that the MIR coefficients increases to 25%, which confirm the gravity of rollover accidents (figure 5).

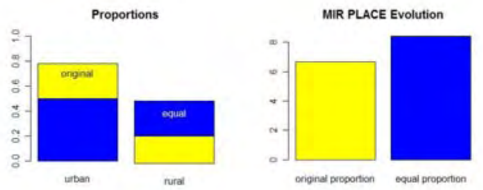


Figure 6: Accident place proportion for GIDAS data (yellow) and equaled proportion (blue). Impact on MIR.

On the opposite, urban and rural accident places do not have a strong impact on injuries severity even after re sampling (figure 6).

Multivariate analysis is then conducted to analyze for a given number of explanatory variables, which group of factors has the highest mutual information ratio, and best explains Maximum Injury Severity. The following graph presents, for MAIS outcome descriptor, the estimation of the highest MIR, as function of the number of factors (**Fehler! Ungültiger Eigenverweis auf Textmarke.**).

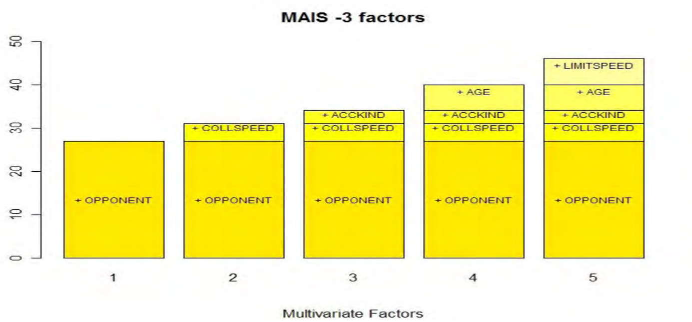


Figure 7: Mutual Information ratio for MAIS descriptor (aggregated modalities) in multivariate case.

For instance, the 3rd column indicates that the group of 3 factors (OPPONENT, Collision SPEED and Accident KIND) has a multivariate MIR of 38%; this group is associated with the highest predictive power for all groups of three factors (figure 4).

It is interesting to observe that, for the single factor analysis, OPPONENT, Collision SPEED and Accident KIND were respectively in first, second and third position, regarding the association strength level. In the multivariate analysis, the Collision SPEED, which was in 4th position for the single factor analysis, combined with the opponent factor, best explains injuries severity.
The previous results were conducted for maximum injury severity. It is possible to focus the analysis on specific injuries. A similar study is then conducted for head injuries.

HWS

Mutual Information ratios are then computed for head injuries for the same potential factors as for MAIS described in Table 1. As observed for MAIS outcome descriptor, the MIR coefficients estimated for HWS are sharper when computed for an aggregated distribution as for the original distribution (figure 8). The OPPONENT is, as for MAIS, the most influential factor explaining head injuries severity however the relation strength is smaller (12,5% as compared to 23%). The same holds true for the factors Accident KIND and TYPE which are again placed second and third. “GUILTY”, who describes whether a driver has been held responsible for causing the accident, is now at 4th place. The GENDER becomes quite important for head injuries, probably indicating that women are more vulnerable than men in this case. The mainly damaged part of the car (DAMAGE) comes also into play, probably indicating that rear end collisions play a high role.

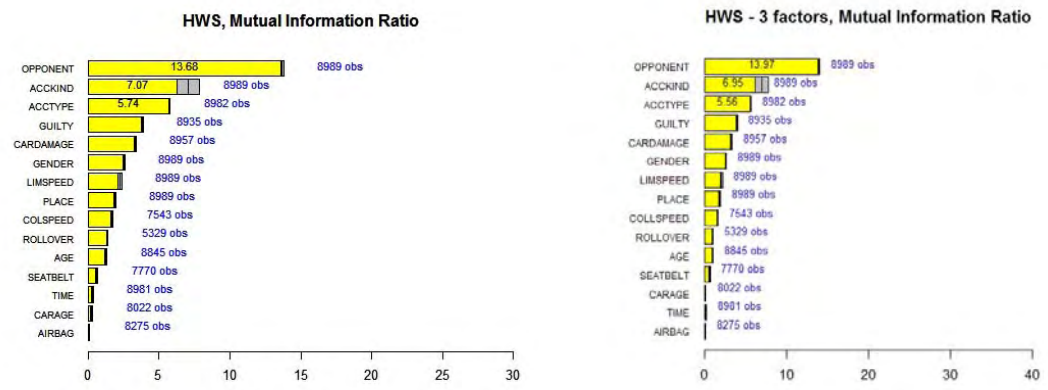


Figure 8: MIR for HWS. Left: initial distribution. Right: aggregated distribution.

Multivariate analysis is then conducted, as for MAIS, to select which group of factors has the highest mutual information ratio, and best explains head injury severity. Results are presented in the following figure (figure 9). Both factors, OPPONENT and GEGNER explain head and MAIS injuries severity.

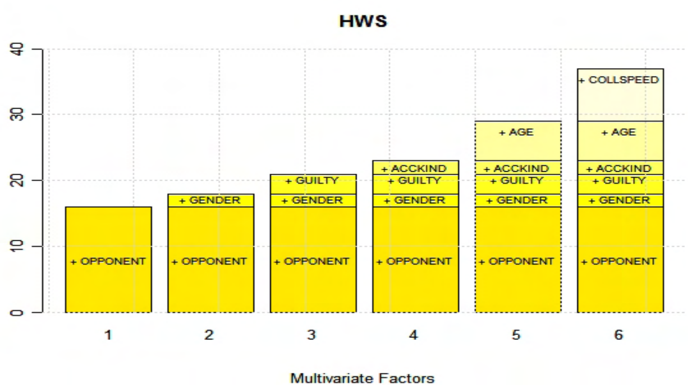


Figure 9: Mutual Information ratio for HWS descriptor in multivariate case

CONCLUSION

Mutual information ratio is used to compute the subset of most influent factors on a given accident outcome Y. Mutual information ratio is model independent and can be used also, before modeling, to select the most pertinent variables. It is also possible to use the selection of factors to design a model to estimate Y given the previous selected variables. We have used Support Vector Machines to compute an empirical relation between Y and the group of factors selected by mutual information: The empirical relation F_S naturally depends on the data set S of observations used during learning. Using the previous factors selected by mutual information, prediction models have been elaborated using support vectors machines and gives quiet good results. A complete study of this work is available in [Mougeot & Azencott 2007].

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The accuracy of vehicle damage based protocols to quantify impact severity

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Abstract - Impact severity is a fundamental measure for all in-depth crash investigation projects. One methodology used in the UK is based on the US Calspan software package CRASH3. The UK's in-depth crash investigation studies routinely use AiDamage3 [1], a software package which is based on an updated version of the original CRASH3 algorithm, including enhancements to the vehicle stiffness coefficients. Real world accident-damaged vehicles are measured and their crush is correlated with a library of stiffness coefficients. These measurements are then used, along with other parameters, to calculate the crash energy and equivalent changes of velocity of the vehicles (delta-v), which is a measure of the impact severity. UK in-depth accident studies routinely validate the crash severity methodologies applied [2] as the vehicle fleet changes. This is achieved by analysing crash test data and using the appropriate residual crush damage and other inputs to AiDamage3 and checking the program's outputs with the known crash severity parameters. This procedure checks, at least in part, the default stiffness values in the data libraries and the reconstruction methods used.

INTRODUCTION

Impact severity is a fundamental measure for all in-depth crash investigation projects. One methodology used in the UK is based on the US Calspan software package CRASH3. The UK's in-depth crash investigation studies routinely use AiDamage3 [3], a software package which is based on an updated version of the original CRASH3 algorithm, including enhancements to the vehicle stiffness coefficients. Real world accident-damaged vehicles are measured and their crush is correlated with a library of stiffness coefficients. These measurements are then used, along with other parameters, to calculate the crash energy and equivalent changes of velocity of the vehicles (delta-v), which is a measure of the impact severity.

In the UK the principal in-depth accident studies which use AiDamage3 as one of their crash severity assessment tools are the Co-operative Crash Injury Study (CCIS) and the On-The-Spot (OTS) study.

CCIS is an ongoing project which has collected in-depth real world crash data since 1983. Vehicle examinations are undertaken at recovery garages several days after the collision. Car occupant injury information is collected and questionnaires are sent to survivors. Accidents are investigated according to a stratified sampling procedure, which favours cars containing fatal or seriously injured occupants as defined by the British Government definitions of fatal, serious and slight. It also favours newer vehicles. More information about the study is available at www.ukccis.org.

OTS crash investigations have been carried out in the UK since 2000. The UK Government funds two teams whom routinely attend the scene of road crashes within 15 minutes of incidents occurring. This ambitious work is undertaken to allow research to be conducted to investigate the causes of crashes, their subsequent injuries and the associated societal costs. The study selects crashes of all severities and involving all road user and vehicle types. It is recognised that only through a detailed knowledge of these complex causal factors will effective countermeasures be developed and ultimately successfully applied to improve road transport safety. Scene evidence is the primary source of data for crash severity assessment for OTS cases, but damage based assessments provide additional and complimentary information for some crashes. More information about the study is available at www.ukots.org.

The description of vehicle properties built into AiDamage is based on US crash tests from the 1990s and there have been no fundamental changes to the properties in the intervening period. As a result, the procedures and protocols used to estimate impact severity using these CRASH3-based stiffness values are now about 15 years old. However, since the introduction of the European frontal impact directive and EuroNCAP in the last 10 years, it is believed that vehicle structures have become stiffer. If vehicles have become significantly stiffer there is a danger that current crash investigations are underestimating the actual change of velocity that occurred. The work described in this paper outlines the ongoing research programme's methodology, which aims to assess the current accuracy of the UK's residual damage based crash severity assessments and highlight how enhancements to current protocols will be made if necessary.

Crash tests under controlled conditions provide an opportunity to compare AiDamage3 calculations of delta-v with known values. Unlike road accidents, the change of velocity of a crash-tested vehicle during impact is either recorded or can be closely estimated from its pre-impact velocity and the relative mass of the object struck. This provides a reliable, independent assessment of velocity change. By measuring crash-tested vehicles and processing them as if they were regular car crash cases, AiDamage3 estimates of velocity change can be obtained that should be representative of the results of accident studies. In practice, the accuracy of the program depends not only on its internal mathematical model, but on many other factors, including the quality of data provided to it, the use and interpretation of its results, the design of the program's user interface and, most importantly, the default values for vehicle stiffness used in the program. With respect to the quality of data provided, CCIS and OTS have standardised protocols for measuring and recording the damage and identifying the direction of force.

METHODOLOGY

Measurements

Two crash tested vehicles were measured and then processed in the same way as those in general accident studies, in order to produce estimates of the changes in velocity, which could then be compared to the speeds used in the tests. The program used to calculate the severity of the crashes for this paper was AiDamage3, which requires both the crush profile and the mass of the vehicle at the time of impact to be entered.

In order to assess the severity of the accident, a variety of measurements are taken of the impact damage suffered by the vehicles involved. The two elements of measuring this are the damage width and the crush profile. The CCIS protocols for collecting this information are outlined below.

Damage Width

Once the location of the most significant damage is identified the damage width must be measured. This is taken along the area of the vehicle which has suffered both direct and indirect damage. Direct contact damage is the area of the damage which was directly caused by contact with the impacting object. Indirect contact damage is the damage due to transmitted forces which have pulled the body shell inwards. This measurement should be taken along the surface of the damaged vehicle. The measurement should reflect the original width of the damaged area before the impact. The damage width is measured by wrapping a tape measure along the surface of the damaged area, at the height of the stiff structure.

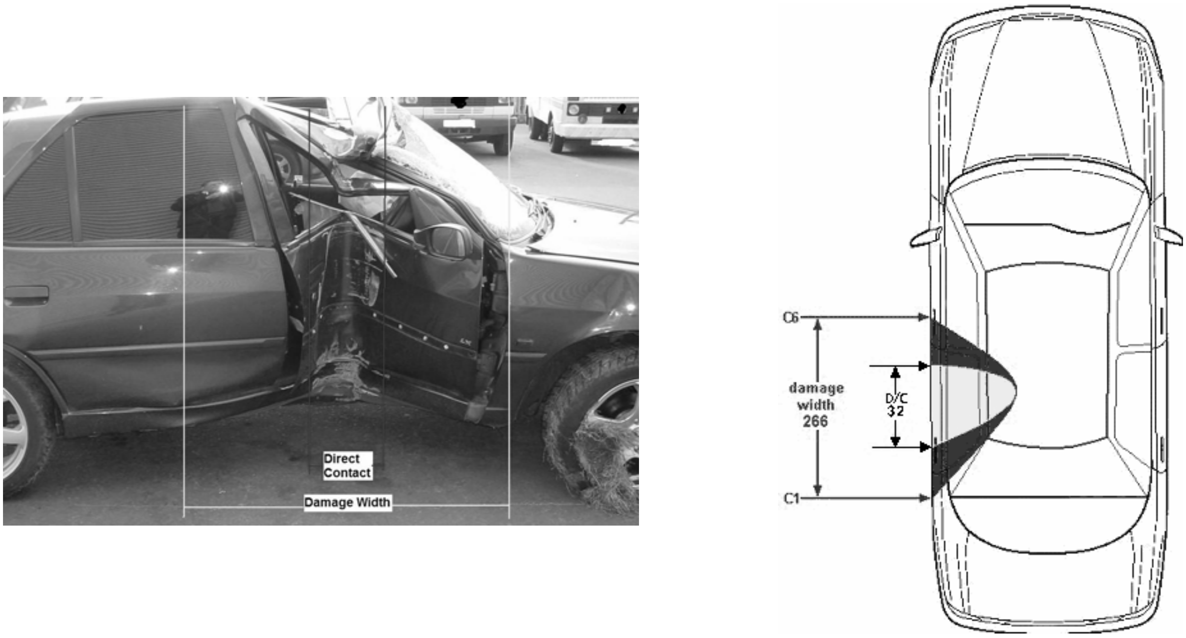

Figure 1. Photograph and diagram to demonstrate direct and indirect damage in a side impact

Figure 1 shows a photograph of a case in which the vehicle collided with a lamp post. The direct contact width was 32cm with the total damage width being 266cm.

Crush Profile

In order to measure the crush profile of the front of a vehicle, a datum line at the back of the vehicle must be set. This is set from the undamaged end of the vehicle to either the undamaged length of the vehicle or a known length. For a side impact, the datum line is set either as a line between two undamaged sections of the vehicle or from the undamaged side of the car to either the undamaged width of the car or a known length.

The crush profile is measured by measuring back from the front datum line to the car at a minimum of three equally spaced points, though it is more usual to take six measurements. These measurements are referred to as C1, C2, C3, C4, C5 and C6, where C1 is always on the nearside for a frontal or rear impact and at the rear in a side impact and C6 (or the last measure) is always on the offside for a front or rear impact and at the front for a side impact. This method is illustrated in Figure 2.

The crush measurements should be taken at points an equal distance apart along the crush profile (not necessarily equidistant along the datum line) at the height of the stiff structure.

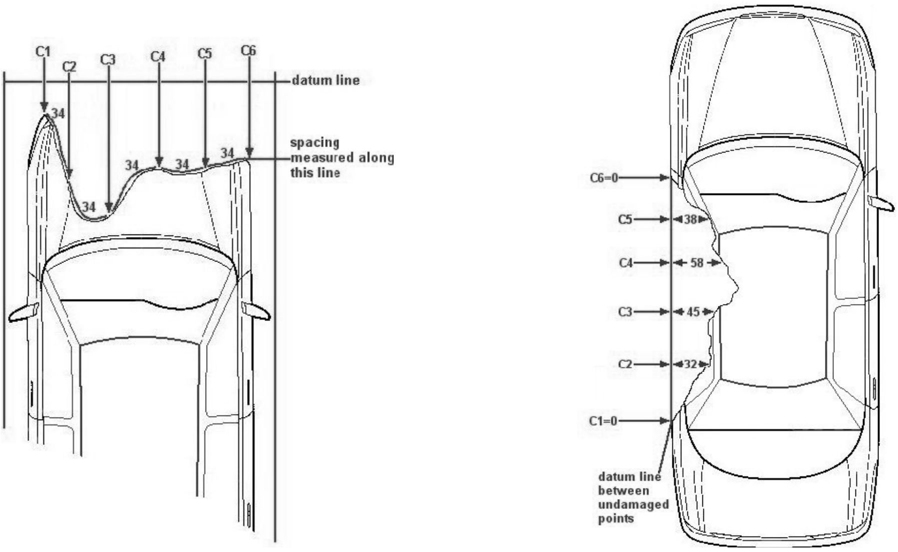

Figure 2. Equally distanced measurements to be taken along the crush profile

The damage width should be assessed so as to avoid consecutive measures of zero in the crush profile as demonstrated in Figure 3. The figure on the left shows measurements with consecutive zeros, whereas the figure on the right, the correct method, includes only measurements across the damaged area with just one measurement of zero at the start of the damage.

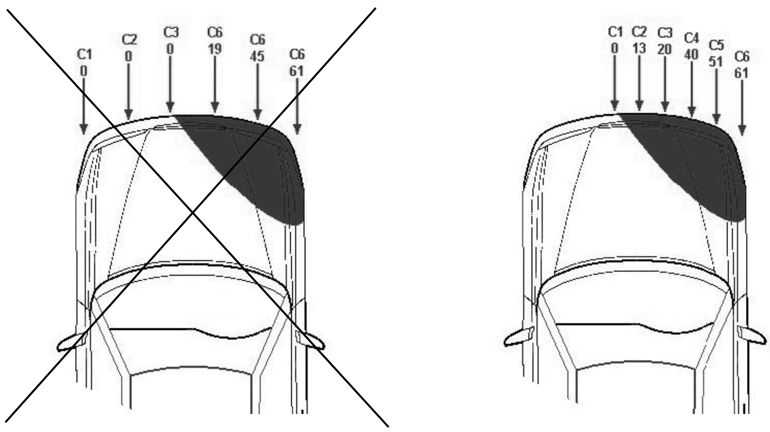

Figure 3. Distribution of measurements across the vehicle

The midpoint offset is also required. It is defined as the distance from the midpoint of the damage profile to the centre of the vehicle. A point is taken half way between the C3 and C4 crush measurements. A measurement of the distance along the crush profile to the original centre line of the vehicle is then taken as the midpoint offset.

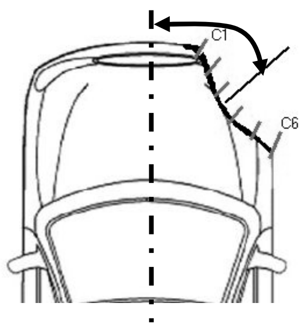

Figure 4. Midpoint offset measurement

If the crush profile incorporates the entire front of the vehicle, then the midpoint offset is zero. The midpoint offset must also be determined as positive or negative as shown in Figure 5.

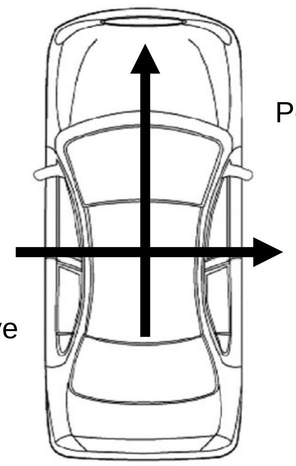

Figure 5. The sign of midpoint offset

If the midpoint offset is towards the rear or nearside of the vehicle then the value is negative. If the midpoint offset is towards the front or offside of the vehicle then the value is positive.

Once all these values have been determined, they can be entered into the AiDamage3 software, along with the mass of the car, in order to obtain values for the energy of the impact, closing speed, and other speed-related measures of impact severity.

Calculation of delta-v

Since the 1950s, a number of papers have been produced on the various aspects of the relationship between the damage caused in an accident and the vehicle's speed. A number of speed-related measures of impact severity have been introduced into the field of accident investigation, including energy equivalent speed (EES), equivalent test speed (ETS), equivalent barrier speed (EBS) and barrier equivalent velocity (BEV). This paper focuses on one of the measures which is used most frequently for analysis: delta-v. Ventre and Provensal (1973) [1] initiated the concept of delta-v as a measure of damage severity, and this is the method used by AiDamage3 to describe accident severity.

Delta-v is the difference in the velocity vector of the centre of gravity of a vehicle between first contact with the impacting object and separation. It has a number of advantages for the type of collision usually discussed in accident investigation. It is determined by the relative velocities of the vehicles at impact and by the relative masses of the two vehicles. It is important to note that, although delta-v is independent of the relative stiffnesses of the vehicles, the damage caused to each vehicle will be related to their stiffnesses.

Crash Tests

This paper is based on two crash tests that have been reconstructed using AiDamage3.

Test 1

The first of these crash tests, between a Renault Clio and an Opel Vectra, was carried out for the CHILD project [4]. The front of the Clio collided with the side of the Vectra. The Vectra was stationary and the Clio was travelling at 80kph, making the closing speed for this collision 80kph. The delta-v of the vehicles was 34kph for the Vectra and 46kph for the Clio.

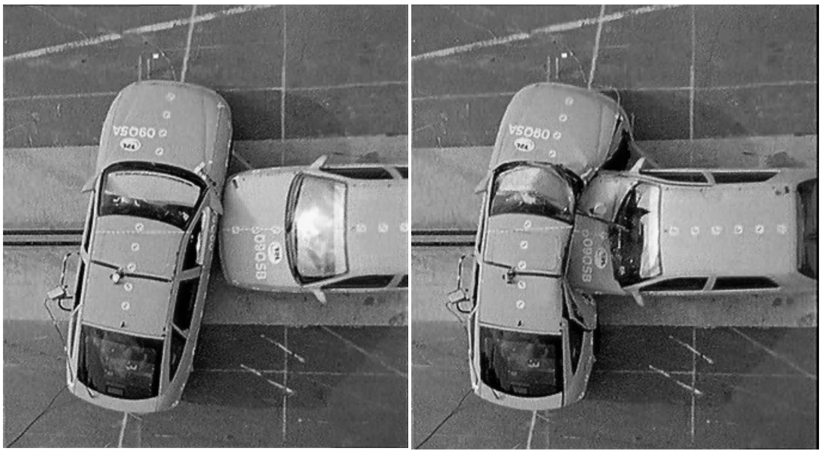

Figure 6. Clio impacting the side of the Vectra

Test 2
The second crash test was between a Vauxhall Combo van and the rear axle of an HGV. Here, the impact speed of the van was 48kph.

Figure 7. The damage to the Vauxhall Combo Van

AiDamage3 Calculations

In order to calculate the energy required to deform each of the vehicles in a car-to-car crash, it is assumed that the crush force per unit width has the form shown in equation 1 [5]. A constant is added in order to account for the maximum possible force that can be applied which results in no residual crush (A):

$$F/w = BC + A \qquad [1]$$

where F is the force required to compress a spring by a certain distance (C), B is the stiffness of the spring and w is the damage width.

The energy is then determined by integrating equation 1 over the damage width, which results in the final energy equation used in CRASH3, and therefore in AiDamage3, as follows:

$$E = w\left(\frac{BC^2}{2} + AC + \frac{A^2}{2B}\right) \qquad [2]$$

where A and B are stiffness coefficients specified in the program, w is the damage width and C is the crush depth.

From the energy absorbed and the masses of the vehicles, the value of delta-v for the vehicle is calculated using the following equation: [3]

$$\Delta v = \sqrt{\frac{2m_2(E_1 + E_2)}{m_1(m_1 + m_2)}} \qquad [3]$$

where m_1 is the mass of the first vehicle, m_2 is the mass of the second vehicle, E_1 is the energy absorbed by the first vehicle and E_2 is the energy absorbed by the second vehicle.

From research in the 1990s, AiDamage3 was updated, to use the following default stiffness values (A and B) for its calculations (these are from the vehicle library newdata.lib) [6]:

Table 1. Default values used by AiDamage3

	Class					
Value	**1**	**2**	**3**	**4**	**5**	**Barrier**
Mass (kg)	945	1119	1332	1669	1756	10^7
Wheelbase (cm)	205-241	241-258	258-280	280-298	298+	100
Length (cm)	403	443	484	522	551	100
Width (cm)	165	172	177	188	189	100
Track (cm)	140	144	149	152	152	100
Overhang (cm)	83	88	105	102	105	0
CoG to front (cm)	180	180	206	222	230	50
Front						
A (N/cm)	316	324	362	377	506	-
B (N/cm^2)	49.7	45.1	48.3	46.0	78.2	-
Side						
A (N/cm)	155	175	170	240	240	-
B (N/cm^2)	41.2	45.7	53.6	65.5	65.5	-

However, the CCIS study has been running since the 1980s and, to preserve compatibility with earlier results, it was decided that CCIS would avoid making a step change in the calculation methodology, and would continue to use the original default values. This decision was supported by a validation exercise undertaken by Lenard et al.[2]. This study found good correlation between real crash test delta-v values and the associated calculated results derived from the CRASH3 default values highlighted in Table 2.

Table 2. Previous default values used by AiDamage3

Value	Class					
	1	2	3	4	5	Barrier
Default Mass (kg)	1000	1380	1600	1926	220	10^7
Wheelbase (cm)	205-241	241-258	258-280	280-298	298+	100
Length (cm)	406	444	498	541	568	100
Width (cm)	154	170	184	196	203	100
Track (cm)	130	139	150	157	162	100
Overhang (cm)	78	94	98	112	112	0
CoG to front (cm)	193	212	228	251	259	50
Front						
A (N/cm)	528.2	454.4	556	623.5	569.7	-
B (N/cm^2)	32.4	29.8	38.6	23.3	25.5	-
Side						
A (N/cm)	135.2	246	303.6	250.5	309.2	-
B (N/cm^2)	25.5	46	39.4	34.8	32.5	-

In order to replicate the method by which the program is used in general accident studies, the class of each vehicle was selected based upon its wheelbase. The actual masses of the vehicles were input into the program, but apart from this the program used the default values appropriate to that class. The masses of the vehicles were taken as the kerb mass plus the masses of any dummies and equipment that would have been in place for that test.

RESULTS AND DISCUSSION

Clio/Vectra impact

The damage to the vehicles was measured as it would be for a CCIS case and reconstructed using the AiDamage3 software. The Vectra was reconstructed as a vehicle in stiffness category 3 and the Clio was stiffness 9 as it was a front wheel drive car in a frontal impact. The A and B values for the Vectra and Clio were 303.6, 39.4 and 653, 26.2 respectively, these being the default values used by current UK in-depth accident investigation studies.

The AiDamge3 result was a closing speed of 83kph, which is slightly higher than the actual value, but this difference is minimal. The delta-v for the Vectra was calculated to be 35kph and 48kph for the Clio, which are very close to the actual test speeds. In this crash, as it was a crash test and set up to the specifications, the angle of the impact was known exactly. The direction of force for the Clio was entered as 10 degrees and that of the Vectra was 80 degrees. In a real CCIS case, it is possible that the angle of the impact would not be judged this precisely as it is difficult to do so from the damage alone without the resting positions of the vehicles. If this had been a real CCIS case, the angle is likely to have been estimated at 0 degrees. This would have resulted in a closing speed of 82 kph.

Combo/HGV impact

Using change in momentum calculations, where the weight through the rear axle of the HGV was estimated at 2.5 tonnes and the pre-impact velocity of the van was known to be 48kph, the delta-v of the van was calculated to be 35kph. As is usual CCIS practice with large vehicles of unknown actual mass, the HGV was entered into AiDamage3 as a “barrier” that was stationary both before and during the crash, with the van entered as a vehicle of size 3, stiffness category 9 (A = 653, B = 26.2). The reconstruction results for this test found the delta-v to be 31kph, which is an underestimate of 4kph compared to the actual delta-v of the test.

Summary

The work described forms part of an ongoing research programme seeking to validate one of the impact severity assessment methodologies used by UK crash investigation studies. Two crash test case examples are presented as part of this work to highlight the current ongoing activity. Where the calculated delta-v and real crash severity values differ significantly, the stiffness values in AiDamage3 are adjusted until the calculated delta-v values are closer to the associated test delta-v values. New values for the stiffness of vehicles are derived where appropriate which relate to the vehicle dimensions. This paper sets out the methodology currently being applied and future publications will outline the precise findings of this work and any changes which have been applied to the stiffness coefficients used.

CONCLUSIONS

From this early analysis presented, it can be seen that the delta-v values calculated are good estimates of the real crash severities observed in tests. However, this work is still ongoing and many more crash test impact configurations involving different impact severities will be analysed to fully validate current procedures and where necessary the appropriate stiffness coefficients used in the AiDamage software will be updated to replicate any changes in the stiffness characteristics of the vehicle fleet.
The authors are working in partnership with AiTS, Birmingham Automotive Safety Centre (University of Birmingham) and the Vehicle Safety Research Centre (Loughborough University) to enhance, where appropriate, the default and specific stiffness coefficients used to make them more representative of newer cars

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AKNOWLEDGMENTS

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Simulation of real pre crash accident scenarios using German In-Depth Accident Study (GIDAS)

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Abstract - The focus of the technical innovation in the automobile industry is currently changing to sensor based safety systems, which are operating in the pre-crash phase of an accident. To get more information about this pre-crash phase for real accidents a simulation of this phase using the GIDAS database is done.

The basics for this simulation are geometrical information about the accident location and the exact accident data out of the GIDAS database. This aggregated information gives the possibility to simulate an exact motion for every accident participant, using MATLAB / SIMULINK, in the pre-crash phase. After the simulation the information about the geometrical positions, the velocities and maneuvers of the drivers to an individual TTC (time to collision) are available. With those results it is possible to develop new useful sensor geometries using pre-crash scatter plots or estimate the efficiency of implemented active safety systems in combination with sensor characteristics.

This simulation can be done for every reconstructed accident included in the GIDAS database, so these results can represent a wide spread basis for the further development of active safety systems and sensor geometries and characteristics.

BASE

As basis for the simulation of the pre-crash accident scene there are mainly three groups of information.

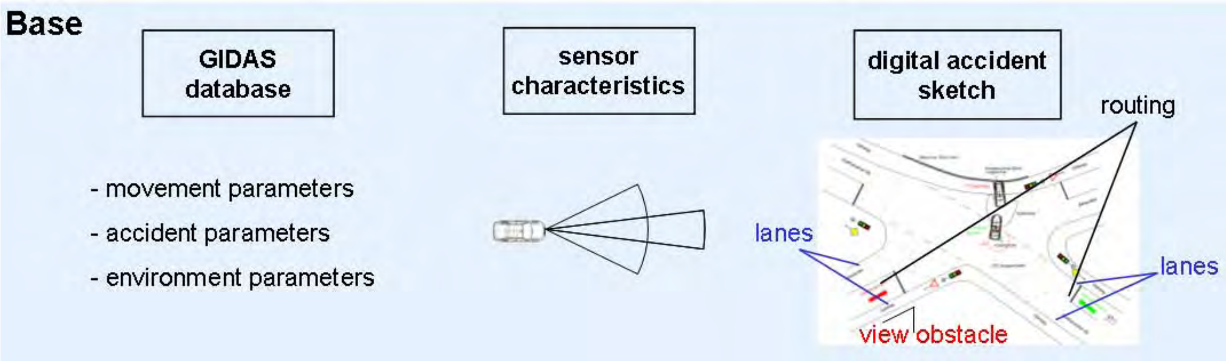

Figure 1. Base

GIDAS database

The first group is the GIDAS database, out of this database movement-, accident- and environment parameters can be extracted. Such parameters are for example the car deceleration or acceleration, speeds, weather, road conditions or the collision angle.

Sensor characteristics

Second group of information are the sensor characteristic features like angle, range and detection latency. These characteristic features are used later in the simulation to calculate if an object is in the geometrical field of the sensor and if it is detected.

Digital accident sketch

The digital accident sketch is build out of the real accident sketch which exists for every accident in the GIDAS database. The main information about the routing of the occupants, the lanes of the occupants and of course about the position of the view obstacles is elevated, put into a digital format and exported to a MATLAB readable file.

SIMULATION

After the base is elevated an automatic simulation done by SIMULINK starts. During this simulation the following main steps are calculated.

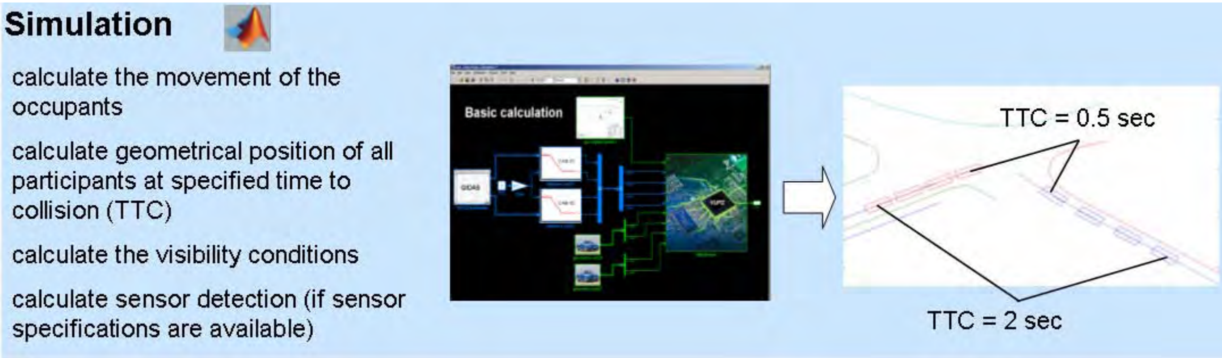

Figure 2. Simulation progress

Movement

The movement calculation uses the parameters out of the GIDAS database to describe an exact movement of each participant. Using this movement calculation the distance to the collision point can be calculated for every given time to collision (TTC) starting two seconds before the crash.

Geometrical position

If the distance at the chosen TTC is calculated for each participant, it is placed onto the digital accident sketch. After placement of both participants distance to the collision the exact point of each participant referring to each other can be calculated.

Visibility check

After calculation of the geometrical positions the visibility to each other can be checked using connection lines between the participants. The visibility is given, if the connection lines between the occupants do not intersect a view obstacle. Possible results of the visibility check are visible or not visible.

Sensor detection

If sensor specifications are available for the actual accident, the simulation is able to check if the occupant is detected by the sensor in time. This calculation is done, by using the sensor characteristics, the actual position of the occupant and the information about the actual visibility. Three results are possible for sensor detection first detected, second not considered, third not in range.

Plotting the results

After simulating the accident and calculating position, visibility and detection the results can be plotted in pre-crash scatter plots shown for example in the results.

RESULT

After the simulation three kinds of results can be differentiated.

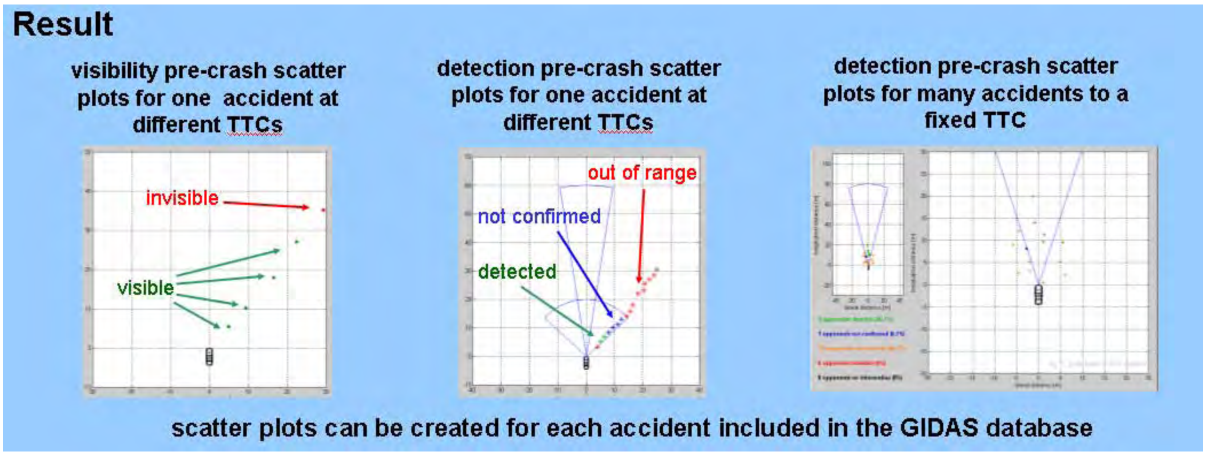

Figure 3. pre-crash scatter plots

Visibility pre-crash scatter plots

A visibility pre-crash scatter plot is drawn in a "fixed to car" coordinate system. It unites the information about the position of the occupant at different TTCs and the information about the visibility of the occupant. Such a scatter plot gives the information of the first visibility to the fixed car.

Detection pre-crash scatter plots (single accident)

Detection pre-crash scatter plots are drawn in a "fixed to car" coordinate system, similar to the visibility pre-crash scatter plots. Different to the visibility pre-crash scatter plots the sensor geometry is included. Using this implemented sensor geometry additional information can be given. The additional information in this plot is the first detection of the occupant. The geometrical points are divided into three groups the out of range, which are not inside of the sensor geometry, the not confirmed, which are in the geometrical field of the sensor but not yet detected and the detected group, which are in the geometrical field of the sensor and confirmed.

Detection pre-crash scatter plots (many accidents)

Different to the other pre-crash scatter plots are these plots only at one fixed TTC, but for more than one accident. Meaning the position of all considered accidents to a fixed TTC is drawn. This geometrical information is added with the detection information drawn by color. Similar to the pre-crash scatter plot for a single accident the information can be detected, not confirmed, and out of range.

Usage of pre-crash scatter plots

Pre-crash scatter plots can be drawn for every accident coded in the GIDAS database. Due to this fact new and existing sensor systems and configurations can be estimated using the representative GIDAS database. It is a beneficent possibility to check the necessity characteristics of a sensor system before placing it into a car.

Benefit Analysis of Driver Information and Driver Assistance Systems

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Introduction

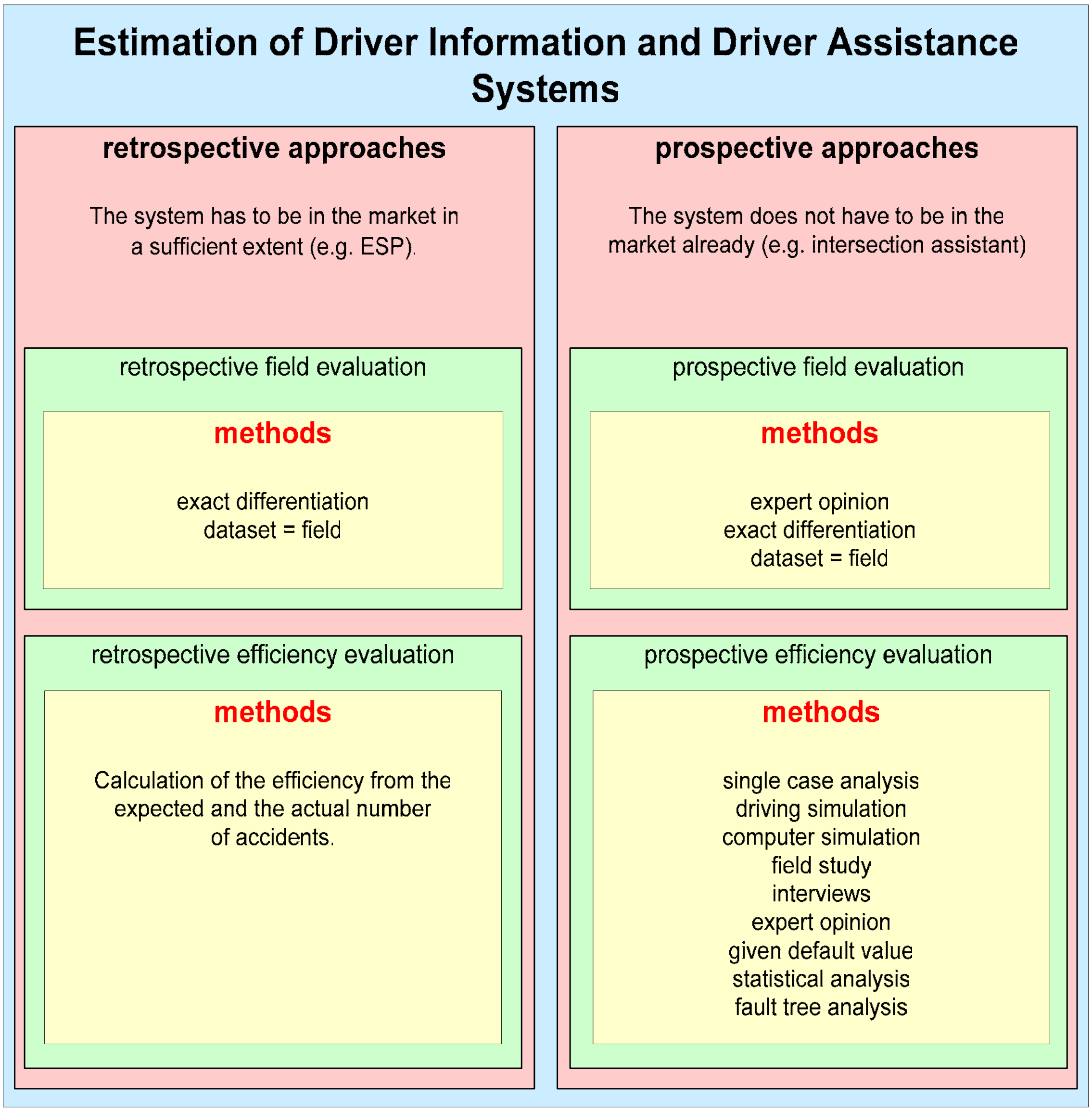
In the last years various new driver information and driver assistance systems made their way into modern vehicles and there are yet countless systems underway. However, expenses for both, the development and the construction of these systems are tremendous. Therefore the interest of evaluating systems keeps growing steadily, not only regarding the results of systems developed in the last years but also regarding system ideas. Only if at least a rough benefit estimation is given, the industry can decide which development should be supported. However, there is still a lack of transparency of possible and useful methods for these kinds of estimations. These were analyses and structured in this study.

Aims and methodology

In a thorough review of 78 national and international studies different approaches for benefit estimations of driver information and driver assistance systems were investigated. The used methods, key elements and results were structured in a toolbox and analyzed in detail. The different approaches were evaluated, further developed and validated for common system examples. The structured toolbox now offers a detailed overview about the possibilities for an evaluation and lists advantages and disadvantages of the different methods. Reference studies that used the specific method can be filtered from the literature database to give examples and detailed explanations.

Classifications of methods and estimations

As the analysis of the different studies showed, the wording and definition of benefit estimation methods varies quite heavily. Thus the different methods were structured in a model of four different levels. Level 1 is the system estimation in general. This estimation can be approached in two different ways: retrospectively and prospectively (Level 2). Within each of these groups there are two basic parts of analyses: the field evaluation and the efficiency evaluation (Level 3). Finally a large group of methods can be used for these evaluations (Level 4).



Picture 1 - General Structure: Benefit Estimation

Estimation of the field of a system

To estimate the field there are retrospective and prospective approaches. If the system is already present in traffic accident databases, all accident scenarios where the system could possibly have had an effect are considered in a retrospective approach. Possible methods are the exact differentiation of the field or the use of all cases in a dataset as the field.

If however a system idea or a very new system without reliable real world accident data available has to be estimated a prospective approach has to be chosen. Here the field covers all accidents that are theoretically addressable by the system. Thus all accident scenarios where the system could have an effect are addressed, without the evaluation of the extent of this effect. Here useful methods are the expert opinion, the exact differentiation of the field or again the use of all cases in the dataset.

Efficiency evaluation

In a retrospective approach the portion of accidents in the field that could have been mitigated or prevented by the system represents the efficiency within the field. It directly depends on the functional specifications of the system and can cover a maximum of 100%, meaning all accidents in the field. The used approaches all represent the methodology of calculating the efficiency from the expected and the actual number of accidents recorded.

In a prospective approach the portion of accidents in the field that could theoretically be mitigated or prevented by the system represents the efficiency within the field. Here a large list of possible approaches is given: the expensive and time consuming single case analysis, driving or computer simulation that usually need a large apparatus of technical equipment, field studies giving realistic results for a rather small group of users, interview and expert opinions for subjective evaluations and statistical analyses or fault tree analysis to put emphasis on scientific comprehension.

Estimation of system combinations

The benefit of a single system has to be distinguished from the estimation of system combinations. If several systems are used in a vehicle the accident can yet only be prevented once. Every system can have an influence itself but a plain addition of the benefits would lead to an overestimation. Special analyses including this idea become more and more necessary since there will be various different system within one vehicle in the future.

A European Fatal Crash Database

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Keywords: **European Fatal Crash Database, Crash causation,**

ABSTRACT

A lack of representative European accident data to aid the development of safety policy, regulation and technological advancement is a major obstacle in the European Union. Data are needed to assess the performance of road and vehicle safety and is also needed to support the development of further actions by stakeholders. This short-paper describes the process of developing a data collection and analysis system designed to partly fill these gaps. A project team with members from 7 countries was set up to devise appropriate variable lists to collect fatal crash data under the following topic levels: accident, road environment, vehicle, and road user, using retrospective detailed police reports (n=1,300). The typical level of detail recorded was a minimum of 150 variables for each accident. The project will enable multidisciplinary information on the circumstances of fatal crashes to be interpreted to provide information on a range of causal factors and events surrounding the collisions.

1. INTRODUCTION

Each year within the European Union (EU-15), there are approximately 40,000 people killed on the roads and over 1.7 million people injured (European Commission, 2005a). Such incidents cost the Community over 180 billion Euros annually, equal to 2% of the EU's Gross National Product (GNP). With the growth in the number of EU member states (to EU-25), the European road death toll is set to increase to even more dramatic heights. To put these figures into perspective, "road crashes are the second most serious cause of death and hospital admission for EU citizens, preceded by cancer and followed by coronary heart disease" and for Europeans under 45 years of age, road crashes are the largest single cause of death (ETSC, 1999).

The number of people killed and injured on the roads started to decrease considerably from 2002 onwards (European Commission, 2005b), with improvements year on year for 2003 and 2004. However, there has not been such steep decline in the overall number of crashes. Incidents are still occurring frequently, although improvements in vehicle design and trauma management have helped to reduce the severity of injuries to the people involved in accidents, the number of slight injuries has not decreased. Despite these improvements in injury outcomes, it is estimated that 97% of all socioeconomic costs for transport crashes within the EU are as a result of those on the roads, and that 97% of the transport related fatalities occur in the road sector (ETSC, 1997).

1.1 Effective development of countermeasures

The EU target of a 50% reduction in fatalities on the roads by 2010 (European Commission 2005a) will only be achieved by the introduction of the most effective countermeasures. It relies on the existence of basic knowledge of crashes and their causation and the availability of road safety data to monitor and assess performance. Reduction of road casualties through vehicle design is typically achieved by taking an 'Active' or 'Passive' safety approach. Passive safety normally involves the implementation of safety technology within the vehicle which is specifically designed to reduce injuries in the event of a crash; airbags and advanced seat belt technology are prime examples of such devices. In more recent times, there has been much activity and research in the field of 'Active safety'. This approach is traditionally associated with technologies that are likely to result in crash avoidance and such technologies include Intelligent Speed Adaptation (ISA), Enhanced Stability Programmes (ESP) and Lane Departure Warnings (LDW). These technologies are implemented into the vehicle as information and control devices with the specific intention of ensuring that every measure is taken to prevent the crash from happening in the first place. Most modern vehicles are equipped with a suitable range of both Passive and Active safety devices such that if the Active safety measures are ineffective and a crash becomes inevitable, a level of protection of the occupants can be assured in the crash through deployment of the Passive safety systems.

Accompanying the development of Active safety systems is recognition of the need for good quality representative crash causation data within the European Union so that such technology can evolve with specific consideration to the nature, circumstances and causes of real-world crashes. However, not only are data required for technological development - they are also seen as essential for the purposes of the development of safety policy and monitoring of regulation within Europe. Data are needed to both assess the performance of road safety stakeholders and also to support the development of further actions. An analysis conducted by the European Transport Safety Council (ETSC, 2001) identified that no single crash database could meet all of the needs and that there were in fact still major gaps particularly in respect of both in-depth crash and injury causation. Specific policy questions at EU level include the role of infrastructure in crash causation, the monitoring of progress towards the 2010 casualty reduction targets and in particular, the role of vehicle and road design in crash and injury causation.

2. SYSTEM DEVELOPMENT

2.1 European Fatal Crash Data Collection Process and Data Resource

The main purpose of the task was to build an effective data gathering structure to ensure that specific data on fatal crashes can be gathered in a systematic and routine manner, with a bias towards understanding and recording crash causation to assist in the development of countermeasures. The data has been collected using completely compatible methods although there may have been variations between teams according to differences in local infrastructure. This activity has included the development of a broad ranging intermediate level, fatal crash database by obtaining reports of police fatal crash investigations from a number of EU Member States participating in the SafetyNet project (including France, Germany, Finland, The Netherlands, United Kingdom, Italy and Sweden). The data itself is of an intermediate level of detail but covering a representative sample of fatal crashes in each country. There have been no new investigations but research teams from each partner country have brought together available information from within the existing police and other emergency services structure. The information provided in the database has provided enhanced knowledge of the factors involved in fatal crashes at EU level and has made good use of the detailed information collected in the police fatal investigations. The dataset has been systematically selected according to a defined sampling plan and the data are representative of the countries in which the data are collected. The main data collection period involved a representative sample of between 2% and 10% of the fatal crashes in each country covered, depending on the magnitude of the fatal crash population. In all, 1,296 fatal accident cases, involving at least 1 fatality per crash, were collated and analysed. These data describe the environmental factors, vehicle and driver factors to provide a description of the whole crash. Specific areas of data describe the overall crash circumstances, driver and vehicle characteristics, specific road infrastructure features, and descriptions of other crash participants.

3. RESULTS

The resuts of the analysis are still being collated and will be published in a forthcoming series of reposrt, paper and other dissemination media. It was not possible to include any analytical results in this paper although table 1 shows the composition of the resultant database in terms of the vehicles and the road-users involved. By far the largest sub-group within the database were the passenger cars and their occupants which comprised 57% of the 'vehicles' grouping and 65% of the road-user groupings.

Total cases 1296		
Vehicles		Road Users
Car	1340	2249
Motorcycle	282	303
Truck	218	231
Bicycle	128	128
Van	86	116
Pedestrian	-	259
Other	336	158
Total	2390	3444

Table 1 – Final database Composition According to Vehicle Class and Road-User Type

4. DISCUSSION

In-depth crash databases contain the necessary post-crash information for analyses of causal factors in crashes. They often contain the detailed injury and vehicle crash data generally gathered by teams of medical and technical experts and police specialists soon after a severe incident. These combined details of road crashes are indispensable for input to road safety regulation.

This project demonstrates (i) the efficient use of existing high quality and under-utilised information resources and the use of such to understand crashes and develop effective countermeasures, and (ii) the development of a novel data capture and categorisation system with the use of existing infrastructure to collect high quality, multidisciplinary crash causation data. Crash causation databases traditionally contain the necessary details of the pre-crash data, where the other databases either contain hardly any data on the pre-crash phase of the incidents or only post-crash data. Self-evidently pre-crash data are indispensable for the analysis of effective countermeasures to prevent road crashes. Since the focus on the relevant pre-crash data generally differs for incidents of different road users, there are activities on crash causation data gathering for car crashes, for motorcycle crashes and pedestrian crashes; the latter two for obvious reasons also include data that are relevant for the causation of injuries. Some national crash causation studies have been carried out in several Member States, either in connection with the in-depth injury causation work (e.g. Medical University of Hannover) or by the police in routine recording of incidents and casualties in the national crash database system (e.g. Great Britain). Additionally, some previous studies have been conducted: The Association of European Car Manufacturers (ACEA) has conducted a European Accident Causation Survey on car crashes with financial support from the European Commission. The focus on research interests of the car manufacturers for this study on the pre-crash conditions of car crashes is quite understandable, since improvement of pre-crash conditions may focus more on road infrastructure as much as vehicle design. However, great care must be taken that any database is independent of the major stakeholders if it is to be used to inform public policy and evaluate the effectiveness of safety systems in an impartial way.

Future directions in pre-crash technology, including that undertaken by the eSafety group involve the development and implementation of many technologies that have the potential for casualty reduction and a representative research in-depth database is needed to ensure that strategic decisions over systems development are directed by estimates of casualty reduction under real-world conditions.

Rigorous statistical analyses of data will be undertaken in the coming months now that the database has been finalised and subjected to quality control reviews. These analyses will be reported on in the coming months.

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6. ACKNOWLEDGEMENTS

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Who doesn't wear seat belts?

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Abstract – Using real world accident data, seat belts were estimated to be 61% effective at preventing fatalities, and 32% effective at preventing serious injuries. They were most effective for drivers with an airbag. Seat belts were estimated as having prevented 57,000 fatalities and 213,000 seriously injured casualties in the UK since 1983. Seat belt legislation was estimated to have prevented 31,000 fatalities and 118,000 seriously injured casualties. A future increase in effective seat belt wearing rate (which takes into account seating position) in the UK from 92.5% to 93% may prevent casualties valued at a societal cost of over £18 million per year.

To target a seat belt campaign, the question "who doesn't wear seat belts?" must be answered. Seat belt wearing rates and the number of unbelted casualties were analysed. It was primarily young adult males who didn't wear seat belts, and they made up the majority of unbelted fatalities and seriously injured casualties.

INTRODUCTION

In the UK on the 31st January 1983, legislation was introduced which made seat belt wearing in the front seats of cars compulsory. This immediately led to an increase of seat belt wearing rates from approximately 40% to over 90% in the front of cars [1]. Now, 25 years on, seat belt wearing rates in the front of cars remain at over 90% according to road side wearing surveys [2], although wearing rates in the rear of cars are significantly lower.

The first objective of this paper was to analyse real world accident data to determine whether seat belts prevent casualties. The effectiveness of seat belts was determined using accident data from the Co-operative Crash Injury Study. Using this effectiveness, the number of casualties prevented by seat belts since 1983 was estimated. This was calculated using the number of car occupant casualties and the observed seat belt wearing rates.

Once it was demonstrated that seat belts are and have been effective at saving lives, an estimate of the possible future savings was made. The potential benefit of raising seat belt wearing rates was estimated, which provides justification for attempting to increase seat belt use.

Having quantified the benefit of increasing seat belt use, the question "who doesn't wear seat belts?" was answered. This will enable targeting of occupants for whom increasing seat belt use would have the greatest effect. Variables which were related to seat belt wearing rates were investigated. The *numbers* of people in different groups who were in accidents and unbelted were also considered. To have the largest effect on casualty numbers, it is these groups that should be targeted.

METHODOLOGY

Sources of data

Co-operative Crash Injury Study (CCIS)

CCIS is an ongoing project which has collected in-depth real world crash data since 1983. Vehicle examinations are undertaken at recovery garages several days after the collision. Car occupant injury information is collected and questionnaires are sent to survivors. Accidents are investigated according to a stratified sampling procedure, which favours cars containing fatal or seriously injured occupants as defined by the British Government definitions of fatal, serious and slight. It also favours newer vehicles. More information about the study is available at www.ukccis.org. CCIS data collected from June 1998 to the present time has been used for this paper.

Heavy Vehicle Crash Injury Study (HVCIS)

HVCIS is an ongoing study which analyses Police fatal accident reports involving at least one large vehicle to identify countermeasures that would have either prevented the collision and/or reduced the severity of the injuries sustained. The project's database contains information on all the pertinent vehicles' crashworthiness performance characteristics and the human factors which were associated with the accident.

On The Spot (OTS)

The OTS accident data collection project started in 2000 and investigates 500 crashes per year. Expert investigators attend the scene of accidents usually within 15 minutes of the incident occurring, using dedicated response vehicles and equipment. OTS investigations allow vital perishable accident data to be gathered, including witness and physical evidence that provides information about the behaviour of the people involved prior to the accident. The project investigates crashes of all severities, involving all vehicle types.

The Department for Transport (DfT) seat belt surveys

The DfT seat belt survey is carried out in geographical areas centred on Crowthorne and Nottingham in England. They are undertaken in April and October each year. TRL staff observe the seat belt use of occupants of stationary vehicles, mainly at junctions controlled by traffic signals. The results allow long-term trends in seat belt wearing to be monitored, since the survey has been carried out in a consistent fashion since 1988. The geographical coverage of the survey is steadily extended by making observations during the summer in two additional survey areas, changed each year to build up a picture of seat belt wearing throughout England. Between 1983 and 1988 seat belt surveys of front seat occupants were carried out, the results of which are summarised by Broughton [1]. Between them these surveys provide the seat belt wearing rates from 1983-2006 which are used in this paper. At the time of writing, the survey results from 2007 were not available and therefore estimates were used.

Effectiveness of seat belts

CCIS records each injury suffered by the casualty, and codes these injuries using the Abbreviated Injury Scale (AIS) [3]. AIS is a threat-to-life scale and every injury is assigned a score, ranging from 1 (minor cuts, bruises etc) to 6 (currently untreatable). The Maximum AIS injury a casualty sustains is termed MAIS.

To determine the effectiveness of seat belts, occupants were selected from CCIS who met the following criteria:

1. 15 years old or greater
2. Known gender, seating position and MAIS
3. Outboard seated occupants
4. The status of lap and diagonal seat belt use known

Children under 15 were excluded to remove any bias caused by children not using suitable child restraints. The final sample included 10,529 car occupants.

For the following analysis, the effectiveness of seat belts was defined as the percent reduction in the chance of an occupant sustaining injury at a given level, compared to the non seat belted condition. The following formula was used [4]:

$$Effectiveness = \frac{(Unbelted\ rate - Belted\ rate)}{Unbelted\ rate}\% \qquad [1]$$

This was used to determine the effectiveness of seat belts in preventing fatal and serious injuries to all car occupants in CCIS. These values were then used in the estimate of the number of casualties prevented by seat belts since 1983. The effectiveness for drivers of different injury severities with and without airbags was also investigated, as well as the difference in effectiveness for front and rear seat passengers.

Casualties prevented by seat belts

In addition to effectiveness, the seat belt wearing rate and the number of car occupant casualties were required to estimate the casualties prevented by seat belts.

The seat belt surveys enabled an "effective seat belt wearing rate" to be calculated, which took into account the wearing rate in different seating positions, and the number of occupants who were sitting in those positions. This could then be used with the estimate of seat belt effectiveness in CCIS (calculated using occupants from all seating positions), and the number of car occupant casualties (which included casualties in all seating positions).

The number of car occupant casualties in Great Britain has been published by the DfT for every year from 1983-2006 in Road Casualties Great Britain (previously Road Accidents Great Britain) [5,6].

Equation 2 was derived which gives the difference in the number of casualties for two different seat belt wearing rates:

$$\Delta C = C_2 - C_1 = \left(\left(\frac{1-\sigma\omega_2}{1-\sigma\omega_1} \right) C_1 \right) - C_1 \qquad [2]$$

where:

- C_1 is the number of casualties of a given severity when the seat belt wearing rate is ω_1
- C_2 is the number of casualties of a given severity when the seat belt wearing rate is ω_2
- σ is the effectiveness of seat belts at preventing casualties of a given severity.

This equation was used to estimate the number of lives saved by seat belts, by setting the seat belt wearing rate $\omega_2 = 0$. This gave equation 3:

$$\Delta C = \frac{C_1}{1-\sigma\omega_1} \qquad [3]$$

where C_1 and ω_1 are the number of casualties and seat belt wearing rate for that year. This calculation was repeated for each year from 1983-2007. The results were summed to give an estimate of the number of casualties prevented by seat belts since 1983.

Effect of increasing seat belt wearing rate

Equation 2 was used to estimate the effect of increasing seat belt use. Setting C_1 as the number of car occupant casualties in 2006, ω_1 as the effective seat belt wearing rate in 2006, and ω_2 as a hypothetical increased seat belt wearing rate, ΔC gave the number of casualties prevented if the seat belt wearing rate in 2006 had been ω_2.

The estimated number of fatal and serious casualties can be expressed in terms of societal cost. The cost savings associated with reducing a fatality to a serious casualty, and a serious casualty to a slight casualty, are given by the DfT [5] and shown in Table 1.

Table 1. Monetary benefit of preventing and reducing fatal and serious casualties

Injury severity	Benefit of preventing injury	Benefit of reducing injury
Fatal	£1,489,450	£1,322,090
Serious	£167,360	£154,460

Who doesn't wear a seat belt?

Survey results and real world data evidence were correlated to describe the characteristics of non-seat belt wearers. The analysis was performed by cross-tabulating seat belt use with variables related to the accident, vehicle or occupant involved in the accident. Some of the variables where there was a statistical relationship (using a chi-squared test to the $p < 0.05$ level) are presented. This begins to paint a picture of the characteristics of occupants who are involved in accidents and are not wearing a seat belt.

RESULTS AND DISCUSSION

Effectiveness of car seat belts

Table 2 gives the effectiveness of seat belts at preventing fatal and serious casualties, calculated using CCIS. This was calculated for all the fatal and serious casualties in CCIS, regardless of seating position or the presence of airbags etc.

Table 2. Seat belt effectiveness for fatal and serious casualties in CCIS

Injury severity	Seat belt effectiveness, σ
Fatal	61%
Serious	32%

Figure 1 shows the seat belt effectiveness at different injury levels for drivers in all types of impacts. It outlines the difference in seat belt effectiveness in vehicles with and without steering wheel mounted airbags.

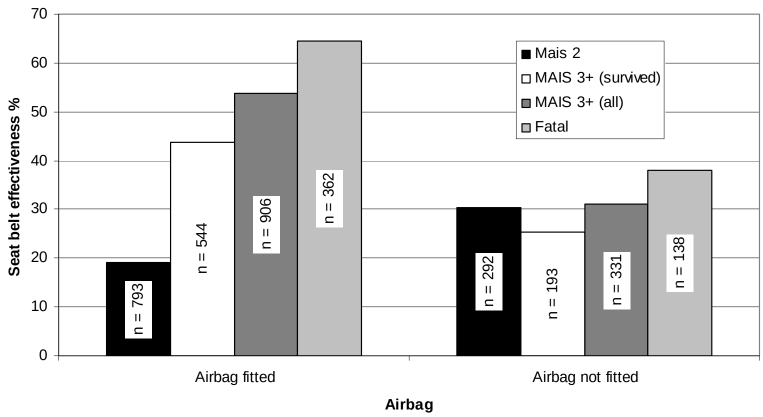

Figure 1. Seat belt effectiveness for drivers

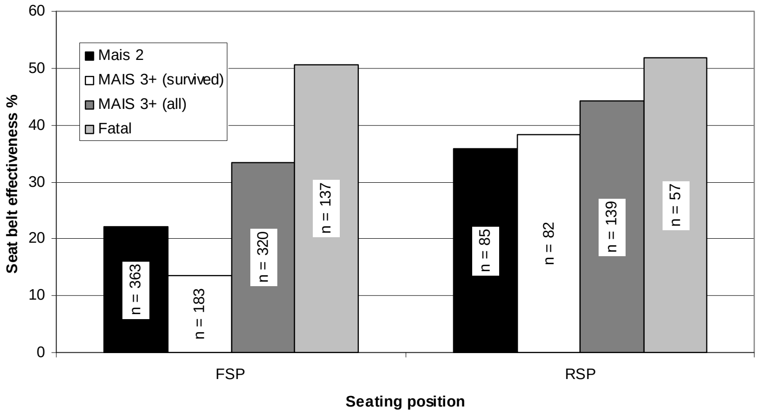

Figure 2. Seat belt effectiveness for passengers

Combining seat belts with steering wheel mounted airbags afforded greater protection to drivers than just wearing a seat belt. There are many other factors that may be associated with this relationship. For example, the drivers with no airbags were typically in older vehicles and therefore would not have benefited from newer vehicle structural improvements or advances to seat belt design. The exact nature of the crashes was not fully investigated and therefore there could be crash severity or impact type differences between older and newer cars that may also skew the results.

Figure 2 shows the differences in seat belt effectiveness for front and rear seat passengers. Seat belts were more effective for rear seat passengers than front seat passengers, although it should be noted that there were a lot more front seat passengers in the sample and their demographics were different to rear passengers. Historically, seat belts in the rear of cars have been identified as being slightly less effective than seat belts in the front. Newer cars in this sample may have improved belt geometry and design in the rear, leading to increased effectiveness.

Casualties prevented by seat belts

Figure 3 shows how the effective seat belt wearing rate varied from 1983-2007. Most of the variation is likely to be caused by differences in the measured wearing rate of rear seat passengers, because of the smaller sample size. The data for 2007 was estimated using the seat belt survey for the previous year.

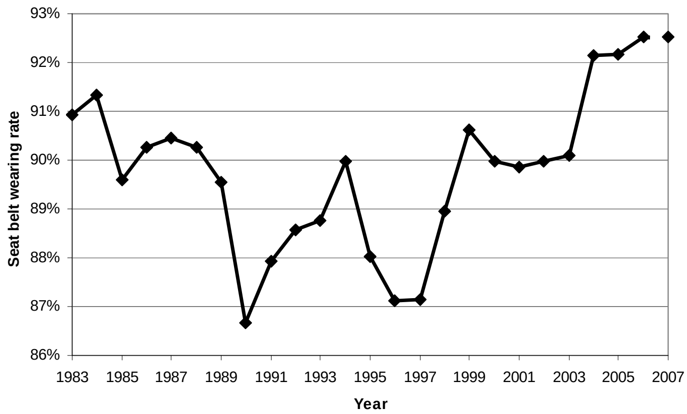

Figure 3. Effective seat belt wearing rate

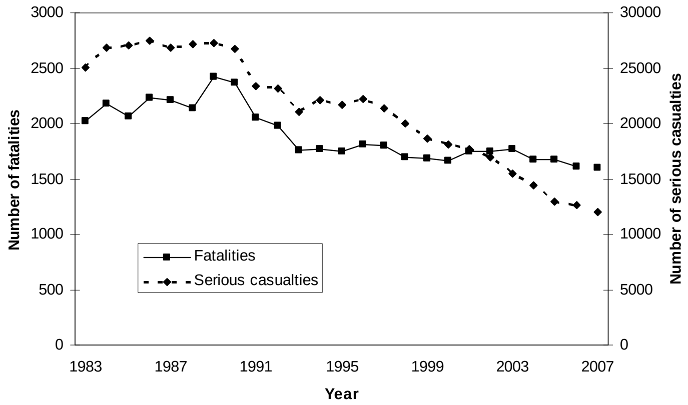

Figure 4. Fatal and serious car occupant casualties

Figure 4 shows the number of car occupant casualties in Great Britain since 1983. The number of fatalities in 2007 was estimated as 1,600, and the number of seriously injured casualties was estimated as 12,000.

The number of casualties prevented each year by seat belts is shown in Figure 5. This was calculated using equation 3, which gives the difference in casualties between a 0% seat belt wearing rate and the effective seat belt wearing rate, shown in Figure 3.

The shape of Figure 5 is very similar to Figure 4 because the seat belt effectiveness was assumed to remain constant, and seat belt wearing rates remained relatively constant over the 25 year period. The result was that the fluctuations in the number of casualties prevented each year mirror the fluctuations in the actual number of casualties. Table 3**Fehler! Verweisquelle konnte nicht gefunden werden.** shows the sum of the fatal and serious casualties estimated to have been prevented over the 25 year period.

Table 3. Total estimate of casualties prevented by seat belts since 1983

Injury severity	Casualties prevented by seat belts
Fatal	57,025
Serious	213,137

It is likely that improvements in restraint systems over 25 years have increased their effectiveness. A typical value for the effectiveness of seat belts in 1983 was about 40% [7]. Assuming a linear rise in effectiveness from 40% in 1983 to 61% in 2007, the estimated number of fatalities prevented was about 41,000.

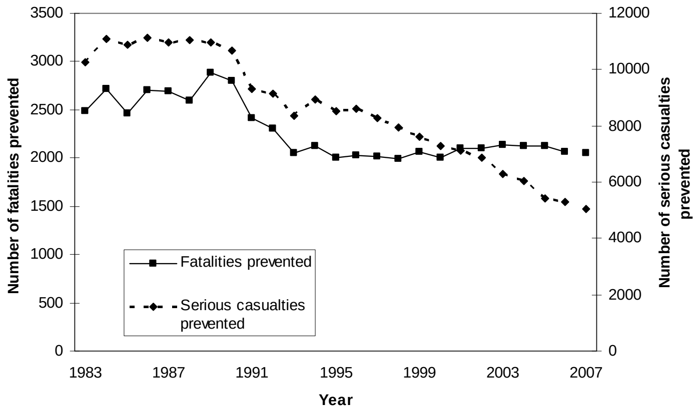

Figure 5. Number of car occupant casualties prevented by seat belts

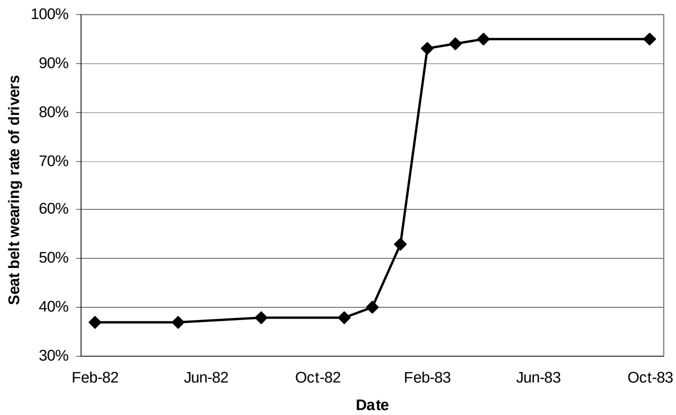

Figure 6. Effect of seat belt legislation on seat belt wearing rates for car drivers

The effect of the seat belt legislation was a rise in seat belt wearing rates from under 40% to over 90%, shown in Figure 6. Using the estimate of effectiveness from Table 2, the estimates of the total numbers of casualties prevented from 1983 to 2007 by this rise are shown in Table 4.

Table 4. Casualties prevented by rise in seat belt wearing rates following introduction of seat belt legislation

Injury severity	Casualties prevented by rise in seat belt wearing rates
Fatal	31,668
Serious	118,218

These models give a lower value for the number of serious casualties prevented than previous estimates. This is because the effectiveness of seat belts for serious casualties, calculated using CCIS, is lower than the effectiveness for preventing fatalities. If the effectiveness for serious casualties was the same as for fatalities (61%), then the number of serious casualties prevented would be estimated at about 680,000.

It should be noted that these equations estimate the casualties prevented by seat belts using only the seat belt wearing rates, seat belt effectiveness, and the number of casualties which occurred. Factors such as any change in driving behaviour for occupants who do / do not wear a seat belt were not taken into account.

The models used in this paper provide estimates of the true number of casualties prevented which, itself, will never be known. But it seems certain that seat belts have saved tens of thousands of lives, and hundreds of thousands of serious casualties since 1983 in the UK alone.

Effect of increasing seat belt wearing rate

Table 5 shows the estimate of the number of casualties that would have been prevented in 2006 if the effective seat belt wearing rate had been higher. It also gives the associated monetary cost saving.

Even a relatively small increase in seat belt wearing rates of about 0.5% would reduce the cost of killed and seriously injured casualties by over £18 million per year. This only considers the benefit to car occupants; large commercial and passenger carrying vehicles were not considered. The purpose of this estimate was to show that there is a very large potential for benefit with relatively small increases in seat belt use.

Table 5. Effect of increasing seat belt wearing rate in 2006

Effective seat belt wearing rate	Casualties prevented		Valuation of casualties prevented
	Fatal	Serious	£ million
92.5%	0	0	0
93.0%	11	28	18.5
94.0%	33	85	56.9
95.0%	55	143	95.3
96.0%	78	200	133.7
97.0%	100	258	172.1
98.0%	122	315	210.5
99.0%	145	373	248.8
100.0%	167	430	287.2

Who doesn't wear a seat belt?

This section details some variables which are strongly related to variations in seat belt wearing rates. The nature of the stratified sampling procedure in CCIS means that the absolute percentages cannot be compared to those from other studies without more detailed weighting, but they can be used to compare trends in the data.

Figure 7 shows a clear relationship between the age of car occupants and seat belt wearing rates. From the age of 10, seat belt use increased with age. This relationship did not hold for children aged 0-9 years, who had relatively high seat belt wearing / child restraint use rates. At this age, it is the attitude of the parents which determines whether the child is wearing a seat belt, although older children aged 10-15 had the lowest seat belt wearing rates of all ages. This is a potential concern as these teenage passengers are frequently driven by slightly older friends or siblings, and these are the young drivers with high crash liability. Non-use of seat belts has been linked to risk-taking [8], so the increase in seat belt wearing rate with age coincides with a reduction in risk-taking behaviour for most drivers.

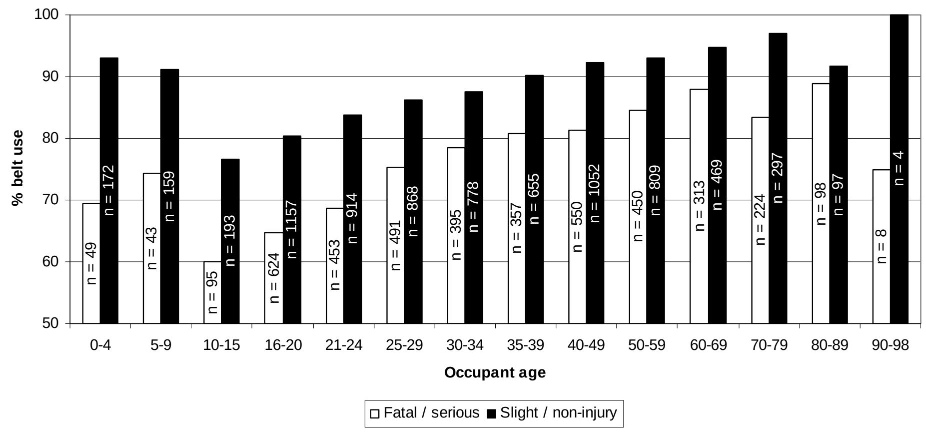

Figure 7. Belt use by occupant age

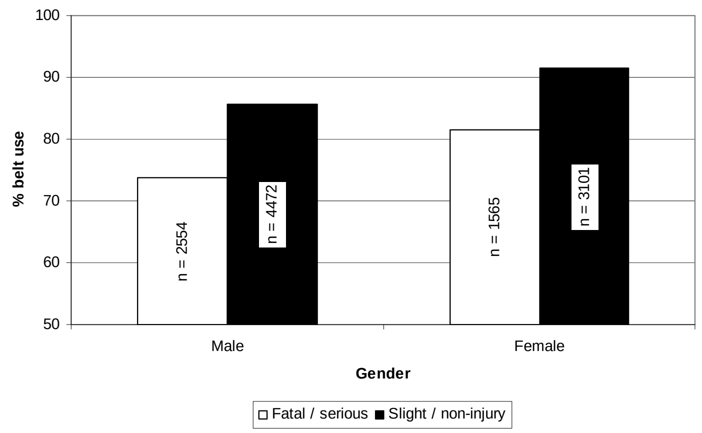

Figure 8. Belt use by gender

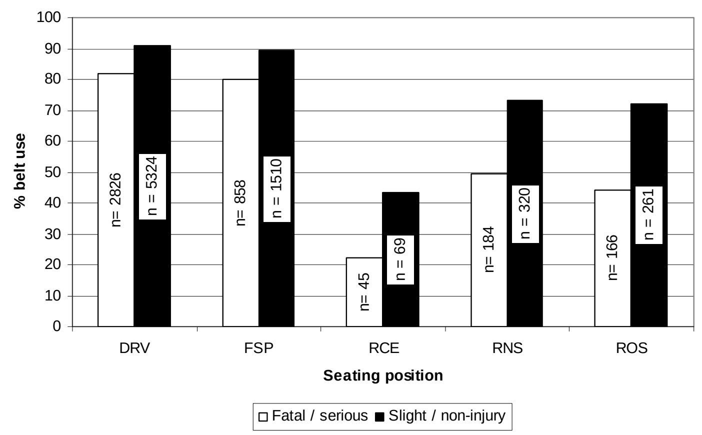

Figure 9. Belt use by seating position

Figure 8 shows that seat belt wearing rates for women were higher than for men. This relationship is seen in all previous literature and seat belt surveys.

Figure 9 shows that one of the most important factors determining seat belt use was the seating position in the car, with rear adult passengers far less likely to wear a seat belt. Other factors play a part here, for example children and young adults are most likely to be rear seat passengers. Also, there is a relationship between the number of occupants in a car and seat belt wearing rates, especially for cars containing young adult males.

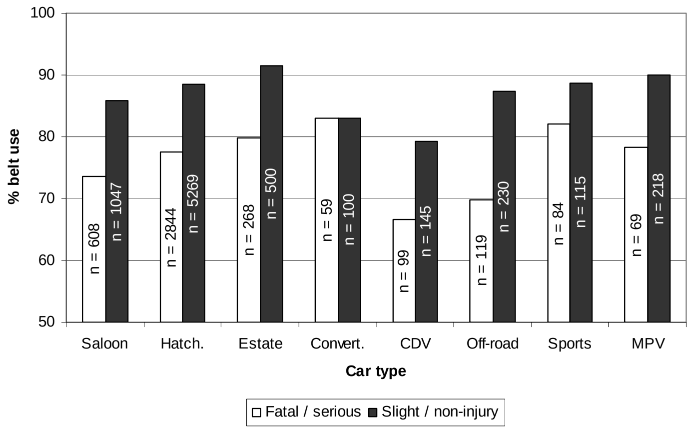

Figure 10. Belt use by vehicle type

Figure 10 shows that the lowest seat belt wearing rates occured in car-derived vans (CDVs). These are the only type of goods vehicle included in CCIS. However, the HVCIS database includes larger goods vehicles, although it only records the seat belt use of fatalities. In HVCIS, the seat belt wearing rate in heavy goods vehicles was 2%, for light goods vehicles it was 35% and for cars it was 80%. The seat belt wearing rate of fatalities would be expected to be lower than average, and seat belt wearing rates in goods vehicles have historically been extremely low.

Figure 11 shows that seat belt wearing rates were lowest in cars aged 12-13 years old. There is a relationship between young people driving older cars [9], and also between the age of vehicle and drivers' socio-economic status, which could both have had an effect here. However, the relationship between the age of the vehicle and seat belt use was not as strong as other variables.

Figure 12 shows that occupants involved in accidents in the early hours of the morning had much lower seat belt wearing rates than occupants in accidents at other times. Young adult males were over-represented at these times, which would account for some of the difference in seat belt wearing rates.

Other variables were investigated and found to have a correlation with seat belt wearing rates. For example, using OTS it was found that company car drivers had relatively low seat belt wearing rates. Wearing rates were also lower in urban areas with low speed limits.

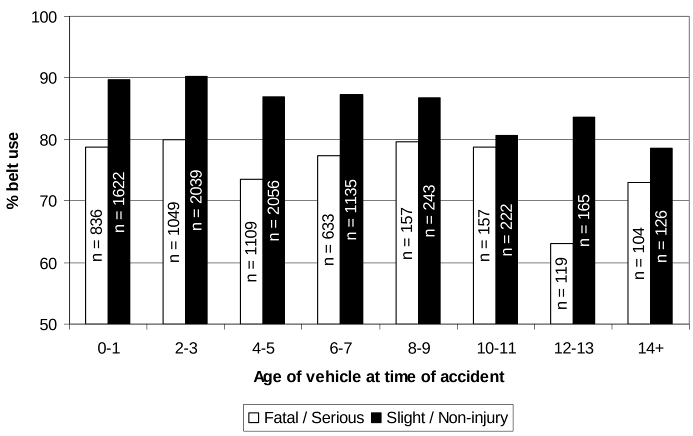

Figure 11. Belt use by age of vehicle

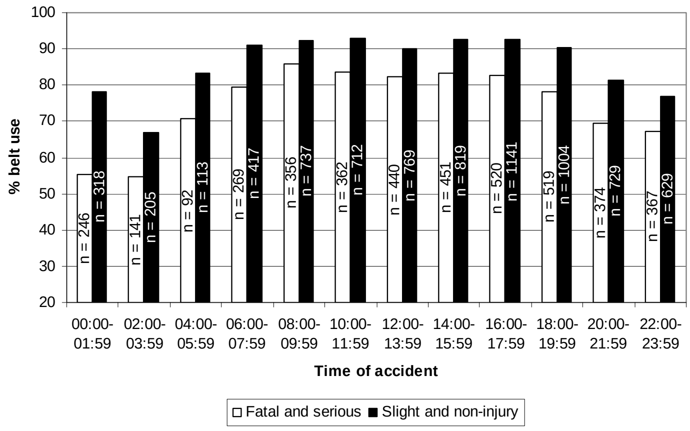

Figure 12. Belt use by time of accident

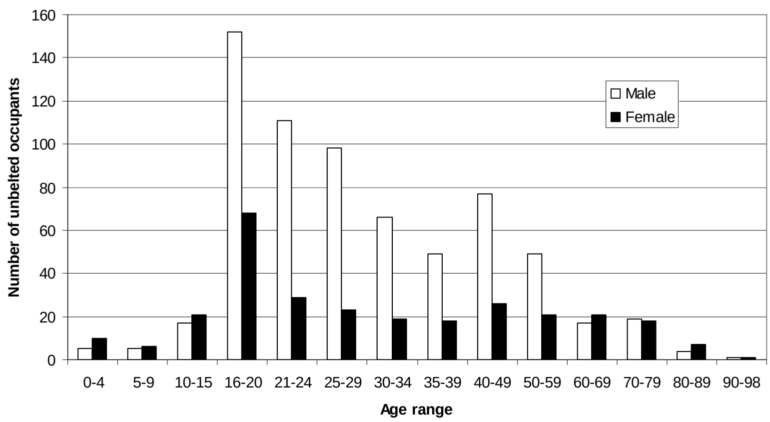

Figure 13. Unbelted killed and seriously injured occupants in CCIS by age and gender, all seating positions

In order to have the largest effect on casualty numbers, it is important to concentrate on the largest groups of occupants who are unbelted and suffer fatal or serious casualties. Figure 13 identifies the number of killed and seriously injured occupants in CCIS who did not wear a seat belt, and groups them by age and gender.

From Figure 13 it is clear that young adult males accounted for a large proportion of occupants killed or seriously injured when not wearing a seat belt. Any seat belt campaign which could improve the wearing rates of young adult males would have a relatively large effect.

Figure 14 shows the age and gender of killed and seriously injured rear seat occupants. Again, in the rear of the car it was young adult males who were the largest group. Although rear seat passengers made up a relatively small proportion (13%) of the casualties in CCIS, their low seat belt wearing rates meant they made up 28% of unbelted casualties.

Figure 13 and Figure 14 show the importance of considering the *number* of unbelted occupants, as well as the seat belt wearing rate. For example, Figure 7 showed that 10-15 year olds had the lowest seat belt wearing rates of all occupants. However, occupants aged 10-15 accounted for relatively few of the occupants not wearing a seat belt. In Figure 14 which only considers rear seat occupants, children aged 10-15 were the 3rd largest group, but this group was much smaller than the 16-20 age group.

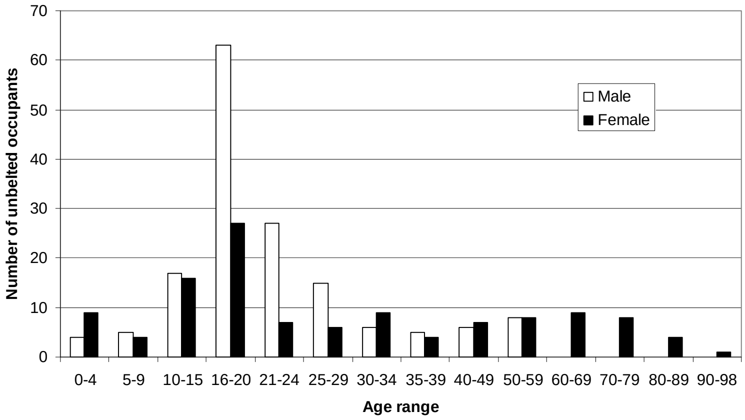

Figure 14. Unbelted killed and seriously injured occupants in CCIS by age and gender, rear seat passengers only

The most important car occupants to target appear to be young adult males, who made up the majority of killed or seriously injured unbelted occupants. Those driving in the early hours of the morning or driving older cars had particularly low seat belt wearing rates, as did those who sat in the rear of the car.

A relation between risk taking behaviour and non-belt use was noted when looking at case studies in OTS. Occupants who were not wearing a seat belt in the OTS database were often in accidents associated with speeding, drink-driving, and other risk-taking behaviour.

CONCLUSIONS

- CCIS was used to determine the effectiveness of car seat belts. For occupants in all seating positions, seat belts were found to be 61% effective at preventing fatalities, and 32% effective at preventing serious casualties. Seat belts were most effective for drivers when used in conjunction with an airbag. Seat belts were also more effective for rear seat passengers than front seat passengers.

- An estimated 57,000 fatalities and 213,000 serious casualties have been prevented by seat belts in the UK since 1983. The rise in seat belt wearing rates due to seat belt legislation has prevented an estimated 32,000 fatalities and 118,000 serious casualties.

- In 2006, if the seat belt wearing rate had been 93% instead of 92.5%, an estimated 11 fatalities and 28 serious casualties may have been prevented. These were valued at £18.5 million.

- Age and gender had a strong relationship with seat belt use. From the age of 10, seat belt wearing rates increased with age, although wearing rates for men were lower than for women. Seat belt wearing rates were much lower for occupants in the rear of the car than for drivers or front seat passengers.

- In CCIS, seat belt wearing rates were lowest for occupants in car-derived vans. From HVCIS it was apparent that seat belt wearing rates in all types of goods vehicle were much lower than those in cars.

- When identifying groups of occupants to target with a potential future safety campaign, it is important to target those who account for a large number of casualties, not just groups with low seat belt wearing rates. It is clear that young adult males account for a very large proportion of occupants who do not wear seat belts. Any seat belt campaign would have the greatest effect on casualty numbers if it could raise seat belt wearing rates of young men.

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This report used accident data from the United Kingdom Co-operative Crash Injury Study (CCIS) collected during the period 1998-2007.

Currently CCIS is managed by TRL Limited, on behalf of the DfT (Transport Technology and Standards Division) who fund the project along with Autoliv, Ford Motor Company, Nissan Motor Company and Toyota Motor Europe. Previous sponsors of CCIS have included Daimler Chrysler, LAB, Rover Group Ltd, Visteon, Volvo Car Corporation, Daewoo Motor Company Ltd and Honda R&D Europe(UK) Ltd.

Data was collected by teams from the Birmingham Automotive Safety Centre of the University of Birmingham; the Vehicle Safety Research Centre at Loughborough University; TRL Limited and the Vehicle & Operator Services Agency of the DfT.

Further information on CCIS can be found at http://www.ukccis.org

The OTS project is funded by the DfT and the Highways Agency. The On The Spot investigations are carried by teams at TRL in Berkshire and the Vehicle Safety Research Centre (VSRC) Loughborough University. The project would not be possible without help and ongoing support from many individuals, especially including the Chief Constables of Nottinghamshire and Thames Valley Police Forces, and their officers.

The views expressed in this report belong to the authors and are not necessarily those of the DfT.

Global Accident Prevention – A road safety initiative of European FIA automobile clubs

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Abstract

In an on-going project since 2005, ADAC has been analyzing accidents documented by the ADAC air rescue service. The knowledge derived from real-life accidents serves as a basis for new test configurations and assessment criteria. In 2007, ADAC began looking into the feasibility of international data collection. The idea of Global Accident Prevention was born. Three European partner clubs have begun pioneering the project (ÖAMTC, ANWB, and RACC).

The aim is to set up an international accident research network to provide a steady stream of information on road accidents. The FIA Foundation supports ADAC in developing and coordinating this initiative.

Introduction

The reduction of the road death toll is a major issue in Europe. The 2001 White Paper on European Transport Policy is an ambitious task for Europe. The first steps towards halving the number of road deaths from 50,000 (2000) to 25,000 (2010) have been successfully taken. With the second and more challenging part until 2010 still being ahead of us, it will be essential to gain maximum knowledge of real-life accidents to effectively implement the improvements in automotive technology, driver training and infrastructure.

Since 2005, as a contribution towards this effort, ADAC has been running a project investigating road accidents documented by ADAC air rescue. The findings on real accidents are used as a basis for new crash test configurations and assessment criteria. Such knowledge can also be used to further develop and improve EuroNCAP procedures.

In 2007 ADAC started to consider cross-border data collection. This gave rise to the idea of a global accident prevention initiative. European automobile clubs operating their own airmed services have pioneered the project (ÖAMTC, ANWB, RACC). The aim is to establish an international accident research network which delivers information on road accidents on an ongoing basis. This initiative of European and worldwide automobile clubs aims to make a major contribution towards improving road safety.

With the FIA Foundation’s support, ADAC works to develop and coordinate the initiative.

Project Structure

In co-operation with the ADAC air rescue service, ADAC accident research has successfully established itself since 2005

The method relies on the initial information from ADAC Air Rescue on registered accidents. This is enhanced with data supplied from the police, experts, fire brigades and hospitals and forensic institutes.

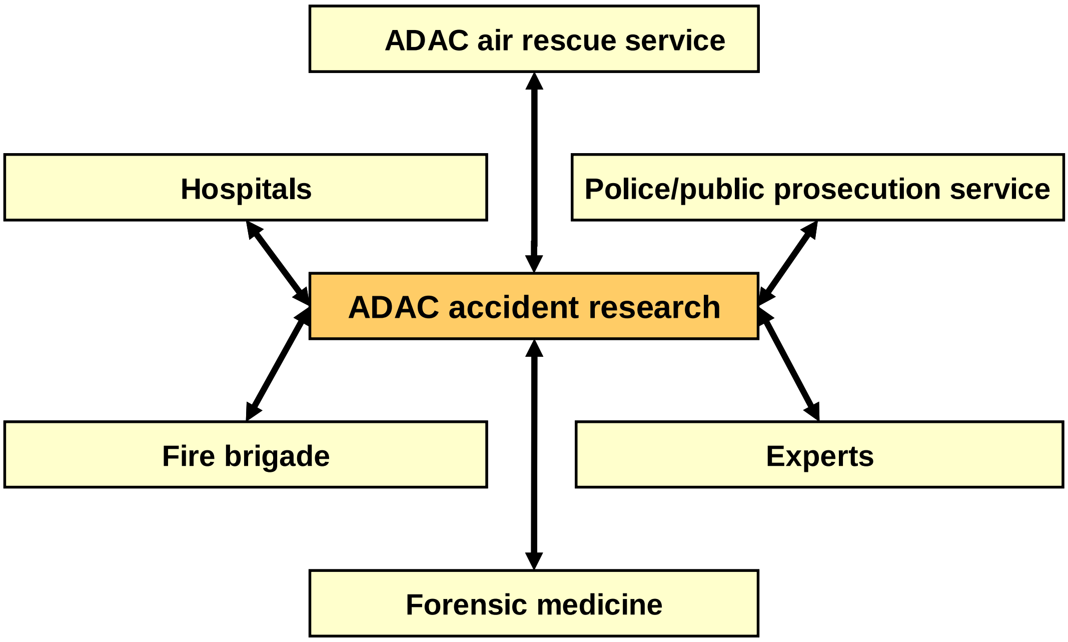

Figure 1: structure of the ADAC accident research

This concept of data collection works efficient and stable. Within the framework of the global accident prevention this methodology of data recording will be implemented on several rescue services in Europe (operated by a FIA club).

In the future the accident investigation will mainly focus on:

- accident prevention measures
- technical rescue in co-operation with fire brigades, associations and manufacturers
- medical/technical research
- accident reconstruction
- active and passive safety issues
- influence of infrastructure
- human factors

These issues will be analysed with the recorded multinational data.

Current Status

The plan is to phase in the selected partner clubs

- ÖAMTC – Austria
- ANWB – Netherlands
- RACC – Spain / Catalonia

aiming at their full integration by December 2008.

Austria: ÖAMTC accident research has started on a strong basis and has provided initial accident data. Six air rescue bases are part of the project. ÖAMTC was able to a large extent to implement ADAC's data concept. The available police data containing key information about the category and type of accident, and the vehicle is currently part of the data set. The approval of ministries and competent government agencies has been obtained permitting the flow of data to be initiated. The data is based on expert opinions and accident reports. Insurers may be potential partner since they could provide vehicle expert opinions. Final discussions are forthcoming. Some hospitals have signalled their willingness to contribute the required clinical data within the framework of medical research projects.

The Netherlands: For a start, ANWB accident researchers propose to cooperate with the Groningen air rescue base. An ANWB "moderator" will be in charge of club coordination and contacting local authorities. The data flow will be set up and organised via the moderator. Government ministries, institutions and agencies need to be contacted and co-opted for the study. Data collection has been set up with the Groningen air rescue crew. The data set is 100% compatible with the ADAC data set and can be transferred to the GAP database without any problems. Data collection is to start in the summer of 2008.

Spain: Several air rescue bases across Spain are proposed to be part of RACC's accident research. Exploratory talks with the competent authorities are under way. A "moderator" will be in charge of club coordination and contacting local authorities. Negotiations about the framework and scope of the project (number of air rescue bases, regions) are being conducted. The data concept will be defined upon conclusion of this phase.

Future development

As the ADAC initiative on global accident research unfolds, we confirm the project targets supported by the FIA Foundation – i.e. the improvement of road safety in Europe by collecting real accident data. We have first results from Austria showing differences in the population of vehicles and thus accident dynamics. Motorway accident patterns are another interesting aspect: Austria has mandatory, Germany advisory speed limits on motorways. The Austrian case volume is still rather low, which is why verified results are not yet available. Although, the outlook is promising. The fact that data has started to flow shows that the implementation of the project is realistic and a follow-up project will build on the success achieved.

Expanding the project structure is an integral part of the work. Discussions are underway to extend data collection to other European countries (e.g.: Hungary) which is an important step towards building a "European Accident Research Club Network".

Relevant Accident Related Factors – Risk and Frequencies of Contributing to Road Traffic Accidents

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Abstract
In the course of the European Project TRACE (Traffic Accident Causation in Europe) an attempt was made to analyse the cause of road traffic accidents from a factors' point of view. By literature review the most important independent risk factors for traffic accidents were identified to be speed, alcohol intake, male gender, young age, cell phone use, and fatigue. However, the impact of an accident related factor also depends on its prevalence in traffic and accidents, respectively. Available to the Partners in the TRACE Project were different accident databases. Causally contributing factors found by accident investigations that are most often coded in accident databases are connected to unadapted speed and inattention. Taking into account the risk increase and the frequency of contribution to accidents the conclusion can be drawn that the most relevant factors for accident causation are: "alcohol", "speed", and "inattention and distraction.

INTRODUCTION

According to Elvik [1], a variety of theories on accident causation exists and up until today no synthesis has emerged. Theories and models are reflecting peoples' views on reality to explain complex relations in simplified ways. The motivation lies in the belief that (every) accident can be prevented, if the causes for this accident can be eliminated. Accident Models shall help to understand the occurrence of traffic accidents and give answers to questions on how and why accidents happen, where and when they take place, and who is involved, and furthermore to find according preventive measures.

Epidemiological studies can reveal risk factors for crashes that increase the chance for an accident to occur or the chance for someone to cause, or just be involved in an accident. Additionally, in-depth accident research identifies factors that contributed to a specific accident and are able to explain the occurrence of the accident. This is done by applying causality to certain factors that led to the accident. Most in-depth accident databases provide a list of factors, from which the investigator can choose the factors that contributed to the accident. Some investigation classifications code key events or triggering factors in addition, to also consider the most important factors, or the last factors, that finally caused the accident in the causal chain in time, respectively.

Of course, usually one factor cannot cause an accident. Most often a combination of contributing factors, forming a sufficient cause, leads to the accident [2,3].

In the course of the European project TRACE, Workpackage3 was concerned with "Types of Factors" to analyse the cause of road traffic accidents from a factors' point of view whereas other work packages were looking at the same event (crash) from a category of road users and types of pre-accident situations angles. Available to the Partners in the TRACE Project were different accident databases. This study is an extraction and a further development on the basis of the work performed for WP3, task 3.1 "Accident related factors" [4].

MATERIAL AND METHODS

In the following a distinction will be made between factors increasing the risk for an accident to occur, called "risk factors" and factors that are thought to be causally contributing to an accident, called "contributing factors". The first factors are derived by statistical methods and the contributing factors

are found by in-depth analysis and collected in databases. A contributing factor can be any event, circumstance, situation, characteristic etc. causally contributing to an accident.
Published studies were screened for their ability to provide adjusted risks for traffic accident occurrence, traffic accident causation and traffic accident involvement of all kinds of factors. Not regarded are risks for special sub-groups (population restriction on certain sites, traffic participants, or mechanisms)., cf. [4].
The relevance of a factor depends on its attributed risk increase but also on its prevalence in traffic and accidents, respectively.
Therefore database analysis on the contributing factors' frequency of occurrence in the accident databases available to the Project partners was performed.
These databases covered the at least parts of the following catchment areas: Czech Republic, France (North), France (South), Germany, Germany (north and east), Great Britain, Great Britain (England (Midlands and Southeast)) Greece (South), Italy, Spain, Spain (Catalonia), and Spain (central). The accident samples requested from the Partners should cover all kinds of accidents in their databases (no restrictions in criteria) and should contain all collected accidents of the year 2004, if this was feasible.
To compare absolute frequencies of factors between databases is not feasible as different sampling and coding procedures and variable categories are used (see Annex 2 and [4]). Therefore keywords were developed that cover meaningful concepts for the contributing factors in the different databases. Keywords were: alcohol, attention, careless, drugs, exceeding speed limit, experience, health status, inappropriate speed, road layout, road surface condition, safety distance, traffic offence (priority), vehicle condition, vigilance, visibility and view obstruction, weather condition. Sometimes re-grouping of aggregated data results was performed for providing comparability.
The absolute frequencies of the contributing factors were set in relation to the sum of all applied factors, to get an idea on how frequently this factor is occurring in the data material of the database. For this relative share of the contributing factors the limits of the 95% Confidence interval were compared to the expected share of the factors. Thus "significant" overrepresented and underrepresented factors for each database were defined (see Annex 3). The "overrepresentation" is expressed as the relation of the actual relative share to the expected share. The overrepresented factors either cover a range of different underlying preceding factors or, these factors are frequently contributing to accidents.
Relevance is defined by regarding risk increase and frequency of occurrence by pragmatic combining results from literature review and database analysis.

RESULTS

By literature review the most important independent risk factors for traffic accidents in general (not for a specific sub-populations of traffic participants or types of accidents) were identified to be "speed", "alcohol intake", "male gender", "young age", "cell phone use", and "fatigue", see Annex 1.
From the database evaluations it can be seen that the most important factors contributing to accidents are "speed" and "inattention/distraction", followed by "alcohol" and "safety distance", see also Annex 3. Table 1 lists only the most frequently coded factors in each database where a keyword has been applicable. E.g. in the French (North) data "inappropriate reaction" was the most frequent factor but no keyword was applicable that would be found in other databases as well.
In a very high share the most frequent factors are related to the individual traffic participant. Frequencies indicate that the vehicle in terms of maintenance or mechanical failures only seldom contributes to accidents (see also Annex 3). Also, apart from adverse weather conditions and visibility restrictions, the environmental influences are not often coded by accident investigators.

Table 1: List of the most frequent contributing factor in each database

Database, all accidents (2004, except indicated)	country	Contributory factor reported in accident database	key word	relative overrepresentation and 95% Confidence Interval	% of accidents
GIDAS_in-depth	Germany (north and east)	inappropriate speed	inappropriate speed	12,3 [8,4;22,0]	12,5
Czech_national (2001-2004)	Czech Republic	visibility	visibility and view obstruction	9,4 [9,1;15,1]	37,5
BASt_Germany_national	Germany	unadopted speed in other cases	inappropriate speed	12,2 [12,0;18,4]	28,0
CIDAUT_in-depth	Spain (central)	Other distraction in/on vehicle	attention	12,3 [1,1;1284,3]	35
Stats_GB_national (2005)	Great Britain	Failed to look properly	attention	24,3 [23,5;31,7]	31,5
SISS_Italy_in-depth	Italy	Driving with exceeding speed	exceeding speed limit	18,0 [16,1;25,5]	8,8
INRETS_in-depth	France (South)	Automatic driving: low attention level due to high experience of the trip (or its monotony)	attention	7,1 [2,2;40,7]	46,5
OTS_in-depth	Great Britain (Midlands and Southeast)	Inattention	attention	6,8 [4,7;15,1]	12,6
LAB_in-depth (1990-2004)	France (North)	Excessive speed	exceeding speed limit	5,8 [3,9;14,0]	33,8
IDIADA_Catalonia_national	Spain (Catalonia)	Inappropriate speed for conditions on the road	inappropriate speed	4,6 [4,3;9,3]	7,1
CIDAUT_Spain_national	Spain	Distraction	attention	4,6 [4,5;8,9]	37,7
HIT_in-depth	*Greece (South)*	*Excessive speed*	*exceeding speed limit*	*5,2 [0,6;1584,0]*	*41*

DISCUSSION

Some factors for accident causation are only found as contributing factors represented in accident databases as contributing factors but not as risk factors. This might be because the factor bears a risk for an accident of nearly reaching 100% or already indicating the occurrence of an accident (like tyre blow out or animals) meaning that if the factor was present then an accident occurred. The other way round some factors are only found as risk factors but are never regarded as causal contributing factor like e.g. gender. Male gender bears a higher risk for accidents, but is not regarded as a causal contributing factor for an accident. Here the risk factor has to be seen as an indicator for certain contributing factors like e.g. speeding, drunk driving and risk taking behaviour.

Comparing the results from different databases is not a trivial task due to different levels of detail and the implications and coding instructions for different factors as well as on the sample criteria the databases cover. Therefore attempts of harmonizing databases across Europe (like e.g. EU-Project SafetyNet, ERSO) should be encouraged. By applying keywords and setting the share of coded factors in relation to the expected share of factors if they were distributed at random gives an idea of the relevance of contributing factors across the selected countries in Europe. Still, speeding and inattention have to be regarded as the most relevant factors. Also at high ranks in the databases are alcohol and safety distance. The factors with a high risk potential like cell phone use [5] might bear an elevated risk for an accident, but the frequency of those factors of contributing to accidents lies either in the lower ranges, or are not covered by the coding structures of the databases.

Taking into account the findings for risk increase (from literature) and frequency of contribution to accidents (from database analysis) the conclusion can be drawn that the most relevant factors for accident causation are: alcohol, speed, and inattention (and distraction).

Those results presented give indications where to set focus on preventive measures not from an environmental or vehicle point of view, except active safety systems like e.g. mandatory intelligent speed adaptation systems, but transfers the responsibility to the individual traffic participant. In detail it implies suggestions covering: more controls and restrictions in alcohol and speed, law enforcement, and alteration of individual behaviour, which could be achieved by education and licensing modalities. Still, the human and society, respectively, is the one developing the roadway system, building vehicles, and participating in traffic. The Human is the one who can avoid accidents. In actual accidents a helping hand from the vehicle and the environment could have avoided the Human from failing in his driving tasks [6]. Therefore in-depth accident research and database coding systems need constant improvement. Traffic accident causation analysis by in-depth investigations has to be improved in the future to find countermeasures from an environmental, traffic system related, infrastructural or vehicle point of view and not by focussing only on the individual. In TRACE e.g. Work Package 5 [6] provides a systematic for analysing accidents more comprehensively.

ACKNOWLEDGEMENTS

The Trace Partners have access to national and in-depth databases. The results presented in this report are based on the work performed by the according organisations keeping the databases.
No guarantee can be given on the correctness of the interpretations of the results. The conclusions drawn might not reflect the views of the organisations and partners, respectively.

The OTS project is funded by the UK Department for Transport and the Highways Agency. The project would not be possible without help and ongoing support from many individuals, especially including the Chief Constables of Nottinghamshire and Thames Valley Police Forces and their officers. The views expressed in this work belong to the authors and are not necessarily those of the Department for Transport, Highways Agency, Nottinghamshire Police or Thames Valley Police.

STATS 19: National Accident Data for Great Britain are collected by police forces and collated by the UK Department for Transport. The data are made available to the Vehicle Safety Research Centre, Ergonomics and Safety Research Institute, at Loughborough University by the UK Department for Transport. The Department for Transport and those who carried out the original collection of the data bear no responsibility for the further analysis or interpretation of it.

In the early 1990s, the LAB (Laboratoire d'Accidentologie de Biomécanique et de comportement humain PSA Peugeot Citroën – Renault) pooled resources with the state-funded INRETS (Institut National de REcherche sur les Transports et leur Sécurité) in a common active safety research program – VSR (Véhicule et Sécurité Routière). 4 teams of investigators were called out to injury accident scenes by the emergency services to collect real-time crash data (approximately 60 accidents per team per annum). In 1999, at the end of this joint program, the two partners chose different but complementary directions. The LAB began to evaluate the effectiveness of new safety systems, whereas the INRETS continued developing its driver failure model. The LAB has since adopted this model and included it in the ongoing in depth accident investigation program.

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Annex 1

Result from literature review on risk factors for traffic accidents (risk for individual crash involvement, causation, or for general crash occurrence)

possible risk Factor	result from risk studies found by literature review
Speed	**enough evidence for increased risk at higher speeds**
Alcohol	**enough evidence for increased risk for crashes**
indicators for fatigue	**enough evidence for increased risk for crashes**
gender/male	**enough evidence for increased risk for crashes (esp at fault)**
Cell phone use	**enough evidence for increased risk (hand hold and hands-free)**
Age	higher risk for young drivers, contradicting results for old drivers
Variance of speed	tendency for increased risk
Anxiety	tendency for increased risk
depression	tendency for increased risk
stress	tendency for increased risk
rain	tendency for increased risk
urban area (vs rural)	tendency for increased risk
Poor road user eyesight	tendency for increased risk
foreign driver	tendency for increased risk
poverty	tendency for increased risk
Benzodiazepines	tendency for increased risk, especially for long-acting B. and during first weeks of use
low education level	tendency for increased risk
Poly-drug use	low evidence, hints for increased risk
curves	low evidence, hints for increased risk
carrying passengers	low evidence, hints for increased risk
vehicle technical defects	low evidence due to sparse studies, hints for lack of mainentance (defective brakes) as risk for large commercial trucks
road condition	low evidence due to sparse studies, tendency for increased risk on wet and slippery condition
vehicle colour	low evidence due to study quality, hints for preventive effect of light colours
Other drugs	low evidence due to sparse studies, mixed effects
number of lanes	low evidence due to sparse studies, mixed effects
Medicinal drugs	not enough evidence except Benzodiazepines
traffic volume	contradicting results, hints for increased risk
night/day	contradicting results
Cannabis	contradicting results, no prove for increased (or decreased) risk

Annex 2

Information on database coding concerning "contributing factors"
Germany national data provide a list of 83 factors and at maximum 3 factors can be applied.
Great Britain national data provide a list of 77 factors and at maximum 6 factors can be applied.
Spain national data provide a list of 13 factors and an unlimited number of factors can be applied.
Czech national data provide a list of 42 factors and 6 factors can be applied.
Catalonia national data provide a list of 47 factors and multiple factors can be applied.
Great Britain in-depth data provide a list of 54 factors and multiple factors can be applied.
Spain in-depth data provide a list of 54 factors and multiple factors can be applied.
Greece in-depth data provide a list of 20 factors and multiple factors can be applied.
France (South) in-depth data provide a list of 61 factors and multiple factors can be applied.
France (North) in-depth data provide a list of 66 factors and multiple factors can be applied.
Germany in-depth data provide a list of 79 factors and 1 factor is applied.
Italy in-depth data provide at maximum 41 factors and at maximum 3 factors can be applied.
In addition Czech national and France (North) and Great Britain in-depth provide a second dimension of coding precipitating factors and causes respectively.

Annex 3

Contributing factors with significant (95% Confidence interval limits of relative share higher or lower than expected share) over- and under-representation in databases

List of Factors with over-representation in corresponding database

Rank in corres-ponding database	Causation factors /Contributing factors	relative share (in %)	95% CI lower limit	95% CI upper limit	expected share (in %)	Relative Over-represen-tation
1	Failed to look properly	31,5	31,3	31,8	1,3	24,3
1	Driving with exceeding speed	24,3	23,6	25,0	1,4	18,0
1	observing right of way	19,7	17,8	21,8	1,3	15,6
2	Careless driving	20,6	20,0	21,3	1,4	15,3
2	Failed to judge other persons path/speed	17,8	17,6	18,0	1,3	13,7
3	Careless, reckless, in a hurry	16,1	15,9	16,3	1,3	12,4
1	1.5. Distraction Other (specify).	22,9	11,1	40,1	1,9	12,3
2	3.8. Not obeying STOP sign.	22,9	11,1	40,1	1,9	12,3
1	crossing intersection	26,3	25,8	26,8	2,1	12,3
2	inappropriate speed	15,5	13,8	17,4	1,3	12,3
1	13 inappropriate speed in other cases	14,7	14,6	-	1,2	12,2
2	49 Other mistakes made by driver	14,2	-	-	1,2	11,8
4	Poor turn/manoeuvre	14,9	14,8	15,1	1,3	11,5
5	Loss of control	14,4	14,2	14,6	1,3	11,1
6	Going too fast for conditions	11,6	11,4	11,8	1,3	8,9
3	14 Insufficient safety distance (Other causes leading to a traffic accident should be allocated to the respective positions, such as speed, overfatigue, etc.)	10,0	-	-	1,2	8,3
3	Driving without keeping safety distance	10,5	10,1	11,1	1,4	7,8
4	28 Failure to observe the traffic signs regulating the priority	9,4	-	-	1,2	7,8
3	3.1. Speeding.	14,3	5,1	30,3	1,9	7,7
1	wet	18,2	18,0	18,4	2,4	7,6
7	Slippery road	9,7	9,5	9,8	1,3	7,4
8	Pedestrian failed to look properly	9,3	9,1	9,4	1,3	7,1
1	Automatic driving: low attention level due to high experience of the trip (or its monotony)	11,6	7,3	17,3	1,6	7,1
1	Inappropriate reaction (panic, exaggerated movements…)	10,3	8,9	11,9	1,5	6,8
1	Inattention	12,6	10,9	14,4	1,9	6,8
2	Carelessness, reckless or thoughtless	12,2	10,6	14,0	1,9	6,6
3	other mistakes by the driver	8,1	6,8	9,6	1,3	6,4
4	5.1. Tiredness.	11,4	3,4	26,7	1,9	6,2
2	under influence of alcohol	14,4	-	-	2,4	6,1
2	Excessive speed	8,7	7,4	10,2	1,5	5,8
4	safety distance	7,2	6,0	8,6	1,3	5,7
9	Following too close	7,4	7,2	7,5	1,3	5,7
5	35 Mistakes made when turning	6,8	6,7	6,8	1,2	5,6
3	Alcohol impairment	8,2	6,9	9,6	1,5	5,4
10	Sudden braking	7,0	6,8	7,1	1,3	5,4
4	Wet road surface	8,0	6,8	9,5	1,5	5,3
2	Rigid attachment to the right of way status	8,7	5,0	13,9	1,6	5,3
3	Atypical manoeuvres from other users	8,7	5,0	13,9	1,6	5,3
1	Excessive speed	25,9	12,1	46,3	5,0	5,2
3	Lack of judgement of own path	9,3	7,9	11,0	1,9	5,0
2	Inappropriate speed for conditions on the road	9,8	9,5	10,2	2,1	4,6
1	Distraction.	35,2	-	-	7,7	4,6
4	Excessive speed	8,2	6,8	9,8	1,9	4,4
2	Disobeying a circulation order.	32,7	32,5	33,0	7,7	4,3
5	turn	5,3	4,2	6,5	1,3	4,2
11	Impaired by alcohol	5,4	5,2	5,5	1,3	4,1
5	Looked but did not see	7,4	6,1	8,8	1,9	4,0
12	Learner/Inexperienced driver	5,1	5,0	5,2	1,3	3,9
6	In a hurry	7,2	5,9	8,6	1,9	3,9
13	Exceeding speed limit	5,0	4,8	5,1	1,3	3,8
4	Driving without respecting the "STOP" sign	5,0	4,7	5,4	1,4	3,7
7	Failure to judge others persons path or speed	6,8	5,6	8,2	1,9	3,7
6	01 Influence of alcohol	4,4	4,3	4,4	1,2	3,6
3	at night, with public lighting - undeteriorated due to weather conditions	8,5	8,4	8,7	2,4	3,6
5	Driving without respecting the "GIVE WAY" sign	4,8	4,4	5,1	1,4	3,5
4	Temporal inconvenience for visibility (sun, other vehicle)	5,8	2,8	10,4	1,6	3,5
3	turning right	7,5	7,2	7,8	2,1	3,5
6	ignoring the traffic	4,2	3,3	5,3	1,3	3,3
4	at night, without public lighting - undeteriorated due to weather conditions	7,8	7,6	7,9	2,4	3,3
14	Careless, reckless or in a hurry	4,2	4,1	4,3	1,3	3,2
15	Aggressive driving	4,1	4,0	4,3	1,3	3,2
16	Disobeyed Give Way or Stop sign	3,9	3,8	4,0	1,3	3,0
4	other	6,3	6,1	6,6	2,1	3,0
5	stopped	6,3	6,1	6,6	2,1	3,0
17	Swerved	3,8	3,7	3,9	1,3	2,9
7	11 Violation of the rule of driving on the right side	3,4	3,4	3,5	1,2	2,9
5	Visibility limited by infrastructure (road equipment, vegetation and buildings)	4,6	2,0	8,9	1,6	2,8
8	Failed to look	5,1	4,0	6,3	1,9	2,7
8	37 Mistakes made when entering the flow of traffic (e.g. from premises, from another part of the road or when starting off the edge of the road) Improper behaviour towards pedestrians	3,2	3,1	3,2	1,2	2,6
5	Poor experience	3,9	3,0	5,0	1,5	2,6
6	Surroundings obscured by infrastructure or roadside element or road geometry	3,9	3,0	4,9	1,5	2,6

6	Automatic driving: low attention level due to high experience of the manoeuvre	4,0	1,7	8,2	1,6	2,5
7	Choose of a too high vehicle speed for the situation	4,0	1,7	8,2	1,6	2,5
9	89 Other causes (list and briefly describe)	3,0	2,9	3,0	1,2	2,5
6	Alcohol	3,3	3,0	3,6	1,4	2,5
5	influenced by action of other road traffic participant	5,8	5,7	5,9	2,4	2,4
6	by day - deteriorated due to weather conditions (fog, snowfall, rainfall etc.)	5,6	5,5	5,8	2,4	2,4
18	Vision affected by parked vehicle	3,1	3,0	3,2	1,3	2,4
6	turning left	5,0	4,7	5,2	2,1	2,3
19	Other	3,0	2,9	3,1	1,3	2,3
20	Road layout	2,8	2,8	2,9	1,3	2,2
7	Crossing an intersection	4,7	4,4	4,9	2,1	2,2
21	Failed to judge vehicles path/speed	2,8	2,7	2,9	1,3	2,2
7	LZA, police officers	2,7	1,9	3,6	1,3	2,1
22	Pedestrian masked when crossing	2,7	2,6	2,8	1,3	2,1
7	Roadside shoulders not driveable (step, bank, trees…)	3,1	2,3	4,1	1,5	2,0
7	rainfall	4,8	4,7	4,9	2,4	2,0
7	Driving without giving the priority to the vehicle coming from the right	2,7	2,5	3,0	1,4	2,0
8	Careless	2,7	2,4	3,0	1,4	2,0
10	10 Use of wrong carriageway (or lane) or unlawful use of other parts of the road	2,4	2,3	2,4	1,2	2,0
8	rush hours	4,0	3,8	4,3	2,1	1,9
9	crossing the road outside the intersection	3,9	3,7	4,2	2,1	1,9
8	pedestrian at other places	2,3	1,6	3,2	1,3	1,8
23	Junction overshoot	2,4	2,3	2,4	1,3	1,8
3	Inadequate velocity.	13,9	13,7	14,1	7,7	1,8
11	73 Rain	2,1	2,1	2,1	1,2	1,8
9	turning, reversing	2,2	1,5	3,1	1,3	1,7
9	Following too close	3,2	2,4	4,3	1,9	1,7
10	Aggressive driving	3,2	2,4	4,3	1,9	1,7
12	72 Snow, ice	2,1	2,0	2,1	1,2	1,7
8	Poor road surface	2,5	1,8	3,4	1,5	1,7
10	wrong lane	2,1	1,4	2,9	1,3	1,6
13	36 Mistakes made when making U-turn or 33, 40) reversing	2,0	1,9	2,0	1,2	1,6
9	Entering in the traffic flow	2,2	2,0	2,5	1,4	1,6
24	Dazzling sun	2,1	2,0	2,1	1,3	1,6
9	Inappropriate speed (related to weather, road surface, infrastructure…)	2,4	1,7	3,3	1,5	1,6
10	Mood (stress, preoccupation, anger…)	2,3	1,7	3,2	1,5	1,5
11	alcohol	1,9	1,3	2,8	1,3	1,5
12	other causes	1,9	1,3	2,8	1,3	1,5
8	rainfall beginning, slight rainfall	3,6	3,5	3,7	2,4	1,5
25	Distraction in vehicle	2,0	1,9	2,0	1,3	1,5
26	Junction restart	1,9	1,8	2,0	1,3	1,5
10	incorporation to traffic	3,1	2,9	3,3	2,1	1,5
14	42 at other places	1,8	1,7	1,8	1,2	1,5
27	Vision affected by road layout	1,8	1,7	1,8	1,3	1,4
28	Failed/Misleading signal	1,8	1,7	1,8	1,3	1,4
29	Impaired by alcohol	1,7	1,7	1,8	1,3	1,3
30	Disobeyed traffic signal	1,7	1,7	1,8	1,3	1,3
31	Rain, sleet, snow or fog	1,7	1,7	1,8	1,3	1,3
11	Impairment through alcohol	2,5	1,7	3,4	1,9	1,3
10	Converting the direction or reversing	1,8	1,6	2,0	1,4	1,3
11	overtaking on the right	2,8	2,6	3,0	2,1	1,3
15	64 without paying attention to the traffic	1,5	1,5	1,6	1,2	1,3
11	Incorrectly turning on the left	1,7	1,5	2,0	1,4	1,3
16	31 Failure to observe the traffic control by policemen or traffic lights (except pos. 39)	1,5	1,5	1,6	1,2	1,3
9	glaze, hardened snow - unsprinkled	3,0	2,9	3,1	2,4	1,3
32	Nervous, uncertain or panic	1,6	1,6	1,7	1,3	1,3
17	12 and exceeding at the same time the speed limit	1,5	1,5	1,5	1,2	1,2
10	by day - deteriorated (dawn, dusk)	2,7	2,6	2,8	2,4	1,1
33	Distraction outside vehicle	1,5	1,4	1,5	1,3	1,1
34	Deposit on road	1,5	1,4	1,5	1,3	1,1
18	27 Failure to observe the rule "right has priority over left"	1,3	1,3	1,4	1,2	1,1

List of Factors with under-representation in corresponding database

Rank in corres-ponding database	Causation factors /Contributing factors	relative share (in %)	95% CI lower limit	95% CI upper limit	expected share (in %)	Relative Under-represen-tation
64	lighting regulations	0,0	0,0	0,2	1,3	0,0
65	defects lighting	0,0	0,0	0,2	1,3	0,0
66	defects steering	0,0	0,0	0,2	1,3	0,0
67	defects towing device	0,0	0,0	0,2	1,3	0,0
68	on crossings	0,0	0,0	0,2	1,3	0,0
69	playing in the road	0,0	0,0	0,2	1,3	0,0
70	leaves, clay	0,0	0,0	0,2	1,3	0,0
71	state of road	0,0	0,0	0,2	1,3	0,0
72	road signs	0,0	0,0	0,2	1,3	0,0
73	street lighting	0,0	0,0	0,2	1,3	0,0
74	guarding of level crossings	0,0	0,0	0,2	1,3	0,0
75	fog	0,0	0,0	0,2	1,3	0,0
76	side wind	0,0	0,0	0,2	1,3	0,0
77	storm, thunder-storm	0,0	0,0	0,2	1,3	0,0
78	unguarded road works	0,0	0,0	0,2	1,3	0,0
79	(domestic) animal on road	0,0	0,0	0,2	1,3	0,0
49	Person hit wore dark or inconspicuous clothing	0,0	0,0	0,3	1,9	0,0
50	Defective lights or signals	0,0	0,0	0,3	1,9	0,0
51	Road works at site	0,0	0,0	0,3	1,9	0,0
52	High winds at site	0,0	0,0	0,3	1,9	0,0
53	Glare from head lights	0,0	0,0	0,3	1,9	0,0
54	Failure to see pedestrian in blind spot	0,0	0,0	0,3	1,9	0,0

83	58 Overfatigue	0,0	0,0	0,0	1,2	0,0
47	not respecting police indications	0,0	0,0	0,0	2,1	0,0
82	79 Insufficiently secured railway crossings	0,0	0,0	0,0	1,2	0,0
67	Absent/poor blinker or stop light	0,0	0,0	0,0	1,4	0,0
68	Absent/poor cehicle arrangement for disabled people	0,0	0,0	0,0	1,4	0,0
69	Driving with dazzling light against other vehicle	0,0	0,0	0,0	1,4	0,0
70	Falling down from vehicle for sudden opening door	0,0	0,0	0,0	1,4	0,0
71	Getting on a moving vehicle	0,0	0,0	0,0	1,4	0,0
72	Misuse of towing linking system	0,0	0,0	0,0	1,4	0,0
73	Stopped vehicle without the right sign	0,0	0,0	0,0	1,4	0,0
74	Walking in the wrong direction	0,0	0,0	0,0	1,4	0,0
42	attempt of suicide, suicide	0,0	0,0	0,0	2,4	0,0
46	getting into or out of the vehicle	0,0	0,0	0,0	2,1	0,0
45	rear lights defect	0,0	0,0	0,0	2,1	0,0
44	front lights defect	0,0	0,0	0,0	2,1	0,0
77	Defective mirrors	0,0	0,0	0,0	1,3	0,0
66	Vehicle	0,0	0,0	0,1	1,4	0,0
81	78 Insufficient road lighting	0,0	0,0	0,0	1,2	0,0
42	walking through an emergency zone	0,0	0,0	0,0	2,1	0,0
43	repairing a vehicle	0,0	0,0	0,0	2,1	0,0
80	54 Towing equipment	0,0	0,0	0,0	1,2	0,0
41	lost wheel	0,0	0,0	0,1	2,1	0,0
79	57 Influence of other intoxicating substances (e.g. drugs, narcotics)	0,0	0,0	0,0	1,2	0,0
78	61 on pedestrian crossings without control by policemen or traffic lights	0,0	0,0	0,0	1,2	0,0
77	77 Irregular condition of traffic signs or installations	0,0	0,0	0,0	1,2	0,0
62	Crashing pedestrian with the load	0,0	0,0	0,1	1,4	0,0
63	Going out from driveway without careless	0,0	0,0	0,1	1,4	0,0
64	Incorrectly crossing on footpath regulated by traffic lights or by policeman	0,0	0,0	0,1	1,4	0,0
65	Overtaking a stooped vehicle for the pedestrian priority on the pedestrian crossing	0,0	0,0	0,1	1,4	0,0
13	State of the signals.	0,1	0,1	0,2	7,7	0,0
59	Coming out from the carriageway	0,0	0,0	0,1	1,4	0,0
60	Holes	0,0	0,0	0,1	1,4	0,0
61	Wheeler detaching	0,0	0,0	0,1	1,4	0,0
75	59 Other physical or mental faults	0,0	0,0	0,0	1,2	0,0
76	85 Road construction site on carriageway not or not sufficiently secured	0,0	0,0	0,0	1,2	0,0
40	brakes defect	0,0	0,0	0,1	2,1	0,0
39	standing on the emergency zone on the right	0,1	0,0	0,1	2,1	0,0
41	spilt oil, petroleum	0,1	0,0	0,1	2,4	0,0
12	Working.	0,2	0,2	0,2	7,7	0,0
57	Falling down for going down by moving vehicle	0,0	0,0	0,1	1,4	0,0
58	Working on the the roadway with the right sign	0,0	0,0	0,1	1,4	0,0
38	overload	0,1	0,0	0,1	2,1	0,0
74	53 Steering mechanism	0,0	0,0	0,0	1,2	0,0
37	standing on the emergency zone on the left	0,1	0,0	0,1	2,1	0,0
55	Falling down from vehicle for incorrectly position	0,0	0,0	0,1	1,4	0,0
56	Not using glasses or prothesis	0,0	0,0	0,1	1,4	0,0
40	driver's death during driving	0,1	0,1	0,1	2,4	0,0
39	muddy	0,1	0,1	0,1	2,4	0,0
36	steering defect	0,1	0,0	0,1	2,1	0,0
72	67 Failure to use proper side of the road	0,0	0,0	0,0	1,2	0,0
73	84 Storm or other weather influences	0,0	0,0	0,0	1,2	0,0
11	Bad state of the vehicle.	0,3	0,2	0,3	7,7	0,0
71	68 Playing on or near carriageway	0,0	0,0	0,0	1,2	0,0
46	Inadequate signing at site	0,1	0,0	0,4	1,9	0,0
47	Steep hill at site	0,1	0,0	0,4	1,9	0,0
48	Narrow road at site	0,1	0,0	0,4	1,9	0,0
34	working on the road	0,1	0,1	0,1	2,1	0,0
35	slow driving causing problems to others	0,1	0,1	0,1	2,1	0,0
38	under influence of medicine, narcotics	0,1	0,1	0,1	2,4	0,0
33	entering or leaving a vehicle	0,1	0,1	0,1	2,1	0,0
70	75 Grooves in connection with rain, snow or ice	0,0	0,0	0,1	1,2	0,0
69	33 Failure to observe the priority of rail vehicles at railway crossings	0,0	0,0	0,1	1,2	0,0
54	Steering misuse	0,1	0,0	0,1	1,4	0,0
63	Driving on wrong side of road (foreign driver…)	0,1	0,0	0,4	1,5	0,0
64	No reaction (sufficient time and space)	0,1	0,0	0,4	1,5	0,0
65	Passenger action	0,1	0,0	0,4	1,5	0,0
66	Heat	0,1	0,0	0,4	1,5	0,0
37	illness, injury etc.	0,1	0,1	0,1	2,4	0,0
68	25 Failure to observe the rear traffic when driving past stationary vehicles, barriers or obstacles and/or without timely and clearly indicating the intention to swerve out	0,1	0,0	0,1	1,2	0,0
67	71 Other impurities caused by road users	0,1	0,0	0,1	1,2	0,0
53	Careless for morbid action	0,1	0,0	0,1	1,4	0,0
66	83 Side wind	0,1	0,1	0,1	1,2	0,0
56	braking for no reason	0,1	0,0	0,4	1,3	0,1
57	overtaking on the right	0,1	0,0	0,4	1,3	0,1
58	securing stopping vehicles	0,1	0,0	0,4	1,3	0,1
59	overloading	0,1	0,0	0,4	1,3	0,1
60	unsecured cargo	0,1	0,0	0,4	1,3	0,1
61	failure to use the pavement	0,1	0,0	0,4	1,3	0,1
62	wrong side of the road	0,1	0,0	0,4	1,3	0,1
63	rutted	0,1	0,0	0,4	1,3	0,1
52	Absent/poor light	0,1	0,0	0,1	1,4	0,1
36	disabled	0,1	0,1	0,1	2,4	0,1
65	44 Insufficient safety measures in the case of vehicles stopping or broken down and accident sites or with regard to school busses with children getting on or off the bus	0,1	0,1	0,1	1,2	0,1
50	Sudden braking with injured occupants	0,1	0,0	0,1	1,4	0,1
51	Tiredness for exceeding driving time	0,1	0,0	0,1	1,4	0,1
35	bad due to temporary vegetation (grass, grain etc.)	0,1	0,1	0,2	2,4	0,1
64	66 Failure to use footway	0,1	0,1	0,1	1,2	0,1

63	47 Overload, maximum number of passengers exceeded	0,1	0,1	0,1	1,2	0,1
32	puncture	0,1	0,1	0,2	2,1	0,1
47	Stopping, delaying, or playing on the carrageway	0,1	0,0	0,1	1,4	0,1
48	Suddenly coming out from a stopped vehicle	0,1	0,0	0,1	1,4	0,1
49	Walking on the roadway midline	0,1	0,0	0,1	1,4	0,1
62	43 Unlawful stopping or parking	0,1	0,1	0,1	1,2	0,1
46	Overtaking a vehicle that was in an overtaking action	0,1	0,0	0,2	1,4	0,1
10	Vehicle failure.	0,6	0,5	0,6	7,7	0,1
43	Disability	0,1	0,0	0,5	1,9	0,1
44	Poor or no street lighting at site	0,1	0,0	0,5	1,9	0,1
45	Surroundings obscured by bend or winding road	0,1	0,0	0,5	1,9	0,1
31	avoiding obstacle on the right manoeuvre	0,2	0,1	0,2	2,1	0,1
34	gusty wind (side wind, storm etc.)	0,2	0,2	0,2	2,4	0,1
61	80 Fog	0,1	0,1	0,1	1,2	0,1
45	Incorrectly placing side by side with other two wheele vehicles	0,1	0,1	0,2	1,4	0,1
62	First rain after dry period	0,1	0,0	0,5	1,5	0,1
9	Weather.	0,7	0,6	0,7	7,7	0,1
44	Absent/poor bycicle reflector	0,1	0,1	0,2	1,4	0,1
33	sudden change of surface state (icing on the bridge, local glaze etc.)	0,2	0,2	0,2	2,4	0,1
76	Dirty windscreen/visor	0,1	0,1	0,1	1,3	0,1
75	Driving too slow	0,1	0,1	0,1	1,3	0,1
32	dazzled by other vehicle	0,2	0,2	0,3	2,4	0,1
60	46 Failure to observe lighting regulations (except pos. 50)	0,1	0,1	0,1	1,2	0,1
43	Explosion or exceeding usury of tyres	0,1	0,1	0,2	1,4	0,1
59	19 Overtaking in spite of insufficient visibility	0,1	0,1	0,1	1,2	0,1
58	88 Other obstacle on the carriageway (except pos. 43, 44)	0,1	0,1	0,1	1,2	0,1
53	other defects	0,1	0,0	0,5	1,3	0,1
54	other behavioural mistakes	0,1	0,0	0,5	1,3	0,1
55	rain, hail, snow	0,1	0,0	0,5	1,3	0,1
31	sudden physical indisposition	0,3	0,2	0,3	2,4	0,1
57	70 Impurity through oil leakage	0,1	0,1	0,1	1,2	0,1
74	Impaired by drugs	0,1	0,1	0,2	1,3	0,1
42	Walking or stopping on the pavements, bank	0,1	0,1	0,2	1,4	0,1
56	16 Unlawful right-hand overtaking	0,1	0,1	0,1	1,2	0,1
30	other bad view conditions	0,3	0,2	0,3	2,4	0,1
55	81 Heavy rain, hail, flurry of snow and the like	0,1	0,1	0,1	1,2	0,1
38	Other personal-factor (give details) (48)	0,2	0,0	0,6	1,9	0,1
39	Tyre worn or insufficient tread	0,2	0,0	0,6	1,9	0,1
40	Earlier accident	0,2	0,0	0,6	1,9	0,1
41	Obscuration due to weather	0,2	0,0	0,6	1,9	0,1
42	Animal out of control	0,2	0,0	0,6	1,9	0,1
54	74 Other influences (among others, leaves, loam washed up)	0,1	0,1	0,1	1,2	0,1
53	52 Brakes	0,1	0,1	0,2	1,2	0,1
73	Defective eyesight	0,2	0,1	0,2	1,3	0,1
41	Overtaking without respecting the "NO PASSING" sign	0,2	0,1	0,2	1,4	0,1
29	other road surface state (during the accident)	0,3	0,3	0,3	2,4	0,1
56	Poor evaluation / anticipation (other vehicle's speed…)	0,2	0,0	0,6	1,5	0,1
57	Vehicle load influencing driving style	0,2	0,0	0,6	1,5	0,1
58	Windscreen and window defects (misted, deteriorated…)	0,2	0,0	0,6	1,5	0,1
59	Speed differential	0,2	0,0	0,6	1,5	0,1
60	Road markings	0,2	0,0	0,6	1,5	0,1
61	Snow	0,2	0,0	0,6	1,5	0,1
72	Traffic calming	0,2	0,1	0,2	1,3	0,1
52	30 Failure to observe the priority by vehicles coming from dirt roads	0,2	0,1	0,2	1,2	0,1
51	41 at stops (also at school busses stopping with the warning flasher device flashing)	0,2	0,2	0,2	1,2	0,1
30	walking through the road on the right	0,3	0,2	0,4	2,1	0,1
50	23 Mistakes made when being overtaken	0,2	0,2	0,2	1,2	0,1
49	76 Other road condition	0,2	0,2	0,2	1,2	0,1
40	Sleepy	0,2	0,1	0,3	1,4	0,1
48	48 Insufficient safety measures with regard to load or vehicle accessories	0,2	0,2	0,2	1,2	0,1
71	Defective traffic signals	0,2	0,2	0,2	1,3	0,1
70	Defective lights/indicators	0,2	0,2	0,2	1,3	0,1
38	Drugs	0,2	0,1	0,3	1,4	0,1
39	Overtaking on a bend, on a hump or in a poor visibility circumstance	0,2	0,1	0,3	1,4	0,1
47	29 Failure to observe the priority of the passing traffic on motorways or motor vehicle roads (§ 18, para. 3)	0,2	0,2	0,2	1,2	0,2
35	Cross from behind parked car	0,3	0,1	0,7	1,9	0,2
36	Defective brakes	0,3	0,1	0,7	1,9	0,2
37	Surroundings obscured by moving vehicle	0,3	0,1	0,7	1,9	0,2
46	50 Lighting	0,2	0,2	0,2	1,2	0,2
45	country paths (fields, woods)	0,2	0,0	0,6	1,3	0,2
46	at pedestrian underpasses	0,2	0,0	0,6	1,3	0,2
47	defects tyres	0,2	0,0	0,6	1,3	0,2
48	defects brakes	0,2	0,0	0,6	1,3	0,2
49	near crossings	0,2	0,0	0,6	1,3	0,2
50	oil	0,2	0,0	0,6	1,3	0,2
51	fouling (dirt)	0,2	0,0	0,6	1,3	0,2
52	Wildlife on road	0,2	0,0	0,6	1,3	0,2
69	Spray	0,2	0,2	0,2	1,3	0,2
37	Braking misuse	0,2	0,1	0,3	1,4	0,2
68	Driver using mobile phone	0,2	0,2	0,2	1,3	0,2
28	other aggravated weather conditions	0,4	0,4	0,4	2,4	0,2
52	Incorrect lane positioning	0,3	0,1	0,6	1,5	0,2
53	Passengers (comfort, distraction…)	0,3	0,1	0,6	1,5	0,2
54	Blind spot	0,3	0,1	0,6	1,5	0,2
55	Defective street lighting	0,3	0,1	0,6	1,5	0,2
45	62 near junctions, traffic lights or pedestrian crossings with heavy traffic at other places:	0,2	0,2	0,2	1,2	0,2
44	65 by other improper behaviour	0,2	0,2	0,2	1,2	0,2
36	Dazzled	0,2	0,2	0,3	1,4	0,2
67	Defective steering/suspension	0,2	0,2	0,3	1,3	0,2
43	15 Abrupt braking without compelling reason by the vehicle in front	0,2	0,2	0,2	1,2	0,2

8	State of the carriageway.	1,4	1,3	1,5	7,7	0,2
42	55 Other faults	0,2	0,2	0,2	1,2	0,2
29	old tyres	0,4	0,3	0,5	2,1	0,2
41	24 Failure to observe the priority of oncoming cars when driving past stationary vehicles, barriers or obstacles (§ 6) (except pos. 32)	0,2	0,2	0,2	1,2	0,2
34	Ignored lights at crossing	0,4	0,1	0,8	1,9	0,2
66	Overloaded vehicle	0,3	0,2	0,3	1,3	0,2
28	walking on the road	0,4	0,4	0,5	2,1	0,2
65	Cyclist wearing dark clothing at night	0,3	0,2	0,3	1,3	0,2
64	Vision affected by buildings etc	0,3	0,2	0,3	1,3	0,2
40	87 Other animal on the carriageway	0,2	0,2	0,3	1,2	0,2
27	others	0,4	0,4	0,5	2,1	0,2
38	drugs	0,3	0,1	0,7	1,3	0,2
39	overtaking despite following traffic	0,3	0,1	0,7	1,3	0,2
40	mistake when being overtaken	0,3	0,1	0,7	1,3	0,2
41	rail-bound vehicles	0,3	0,1	0,7	1,3	0,2
42	other mistakes by pedestrians	0,3	0,1	0,7	1,3	0,2
43	dazzle, glare	0,3	0,1	0,7	1,3	0,2
44	other obstacles	0,3	0,1	0,7	1,3	0,2
51	Distraction – non driving task	0,3	0,1	0,7	1,5	0,2
35	Overtaking a moving vehicle	0,3	0,2	0,4	1,4	0,2
39	60 at places where the pedestrian traffic was controlled by policemen or traffic lights	0,3	0,3	0,3	1,2	0,2
26	walking through the road on the left	0,5	0,4	0,6	2,1	0,2
63	Disobeyed double white lines	0,3	0,3	0,3	1,3	0,2
62	No lights at night	0,3	0,3	0,3	1,3	0,2
61	Temporary road layout	0,3	0,3	0,3	1,3	0,2
33	Surroundings obscured by buildings, fences, vegetation	0,4	0,2	0,9	1,9	0,2
60	Dazzling headlights	0,3	0,3	0,3	1,3	0,2
38	38 at pedestrian crossings	0,3	0,3	0,3	1,2	0,2
59	Vehicle travelling along pavement	0,3	0,3	0,4	1,3	0,2
37	32 Failure to observe the priority of oncoming vehicles (traffic sign No. 208 of Road Traffic Regulations)	0,3	0,3	0,3	1,2	0,2
50	other	0,4	0,1	0,8	1,5	0,3
27	outlook covered by parking vehicle	0,6	0,6	0,6	2,4	0,3
25	other infractions	0,5	0,5	0,6	2,1	0,3
37	snow, ice	0,3	0,1	0,8	1,3	0,3
34	Incorrectly overtaking on the right	0,3	0,3	0,5	1,4	0,3
36	39 at central islands	0,3	0,3	0,3	1,2	0,3
35	51 Tyres	0,3	0,3	0,3	1,2	0,3
31	Tyre pressures wrong	0,5	0,2	1,0	1,9	0,3
32	Poor surface at site	0,5	0,2	1,0	1,9	0,3
34	21 Mistake made when returning to right lane	0,3	0,3	0,3	1,2	0,3
33	56 Influence of alcohol	0,3	0,3	0,3	1,2	0,3
24	U turn	0,6	0,5	0,7	2,1	0,3
32	02 Influence of other intoxicating substances (e.g. drugs, narcotics)	0,3	0,3	0,4	1,2	0,3
23	escape	0,6	0,5	0,7	2,1	0,3
47	Avoidance manoeuvre due to other vehicle	0,4	0,2	0,9	1,5	0,3
48	Reversed road camber	0,4	0,2	0,9	1,5	0,3
49	Wind	0,4	0,2	0,9	1,5	0,3
33	Incorrectly maneuvering to stop	0,4	0,3	0,5	1,4	0,3
58	Door opened carelessly	0,4	0,4	0,4	1,3	0,3
28	Interaction or competition with other road users	0,6	0,2	1,1	1,9	0,3
29	Tyre deflated before impact	0,6	0,2	1,1	1,9	0,3
30	Glare from sun	0,6	0,2	1,1	1,9	0,3
32	Driving without respecting the speed limits	0,4	0,3	0,5	1,4	0,3
57	Disability or illness	0,4	0,4	0,4	1,3	0,3
35	overtaking despite inadequate visibility	0,4	0,1	0,8	1,3	0,3
36	stopping, parking	0,4	0,1	0,8	1,3	0,3
26	dazzled by sun	0,7	0,7	0,8	2,4	0,3
31	Driving without respecting transit or access signs	0,4	0,3	0,5	1,4	0,3
7	Drowsiness or illness.	2,4	2,3	2,5	7,7	0,3
30	Side skid for driving with exceeding speed	0,4	0,3	0,5	1,4	0,3
56	Vision affected by vegetation	0,4	0,4	0,5	1,3	0,3
25	influenced by avoiding to the wild or domestic animals	0,8	0,7	0,8	2,4	0,3
55	Vehicle in course of crime	0,4	0,4	0,5	1,3	0,3
44	No vehicle lighting (case vehicle)	0,5	0,2	1,0	1,5	0,3
45	Failed to look, looked but did not see…	0,5	0,2	1,0	1,5	0,3
46	Poor infrastructure design	0,5	0,2	1,0	1,5	0,3
22	standing on the sidewalk	0,7	0,6	0,8	2,1	0,3
31	69 Other improper behaviour of pedestrians	0,4	0,4	0,4	1,2	0,3
29	Maneuvering	0,5	0,4	0,6	1,4	0,3
26	Other vehicle-factor (give details) (63)	0,6	0,3	1,2	1,9	0,3
27	Surroundings obscured by stationary or parked car	0,6	0,3	1,2	1,9	0,3
30	45 Behaviour contrary to traffic regulations when getting on or off a vehicle, loading or unloading	0,4	0,4	0,4	1,2	0,3
54	Impaired by drugs	0,5	0,4	0,5	1,3	0,4
29	20 Overtaking without observing the rear traffic and/or without timely and clearly indicating the intention to swerve out	0,4	0,4	0,4	1,2	0,4
34	mistake in returning to correct lane	0,5	0,2	0,9	1,3	0,4
28	03 Overfatigue	0,4	0,4	0,5	1,2	0,4
53	Inexperience of driving on left	0,5	0,4	0,5	1,3	0,4
28	Sudden illness	0,5	0,4	0,6	1,4	0,4
24	fog	0,9	0,8	0,9	2,4	0,4
43	Sensory deficiency	0,6	0,3	1,1	1,5	0,4
27	82 Dazzling sunshine	0,5	0,4	0,5	1,2	0,4
24	Bend or winding road at site	0,7	0,3	1,3	1,9	0,4
25	Other local-factor (give details) (74)	0,7	0,3	1,3	1,9	0,4
52	Emergency vehicle on call	0,5	0,5	0,5	1,3	0,4
26	40 when turning	0,5	0,5	0,5	1,2	0,4
51	Disobeyed pedestrian crossing	0,5	0,5	0,5	1,3	0,4
23	dry, polluted (sand, leaves, gravel etc.)	0,9	0,9	1,0	2,4	0,4
27	Incorrectly crossing	0,5	0,4	0,7	1,4	0,4
25	86 Wild animals on the carriageway	0,5	0,5	0,5	1,2	0,4

26	Other misuse	0,5	0,4	0,7	1,4	0,4
50	Inadequate/masked signs or markings	0,5	0,5	0,6	1,3	0,4
32	failure to observe priority of oncoming traffic	0,5	0,2	1,0	1,3	0,4
33	pedestrian at stops	0,5	0,2	1,0	1,3	0,4
22	glaze, hardened snow - sprinkled	1,0	0,9	1,0	2,4	0,4
21	bad due to permanent vegetation (trees, bushes etc.)	1,0	0,9	1,0	2,4	0,4
22	Impairment through illness	0,8	0,4	1,4	1,9	0,4
23	Distraction through stress or emotional state of mind	0,8	0,4	1,4	1,9	0,4
40	Driving without licence	0,6	0,3	1,2	1,5	0,4
41	Navigation	0,6	0,3	1,2	1,5	0,4
42	Wheel lock-up	0,6	0,3	1,2	1,5	0,4
24	63 by suddenly emerging from behind obstacles obstructing the visibility	0,5	0,5	0,5	1,2	0,4
24	Side skid for avoiding an accident	0,6	0,5	0,7	1,4	0,4
25	Other condition	0,6	0,5	0,7	1,4	0,4
29	overtaking despite oncoming traffic	0,6	0,3	1,1	1,3	0,5
30	failure to consider following traffic	0,6	0,3	1,1	1,3	0,5
31	rain	0,6	0,3	1,1	1,3	0,5
6	Driver’s lack of experience.	3,6	3,5	3,8	7,7	0,5
21	Not respecting crossing regulations	1,0	0,9	1,1	2,1	0,5
20	bad due to surrounding constructions (buildings, full railing, scaffold etc.)	1,1	1,1	1,2	2,4	0,5
49	Pedestrian wearing dark clothing at night	0,6	0,6	0,7	1,3	0,5
48	Defective brakes	0,6	0,6	0,7	1,3	0,5
5	Alcohol or drugs.	3,8	3,6	3,9	7,7	0,5
19	continuous snow layer, slush	1,2	1,1	1,2	2,4	0,5
34	Incorrect headway	0,8	0,4	1,3	1,5	0,5
35	Habit	0,8	0,4	1,3	1,5	0,5
36	Inattention	0,8	0,4	1,3	1,5	0,5
37	illness	0,8	0,4	1,3	1,5	0,5
38	Contrast	0,8	0,4	1,3	1,5	0,5
39	Black ice	0,8	0,4	1,3	1,5	0,5
23	04 Other physical or mental faults	0,6	0,6	0,6	1,2	0,5
23	Crossing on a footpath not regulated by traffic lights or by policeman	0,7	0,6	0,8	1,4	0,5
27	at pedestrian crosssings	0,6	0,3	1,2	1,3	0,5
28	pedestrian when turning off	0,6	0,3	1,2	1,3	0,5
47	Poor or defective road surface	0,7	0,6	0,7	1,3	0,5
20	Impairment through drugs	1,0	0,5	1,6	1,9	0,5
21	Distraction through physical object outside of vehicle	1,0	0,5	1,6	1,9	0,5
22	Not giving the priority to pedestrian on the pedestrian crossing	0,7	0,6	0,9	1,4	0,5
21	Not driving on the right side of the roadway	0,7	0,6	0,9	1,4	0,5
20	rearwards movement	1,2	1,1	1,3	2,1	0,6
19	Impairment through fatigue	1,1	0,6	1,7	1,9	0,6
46	Stolen vehicle	0,8	0,7	0,8	1,3	0,6
19	exceeding speed	1,2	1,1	1,4	2,1	0,6
33	Carriageway/shoulder grip differential	0,9	0,5	1,5	1,5	0,6
45	Defective tyres	0,8	0,7	0,8	1,3	0,6
20	Incorrectly turning on the right	0,8	0,7	1,0	1,4	0,6
44	Wrong use of pedestrian crossing	0,8	0,7	0,8	1,3	0,6
22	22 Other mistakes made when overtaking (e.g. without sufficient lateral distance; at pedestrian crossings, (cf. pos. 38, 39)	0,7	0,7	0,7	1,2	0,6
18	View obscured from window	1,1	0,6	1,8	1,9	0,6
18	tired, fall asleep	1,5	1,4	1,5	2,4	0,6
17	icing, glaze formation	1,5	1,5	1,6	2,4	0,6
18	other actions	1,4	1,2	1,5	2,1	0,6
43	Illegal turn/direction	0,8	0,8	0,9	1,3	0,6
17	suddenly crossing a road	1,4	1,2	1,5	2,1	0,6
42	Unfamiliar with model of vehicle	0,9	0,8	0,9	1,3	0,7
4	Other factor.	5,2	5,0	5,3	7,7	0,7
16	overtaking on the left	1,4	1,3	1,6	2,1	0,7
41	Cyclist entering road from pavement	0,9	0,8	0,9	1,3	0,7
21	17 Overtaking in spite of oncoming traffic	0,8	0,8	0,9	1,2	0,7
16	at night, without public lighting - deteriorated due to weather conditions (fog, snowfall, rainfall etc.)	1,7	1,6	1,8	2,4	0,7
19	Incorrectly stopped vehicle	1,0	0,8	1,1	1,4	0,7
15	sudden brake	1,5	1,4	1,7	2,1	0,7
18	Steering for turning on the left (private acces, petrol station)	1,0	0,8	1,2	1,4	0,7
15	other unfavourable condition	1,8	1,7	1,8	2,4	0,7
20	18 Overtaking in spite of unclear traffic situation	0,9	0,9	0,9	1,2	0,8
17	Overtaking in an intersection	1,0	0,9	1,2	1,4	0,8
14	avoiding obstacle on the left manoeuvre	1,7	1,5	1,8	2,1	0,8
16	Driving without respecting the traffic light or police order	1,1	0,9	1,3	1,4	0,8
14	other influence	2,0	1,9	2,0	2,4	0,8
15	Side skid for careless driving	1,1	1,0	1,3	1,4	0,8
13	at night, with public lighting - deteriorated due to weather conditions (fog, snowfall, rainfall etc.)	2,0	1,9	2,1	2,4	0,8
12	snowfall	2,0	1,9	2,1	2,4	0,8
13	parking	1,9	1,7	2,0	2,1	0,9
40	Vehicle blind spot	1,1	1,1	1,2	1,3	0,9
39	Dangerous action in carriageway	1,1	1,1	1,2	1,3	0,9
38	Animal/Object in carriageway	1,2	1,1	1,2	1,3	0,9
37	Illness or disability	1,2	1,2	1,3	1,3	0,9
19	26 Incorrectly changing the lane when driving side by side or failure to observe the "zip method" (merging of two queues with alternate priority of the respective cars	1,1	1,1	1,2	1,2	0,9

Powered two wheelers accident investigation and reconstruction

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Abstract - One of the major problems of road safety in Europe is the powered two wheelers accidents. One of the European countries with one of the highest rates is Portugal where in 2006, mopeds and motorcycles fatalities represented 27% of all road users deaths. In this work, a deep analysis and overview of the current state of mopeds and motorcycles accidents for the 2004-2006 period is presented. Within this period 830 PTW occupants die, 2958 have been severely injured and 25000 suffer slight injuries. A detailed analysis of the conditions of these accidents has been carried out, using the data of the national accident database. This analysis provides global information, about geographic environmental conditions, driver's characteristics among others. From this data detailed information is obtained allowing to know when, where and who. In order to answer the question why more a widely collection of data has been collect for 70 accidents. The data has been collected using OECD methodology. For these accidents a detailed reconstruction has been carried out, what is especially important for fatal accidents where for instance speed in an important factor. From these collection and analysis of data a wider overview of facts and measures are extracted. Among them, some are emphasized such as that the quality and non-use of helmets plays an important role in severe and fatal accidents especially for accidents involving moped vehicles, or speed is the most important factor in fatal accidents involving motorcycles.

Concerning motorcycle accident reconstruction, different tools can be used depending of the accident scenario and complexity. For simple cases, with specific characteristics, analytical formulation based in vehicle crash dynamics can be use in order to determine the impact speed of the vehicles impact, analysing the skid marks, deformations, victims rest position and considering parameters (EES, vehicle deceleration, etc). Aspects such as the energy absorption capability of motorcycles are also discussed. In the general cases the accident reconstruction software Pc-Crash has been used for the reconstruction of the accident. In very complex cases, has for instance the impact between motorcyclist and barriers, Madymo software is used especially to determine speed from injuries. An example of the impact of a motorcyclist and a motorcyclist-friendly barrier is present to illustrate the benefits and limitations of such systems.

NOTATION

MT1 Motorcycle type 1
MT2 Motorcycle type 2
MT3 Motorcycle type 3
PTW Powered two wheels
TWV Two wheels vehicles
VCL Vehicle control loss

INTRODUCTION

Portugal is one of the countries with one of the highest rates of accidents involving PTW in Europe. According to the Portuguese accident database in the 2004-2006 period, 28730 accidents with injuries occurred, 830 persons died (within the 30 days: correction factor= 1.14), 2958 severe and 24942 slight injuries occurred (Table 1).

Despite the fact that the PTW only represent 9,3% of the total vehicle in circulation in Portugal, it represents 27% of all road users deaths. This numbers are unacceptable, having a high impact in the country, generating implications in a social point of view and a socio-economical cost for the country, leading to an alarming situation, in which the number of fatalities per 1000 vehicles in circulation concerning the PTW overcomes the light vehicles and heavy trucks fatalities (Figure 1), and that's why it is highly recomendable the in-depth study of all road accidents in order to trace a strategy which the main goal is to reduce the number of fatalities and accidents involving PTW, and subsequently reduce the socio-economical cost for the country.

Table 1. Road injuries in Portugal 2004-2006 [1]

	Injuries								
	Fatal(*)			**Serious**			**Slight**		
Year	2004	2005	2006	2004	2005	2006	2004	2005	2006
PTW	302	294	234	1092	985	881	9072	8308	7562
Pedestrians	232	214	156	766	714	617	5849	5568	5612
Light Vehicles	644	620	477	2097	1830	1754	30381	28969	27955
Heavy Trucks	31	33	19	70	66	66	974	1071	909
Others	84	86	83	165	167	165	1543	1571	1616
Total	1293	1247	969	4190	3762	3483	47819	45487	43654

(*) Fatalities on accident scene applying the corrective factor 1,14.

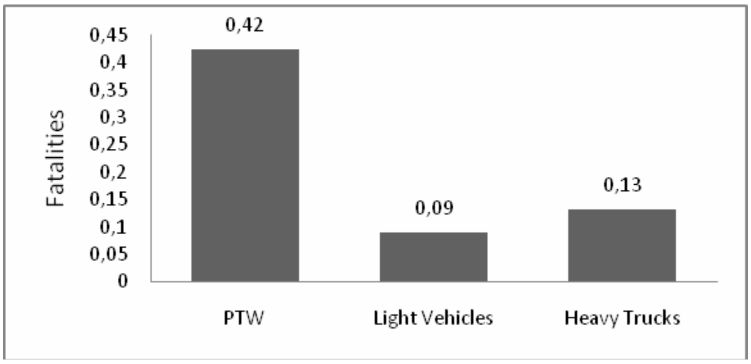

Figure 1. Fatalities per 1000 vehicles in circulation on Portugal, 2006.

The reduction of the Portuguese road fatalities, involves between others, countermeasures like campaigns providing PTW safety information, law enforcement, skills training and incremental technological advances such as ABS. Despite these efforts devising effective countermeasures requires comprehensive research into current causes of PTW crashes and defining aspects related to the population at risk. Making an effort all can help to accomplish much more towards improving the PTW safety, and it is necessary to remember that European harmonization requires homogenous definitions to establish meaningful comparisons.

The work presented hereunder is part of the in-depth research project of accidents involving PTW pedestrian accidents and that has the objective of understanding what are the factors responsible for the high number of injuries and fatalities in Portugal. Also the development of models for accident reconstruction of such accidents is an objective of this project.

VEHICLE FACTORS

In Portugal there are 4 types of PTW, mopeds and 3 different classifications of motorcycles, which are presented in Table 2. Each of those types of PTW, have different contributions concerning the number of accidents, and in the type of injuries that result from those accidents.

In Figure 2 is presented the percentage of accidents with injuries for 2004-2006, in which it can be concluded that mopeds are the major problem, when we talk about the high number of accident involving injuries, followed by the motorcycle type 3, that is capable of achieve the highest speeds, and acceleration.

The conclusion is obvious, mopeds are the type of PTW more involved in accidents with injuries in Portugal, and however are mopeds the most dangerous category of PTW in Portugal? According with the number of accidents in the period of 2005-2006 the answer is no, and it is based in Figure 3 and in Figure 4.

Table 2. PTW categories in Portugal

	**Moped:** Motor vehicle with two wheels, with an engine size of less than 50 cc. Design speed between 25 km/h and 50 km/h. One or two seats.
	**Motorcycle type 1:** Motor vehicle with two, three or four wheels, with an engine size of 50 cc. With a trailer possible. With a sidecar possible.
	**Motorcycle type 2:** Motor vehicle with two, three or four wheels, with an engine size of more than 50 cc but less than 25 kW of power. With a trailer possible. With a sidecar possible.
	**Motorcycle type 3:** Motor vehicle with two, three or four wheels, with an engine size of more than 50 cc and more than 25 kW of power. With a trailer possible. With a sidecar possible.

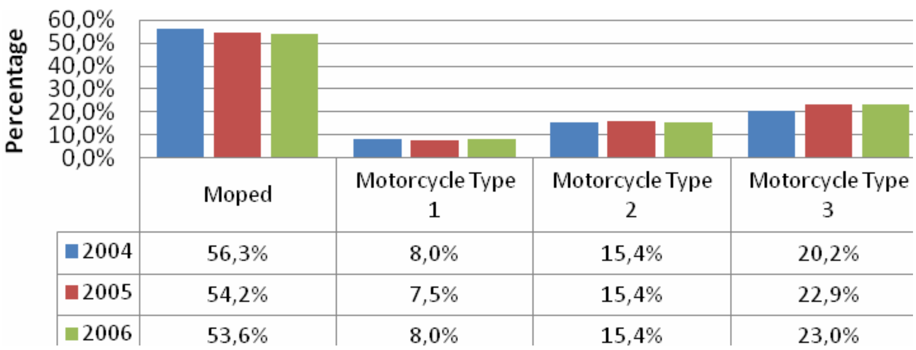

Figure 2. Percentage of accidents involving injuries with PTW in Portugal, 2004-2006.

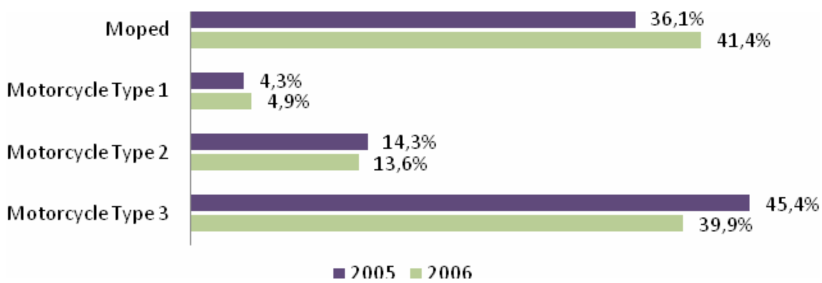

Figure 3. Fatal injury percentage per type of PTW in Portugal, 2005-2006.

Once again it is evidenced that mopeds are a category involved in a high number of accidents and consequently they produce a high number of fatal accidents. But also motorcycle type 3 produce a high number of fatal injuries, and it is the PTW category that is more dangerous in Portugal (motorcycle type 3), which produce the highest number of fatal injuries per 100 accidents involving injuries. Despite the low number of accidents that involve injuries that this category, motorcycle type 3, presents when compared with mopeds, they cause more deaths.

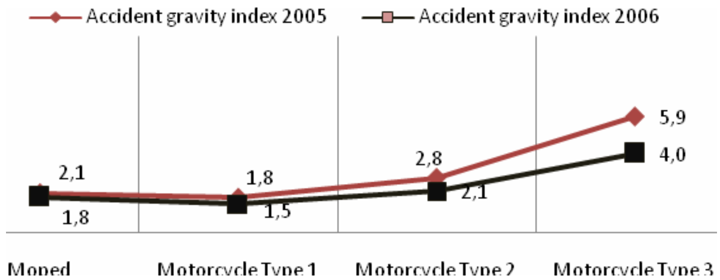

Figure 4. Accident gravity index of PTW in Portugal, 2005-2006.

It is important to understand which is the most common accident configuration. The statistical data for the configuration of accidents with injuries involving PTW in Portugal is presented in tables 3 to 5. In highlight there is the most frequent configuration of accidents with injuries involving PTW, and the most common in the period of 2004-2006 are, the lateral collision with another moving vehicle, followed by vehicle control loss, and at last the frontal collisions.

Table 3. Configuration of accidents with injuries involving PTW in Portugal, 2004.

Accident configuration	Moped	MT1	MT2	MT2
Running over animals	0,0%	0,0%	0,0%	0,0%
Running over of laborers	2,6%	3,8%	3,9%	4,3%
Lateral collision with another moving vehicle	36,8%	43,6%	36,7%	34,6%
Chain collision	0,1%	0,1%	0,2%	0,2%
Runaway collision	1,5%	1,7%	0,9%	0,9%
Back collision with another moving vehicle	8,9%	8,8%	8,1%	11,7%
Frontal collision	15,9%	15,2%	17,2%	12,9%
Collision with other situations	1,6%	1,5%	2,0%	1,4%
Collision with obstacle or vehicle in road	4,4%	3,6%	3,1%	3,3%
VCL with rollover	1,8%	0,8%	1,4%	1,5%
VCL with collision with immobilized vehicle or obstacle	3,0%	2,3%	4,3%	4,2%
VCL without road barrier	1,7%	1,3%	1,9%	1,5%
VCL with road barrier	0,2%	0,5%	0,4%	1,3%
VCL with runaway	0,1%	0,6%	0,3%	0,4%
VCL with transposition of the road barrier	0,1%	0,1%	0,4%	0,9%
Simple VCL (Vehicle Control Loss)	21,5%	16,0%	19,2%	21,0%

Table 4. Configuration of accidents with injuries involving PTW in Portugal, 2005.

Accident configuration	Moped	MT1	MT2	MT2
Running over animals	0,7%	0,0%	1,2%	0,7%
Running over pedestrians	2,9%	3,1%	4,0%	3,8%
Lateral collision with another moving vehicle	34,5%	41,2%	38,2%	36,0%
Chain collision	0,1%	0,3%	0,3%	0,3%
Runaway collision	1,6%	1,3%	1,6%	1,6%
Back collision with another moving vehicle	9,5%	9,2%	9,4%	8,6%
Frontal collision	15,1%	17,8%	13,7%	11,1%
Collision with other situations	1,9%	1,9%	2,1%	2,0%
Collision with obstacle or vehicle immobilized in road	4,4%	3,0%	2,4%	4,4%
VCL with rollover	1,3%	0,7%	1,9%	1,3%
VCL with collision with immobilized vehicle or obstacle	3,2%	3,4%	2,6%	3,7%
VCL without road barrier	2,2%	1,0%	1,4%	1,5%
VCL with road barrier	0,3%	0,1%	0,4%	1,1%
VCL with runaway	0,3%	0,1%	0,2%	0,3%
VCL with transposition of the road barrier	0,3%	0,0%	0,1%	0,8%
Simple VCL	21,6%	16,6%	20,3%	22,6%

Table 5. Configuration of accidents with injuries involving PTW in Portugal, 2006.

Accident configuration	Moped	MT1	MT2	MT2
Running over animals	0,6%	0,8%	0,9%	0,5%
Running over pedestrians	2,8%	2,1%	4,2%	3,1%
Lateral collision with another moving vehicle	34,4%	38,1%	35,7%	34,5%
Chain collision	0,2%	0,2%	0,2%	0,4%
Runaway collision	1,5%	0,8%	1,1%	1,3%
Back collision with another moving vehicle	9,2%	10,8%	7,9%	10,3%
Frontal collision	13,8%	15,8%	14,7%	11,1%
Collision with other situations	2,5%	1,8%	2,6%	3,2%
Collision with obstacle or vehicle immobilized in road	3,9%	4,5%	2,9%	3,4%
VCL with rollover	1,6%	1,2%	1,8%	1,5%
VCL with collision with immobilized vehicle or obstacle	2,7%	3,2%	3,5%	4,6%
VCL without road barrier	2,3%	1,8%	3,1%	2,3%
VCL with road barrier	0,5%	0,6%	0,5%	0,8%
VCL with runaway	0,3%	0,6%	0,2%	0,1%
VCL with transposition of the road barrier	0,2%	0,0%	0,3%	0,7%
Simple VCL	23,6%	17,9%	20,5%	22,2%

The main causes and problems behind lateral collision with another moving vehicle are bad conspicuity and visibility in junctions and the difficult of PTW being noticed by other vehicles in road, disrespect of priority rule, and inappropriate speed for the circulation conditions. Concerning the simple vehicle control loss, the main causes are high speed, poor driving skills, and deficient road construction and maintenance.

In Portugal the most critical types of PTW are the mopeds had to the high number of vehicles in circulation, and the motorcycles type 3, had to the fact of being extremely powerful and capable of very high acceleration and speed.

ENVIRONMENTAL FACTORS

The environmental and conditions in which the PTW are subjected in Portugal, is another important issue with direct influence in accidents with injuries involving PTW. The statistical data present in figure 5 demystifies the general idea that the majority of the accidents involving PTW occur in bad weather conditions, in fact it is in the optimum conditions that the majority of accidents happens, and this conclusion is also in conformity with the data present in figures 6 in which it is shown the distribution of accidents with injuries with PTW per month.

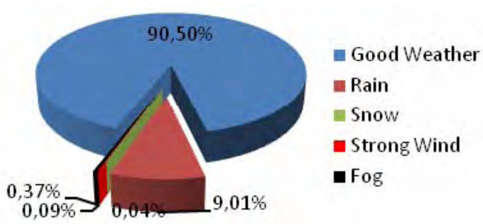

Figure 5. Weather conditions in accidents with injuries involving PTW in Portugal.

The months of June, July and August, which are the months with better weather conditions, this results have reveal that in those months there are more PTW in circulation, but also that when drivers are confronted with adverse conditions they tend to be more awareness of possible dangerous. Another aspect related with the road configuration, that is, if it is a straight road or bend, and in which more accidents occur. In figure 9 it is present the percentage of accidents that occurred without direct intervention of other vehicles, and the results show that for each accident in which the driver loses control of the vehicle in a bend configuration road, there are three that occur in a straight road configuration.

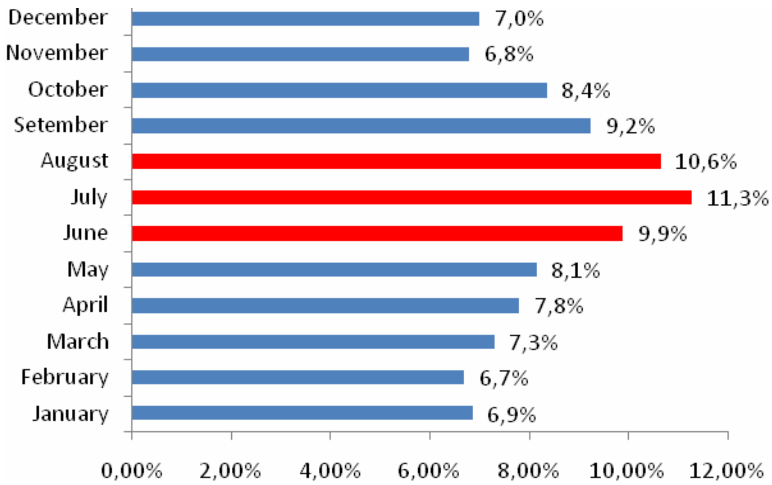

Figure 6. Accident with injuries involving PTW distribution per month in Portugal, 2005

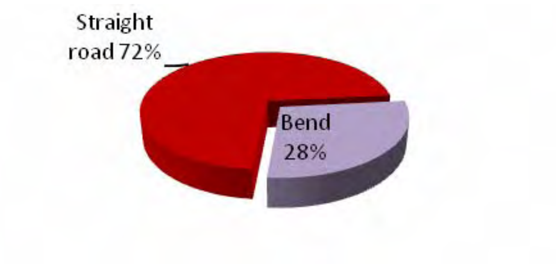

Figure 7. Simple vehicle control loss accidents with injuries involving PTW, according to road configuration in Portugal.

Those results only corroborate the previous statements, in which speed is a key issue but speed isn't an external factor that cannot be controlled or avoided, by the drivers of the PTW, and that's why human factors have a decisive contribution in road safety.

HUMAN FACTORS

There are some causes of PTW accidents that cannot be avoid by the driver of those vehicles, like in other category of vehicles, however PTW had to its features do not offer great conditions of safety for those who circulate in this type of vehicle, and that's why the driver must be aware and conscientious of the type of driving that he practices. It is imperative to study and specify behaviors of PTW drivers in order to improve their skills, make more efficient law enforcement, and trace the right path to a better national road safety strategy in Portugal.

In figure 10, it is shown that female drivers suffer more slight injuries compared to male drivers, however the male drivers suffer more serious and fatal injuries, this statistics reveal that in Portugal the PTW female drivers are more aware, and circulate more carefully and adequate speed when compared to the male drivers.

It is also important to filter the age interval in which occur more fatalities involving PTW, analyzing the data present in figure 11, it is evidenced that for less power PTW (moped, motorcycle type 1 and motorcycle type 2) the peak of fatalities is situated in an interval of ages between 16 years old and 21 years old, and for the most powerful type of PTW, motorcycle type 3, an interval between 21 years old and 30 years old, that correspond at the first years of licensing for each of those vehicles. According to this numbers the lack of driver skills, which a driver faces in his first years driving PTW, is an important factor, to have in consideration.

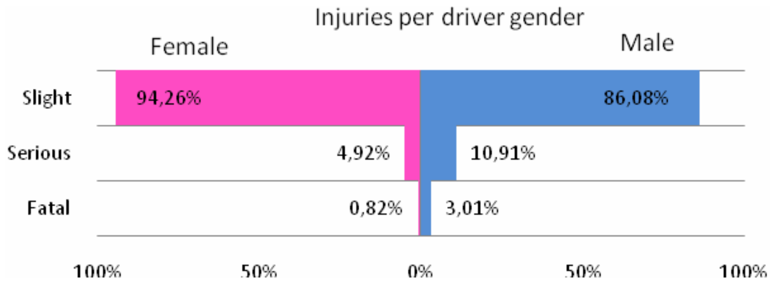

Figure 8. Injuries per driver gender involving PTW in Portugal.

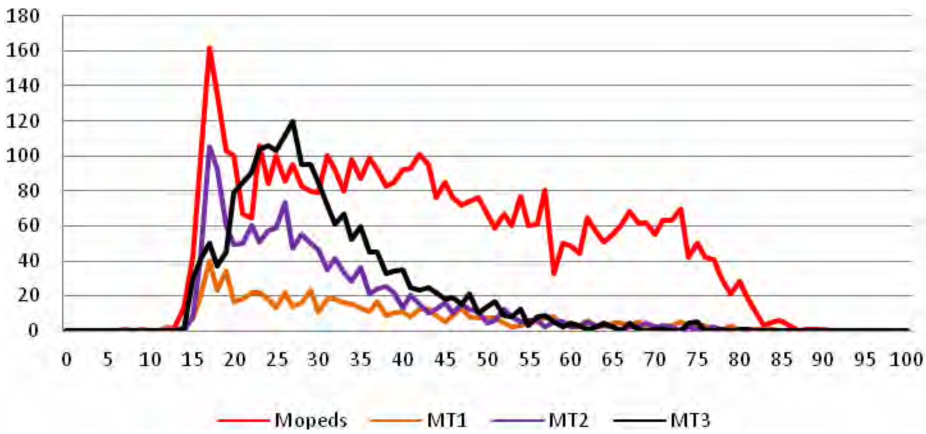

Figure 9. Drivers' age in fatal accidents.

It is also necessary to train drivers for the known problem that is alcohol, impairment by alcohol is an important factor influencing both the risk of a road accident, the severity of the injuries, as well post-crash outcome of injuries, even with a maximum legal blood alcohol content of 0,05g/l (in Portugal), in inexperienced young adults it represents 2,5 times the risk of involving in a road accident compared with more experienced drivers [3]. Through the graphic representation (figure 12), it is reveal that from all the drivers of PTW, who were involved in accidents with injuries, which had been submitted to blood alcohol test, and reveal a alcohol blood concentration greater than the legal 0,05g/l, 72% presented a alcohol blood concentration greater than 1,2g/l, running a risk of fatal injury accident 16 times when compared with a driver with zero alcohol blood concentration. However the number of drivers with alcohol above the limit is about 8%, which however is a very concerning number. This is an alarming situation and requires drastic measures (severe law enforcement) to avoid this kind of situations in the near future.

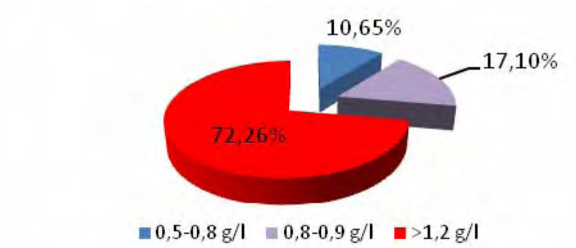

Figure 10. Alcohol test results in drivers involved in PTW accidents with injuries in Portugal.

Another situation that occur in Portugal, despite the use of helmet to be mandatory in Portugal, still many exist that don't use the helmet, this is a situation that requires a special attention on the part of the authorities. Some drivers believe that the use of a helmet is inefficacious in possible crash-injury situation and it's a waste of money, but they couldn't be more wrong, helmets work, helmet effectiveness has been confirmed in studies, and in real life situations. Safety conscious riders should wear helmets by deliberate choice every time they ride, but sadly this is not the situation present in Portugal. The statistic data present in table 6, only confirms the helmet safety effectiveness, in each of PTW category in Portugal, the use of helmet has at least saved three times more riders from fatal injuries, compared with the ones who weren't using helmet, and drastically raise the percentage of not injured riders. Helmets saves lives, it is simply the best protective gear that a rider can use while riding a PTW, and a helmet makes riding a PTW more fun, due to comfort, the cut of noise, wind blast, deflects bugs among other features. Some of the solutions may pass for better PTW helmets, more attractive prices, campaigns, law enforcement, but the truth is that riders must be a responsible community and approach this problem in a very serious way, and then the solution will be simple: always wear a helmet when riding PTW.

Riders should have in mind that it´s impossible to predict when or what kind they will be, but crashes happen…

METHODOLOGIES

The methodologies for the study of accidents involving motorcycle, presented hereunder, are based on the on-scene in-depth motorcycle accident investigations methodology by the OECD [10]. The starting point is the information from the police reports that includes the more relevant data including diagrams and other information required for the reconstruction. The information contained in the Police reports is sometimes incomplete, and one of the aims of this undergoing work is also to collaborate with the police and traffic authorities in order to improve the quality and the quantity of the data collected at the crash scene. Next when some information is missing or some questions arise, the vehicle (if still available) has been mechanically inspected in order to detect mechanical failures or malfunctions as also evidences related with the contact between vehicles or vehicle and road users. From these data, a 3D accident reconstruction has been performed, as in the cases presented hereunder using the software PC-Crash [9]. All the data resulting from the reports and accident reconstruction is included in a Microsoft Access Database. Of course a detailed 3D accident reconstruction is almost impracticable to do for all the accidents occurred. In the future also non-accident population is to be included. For now the non-accident population is rather obtained from the statistical data.

Table 6. PTW rider injury related with use of helmet in Portugal.

<table>
<tr><th>PTW</th><th>Use of helmet</th><th>Non-use of helmet</th></tr>
<tr><td>Mopeds</td><td>
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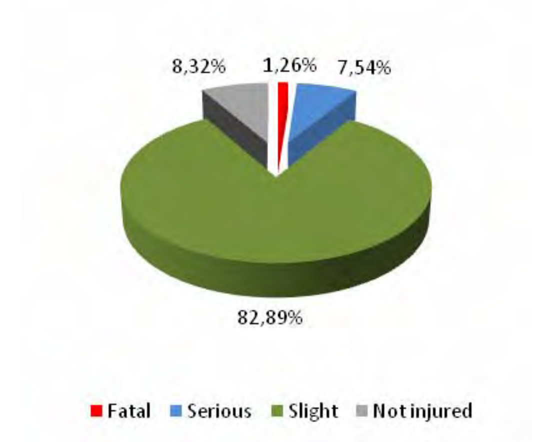
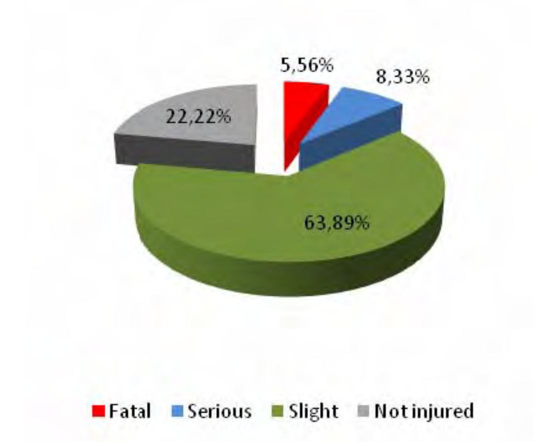
<tr><td>MT1</td><td>
</td><td>
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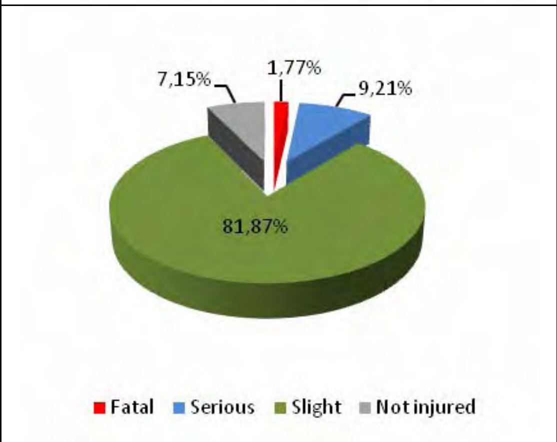
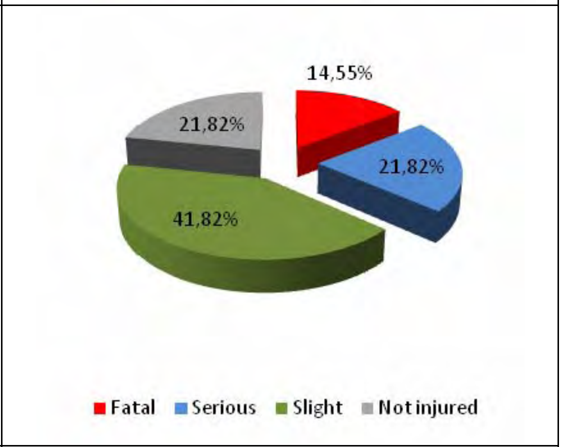
<tr><td>MT2</td><td>
</td><td>
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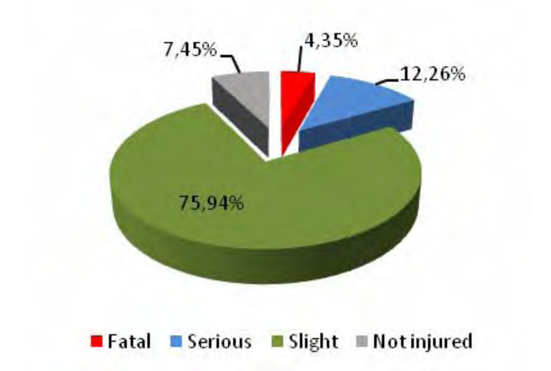
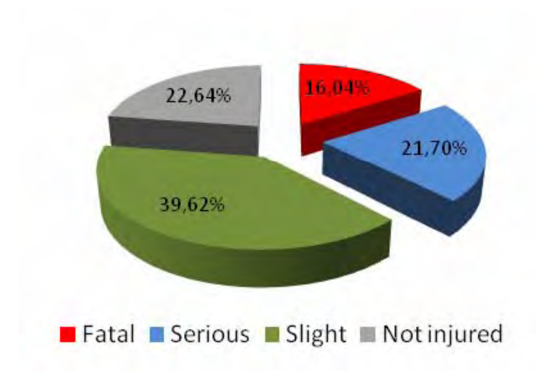
<tr><td>MT3</td><td>
</td><td>
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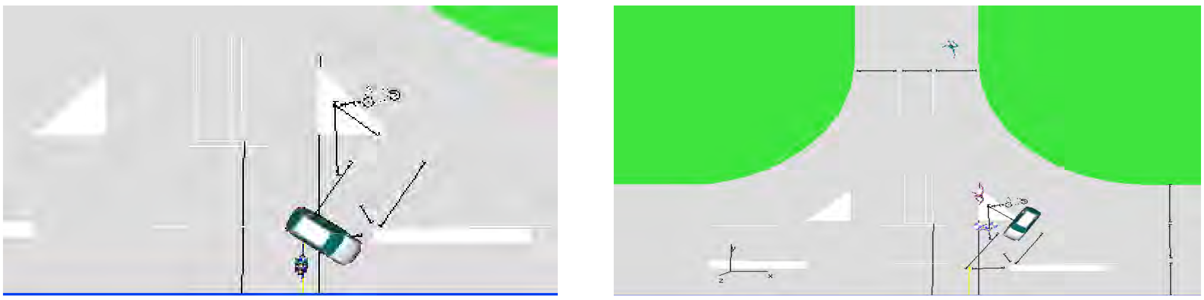
ACCIDENT RECONSTRUCTION

In opposition to automotive vehicles where the pre and post crash movement is in the majority of the cases planar, motorcycles have frequently three-dimensional motion and sliding/skidding during fall down. Due to these three-dimensional motions the classical accident reconstruction techniques based on deformation or speed from skid and sliding marks can lead to erroneous results. Also the estimation of speed from skid marks should be used carefully because a significant number of the drivers in an emergency situation only use the rear brake. One example of a motorcycle accident form the in-depth database is presented in Figure 11. In Figure 12 some frames of the reconstructions are presented. This is an example in which the accurate estimation of the energy absorbed by the vehicles play an important role. Motorcycles are not designed for crashworthiness, and, in general, in collision with other vehicles, the larger amount of energy is absorbed by the other vehicle.

Figure 11. Vehicles' damage



a) Impact　　　　b) Rest Positions

Figure 12. Reconstruction of an accident involving a moped vehicle.

The accurate reconstruction of accidents involving motorcyclists and pedestrians requires, in general, the use of three-dimensional models. These models are necessary to reproduce the motion of the vehicles as also to estimate the injuries in pedestrians and to correlate them with the medical reports in order to allow the determination of the vehicle' speeds.

Multibody dynamics models are used in many fields, from vehicle dynamics, human body models and crashworthiness. These models are to be adapted to accident reconstruction of motorcycle accidents, giving a more reliable description of the vehicles' pre and post crash dynamics, and will include also models for occupants such as the Madymo models [11]. Scientific visualization tools or even CAD 3D models can be used to illustrate these aspects of the accident, as indicated in Figure 13.

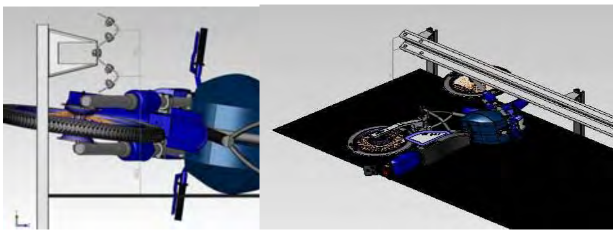


Figure 13. CAD 3D models for accident visualization and modeling.

The reconstruction of motorcycle accidents is a difficult task. The information about crash-tests is limited and the commercial accident reconstructions available sometimes have some difficulties dealing with some accident scenarios. In addition to the necessary crash data, multibody dynamics models can give an important contribution providing a more accurate modeling of the pre and post crash dynamics of the vehicle as also to include crashworthiness description. One of the methods to accurately develop safer hardware road structures as also to evaluate the biomechanical injuries for motorcyclists is the development of combined CAD+Finite elements+multibody models. In Figure 14 these models developed by Silva [13] are presented.

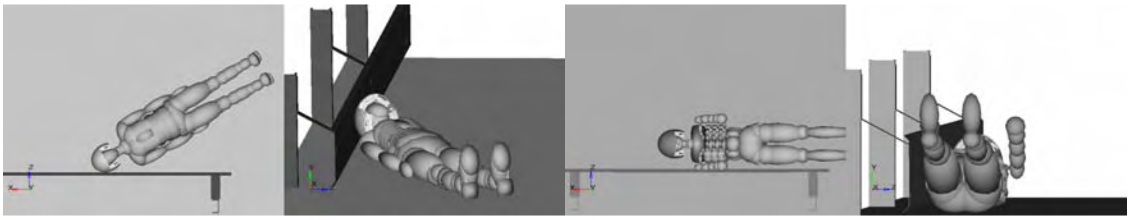


Figure 14. Guard rail models for motorcyclist protection.

These models combine CAD and finite elements models of the structures, and anthropomorphic models of the human body. The CAD models have been developed with commercial software Soli Works, the migrated to finite elements commercial software Ansys where the meshes are generated, and the integrated with the anthropomorphic models in Madymo where the simulations are performed. With these models the deformation of the structures is taken into account, and these can be used not only to develop safer structures but also to evaluate the injuries, and correlate them with medical data. With this approach complex accident can be reconstructed more accurately.

MOTORCYCLE ACCIDENTS: IN-DEPTH INVESTIGATION OF MOTORCYCLE ACCIDENTS

For now about 70 in-depth motorcycle accidents investigations have been carried out using the OECD and Maids methodology. Due to the complexity of such task, that involves a fully reconstruction of the accident this work is still ongoing. The accident reconstruction has been carried out using three-dimensional reconstruction techniques that have been briefly described in previous section. The determination of the impact speed and the pre-impact direction of the vehicles is a crucial point that is request by courts. In the data presented, it can be observed that only in one case no helmet use is observed. This agrees with the Portuguese statistics that reveals that the helmets use is greater than 90%. Alcohol use is considered one of the major causes of accidents. Even if the primary contribution for the accident is the other vehicle driver, speed plays a crucial role in the severity of the accident. For the fatal accidents speeds is the primary contribution factor for motorcycles (MT2 and MT3). In addition concerning motorcycles the typical driver characteristics is 20-30 year old male.
Because of this the enforcement of speed and impaired driving laws becomes difficult. The behavior of those which breaks the traffic rules is an element of risk causing road traffic accidents [12]. For

PTW, the primary contribution of the accidents is an action of the Other Driver. This aspect has a very extensive contribution in accident involving moped vehicles or motorcycles MT1.
About 80% of all accidents occurred at good weather and light conditions.
The in-depth mechanical inspection of the vehicles is very important. Some details are not registered in the police reports but sometimes they play a crucial role for the determination of the accident' causes. Traffic police reports usually don't contain detailed information to fully understand the causes of the motorcycles accidents. Detailed photographs are in the majority of the cases absent and also mechanical inspection of the vehicles is not performed.

CONCLUSIONS

In this work an overview of the work carried out concerning PTW safety and methodologies for motorcycle accident reconstruction have been presented. Pedestrians and motorcyclists are worldwide two groups of risk. However in Portugal, the contribution of these groups for the overall injuries is much higher than the European average. From the accidents already analyzed especially involving motorcycles, the problems of conspicuity of PTW are a problem for the accidents in general, and the fact that the motorcyclist is not protected by any safety cage have a decisive contribution for the injuries. Speed has an important contribution in fatal accidents, especially for young drivers driving a sport motorcycle. Several tools can be used for motorcycle accident reconstruction, as speed form skid marks, Pc-Crash or Madymo models.

ACKNOWLEDGEMENTS

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Application of the New Diagnostic Dictionary (AIS 2005) for Traffic Accident Research

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[7] Autoliv Development, Autoliv Sweden

Introduction

Each year the traffic accident research teams in Dresden and Hanover provide an in depth investigation of approximately two thousand accidents, aggregated in the GIDAS database. To accomplish a comprehensive review of each traffic accident recorded, a sensible and thorough encoding of suffered injuries is indispensable. The Abbreviated Injury Scale by AAAM offers a valuable and handy solution to achieve this goal. However, there were a few difficulties in the use of the AIS that came up in the past, which let to necessary improvements for the utilization of the AIS 2005 for GIDAS.

Information about single injuries in GIDAS

In GIDAS every single injury is coded in detail. The exact definition is given in the notation and the AIS code of the injury as well as the classification of the kind of injury. The location is specified regarding the body part, the exact part of an organ or tissue and the side. Whenever possible medical classifications such as the AO classification or classifications according Aitken, Weber or LeFort are given. Furthermore the extent or size of the trauma is indicated. Since the investigation teams also keep track of the patients in hospital or during therapy, there is detailed information given about the immediate treatment, the hospital management and any follow-up therapy as well as possible complications. To establish the connection to the technical data of the accident the interdisciplinary team also “decides” about the injury causing vehicle parts, the location, possible correlations of injuries and damages and influences of intrusion.

Previous Difficulties

During the last years of using the AIS to specify the injuries in the GIDAS database there were repeating difficulties. Codes of not existing AIS specifications that resulted from typing errors were frequently found and injury specifications were often not consistent with the AIS code. This led to difficulties in data analysis and statistical use of the data that resulted in necessary reviews of the encoded data and additional effort for corrections. Furthermore an ingenious encoding of partly “unknown” injuries was almost impossible and required a sensible standardization.

New Diagnose List

The new AIS 2005 dictionary offered by AAAM was an attractive opportunity to approach the previous difficulties. After translating the AIS 2005 into German and digitalizing it in a database a specific ID number was assigned to each injury. Also injury details like the location or the kind of injury mentioned above that were precisely mentioned in the AIS injury description and concordant to the GIDAS variables were assigned in the diagnose list. Thus only the ID from the list has to be coded in the database and all other information can be filled in automatically, excluding typing errors immediately. If for example a whiplash injury has to be coded, it can be filtered easily in Unidato, using a hierarchical structure. Now the AIS code 2005 (640278.1) is assigned automatically, the location is set “cervical spine”, the characteristics describe “distortion – soft tissue or muscle”, and the injury causation is set to “body movement” – without human intervention and human typing errors.

Since there were also codes necessary for unknown injuries to provide the information that there were more injuries than exactly given new codes were added for these traumas with limited information. The four codes added allow the encoding of unknown fatal injuries when the patient was killed, unknown severe injuries for inpatients and unknown slight injuries for outpatients. Furthermore a code for an unknown injury that is not further specified at all was added. Thus the information is now harmonized and easy to filter.

Perspective

To further develop and improve the encoding of single injuries in GIDAS there are still several goals set. Therefore the definition of all explicit information for each injury including extent, size and maybe therapy has to be provided. More and more information has to be coded in the database using the automatic filter. Finally more exact and accurate information in the database and fewer mistakes will allow consistent filter possibilities for data analysis and yet higher data quality for traffic accident research with GIDAS.

A European Perspective of In-Depth Data Sampling on Cognitive Aspects of Motorcycle Helmets within COST 357

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ABSTRACT

In the context of the COST357 research project, the climatic conditions and requirements for protective helmets for motorcyclists have been examined. The extent to which these factors would influence motorbike handling and accidents in which motorcyclists are involved have also been examined. This project addresses how cognitive abilities of motorcyclists relate to helmet construction factors. In particular, the aspects of motorcycle driver helmets are to be parameterized in order that they may be used subsequently as a basis for future requirement profiles. The task of one working group of the COST357 project has been to analyse accident events and to identify helmet design issues which affect motorcycle drivers while wearing a helmet. This has been achieved by collating accident data across different countries recorded in the course of in-depth investigations at the site of accidents and by combining this with field studies of motorcyclists participating in traffic, but not involved in accidents. This paper presents the study methodology, database and first results of this international survey. The basis of the study has been a total of 424 interviews of motorcyclists and 134 motorcycle accidents, which were collected across Germany, Greece, Italy, Ireland, Portugal and Turkey and combined in a single database.

DESCRIPTION OF THE PROJECT AND OBJECTIVE

Two-wheeled motor vehicles are involved in 14% of all traffic accidents occurring in the European Union. This directly affects over 6000 people annually. Statistics show that a full face helmet with its full facial protection can be a life saver in an accident and protect against severe head injuries. Given the multiplicity of factors which lead to such accidents, this project considers those cases where the field of view of the motorcyclist was impaired by negative characteristics of the helmet or where there were construction defects in the helmet, which constituted an accident hazard. Previous analyses of accidents usually provide no information as to whether the helmet was optimized for the cognitive needs of the wearer or whether it influenced the accident event. A well-arranged study containing a literature research about aero-acoustics, temperature behaviour and ventilation problems as well as psycho physiological performance features of the helmet during driving has been published in 2007 by the University of Heidelberg on behalf of the Bundesanstalt für Straßenwesen (Federal Highway Research Institute - 1). It contains references that in helmets particularly sound pressure and ventilation contribute substantially to the well-being of the driver, a relation to accidents could not be established, however. At higher speeds high sound pressure levels occur (Hüttenbring - 2). The visor seems to contribute considerably to the noise emission (Lower M.C. et al. - 3). An impairment of the perception of acoustic signals as for example of sirens doesn't seem to exist, in fact with attenuated full face helmets the signal quality in this frequency range is improved (Van Moorhem - 4 and Mc Knight - 5). Differences up to 5 °C and humidity differences up to 35% are supposedly possible (Jung und Schenk - 6). Brühwiler determined in an experimental investigation that the removal of humidity for closed helmets is similar, but diverges strongly for open ventilation. This raised the question of physiological effects from heat on the psychomotor efficiency of motorcyclists (Brühwiler - 7). A study relating helmets to accidents is an analysis of 463 motorcycle accidents in the years from 1993 to 1996 in Auckland (New Zealand), which was compared to a control group of 1233 interviewed motorcyclists. The colour of the helmet thus plays a role in the accident event, wearers of white helmets had a lower accident risk than drivers with black helmets (Wells et al. - 8), lower by about 24%. The BAST study conducted experiments at 12 different protective helmets and found inside temperatures of 20°C to 37°C at most for outside temperatures of 15°C to 36°C measured and found room for improvement because of functional and design errors. A temperature of 24°C to 27°C can be classified as comfortable (Deetjen et al. - 9). The colour of the helmet has an influence on the temperature level inside the helmet, inside black helmets temperatures of up to 37 °C occurred during exposure to summer sun, whereas for helmets in light colours only up to

30°C were measured, which would result in physiologically unfavourable wearing conditions particularly at lower speeds. During the psycho physiological investigations conducted, no characteristics and/or correlation could be established in the EEG and ECG, except for one significantly affected pulse frequency, thus no requirements could be formulated on this account.

These ergonomic factors include minimizing distractions from noise or overheating, maximizing useful visual information, limited fields of view through the visor, and the construction of helmet openings for the visor and for air ventilation. While car drivers and motorcycle drivers are respectively responsible for two thirds (2/3) and one thirds (1/3) of accidents, the helmet can actually play a significant, albeit unknown, role in improving perception. It is usually the helmet that is the highest part of a motorcycle driver and is consequently visible from all sides.

In the context of the COST357 research project, with the acronym "PRO HELM", for "Accident **PR**evention **O**ptions with motorcycle **HELM**et", the climatic conditions and requirements of the protective helmet for motorcyclists are examined. The project aims to provide insight into how the cognitive abilities of motorcyclists and other road users are affected by the helmet construction. Various parameters of motorcycle drivers' helmets are quantified for the first time ever in order to provide scientists with the necessary background information required in subsequent study of interactions between complex factors. The range of member countries cooperating in this study should provide interested researchers with additional data pertaining to geographical and climatic variations.

This 4-year project (2005-09) is led by a management committee which is represented by all signatory nations [COST357]. The activities are divided into 10 tasks, which are implemented by four working groups. This present study has been undertaken by WG 1. WG 1 was charged with carrying out a prospective study on data sampling of cognitive aspects of motorcycle helmets and how these conditions influence accidents of motorcyclists.

STUDY APPROACH AND METHODOLOGY

The objective of the present study has been to find out when motorcycle helmets do not work optimally; such incidences could relate to when the driver is influenced by adverse thermal, visibility or acoustic conditions from inside the helmet or if the helmet visor provided an inadequate field of view of surrounding traffic. Two practical approaches were followed to obtain information on these topics. Firstly, accidents were reviewed as a source of information; secondly, a prospective survey of motorcycle drivers who had not necessarily been involved in any accidents was used to glean information on failures and problems in relation to the use of helmets. The following important influences on the field of vision of a helmet were assessed:

- temperature, humidity and comfort
- limits for physiological properties like ventilation, weight of helmet, view of driver
- helmet visibility from all directions for reasons of conspicuity

A field survey in different European countries was initiated and a suitable questionnaire was developed to determine the current conditions of helmets within an accident event as well as in the general field of traffic users. The questionnaire considered personal data as well as general helmet data, data on helmet features, conditions, sensations, usage and a comprehensive measurement of vision limitations through the visor of the helmet. Figure 1 describes the questionnaire. In total a number of between 87 to 95 different items were queried in the survey.

The data collected with the questionnaire includes a total of:

87 variables at a survey with motorcycle riders or
95 variables when collecting data after a motorcycle accident

- Personal data: 20 variables
- General helmet data: 11 variables
- Helmet features: 5 variables
- Helmet condition: 5 variables
- Helmet sensation: 14 variables
- Helmet usage: 13 variables
- (Accident situation: 8 variables)
- Additional information in Expert findings/Measurements: 19 variables


COST
FRAGEBOGEN
Persönliche Daten
COST 357
Helm Basisdaten

Figure 1. *Questionnaire for the pan-European survey on helmet conditions.*

Motorcyclists were asked for their experiences while driving wearing a helmet without having been involved in an accident ("field study"). They were also asked the same questions after an accident and the relevant helmets were investigated ("accident study"). The motorcyclists reported any negative effects pertaining to vision, heat, conspicuity and ventilation and they also made suggestions for further developments of helmets. This personalised information was recorded at the same time as the measurement results, for which a separate form had been developed for use during the survey at the accident scene.

The precise methodology differed depending on the research activities and procedures in the individual countries. Germany and Italy have an in-depth-investigation team with access to the scene of the event directly after an accident, Greece surveys drivers retrospectively in their homes and some countries only conduct field studies (Ireland, Turkey). Of these teams, those in Ireland, Portugal and Turkey carry out their activities by following the same methodology of other national research sources i.e. police surveys, forensic expert activities. These COST357 Investigation centres were mostly ready to the implement the methodology and to commence investigations in March 2007. By April 2008, all investigations had started and been carried out in a total of 6 different countries. The scheduled deadline for completing data collection is the end of September 2008.

DESCRIPTION OF QUESTIONNAIRE AND MEASUREMENTS

As well as developing a suitable questionnaire, some measurement tools were prepared to determine the maximum geometry of the vision hatch and the horizontal and vertical vision field. A special device, a so-called gonimeter or perimeter, was developed for this purpose, as shown in Figure 2. The subject fixes his eyes on the midpoint of the perimeter's semicircle while the tester moves a pointer to identify the limits of the subject's peripheral vision.

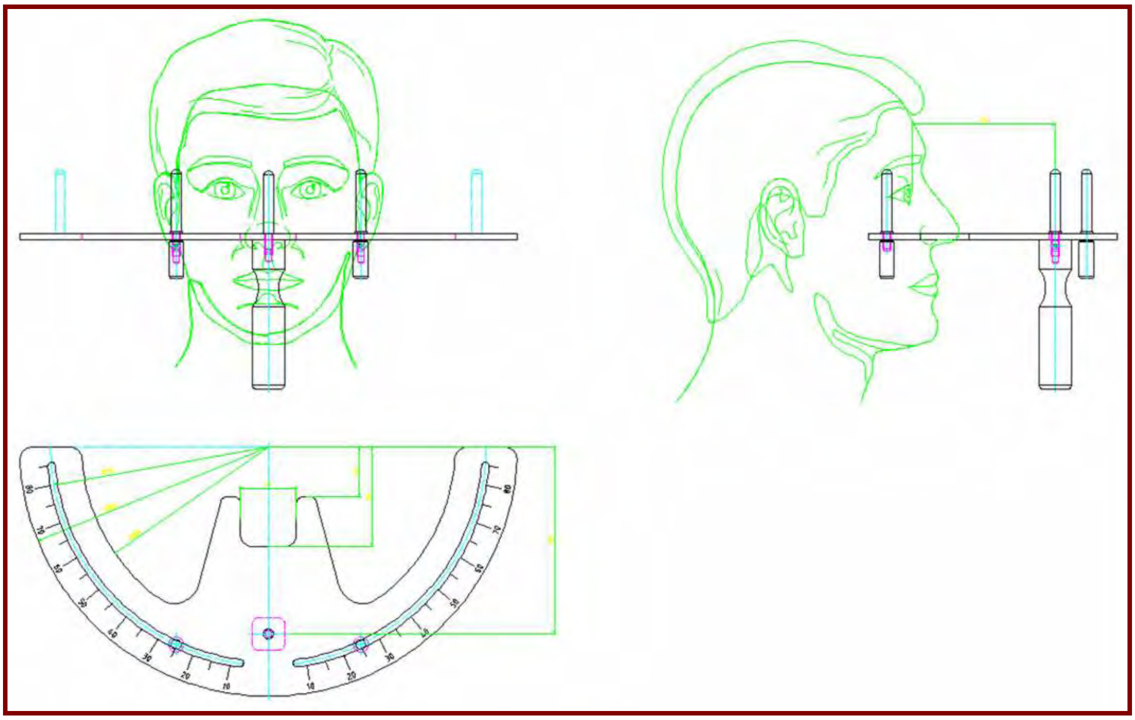

Figure 2. *For the horizontal field of vision test, the goniometer is placed orthogonally on the nose of the rider. The rider is told to focus on the centre-pin of the device and to move the pin of the protractor horizontally to each side until it can no longer be seen. The angle of the field of vision of both sides is recorded.*

Sets of different reference lenses were prepared from real visors to measure the light transmittance of the motorcyclists' visors. This required prior treatment by a grinding machine and validation with a transmittance testing device as shown in Figure 3. By comparing the tested visors against the reference lenses, it was possible to measure light transmittance values in the range of = 14% to 91%. The same method, but with a different set of reference lenses, was used for light diffusion tests. The light diffusion of the visor or goggles was compared against the different reference lenses. The diffusion value of the reference lenses that matched closest to the light diffusion of the visor or goggles was recorded. 4 different reference lenses were used for light diffusion, ranging from D = 2% to 25%.

Figure 3. *There are 6 different reference discs L with light transmittance values of τ = 14%, 57%, 64%, 81%, 83% and 91%. There are also 4 different reference discs with light diffusion values of D = 2%, 8%, 16% and 25%.*

SAMPLING OF DATA BY TEAMS IN DIFFERENT COUNTRIES

The cases were collected by the teams in different countries by using the same questionnaire and the same measurement tools and a similar data sampling process was used in all countries. A database, COST357, was developed and the data stored at the MUH Germany. All of the data were submitted to the MUH on Microsoft Access-Format 2003.

Greek Case Data

The research was conducted in the county of Heraklion, the capital of the island Crete, at the Technological Educational Institute of Crete. The sample comprised 100 subjects. For the "accident study", a prior survey by the Institute was used. That included 300 people and was carried out in 2006. Those motorcyclists who had been involved in an accident while wearing a helmet and who still had their helmet were contacted to conduct the necessary measurements. The Greek COST 357 study used 50 cases retrospectively from this survey.

Italian Case Data

The study in Italy was carried out by two CORSS (Centro Interdipartmentale di Studi e Ricerche sulla Sicurezza Stradale) teams. They prepared the Italian documentation at Pavia University and compiled data on the basis of the developed protocol and questionnaire of COST357.

Cases of helmet users who were involved in an accident were collected for the "accident study". Participants were interviewed a few days after the accident after the team leader had contacted the police forces (Polizia Locale, Polizia Stradale, Carabinieri) and obtained their cooperation for the accident study. The team leader provided the police forces with an abstract of the Ethics Committee approval and provided them with a description of the research project. They also discussed the significance and scientific merit of the study with the police forces. The police, in turn, informed the team when an accident had occurred and pertinent information regarding accidents and riders was extracted from the police reports. The motorcycle drivers were contacted by phone and an appointment was made to interview them and to obtain measurements from their helmets. The investigation area is the District of Pavia, from where more than 40 cases have been examined.

The cases of the "field study" came from two areas of Italy: Pavia, in northern Italy and Messina, in the south. The Pavia team collected data at four petrol stations in District of Pavia. The investigation team contacted each petrol station manager and explained the study to him. The riders that this identifies are not representative of the population in this sample region. The team from Messina collected data both at petrol stations and at two high schools. They contacted the petrol station managers to use the station as a site for data collection and contacted the principals of the schools to obtain cooperation and consent to distribute the questionnaire among the students. The students' parents were asked to give their informed consent to permit their sons (if aged under 18) to participate in the study.

German Case Data

In Germany the study is carried out at the Accident Research Unit of the Medical University Hannover (ARU-MUH) applying two different approaches. Accident files of GIDAS (German In-Depth-Accident-Study) are used to select cases in which a motorcyclist wearing a helmet was injured and to identify whether the motorcyclist was able to participate in the survey and the helmet was available for measuring the relevant COST issues. The Accident Research Unit ARU at the Medical University Hannover has many years of experience in accident documentation, in-depth-investigation and accident reconstruction (Otte - 10). In Germany, specialist teams in Hannover and Dresden go directly to the scene of the accident to collect the necessary information to complete detailed accident reconstructions as well as medical data about how those involved were injured and treated. The COST 357 team member collects information of an accident that has taken place and goes out to interview the motorcyclist and measure the helmet. Secondly, a "field study" (case control study) was carried out on a survey of motorcycle drivers who were not involved in an accident. The test persons were found at petrol stations, at motorcycle meeting points and were stopped by the police. They were requested to be interviewed and to allow their helmet to be examined and measured. The investigation area is the region of Hannover. The cases are randomly selected motorcycle drivers in traffic accidents from different places in the area of Hannover.

Portuguese Case Data

The study in Portugal is conducted by the IDMEC IST Technical University of Lisbon. The sampling area was the region of Lisbon. During weekday daytime hours between 08.00 to 18.00 hours the police randomly stopped motorcycle riders, who were then interviewed by members of the COST team. They were asked if they were willing to participate in the control study. Interviews were carried out at motorcycle meeting points and at petrol stations.

Irish Case Data

The investigation started in Ireland in September 2007 and was undertaken by the School of Electrical, Electronic & Mechanical Engineering of University College Dublin (UCD) to gather survey data from an urban area (Dublin city) and a rural area (Co. Donegal). Participants were contacted by four different means, namely:

1. *Online internet sites for motorcycle enthusiasts*

Threads requesting participants for the survey were placed in the relevant sections of some popular enthusiast websites in Ireland: (www.biker.ie; www.irishbikerforum.com; www.ukgser.com (Irish section)). Contact was made with interested respondents via email prior to meeting at a suitable location to collect data: this was generally the participant's home, workplace, UCD campus or another mutual location.

2. *Motorcyclist known to the researcher*

A small number of motorcyclists known personally to the researcher were surveyed. This led to further contact with other riders in the area. These riders were telephoned and invited to participate. The general location was mid to south Donegal; this is a mainly rural area.

3. *M.A.G. Ireland*

Motorcycle Action Group (M.A.G.) Ireland is a voluntary organisation representing Irish motorcyclists. Their URL is www.magireland.org; they also publish *"Roadrunner",* a quarterly magazine which is issued to their approximately 2000 members. An advertisement was placed in Roadrunner describing COST 357 and inviting readers to participate in the survey. Those who did respond were similarly met at their workplace, home, UCD campus or some other mutual location. They also tended to come from the Dublin region.

4. *Gardaí (National Police)*

200 letters were given to the Gardai for distribution. Half were given to riders in their Traffic Division and half were sent to civilian riders involved in road traffic accidents informing them of the study and inviting people to participate. The traffic divisions of two major Garda stations in Dublin, Pearse Street and Blackrock, were contacted directly and both agreed to participate. In both cases the stations had to be visited several times as the riders worked in shifts. As the helmets examined are standard issue, they were of the same model. Also several of the Garda riders had accidents in the past and some recently damaged helmets were available to examine.

Turkish Case Data

Two types of data collection procedures were used. First, non-professional riders were approached in two motorcycle shops in Ankara. Measurements and interviews were conducted among customers and acquaintances of the customers who visited the shops. Second, in addition to non-professional riders, a sample of professional riders was collected in the police stations, pizza delivery shops and post offices in Ankara. Measurements and interviews were conducted among police motorcyclists, post officers delivering mail by motorcycle and pizza delivery riders.

DATA AVAILABILITY:

The following table shows the data stored in the COST 357 database for analysis purposes, as collated *by the end of May 2008.*

Partner	**Total number of cases**	**Accident cases**
Germany	60	6
Greece	100	48
Ireland	54	11
Italy	148	46
Portugal	21	9
Turkey	41	14
Total	**424**	**134**

Table 1. *Total numbers of database cases and "accident study" cases at end May 2008 ("field study" = total – "accident study").*

The COST 357 data set contains a total of 424 subjects from field questionings and 134 "accident cases". To analyse the results it appears particularly important to first regard the epidemiological data such as age of the motorcyclists, their driving experience and the type of protective helmet used (full face helmets, half shells or open face helmets), as well as their proportional incidence, the different driving behaviour and habits when carrying protective clothing and helmets in the different European countries. Concerning the age of the motorcyclists it is noticeable (c.f. Figure 4) that in Germany almost all age groups are relatively evenly distributed, whereas in Italy 45% are aged 15 - 25 years, in Ireland 35% are aged 26 - 35 years, while in Portugal 52 % are between the 26 – 35. In Greece and Turkey the two age groups 15 - 25 years and 26 - 35 occurred with nearly the same frequency of approximately 30%. The highest portion of older motorcyclists (older than 55 years) was 13% in Germany.

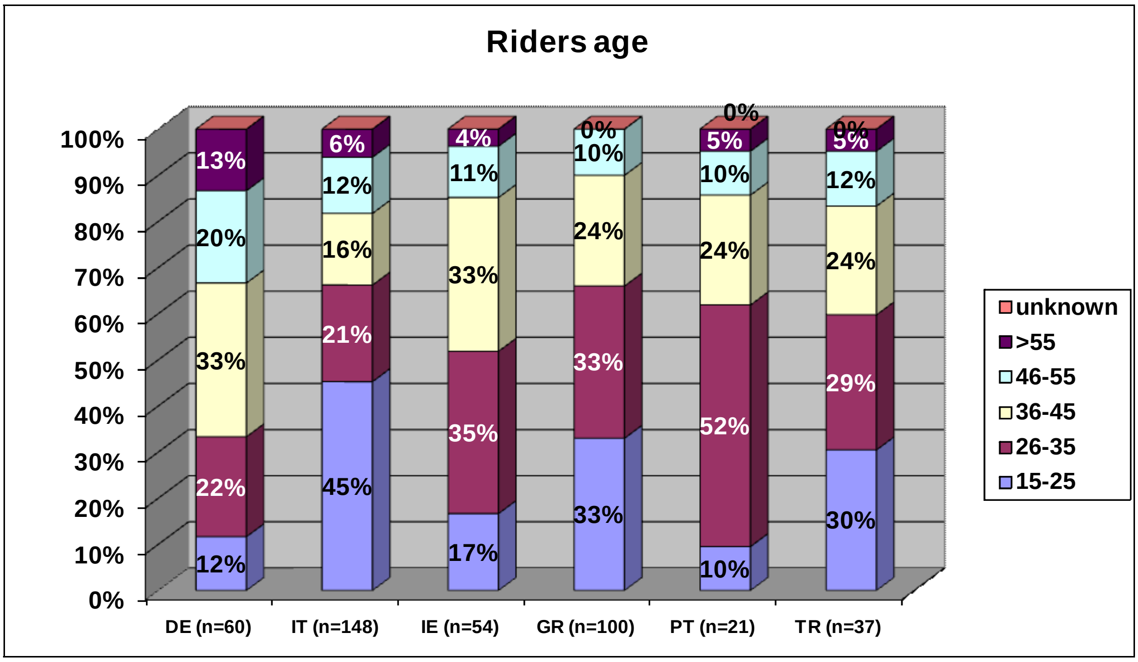

Figure 4. *Riders' age distribution of interviewed motorcyclists.*

The motorcyclists that took part in the investigation usually had many years of motorcycling experience. Thus about ¼ of all had been driving motor cycles for more than 20 years, respectively had a licence for so many years. The riders were asked about "how long they are motorcycle riding". Remarkably and contrary to the trend of all other countries was Portugal with predominantly motorcyclists of many years standing and Turkey where 2/3 of all investigated drivers reported no more than 2 years driving experience.

It can be assumed that half of the investigated motorcyclists had already been involved in an accident before. Only in Greece and Portugal was the incidence of previous accidents higher (Greece: 72.2%, Portugal 85.7%). In Ireland and Turkey the motorcyclists owned their helmets on average for less than 3 years when the investigation was carried out, while they had been worn for 3.5 years in Italy, 3.9 years in Greece, 4.5 years in Germany and 5.1 years in Portugal. Full face helmets were predominantly used across Europe, from 51% (Turkey) to 63% in Germany and 80% in Ireland. In Italy, however, only 20% of riders wore full-face helmets; 70% wore open-face helmets.

RESULTS OF INTERVIEWING MOTORCYCLISTS

The questionnaires dealt with the protective helmet, the wearing conditions of the helmet and the general motorcycle driving characteristics. For motorcycle accidents, approximately 30 characteristics were incorporated into the interview to record the condition of the protective helmet: these were collected by the interviewers – i.e. the experts. These also included the measured values of the horizontal and vertical opening angle, field of view, transmittance degrees and light diffusion values of the glass insert of the protective helmet glass, the so-called visor.

Motorcycle helmets in accident events

69% of the helmets registered in accidents had abrasions on the outside; 12% were partly cracked. Only 20% of the protective helmets involved in accidents were considered to be completely intact. 47% of the helmets were damaged at the side, 12% at the back, 12% at the front and only 7% showed damage on the upper section (top). In 7.7% of the cases the motorcyclists lost the helmet during the actual accident (n=7 of those who had closed the chin strap). Helmet loss occurred at an frequency of 40% mainly during lateral impacts, i.e. to either the right (30%) or left side (40%), and also in frontal impact situations 20% of loss of helmets (Figure 5).

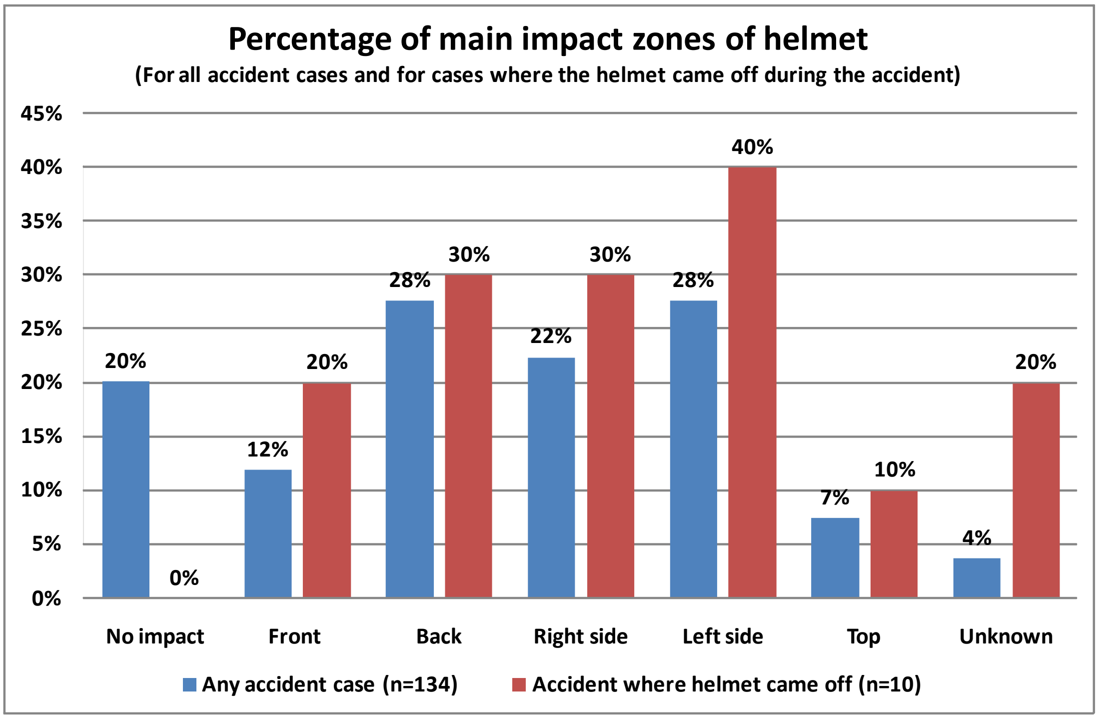

Figure 5. *Loss of helmet in the course of an accident.*

It is remarkable that for these cases the proportional frequency of the impact zones at the rear of the helmet (30%) is only slightly higher than for helmets which had not been lost (28%). This implies that helmet loss rarely occurs due to a primary impact at the back of the head. In contrast to the strip-off conditions, where a helmet is pulled off a test-head from the rear according to standard ECE 22, real-world accidents allow for relative motion of the head in lateral and dorsal directions: such motions can lead to helmet loss.

Protective helmets in the "field study"

18.6% of those motorcyclists questioned indicated that the helmet significantly limits their field of view. 27% of the interviewed riders reported that visors frequently opened of their own accord. 32.6% considered their helmet to be too noisy and 14% regarded the chin strap as being uncomfortable. 2/3 of the causes of noisy helmets were from wind noise (68.9% air flow noise), while 11.9% was from air turbulences, 3.7% from rattling noises, and 8.9% from whispering noises. It is noteworthy that taller people particularly complained of noise. Figure 6 shows the percentages of helmet noise to be only 14% for people less than 165cm tall, 30% for people between 170 and 174cm high and 46% for those between 185 and 189cm.

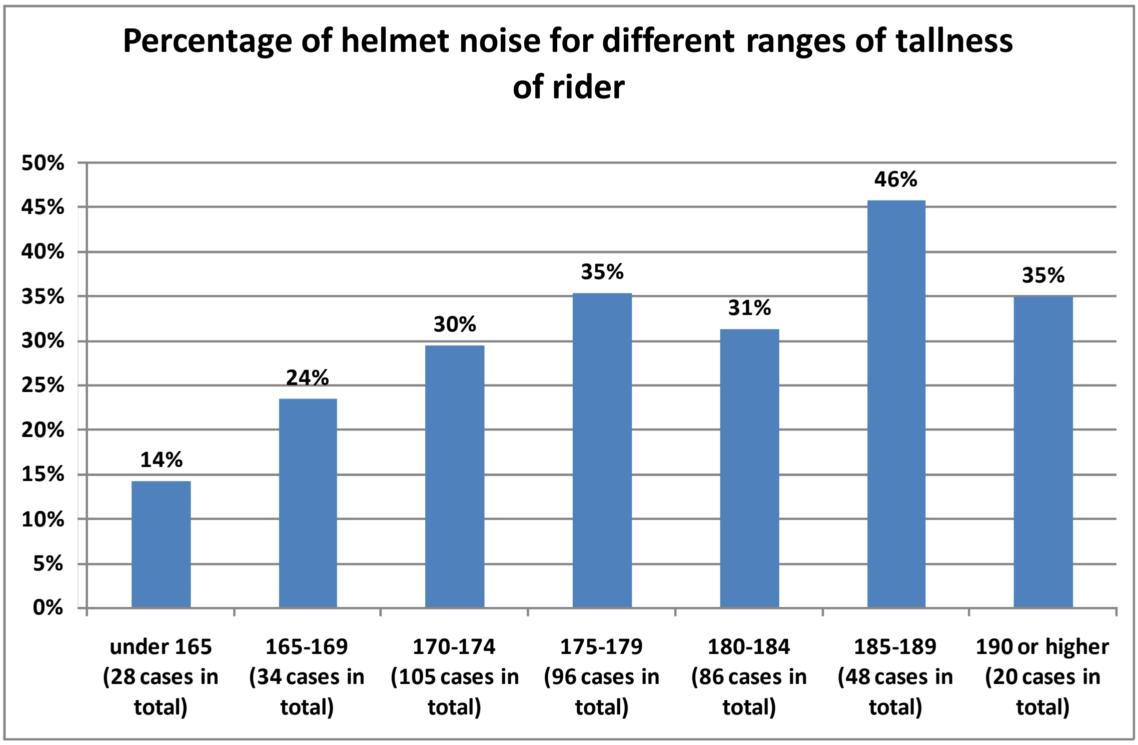

Figure 6. *Percentages of helmet noise for different heights of riders (heights given in cm).*

The measured fields of view of the helmets indicated quite a different distribution between the different countries. Thus, over 80% of the helmets in Portugal had view angles between 140 and 180 degree, most of them between 150 and 170 degrees. In Ireland, also approximately 80% were between 160 and 180 degrees. In Turkey, 65% had field of view angles of only 140 to 160 degrees. It is possible, however, that these differences are due to the goniometer being used differently or interpreted differently by the various measuring team members within the same country. The variations that have been reported cannot be explained solely from a technical perspective. Since relatively identical fields of view have been reported for the right and left sides in each country, it is likely that the measurement teams in each country followed a consistent process. The measured fields of view for Germany show an approximate normal distribution with a maximum between 130 and 170 degrees, and no measurements above 170 degree field of view through the visor field. Figure 7 shows also the general distribution of all measurements of the horizontal field of view as a result of all measured helmets.

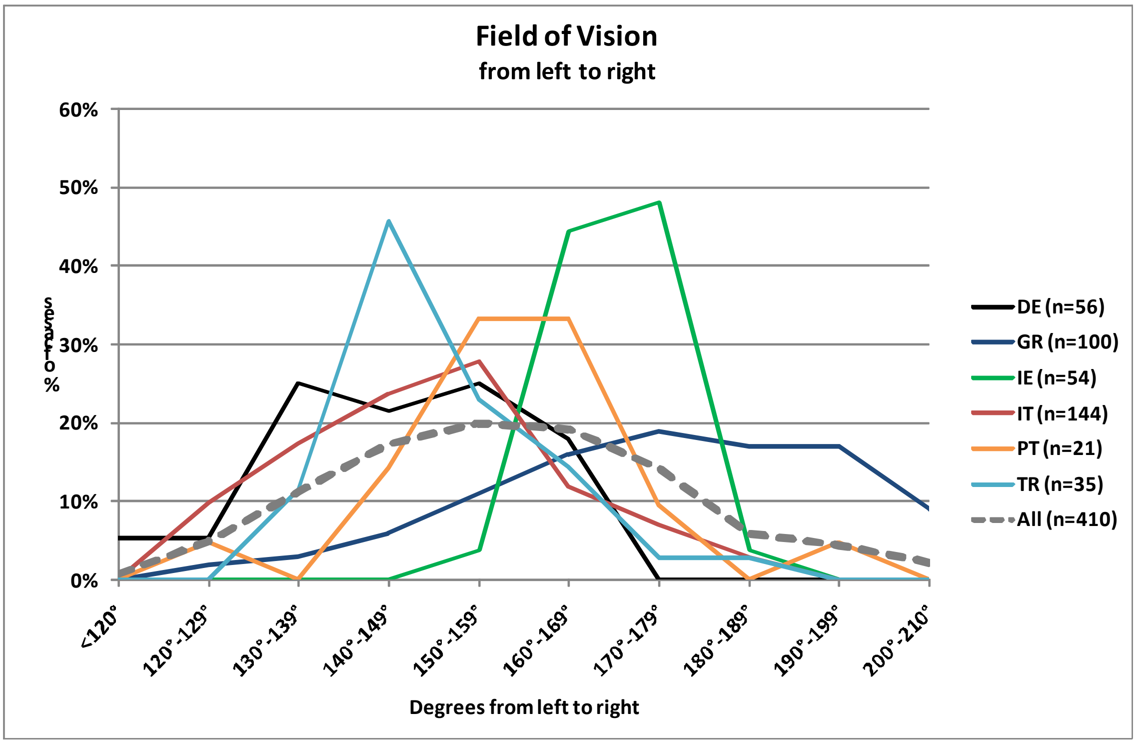

Figure 7. *Frequencies of measured degree of horizontal field of vision of driver.*

The light transmittance degree of each visor was determined by comparing the individually validated lenses having known light transmittance values against the visors of the protective helmets. Transmittance values of $\tau > 91\%$ were predominantly reported in all countries except Portugal where the majority could be found with $\tau = 58 > 64\%$ (c.f. Figure 8).

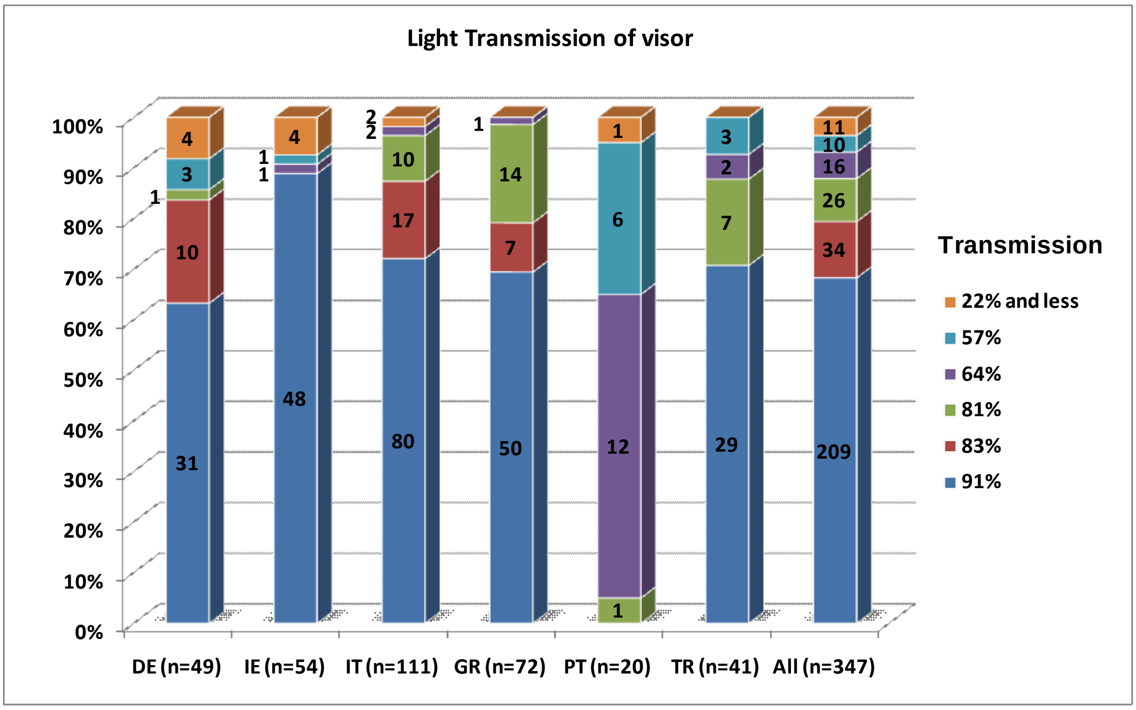

Figure 8. *Frequencies of measured light transmittance values of visors. The values for light transmission are grouped in 22% and lower, 57%, 64%,81%, 83% and 91 to 100% light transmittance*

It is remarkable that such high transmittance values were reported so frequently (about 85%) in Ireland and seldom in Portugal. It is possible, however, that these extremes may be due to inherent climatic differences between these countries, but could be also the result of very low registered number of cases in Portugal. The Column of all measurements together is shown in 68.3% light transmittance degrees of more than 83%, pointing out high level of quality concerning light transmission on current helmets.

The light diffusion values of the visors were determined by a similar comparison against sets of validated lenses. Here, the predominantly high-quality helmets yielded very small light diffusion values of D < 8% in all countries (60,4% of all measurements) although this was proportionally lower in helmets in Italy, Turkey and Greece (c.f. Figure 9). In Greece, Italy and Turkey helmets with visors with light diffusion values D = 25% were also found.

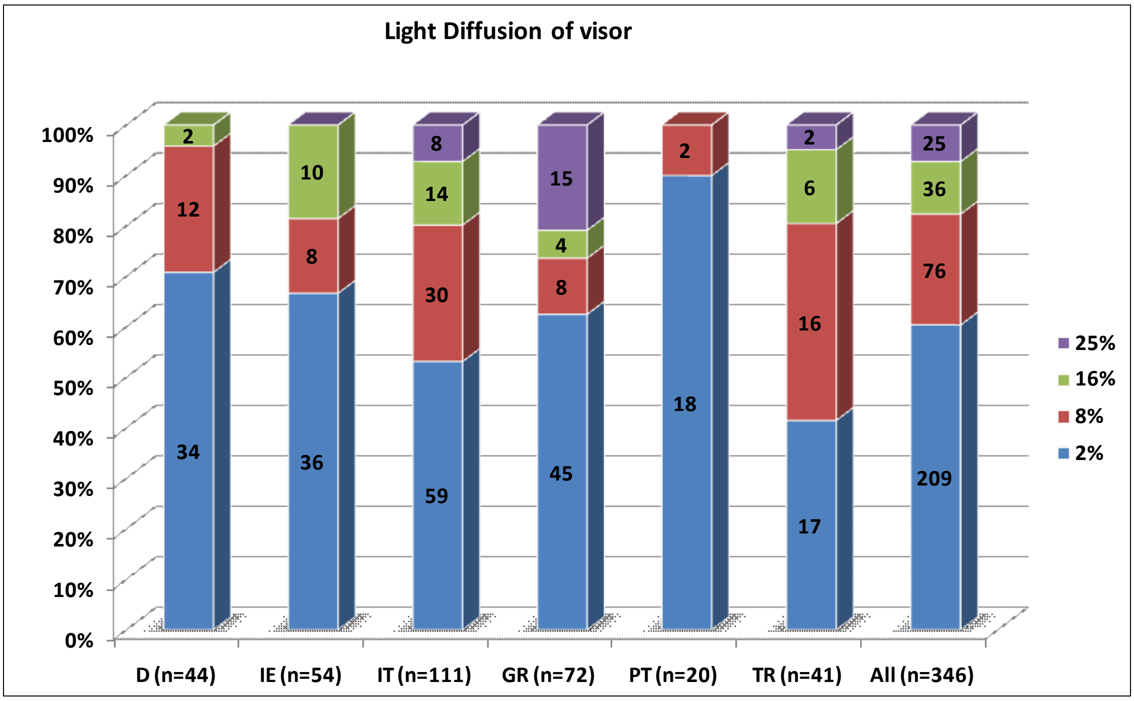

Figure 9. *Frequencies of measured light diffusion values of visors, the values of light diffusion are grouped in less than 2%, 8%, 16% and 25% diffusion.*

CONCLUSIONS

Within the framework of the COST357 research project, the environmental requirements for protective helmets for motorcyclists have been examined. This has been achieved by interviewing motorcyclists to determine existing problem areas with their motorcycle helmets. A comprehensive questionnaire with more than 100 different items of request was used during interviews and helmet inspections to address wearing comfort, age and condition of helmets and, by using customized instrumentation, to measure the field of view, light transmittance and light diffusion of helmets visor.

First, and as expected, differences showed up in the different countries, largely as a result of the climatic differences in these countries. Thus, in southern countries such as Italy, Greece, Portugal and Turkey as opposed to northern countries including Germany and Ireland, more open face helmets were worn frequently than full face helmets.

The study of 424 interviewed drivers without accident and 134 interviewed drivers with accident is shown important parameter of the conditions of their helmets and visors. First of all most of the inspected helmets were under good conditions. 68.3% of all helmets are given light transmittance degrees of more than 83%, pointing out high level of quality concerning light transmission on current helmets. The predominantly high-quality helmets yielded very small light diffusion values of D < 8% in all countries (60.4% of all measurements) although this was proportionally lower in helmets in Italy, Turkey and Greece. A poor general state having light transmittance values of less than 80% and light diffusion values of more than 25% were more frequently found in the southern countries, while in northern European countries significantly lower diffusion values were measured. Nevertheless, approximately 1/3 of all motorcyclists who were questioned indicated that their helmet was too noisy and 18.6% regarded their field of view as being too small. The helmet measurements confirmed these data. The measured fields of view of the helmets indicated quite a different distribution between the different countries. Thus, over 80% of the helmets in Portugal had view angles between 140 and 180 degree, In Ireland, also approximately 80% were between 160 and 180 degrees.

In Turkey, 65% had field of view angles of only 140 to 160 degrees. It is possible, however, that these differences are due to the measurement device being used differently or interpreted differently by the various measuring team members within the same country. The variations that have been reported cannot be explained solely from a technical perspective. Since relatively identical fields of view have been reported for the right and left sides in each country, it is likely that the measurement teams in each country followed a consistent process. The measured fields of view for Germany show an approximate normal distribution with a maximum between 130 and 170 degrees, and no measurements above 170 degree field of view through the visor field. These measurements of field of vision are conformable with the test regulation regarding ECE 22. The current ECE 22-guideline [ECE 22-05)] specifies a minimum opening angle of horizontally 105 degree for helmets (c.f. Figure 10). The default values of the standard regarding light diffusion (ECE 6.15.3.5) is given with D < 2.5% (abrasion < 20%), nearly 60% of the helmets are reaching this demand, 40% had visors with default values in light diffusion criteria. Luminous transmittance (ECE 6.15.3.4) with ECE standard values of at least 50 to 80% appear not to be always attainable in practice in nearly 70% of the worn helmets.

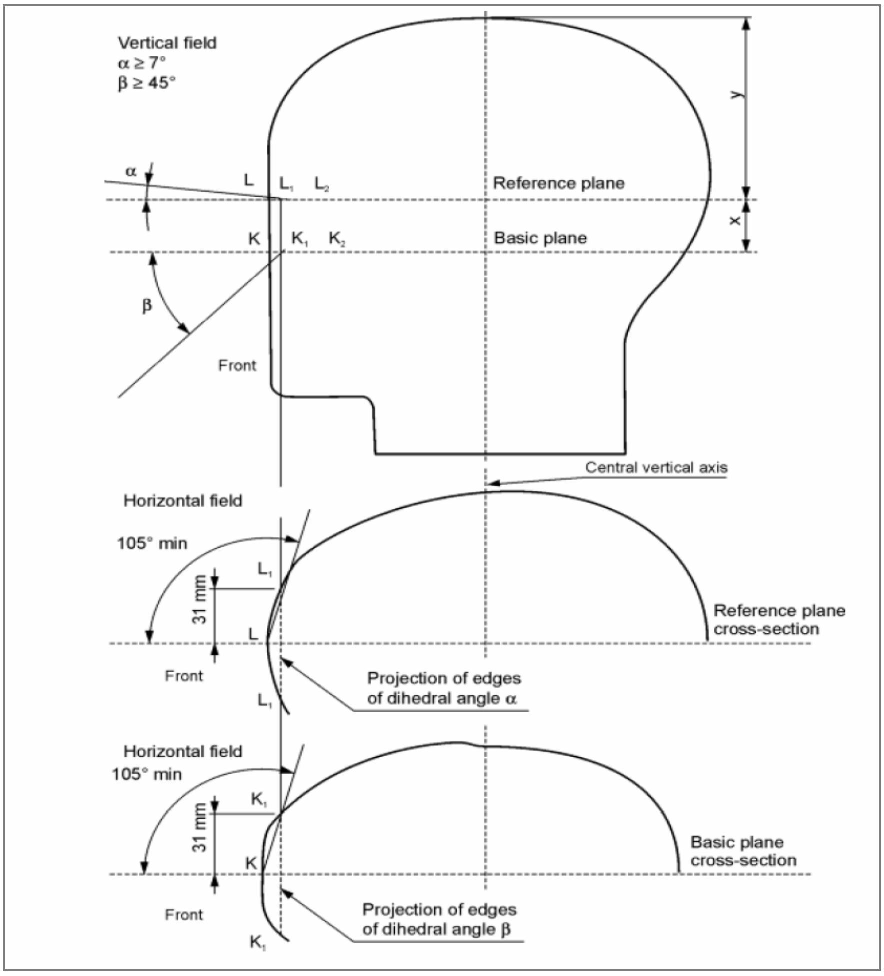

Figure 10. *Peripheral vision of the helmet standard ECE 22.*

The study yielded further interesting results. It is clear that the helmets worn by motorcyclists are not as old as might have been expected, being typically 2.8 years old in Ireland and 5.1 years old in Portugal. Even if southern countries have a perceived image of poor helmet use, the fact is that full face helmets, which provide better protection than half shells or open face helmets, are predominantly worn (usage rates exceed 50%) in all countries, except for Italy (only 20%). Special attention needs to be given to improving the helmet fastener, as the study showed a relatively high incidence (7.7%) of helmet loss during accidents. A detailed investigation of impact situations revealed that lateral and frontal impact situations provided the greatest hazards in this respect. This suggests that ECE 22 test conditions ought to be more closely representative of real-world accidents.

This present research also highlights the difficulty of obtaining comparable results from different countries when using different collection methodologies and basic conditions with relatively close tolerances. In spite of using a uniform questionnaire and test chart that was created by international mutual agreement, the results nevertheless showed large variations. Intensive training for all people actively involved in testing and measurement seems indispensible to ensure uniform handling of the developed measurement equipment. This study also indicates that co-operation between existing In-Depth-Teams in different countries is successfully able to collect data at short notice and to implement new collection systems, as was achieved by the COST 357 programme. In all six of the participating countries (Germany, Greece, Ireland, Italy, Portugal and Turkey) some prior experience of collecting “in-depth” data existed.

The results represented here are to be regarded as the first advance results of the COST 357 project. This study of WG1 will continue until the end of September 2008, following which the final results will appear in a subsequent publication and/or the final report (Website: www.cost357.org).

ACKNOWLEDGEMENTS

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Statistical Analysis of Bicyclist Accident in Changsha of China and Hannover of Germany

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ABSTRACT

The bicyclist accidents were analyzed to get better understanding of the occurrences and frequency of the accidents, injury distributions, as well as correlation of injury severity/outcomes with engineering and human factors in two different countries of China and Germany.

The accident cases that occurred from 2001 to 2006 were collected from IVAC database in Changsha and GIDAS database in Hannover. Based on specified sampling criteria, 1,570 bicyclist cases were selected from IVAC database in Changsha, and 1806 cases were collected from Hannover, documented in GIDAS database. Statistical analyses were carried out by using these selected data. The results from the statistical analysis are presented and discussed in this study.

1 INTRODUCTION

Bicyclists represent a population with high risk of traffic injuries since they are unprotected in vehicle collisions, and they are one of the most vulnerable road users in city traffic. At present there are more than 500 million bicycles in China. It is a country reserved the largest number of bicycles over the world. In recent two decades, with a rapid increasing of the vehicle fleet on the road in China, there is also a great increasing of the vehicle traffic accidents. Each year the total number of the road vehicle traffic fatalities becomes highest in the world. In 2005, 98,738 road users were killed and 469,911 were injured in vehicle traffic accidents. Of which there are 11,407 bicyclist fatalities accounted for 11.55% of total reported traffic fatalities, and 51,302 injured accounted for10.92% of reported traffic injuries [1]. The bicyclist accidents were identified as a vital issue in urban traffic safety and therefore a high priority should be given to this road user group in research of safe urban transportation.

In urban area of Changsha, bicyclists are frequently involved in vehicle accidents. The objective of this study is to identify the occurrence and type of the traumatic injuries of the bicyclists in vehicle collisions, and to investigate the correlation of traffic injuries with human factor and engineering, environment factors, by using valid and reliable materials collected from traffic administration authorities and local hospital. For this purpose, the bicyclist accident cases were collected from Changsha, China, and also cases collected from Hannover, Germany, based on same sampling criteria. The knowledge from the study is a prerequisite for developing guidelines to improve safety of the bicyclists. The study is presenting the benefit of existing in-depth-research and using the data in common approaches.

2 METHOD AND MATERIALS

2.1 Accident data collection

The vehicle-to-bicyclist accident cases from the IVAC database and GIDAS database were collected based on the following standards: (1) the accident occurred during the period from 2001 to 2006, and (2) the bicyclist accidents occurred in the urban area.

2.1.1 Accident data from police sector in Changsha

Changsha is the capital city of the Hunan province located in middle of China, with a population 2,060,000 (6,133,000 including residents in suburb) and registered vehicles 452,809 in 2006. The bicyclist accident cases registered during 2001-01-01 to 2006-12-31 in Changsha were used in this study.

An analysis on police documentations for bicyclist accidents from 2001 to 2006 was carried out, and the **1570** cases were collected for a statistical study of bicyclist accidents in Changsha, with information about location and type of an accident, accident vehicle, involved road users, as well as road environment etc. The three levels of victim's injuries were registered as minor, serious or fatal injury.

Furthermore, an in-depth investigation of bicyclist accidents have been carried out by a team in cooperation between researchers from Hunan University, local police sector, and medical first aid. The accident data was collected and documented from on-site and retrospective investigations in Changsha urban area with detailed information about bicyclist victims on age, gender, height/weight, injuries, speed determination and details of the accident cars as well as the accident scene.

2.1.2 GIDAS accident data from Hannover Medical University

In the area of Hannover nearly 1000 accidents with injured person are collected there annually in a continued and representative way. These accident cases were documented in the accident database GIDAS (German In-Depth Accident Study) by Accident Research Unit at Medical University of Hanover. The **1806** bicyclist accident cases were collected from GIDAS database for the accident occurred from 2001 to 2006.

The collected cases in the GIDAS database contain very detailed information about bicyclist victims on age, gender, height/weight, injuries, speed determination and details of the accident cars as well as the accident scene.

2.2 Statistical analysis of bicyclist accidents

A study of vehicle-to-bicyclist accidents was conducted by using the collected **1,570** bicyclist accident cases from Changsha, China and **1,806** bicyclist accident cases collected from the accident database GIDAS. First, a general statistical analysis was carried out using the accident cases in terms of involvement of accident vehicle, accident scenarios, injury distributions, injury patterns, and injury severity etc. Secondly, a comparison was carried out in terms of statues of bicyclist accidents in both Changsha and Hannover urban areas. The factors influenced the injury outcomes were proposed and discussed in terms of vehicle transport environment and road users. The results were discussed with regard to accident data collection, accident sampling and injury distributions etc.

3 RESULTS AND ANALYSIS

The results from statistical analysis based on the collected bicyclist accident cases are presented for the frequency of bicyclist accidents, injuries, and injury severities with respect to the different factors.

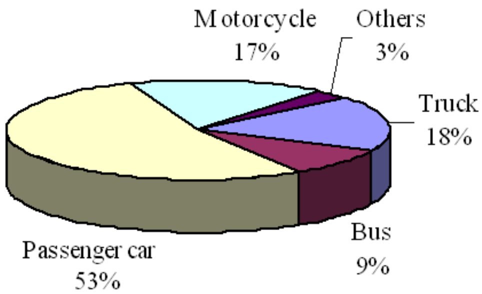
3.1 Analysis of involvement of vehicles

The distribution of vehicle types in bicyclist accidents in Changsha is presented in Table 1 with 1646 involved vehicles. The passenger cars participated in 53% of the bicyclist accidents, motorcycles and trucks participated in about 17% and 18% bicyclist accidents. In Hannover the passenger cars accounted for 64% of reported bicyclist accidents, which indicated the passenger cars are involved more frequently in bicyclist accidents in Hannover (Figure 1).

Table 1: Distribution of vehicle type in bicyclist accidents

Vehicle	Changsha, China		Hannover, Germany	
	AF*	RF*	AF	RF
Truck	295	**17.92**	95	5.26
Bus	152	9.23	27	1.5
Passenger car	875	**53.16**	1157	**64.06**
Motorcycle	274	**16.65**	20	1.11
bicycle			223	**12.35**
pedestrian			59	3.27
None			223	**12.35**
Others	50	3.04	2	0.11
Total	1646	100	1806	100

* AF=Absolute Frequency, RF=Relative Frequency



(a) (b)

Figure 1. Distribution of vehicle type for bicyclist accidents in (a) Changsha and (b) Hannover.

3.2 Injury severity

There are 1594 casualties in total of 1,570 vehicle to bicyclist accidents collected in Changsha. Among those casualties, 9.2% bicyclists were killed, 10.7% bicyclists were serious injured, 76.5% were slightly injured, and 3.6% bicyclists had no injuries (Table 2). In Hannover, the relative frequency 0.83% of the bicyclist fatalities is much lower than that from Changsha. The relative frequency of the slightly injured bicyclists is the quite the same in both Changsha and Hannover.

Table 2 Proportions of bicyclist injury severity

Value label	Changsha China		Hannover Germany	
	Absolute Frequency	Relative Frequency(%)	Absolute Frequency	Relative Frequency(%)
Fatalities	**146**	**9.2**	**15**	**0.83**
Seriously injured	171	10.7	318	17.61
Slightly injured	**1219**	**76.5**	**1345**	**74.47**
No injuries	58	3.6	128	7.09
Total	1594	100	1806	100

3.3 Age and Gender

Table 3 shows that in the bicyclist accidents, male had a higher rate for the gender distribution in Changsha: male 67.2%, and female 32.8%. In the bicyclist accidents, bicyclists ranged from 36-40 years old have a high percentage compared with other age groups. Small children (0-10) and old people (61-100) were not so often involved in the bicyclist accidents. The gender distribution for the bicyclist accidents in Hannover: male 57.1%, and female 42.9%. The distributions of relative frequency by the age are quite the same in both Changsha and Hannover.

Table 3: The distribution of bicyclist accident frequency by age and gender

Age	Changsha, China						Hannover, Germany					
	Male		Female		Total		Male		Female		Total	
	AF*	RF* (%)	AF	RF (%)	AF	RF (%)	AF	RF (%)	AF	RF (%)	AF	RF (%)
0-5	4	0.4	1	0.2	5	0.3	11	1.00	13	1.90	24	1.40
6-10	10	1.1	4	0.9	14	0.9	39	3.70	21	3.00	60	3.40
11-15	**76**	**8.3**	**54**	**12.1**	**130**	**8.2**	**99**	**9.40**	**63**	**8.10**	**162**	**8.80**
16-20	78	8.5	60	13.4	138	8.7	77	7.60	61	8.40	138	7.90
21-25	61	6.7	25	5.6	86	5.4	55	5.40	71	9.90	126	7.30
26-30	61	6.7	41	9.2	102	6.4	70	6.80	60	8.40	130	7.50
31-35	66	7.2	47	10.5	113	7.1	88	8.70	40	5.40	128	7.30
36-40	**108**	**11.8**	**78**	**17.4**	**186**	**11.7**	**98**	**9.60**	**69**	**9.10**	**167**	**9.30**
41-45	75	8.2	44	9.8	119	7.5	87	8.60	52	6.80	139	7.80
46-50	99	10.8	56	12.5	155	9.7	67	6.90	42	5.40	109	6.30
51-55	89	9.7	20	4.5	109	6.8	52	5.10	38	4.40	90	4.80
56-60	63	6.9	11	2.5	74	4.6	65	6.40	36	4.40	101	5.50
61-65	46	5.0	4	0.9	50	3.1	62	5.90	51	6.10	113	6.00
66-70	45	4.9	1	0.2	46	2.9	56	5.20	36	4.40	94	5.00
71-75	23	2.5	1	0.2	24	1.5	46	4.10	43	5.50	89	4.60
76-80	10	1.1	—	0.0	10	0.6	24	2.20	41	4.90	65	3.40
81-85	2	0.2	1	0.2	3	0.2	14	1.20	14	1.50	28	1.30
86-90	—	—	—	—	—	—	3	0.30	3	0.40	6	0.30
91-95	—	—	—	—	—	—	—	—	—	—	—	—
96-100	—	—	—	—	—	—	—	—	—	—	—	—
Unknown	—	—	—	—	230	14.4	19	2.00	14	1.90	33+6	2.20
Total	916	100	448	100	**1594**	100.0	1032	100	768	100	**1806**	100

* AF=Absolute Frequency, RF=Relative Frequency

3.4 Age and Injury Severity

Table 4 shows the distribution of injury severity by different age groups. It indicates that bicyclists of age groups 11-20 and 36-50 had a larger fatality rate than other age groups of bicyclists. The zero fatality rate of age group 86-100 years old is due to the scarce of the accident data of this age group (only 1 case). The frequency of injury severity vs the age in Changsha is similar with the status in Hannover.

Table 4: Age vs Injury severity

Age	Changsha, China										Hannover, Germany									
	Total		Injury severity								Total		Injury severity							
			Fatalities		Seriously injured		Slightly injured		No injuries				Fatalities		Seriously injured		Slightly injured		No injuries	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
0-5	5	0.3	0	0.0	0	0.0	5	0.4	0	0.0	24	1.4	—	—	4	1.2	15	1.2	5	3.9
6-10	14	0.9	2	1.4	1	0.6	11	0.9	0	0.0	60	3.4	—	—	11	3.7	45	3.4	4	3.4
11-15	**130**	8.2	8	5.5	20	11.7	95	7.8	7	12.1	**162**	8.8	—	—	34	10.4	112	8.3	16	12.7
16-20	**138**	8.7	1	0.7	10	5.8	117	9.6	10	17.2	**138**	7.9	1	—	15	4.2	108	8.1	14	10.6
21-25	86	5.4	1	0.7	7	4.1	75	6.2	3	5.2	126	7.3	—	2.5	12	4.1	104	7.7	10	7.4
26-30	102	6.4	9	6.2	8	4.7	80	6.6	5	8.6	130	7.5	—	—	13	3.6	108	8.0	9	6.7
31-35	113	7.1	11	7.5	8	4.7	89	7.3	5	8.6	128	7.3	2	—	23	8.2	92	7.0	11	8.6
36-40	**186**	11.7	15	10.3	32	18.7	128	10.5	11	19.0	**167**	9.3	1	11.4	26	7.2	131	9.8	9	6.9
41-45	119	7.5	13	8.9	18	10.5	86	7.1	2	3.4	**139**	7.8	1	6.4	20	6.7	106	7.8	12	9.2
46-50	**155**	9.7	15	10.3	17	9.9	119	9.8	4	6.9	109	6.3	—	4.3	16	6.2	91	6.8	2	1.6
51-55	109	6.8	13	8.9	9	5.3	86	7.1	1	1.7	90	4.8	1	—	18	5.0	65	4.7	6	5.0
56-60	74	4.6	11	7.5	14	8.2	49	4.0	0	0.0	101	5.5	1	3.4	18	5.3	77	5.7	5	4.0
61-65	50	3.1	10	6.8	8	4.7	31	2.5	1	1.7	113	6.0	1	7.4	29	9.3	82	6.1	1	0.8
66-70	46	2.9	9	6.2	3	1.8	34	2.8	0	0.0	94	5.0	2	4.4	21	6.8	67	4.9	4	3.4
71-75	24	1.5	3	2.1	4	2.3	16	1.3	1	1.7	89	4.6	3	11.9	26	8.4	58	4.3	2	1.7
76-80	10	0.6	4	2.7	—	—	6	0.5	—	—	65	3.4	1	35.5	17	5.2	43	3.2	4	2.9
81-85	3	0.2	—	—	—	—	3	0.2	—	—	28	1.3	1	6.9	12	3.6	15	1.2	—	—
86-90	—	—	—	—	—	—	—	—	—	—	6	0.3	—	5.9	2	0.8	4	0.3	—	—
91-95	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
96-100	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
unknown	230	14.4	21	14.4	12	7.0	189	15.5	8	13.8	37	2.2	—	—	1	0.3	22	1.6	14	11.2
total	**1594**	100	146	100	171	100	1219	100	58	100	**1806**	100	15	100	318	100	1345	100	128	100

3.5 Date and Time of the Accident

Table 5 shows that bicyclist accidents occurred most frequently from August to November in Changsha. This could be due to that it is the season good for people to travel by bicycles in Changsha. In Hannover the bicyclist accidents occurred more often in the summer.

Table 5: Month of the year

Month	Changsha, China		Hannover, Germany	
	AF*	RF*(%)	AF	RF(%)
January	121	7.71	58	3.21
February	123	7.83	76	4.21
March	124	7.90	116	6.42
April	113	7.20	130	7.2
May	119	7.58	**236**	13.07
June	111	7.07	**204**	11.3
July	102	6.50	**193**	10.69
August	134	8.54	**218**	12.07
September	**177**	11.27	210	11.63
October	**160**	10.19	147	8.14
November	**171**	10.89	126	6.98
December	115	7.32	92	5.09
Total	1570	100	1806	100

* AF=Absolute Frequency, RF=Relative Frequency

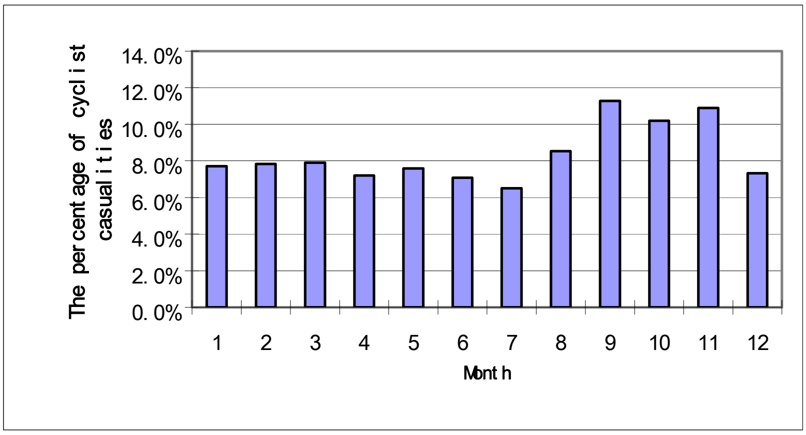


Figure 2 Accident frequency in month of the year in Changsha,

Table 6 and Figure 3 show that the bicyclist accidents occured most frequently in the morning and afternoon. The frequency of the accidents has two peaks: 7:00-9:00 AM and 5:00-7:00 PM when most people were traveling to work or home during the time period. The similar frequency of bicyclist accidents could be observed for accident data from Hannover.

Table 6 Time of the day

Time	Changsha, China		Hannover, Germany	
	AF*	RF*(%)	AF	RF(%)
00:00-00:59	44	2.80	16	0.89
01:00-01:59	20	1.27	3	0.17
02:00-02:59	10	0.64	2	0.11
03:00-03:59	4	0.25	3	0.17
04:00-04:59	9	0.57	3	0.17
05:00-05:59	19	1.21	7	0.39
06:00-06:59	60	3.82	33	1.83
07:00-07:59	**140**	**8.92**	**111**	**6.15**
08:00-08:59	98	6.24	93	5.15
09:00-09:59	78	4.97	105	5.81
10:00-10:59	89	5.67	127	7.03
11:00-11:59	95	6.05	124	6.87
12:00-12:59	72	4.59	142	7.86
13:00-13:59	83	5.29	121	6.7
14:00-14:59	88	5.61	134	7.42
15:00-15:59	71	4.52	**154**	8.53
16:00-16:59	92	5.86	133	7.36
17:00-17:59	**105**	**6.69**	**146**	**8.08**
18:00-18:59	**103**	**6.56**	**139**	**7.7**
19:00-19:59	68	4.33	73	4.04
20:00-20:59	83	5.29	54	2.99
21:00-21:59	78	4.97	39	2.16
22:00-22:59	32	2.04	22	1.22
23:00-23:59	29	1.85	22	1.22
Unknown	103	6.56	1806	100
Total	1570	100	16	0.89

* AF=Absolute Frequency, RF=Relative Frequency

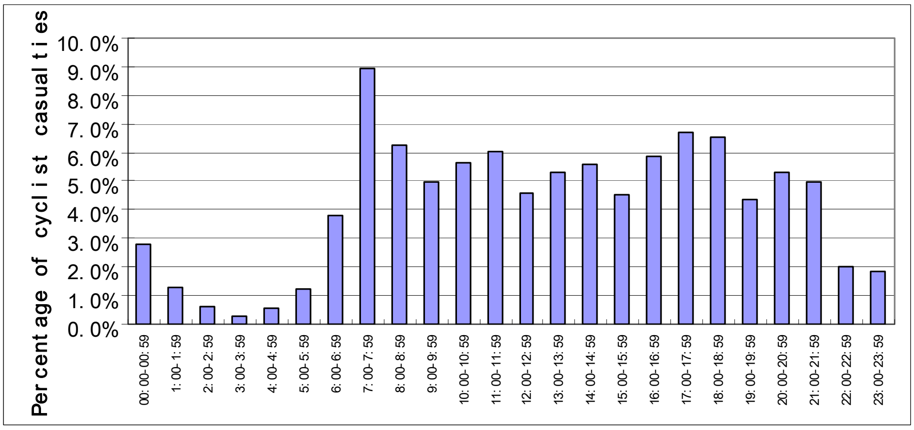


Figure 3 Time of the day

3.6 Light Conditions

Table 7 and Figure 4 show that most bicyclist accidents occurred while the light condition was good either during the daylight or had the street light on during darkness.

Table 7: Light conditions duringbicyclist accidents

	Changsha, China		Hannover, Germany	
	AF*	RF*(%)	AF	RF(%)
Daylight	**1117**	**71.15**	**1500**	**83.06**
Darkness-lights on	339	21.59	146	8.08
Darkness-lights off	113	7.20	160	8.86
Total	1570	100	1806	100

* AF=Absolute Frequency, RF=Relative Frequency

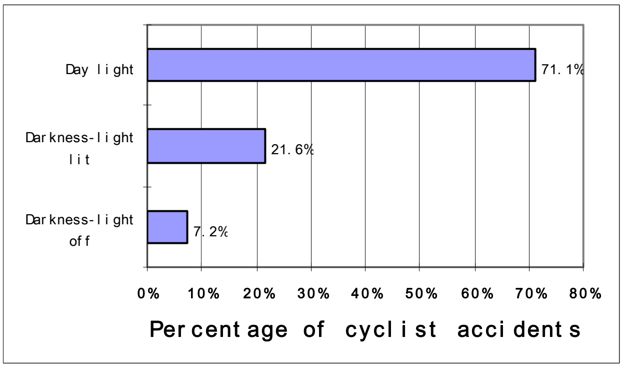


Figure 4 Light conditions during bicyclist accidents in Changsha,

3.7 Weather

Table 8 and Figure 5 show that among all known weather conditions, fine weather was the most representative weather when bicyclist accident happened. The bad weather such as fog and snow only accounted for a small portion (0.6%) of all weather conditions. However, to evaluate the risk of bicyclist accidents under different weather conditions, the distribution of weather condition during period 2001-2006 should be counted.

Table 8 Weather conditions during bicyclist accidents

Month	Changsha, China		Hannover, Germany	
	AF*	RF*(%)	AF	RF(%)
Fine	**965**	**61.46**	**1056**	**58.47**
Cloudy	294	18.73	569	31.51
Rain	295	18.79	161	8.91
Snow	5	0.32	10	0.55
Fog	5	0.32	7	0.39
Others	6	0.38	3	0.17
Total	1570	100	1806	100

* AF=Absolute Frequency, RF=Relative Frequency

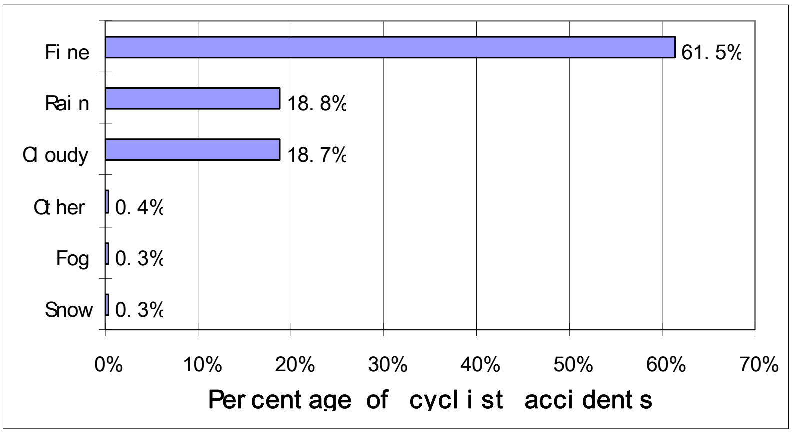


Figure 5 Weather conditions during bicyclist accidents

3.8 Road types

Table 9 and Figure 6 show the distribution of accidents vs road transect in Changsha (2006). The most vehicle-bicycle collisions took place on motor vehicle ways. Bicyclist themselves should more aware of the safety by following the traffic requirement. The distribution of accidents vs road transect in Hannover is quite different from that in Changsha, including the road transect for non-motor vehicle way and bicycle path.

Table 9: The distribution of bicyclist accidents vs road transect

	Changsha, China		Hannover, Germany	
	AF*	RF*(%)	AF	RF(%)
Motor vehicle way	**63**	**65.63**	**545**	**32.67**
Non-motor vehicle way	5	5.21	529	31.71
Mixed way	**22**	**22.92**	**0**	**0**
crosswalk	2	2.08	47	2.82
bicycle path	**0**	**0**	**547**	**32.79**
Others	4	4.17	0	0
Total	96	100	1668	100
Rejected Observations			138	

* AF=Absolute Frequency, RF=Relative Frequency

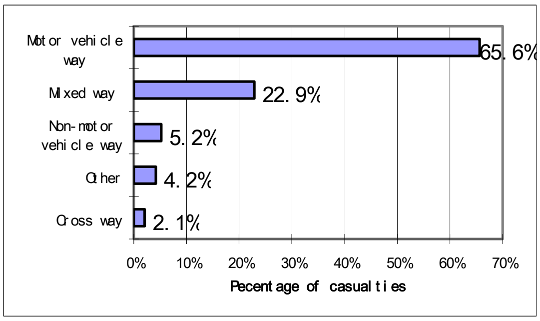


Figure 6. The distribution of bicyclist accidents vs road transect in Changsha,

Table 10 and Figure 7 show that straight road were the predominated road line type for bicyclist accidents in Changsha. While under corner or slope condition, there were much lower frequency of bicyclist accidents. In Hannover, the bicyclist accidents took place more frequently on intersections.

Table 10 The distribution of bicyclist accidents vs road line type

	Changsha, China		Hannover, Germany	
	AF*	RF*(%)	AF	RF(%)
straight	**1401**	**89.24**	**545**	**30.18**
slope	88	5.61	40	2.21
intersection	**0**	**0**	**1011**	**55.98**
others	0	0	210	11.63
Corner only	43	2.74	0	0
Corner & Slope	38	2.42	0	0
Total	1570	100	1806	100

* AF=Absolute Frequency, RF=Relative Frequency

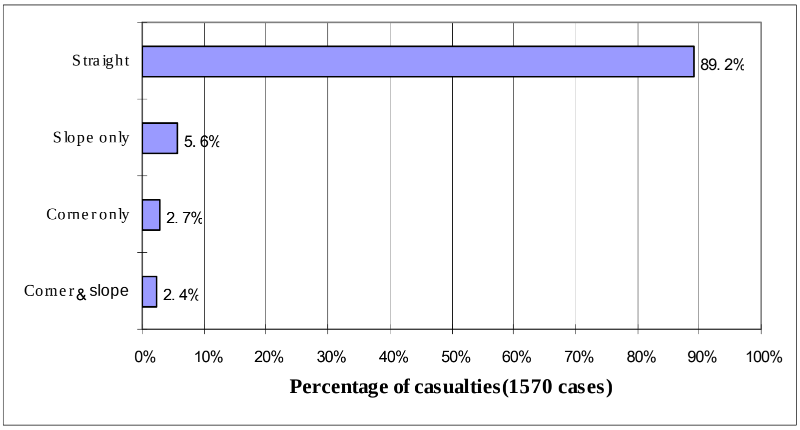


Figure 7 Road line type of bicyclist accidents in Changsha

Table 11 and Figure 8 show that dry road surface were the predominated road condition in reported bicyclist accidents. In Hannover the situation for road surface condition is quite the same as in Changsha, the bad road surface conditions has accounted for a small part of the bicyclist accidents.

Table 11 Road surface conditions of bicyclist accidents

	Changsha, China		Hannover, Germany	
	AF*	RF*(%)	AF	RF(%)
Dry	**1417**	**90.25**	**1546**	**85.6**
Wet	127	8.09	236	13.07
Ice and snow	3	0.19	20	1.11
Bumpy and loblolly	11	0.70	0	0
Unknown	0	0	4	0.22
Other	12	0.76	0	0
Total	1570	100	1806	100

* AF=Absolute Frequency, RF=Relative Frequency

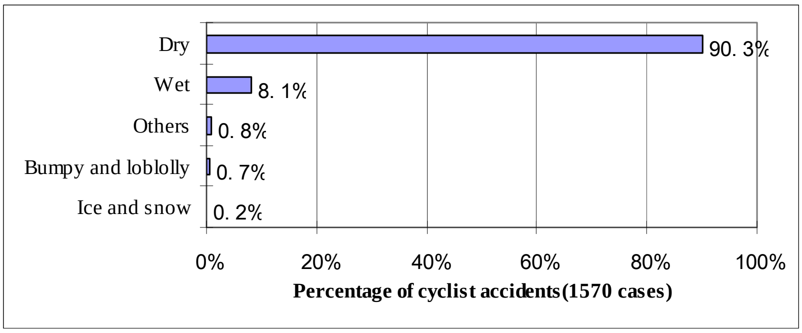


Figure 8 Road surface conditions of bicyclist accidents in Changsha

Table 12 and Figure 9 show that bicyclist accidents took place more frequently in conditions without traffic control and symbol, the rate of accidents was higher than controlled road condition. Road mark and lines showed little function of traffic control for the high rate of bicyclist accidents.

Table 12: Road control conditions in bicyclist accidents

	Changsha, China		Hannover, Germany	
	AF*	RF*(%)	AF	RF(%)
None, no intersection			**1018**	**56.37**
Traffic light	22	1.40	273	15.12
Road signs	**525**	**33.44**	263	14.56
Crosswalk			47	2.6
No road signs			84	4.65
Police	6	0.38		
Police & Traffic light	51	3.25		
Traffic light & signs	117	7.45		
No control	**752**	**47.90**		
Other equipments	51	3.25		
Others	0	0.00	120	6.64
Unknown	46	2.93	1	0.06
Total	1570	100	1806	100

* AF=Absolute Frequency, RF=Relative Frequency

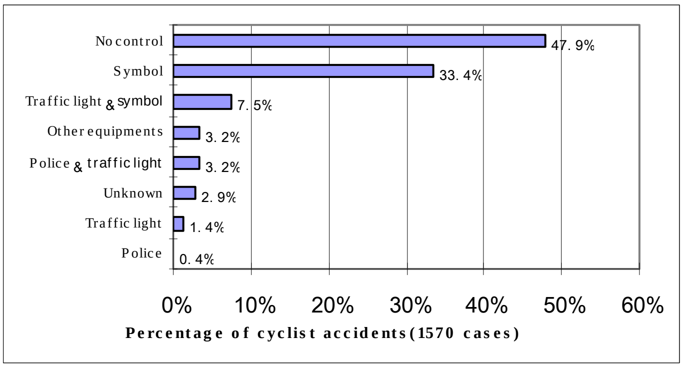


Figure 9 Road control conditions during bicyclist accidents

3.9 Type of Cyclist Accidents

Table 13 and Figure 12 show that the more common types of bicyclist accidents were lateral impact and front impact, in both Changsha and Hannover city area.

Table 13 Type of bicyclist accidents

	Changsha, China		Hannover, Germany	
	AF*	RF*(%)	AF	RF(%)
Lateral Impact	**775**	**49.36**	**871**	**48.23**
Front Impact	**379**	**24.14**	**629**	**34.83**
Rear Impact	127	8.09	75	4.15
Scratching	179	11.40		
Fall			103	5.7
Roll over	5	0.32	45	2.49
Others	104	6.62	83	4.6
Unknown	1	0.06		
Total	1570	100	1806	100

* AF=Absolute Frequency, RF=Relative Frequency

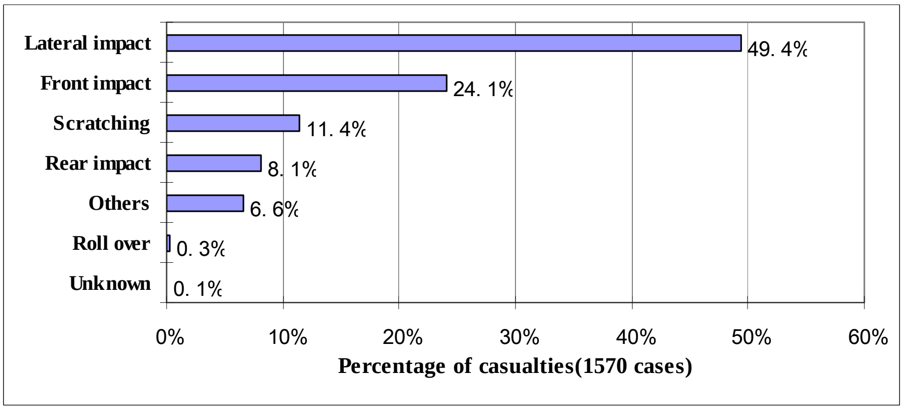


Figure 10 Type of bicyclist collisions

3.10 Distribution of Injuries by Body Regions

Table 14 and Figure 11 show that the head and lower extremities were found to be the most frequently injured. The injury region datum which were used in the figure were all registered in police data, while bicyclist accidents cases with no registered injury regions were ignored.

Table 14: Distribution of injuries by body regions for bicyclist accidents in Changsha

	Changsha, China									
	Not injured		Slight		Serious		Dead		Total	
	AF*	PF*	AF	RF	AF	RF	AF	RF	AF	RF
Head	1391	87.3	**82**	**5.1**	**46**	**2.9**	**75**	**4.7**	1594	100
Neck	1592	99.9	2	0.1					1594	100
Thorax & Back	1569	98.4	15	0.9	8	0.5	2	0.1	1594	100
Up limbs	1531	96.0	56	3.5	7	0.4			1594	100
Waist & Abdomen	1570	98.5	18	1.1	6	0.4			1594	100
pelvis	1592	99.9					2	0.1	1594	100
Low limbs	1366	85.7	**196**	**12.3**	**30**	**1.9**	**2**	**0.1**	1594	100
others	1325	83.1	259	16.2	10	0.6			1594	100

AF=Absolute Frequency, RF=Relative Frequency

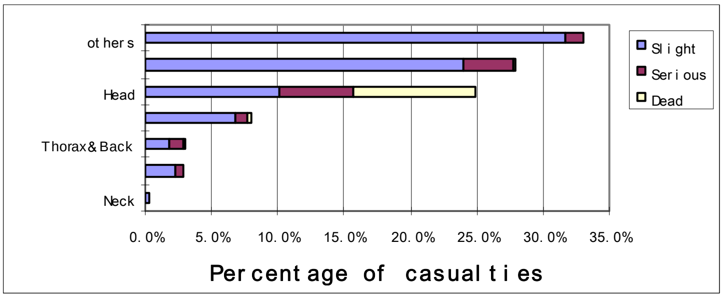


Figure 11. Distribution of injuries by body regions

Table 15 shows that the head and lower extremities were found to be the most frequently injured. The injury region datum which were used in the figure were all registered in police data, while bicyclist accidents cases with no registered injury regions were ignored.

Table 15: Distribution of injuries by body regions for bicyclist accidents in Hannover

	Hannover, Germany											
	Not injured		Slight AIS1		Serious AIS2-4		Dead AIS5-6		Unknown		Total	
	AF	RF	AF	RF	AF	RF	AF	RF	AF	RF	AF	RF
Head	1128	62.5	**516**	**28.6**	**125**	**6.9**	**7**	**0.4**	30	1.7	1806	100
Neck	1723	95.4	68	3.8	2	0.1	1	0.1	12	0.7	1806	100
Thorax & Back	1408	78	307	17	74	4.1	4	0.2	13	0.7	1806	100
Up limbs	1045	57.9	**696**	**38.5**	53	2.9			12	0.7	1806	100
Waist & Abdomen	1711	94.7	70	3.9	6	0.3	1	0.1	18	1	1806	100
pelvis	1581	87.5	198	11	15	0.8			12	0.7	1806	100
Low limbs	829	45.9	**868**	**48.1**	**96**	**5.3**			13	0.7	1806	100

4 DISCUSSIONS

The annually fatalities in the reported accidents of China increased from 49,271 in 1990 to 98,738 in 2005. The vehicle traffic accidents steeply increased in the past decade in China, and traffic injuries are common issue worldwide. The road traffic authority made large efforts to control incidence of the accidents, but the tendency of the accident growth is still a critical issue in China, even though the reported traffic accidents decreased in resent two years.

In the year 2006, 2.2 million traffic accidents with altogether 427,000 casualties (fatalities and injuries) occurred in Germany. 77,054 of these (18 %) were bicyclists, of those 486 (0.6 %) were killed, 14,233 (18.4 %) were severely injured and 62,335 (81 %) slightly injured. If the development over the past 15 years is regarded for Germany, then no trend towards a reduction of accidents involving bicyclists can be recognized, as is the case with pedestrians. Thus for the year 1992 altogether 78,695 bicycle accidents occurred and 47,884 accidents involving pedestrians were reported, in 2006 in contrast 82,819 bicyclists were involved in an accident and only 38,917 pedestrians.

Therefore in both countries the accidents with bicyclists have to be recognized. The injury situation related to traffic accidents seems to have different pictures for China and Germany [Kong et al., ESAR2006]. Particularly, the fatalities of vulnerable road users (VRUs) formed a main proportion of all reported fatalities in traffic accidents.

The present study is based upon an analysis of 1570 bicyclist accidents in urban area of Changsha in China and 1806 cases in the area of Hannover in Germany. The evaluation method was described and the available accident data were analyzed. The used samples are acceptable as a preliminary study. The presented methodology for an in comparison of different in-depth accident studies could be used for comparison of the injury risk and injury outcome for different countries. Such methodology can be used for further studies with new collection of accident data in the area and special research issues.

4.1 Involvement of vehicle

The analysis of bicyclist accidents in Changsha indicated that passenger cars, trucks and motorcycles are most frequently involved in vehicle bicyclist accidents compared to Germany where the major collision partner of a bicyclist is a passenger car (64%). In Changsha 53% of the reported bicyclist accidents are respobsible by passenger cars, truck 18%, and motorcycle 17%. Due to the difference of involved vehicles from country to country, the priority of safety countermeasures should be given considering the frequency of involved vehicles.

4.2 Bicyclist injuries

The bicyclist accident is a common problem in both motorized countries and motorizing countries, which occur frequently in city build up area. The combined results of the analysis of the two different areas of China and Germany are shown major resources for further countermeasures on car safety developments.

The injury severity and risk for bicyclists in Germany can be seen as much less danger as in China. As shown in Table 2, the relative frequency of the bicyclist fatalities is 9.2% in Changsha vs 0.8% in Hannover. In Changsha, 50% of the bicyclist fatalities attributed to fatal head injuries (Table 14). One of the possible reasons for the high relative frequency is due to that the bicyclists travel in Changsha without using any helmet.

The gender distribution for the bicyclist accidents In Hannover the male bicyclists accounted for 57.1% of reported bicyclist accidents, and female 42.9%. A higher rate for the gender distribution in Changsha is male 67.2%, and female 32.8%. One of the possible reason for the higher rate is due to that more males travel by bicycles than females do.

The findings of the distribution of bicyclist to different body segments are compared between the results from both institutes. As a common tendency, the head and the lower extremities have been found to be the most frequently injured body regions.

4.3 Needs of bicyclist protection and counter-measures

There is great potential of reduction of the accidents and fatalities in China by enhancing safety consciousness of all road users, improving the traffic administration, and strictly implementing traffic laws.

As findings mentioned above, the high rate of bicyclist fatalities is due to the fatal head injuries, it is therefore important for bicyclist to use helmet for head protection from vehicle collisions.

4.4 Limitations

It is also noticed that the limitations existed in this study. The data sources partly reflects the real situations of bicyclists in traffic accidents in Changsha and Hannover and not in the whole countries of China and Germany. Compared to this the data of GIDAS Hannover are comprehensive and give information on every issue of accident and injury details.

Another problem existed on the police records in Changsha, the provided data on the injury severity, which seldom provided exact details of the locations and extent of the injuries, and it bring up a difficulty to classify the injuries according to the AIS code. This problem can be soöved by further in-depth studies using detailed accident data collected from hospital and police sectors, as well as on-site and retrospective investigations.

5 CONCLUSIONS

Bicyclist accidents represent a group of vulnerable road users with high risk of injuries, therefore a priority should be given to this road user group in research of safe urban transportation.

About two thirds of victims in vehicle-to-bicycle collisions are male bicyclicts.

The head and lower extremity injuries are the predominant types of bicyclist injuries. It is necessary to give the priority of injury prevention to the head and lower extremities.

The head injuries are main responsible for the high relative frequency of bicyclist fatalities. It is vital for bicyclist to use helmet for head protection from vehicle collisions.

It can be seen that the bicyclist accidents and injury outcomes in Changsha are quite different from that in Hannover. The further in-depth study is needed to develop efficient counter-measures for improvement of bicyclist safety.

6 ACKNOWLEDGEMENTS

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Injury prevention in motorcycle accidents: Italian evidence from MotorcycleAccidents in-Depth Study (MAIDS)

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Abstract
The purpose of this work is to investigate the association between the injuries in motorcycle accident and the main accident configurations. The data were provided by a multicentric case-control study MAIDS regarding the risk of crash and injuries of motorcyclists. Chi-square test was used to evaluate the relationship between the variables and a logistic regression was performed to evaluate the association of injury severity with some variables supposed to be predictive factors. Lesive patterns characterized by internal haemorrhages are mainly associated with fronto-lateral crashes, above all in urban areas. Lacerations or abrasions, mainly reported in torso and lower extremities, are mostly associated with single crashes or accidents in queue also for crashes occurred to low speed (< 50 km/h). The severity of injuries is highly associated with impact speed, regardless of the crash configuration. Fractures and haemorrhages play an important role in determining the severity of injuries. The upper extremities are the most frequently traumatised anatomic areas.

Introduction

In literature several studies deal with injuries on individuals involved in road accidents.
Most surveys try to find a causal link between injuries and determinants. Some of them lack an epidemiologic design, do not arise from ad hoc surveys and do not provide information on the accident dynamics. This is due to the fact that the health data and those on the cinematic reconstruction of the accident come from different unlinked sources. The gradual increase in the number of injured people involved in two-wheel accidents regarding both passengers and/or run-over pedestrians and above all riders, strongly calls for a thorough and up-to-date knowledge of injury patterns. The detailed analysis of “road injury”provides interesting evidence to improve people’s active and passive safety (to adopt specific preventive measures and/or achieve better standards of the currently used protective systems). Accordingly, the analysis provides good and useful epidemiologic background information on the proper reconstruction of the accident traumatologic dynamics and it corretly ascribes accident responsabilities [1].
The study aims at pointing out the etiopathogenetic relationship between the injury pattern on involved people and crash configuration. Therefore, the analysis of scientific evidence has been based on:

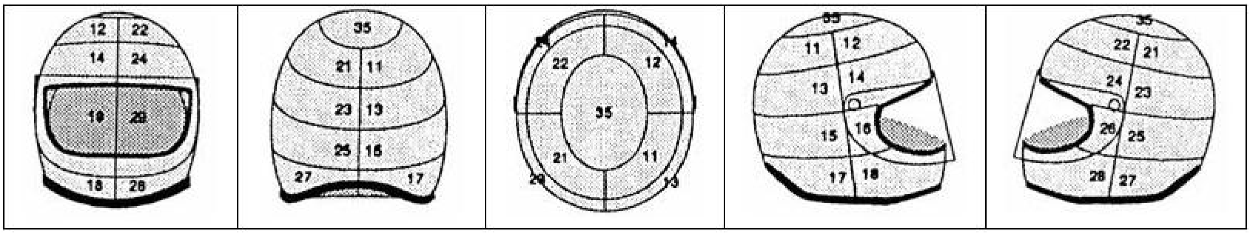
- the dynamic-cinematic reconstruction of the traumatic event identifying the lesive pattern of injured people registered by medical practitioners;
- clinical- anatomopathological in-depth study of lesions;
- analysis of injuries related to crash configuration.

Methods

The current study develops an ad hoc research methodology that hinges on existing data sources provided by the international database MAIDS (Motorcycle Accidents in-Depth Survey) [2-5]. MAIDS study is a multicentric case–control research conducted in Italy, Spain, Germany, Holland and France from 1999 to 2001, with the specific aim of identifying risk factors of motorcycle crashes and risk factors to discriminate between serious and minor injuries. The target population is formed of all two wheeled vehicles circulating through definite areas. Cases consist of motorcycles and their riders that were involved in accidents with injuries; to be enrolled in the study either the rider and/or passenger had to be injured and transported to an emergency ward. Controls consist of riders and vehicles that were not involved in an accident; trained research workers at sampled petrol stations contacted them. Variables grouped into three major subjects, mechanical, environmental and human, were collected. They concern the place where accidents happened, crash dynamics, mechanical characteristics of vehicles, damage produced by the crash, the personal, social and behavioural characteristics of riders, drivers and passengers, and a detailed set of information regarding injuries.

In Italy the MAIDS study was carried out by CIRSS, Centre of Studies and Research on Road Safety of the University of Pavia, including about 900 road accidents involving two-wheels. The present study considers the 200 two-wheel crashes occurred in Italy in the Province of Pavia between 1999 and 2001. For the Italian cases a revision of the injured people's interviews and their clinical records has been made. All the accidents of the survey have been examined considering the traumatic lesion abscribed to the accident to assess a direct causal link between the accident dynamics and the injury pattern. From the MAIDS study the following variables have been considered and analized:
accident configuration;
injury pattern;
body region traumatized (head: face and neck; trunk: thorax, abdomen and pelvis; lower extremities and upper extremities);
injury severity;
impact speed (< 50Km/h; ≥ 50 Km/h).
The most common collision typologies have been grouped into five classes: head-on and side impact collisions (frontal-lateral collision: crash with opposite/perpendicular traffic); side impact accidents (crash with perpendicular traffic); rear-end collisions (crash with a vehicle travelling on the same road in the same direction); single accidents (only one vehicle is involved in the accident); other (special cases: the vehicles in the collision can suffer more than one type of impact).
This distinction has been made to better define the statistical-epidemiological relationship between the lesive pattern and type of accident considering impact speed.
The most frequent types of injuries have also been grouped into three classes: contusions-abrasions (including luxations and sub-luxations, sprains, blunt injuries, abrasions, ecchymosis); fractures-haemorrhages (including the injuries that together with fractures are associated with mono and polidistrectual haemorrhages); internal bleeding (including all injuries involving the fracture of internal organs, not necessarily related to bone fractures).
Injury severity has been coded using the AIS98 (Abbreviated Injury Scale) system. The Abbreviated Injury Scale, decided by consensus, is an anatomically-based system that classifies each injury according to the body region on a 6-point ordinal severity scale ranging from AIS 1 (minor) to AIS 2 (moderate) to AIS 3 (serious) to AIS 4 (severe) to AIS 5 (critical) to AIS 6 (currently untreatable).
The helmet has been given particular attention. It has been analyzed according to the reported damage, classified on the basis of typology and region. A further analysis has been focused on the existing relationship between cranium-brain injury severity and the damage reported on the helmet. Thus, the helmet has been divided into different parts marked by a number shown in the figure below. Each part corrisponds to topographical and anatomical regions. Such regions have beeen grouped into five areas: top; front left; back left; front right; back right. The numbers corrisponding to the above-mentioned regions are the following:
top region: 35, 11, 12, 21, 22
front left: 24, 26, 28, 29
back left: 23, 25, 27
front right: 14,16, 18, 19
back right: 13, 15, 17
Then, for the following analyses, in order to make them more consistent, the helmet regions have been grouped into three sections: top region, left region (front left and back left), right region (front right and back right) and they have been compared to the related injury severity coded in "minor" (AIS1) and "serious" (AIS2-AIS-6).

Figure 1:Region of the helmet



A multiple logistic regression analysis has also been performed to assess the relationship between injury severity and some variables considered to be predictive included in the model: impact speed, crash typology, injured body region and type of injury.

Results

Table 1 provides an overview of the 200 motorcycle riders trauma status according to the six different levels of the AIS coding system. A total of 471 injuries were recorded for 200 riders involved in road crashes. Most riders were slightly injured and only 1.5% of them were seriously injured. This low frequency is explained by the fact that most Italian accidents were registered in an urban area.
The following relevant results have been found out by analyzing the main injury pattern registered according to accident configurations. As regards the accident configurations examined for the 200 Italian cases, head-on and side impact collisions show the highest percentages followed by rear-ends (56% and 16.5% respectively), while the rider' s injuries are mainly localized in lower extremities and cranium (21% and 11% respectively). The most injured anatomical parts turn to be lower extremities and trunk (29.3% and 27.8% respectively), followed by the cranium and upper extremities (22.1% and 20.8% respectively). As for the frequency of the different accident configurations considered jointly with the injury region, lower extremities and trunk are the most injured, followed by the cranium and upper extremities. If single and/or side crashes are considered, trunk and lower extremity injuries show the highest percentages, mainly contusions and abrasions. Fractures and haemorrhages are lower in this accident typology and they are mainly localized in the cranium and upper extremities. As to frontal-lateral accidents, contusions and abrasions result to be more frequent, followed by fractures and haemorrhages localized in lower extremities and trunk and, to a lower extent but with approximately overlapping percentages, in the cranium and upper extremities. As to single accidents, the injury pattern is quite the same as the one above mentioned. In particular, if no fractures are reported, thorax-abdominal injuries have the highest percentages. In case of fractures, injuries are mainly localized in the pelvis region. As to rear-end collisions, contusions and abrasions show the highest percentages in the trunk and lower extremities, followed by the cranium and upper extremities. In rear-end, single and other crashes, haemorrhagic lesions caused by the damage of internal organs are not significantly reported. Anyway, haemorrhagic lesions are almost exclusively reported in head-on and side impact collisions (Tabb.2-3).
If impact speed is considered, the most frequent crash typology is the frontal-lateral followed by rear-ends which, for speed ≥ 50Km/h, show the same percentage as side crashes. If speed is < 50Km/h, side crashes and single crashes have approximately the same frequencies (Tab.4).
If the injury region and impact speed are jointly considered, for speed above and below 50Km/h, the most injured anatomical regions are lower extremities and trunk respectively, followed by the cranium and upper extremities (Tab.5).
Besides, as regards the frequency of injury pattern by impact speed, both above and below 50Km/h, contusions and abrasions turn to be higher, proportionally followed by fractures and haemorrhages which, if speed is ≥ 50Km/h, are slightly less than half of all injury patterns (Tab.6).
Finally, the analysis of the relationship between the helmet damaged sections and severity of brain lesions has pointed out that there is no statistical significant relation (p>0.05) between the two variables considered (Tab. 7). Moreover, it is important to say that 89% of riders wore the helmet.

The logistic analysis (Tab.8) highlights that injury severity is highly associated with impact speed, regardless of the accident configuration (OR = 3.6; $p < 0.01$). If the injury pattern is taken into account, fractures and haemorrhages play a considerable role in determining injury severity, while as regards injured body regions, upper extremities turn to be the most traumatized anatomical regions (OR = 11.41; $p < 0.001$).

Discussion

The analysis of the relationship between injuries and two-wheel crashes has allowed to link the various injury patterns to the different accident configurations.
Regarding the injury pattern, there is a clear high percentage of contusions and abrasions immediately followed by fractures and haemorrhages. The most frequent crash configuration, considered that most accidents occurred in an urban area, is the frontal-lateral collision, followed by rear-ends, side crashes and single crashes.
If the injury region and injury pattern are jointly analyzed, the cranium and lower extremities turn to be more traumatized with fractures and haemorrhages, while the trunk and upper extremities suffer more from contusions and abrasions. If, on the contrary, the injury region is seen in relation to the accident, the trunk and lower extremities are the most frerquently traumatized anatomical regions, followed by cranium and upper extremities, with no significant differences among the various accident configurations.
The relationship between the injury pattern and accident configuration shows a high percentage of contusions and abrasions followed by fractures and haemorrhages, respectively in frontal-lateral crashes, rear-ends and single accidents. Internal bleeding has been reported almost exclusively in frontal-lateral collisions, often together with concealed lesions caused by lacerations. On the basis of such evidence, it seem reasonable to say that frontal-lateral crashes are potentially the most dangerous collisions. Thus, it is advisable to plan, in such cases, clinical exams for an early diagnosis of possible internal lesions.
Speed does not significantly affect the elective distribution of the lesive pattern and turns to be almost independent of the different accident configurations.

Conclusions

The analysis carried out owes much of its importance to the unique availability of data sets coming from a database of an ad hoc study. It throughly investigated all the accident features related both to the driver’s health consequences and to the collision dynamics.
Some relevant conclusions can be drawn from the results.

- Injury severity is highly associated with impact speed, regardless of the accident configuration.
- Injury patterns characterized by internal bleeding are mainly linked to frontal-lateral collisions, above all in urban areas. Therefore, considering the high frequency of such injury pattern, frontal-lateral collisions, even if speed is less than 50 Km/h, are likely to cause concealed lesions which may be fatal.
- Contusions and abrasions, localized mainly in the trunk and lower extremities, are primarily associated with single crashes or rear-ends. If the trunk is the most traumatized anatomic region, both for contusions-abrasions and fractures-haemorrhages, single and side collisions are the most frequent accident configurations, even if speed is less than 50 Km/h.
- In case of contusions-abrasions associated with fractures-haemorrhages localized not only in the trunk but also in the cranium and lower extremities, frontal-lateral accidents are the most frequent accident configurations, even if speed is less than 50 Km/h.
- In case of lesions involving different anatomic regions, the pattern may be ascribed to single and other types of accidents, above all if the cranium and upper extremities are injured.

Such evidence may be useful to plan adequate actions on road safety education, train health operators dealing with road emergencies and train police forces in charge of road safety.

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Table 1 – Distribution of injuries based on the AIS98 code.
No of injured people and No of injuries

		Injury severity (AIS)						
		1	**2**	**3**	**4**	**5**	**6**	Total
Injured people	n	136	36	13	3	9	3	200
	%	68.0	18.0	6.5	1.5	4.5	1.5	100.0
Injuries	n	367	58	30	3	10	3	471
	%	77.92	12.31	6.37	0.64	2.12	0.64	100.0

Table 2 – Frequencies of accident configuration by injury region

Injury region	**Accident configuration**					Total
	Head-on and side impact	Side	Rear-end	Single	Other	
Cranium	57 21.2%	13 24.1%	18 22.2%	12 23.1%	4 26.7%	104 22.1%
Trunk	71 26.4%	16 29.6%	25 30.9%	14 26.9%	5 33.3%	131 27.8%
Upper extremities	56 20.8%	11 20.4%	16 19.8%	12 23.1%	3 20.0%	98 20.8%
Lower extremities	85 31.6%	14 25.9%	22 27.2%	14 26.9%	3 20.0%	138 29.3%
Total	269 100.0%	54 100.0%	81 100.0%	52 100.0%	15 100.0%	471 100.0%

Table 3 - Frequencies of accident configuration by injury pattern

Injury pattern	Accident configuration					Total
	Head-on and side impact	Side	Rear-end	Single	Other	
Contusions-abrasions	178 66.2%	37 68.5%	67 82.7%	38 73.1%	11 73.3%	331 70.3%
Fractures- haemorrhages	79 29.4%	16 29.6%	14 17.3%	14 26.9%	4 26.7%	127 27.0%
Internal bleeding	12 4.5%	1 1.9%	/ /	/ /	/ /	13 2.8%
Total	269 100.0%	54 100.0%	81 100.0%	52 100.0%	15 100.0%	471 100.0%

Table 4 - Frequencies of accident configuration by impact speed

Accident configuration	Impact speed		Total
	< 50 km/h	≥ 50 km/h	
Head-on and side impact	95 54.3%	12 70.6%	107 55.7%
Side	22 12.6%	2 11.8%	24 12.5%
Rear-end	31 17.7%	2 11.8%	33 17.2%
Single	24 13,7%	/ /	24 12,5%
Other	3 1.7%	1 5.9%	4 2.1%
Total	175 100.0%	17 100.0%	192 100.0%

Table 5 – Frequencies of injury region by impact speed

Injury region	Impact speed		Total
	<50 km/h	≥ 50 km/h	
Cranium	89 22.6%	10 18.5%	99 22.1%
Trunk	106 26.9%	18 33.3%	124 27.7%
Upper extremities	82 20.8%	11 20.4%	93 20.8%
Lower extremities	117 29.7%	15 27.8%	132 29.5%
Total	394 100.0%	54 100.0%	448 100.0%

Table 6 – Frequencies of injury pattern by speed impact

Injury pattern	**Speed impact**		Total
	< 50 km/h	≥ 50 km/h	
Contusions- abrasions	287 72.8%	30 55.6%	317 70.8%
Fractures-haemorrhages	100 25.4%	20 37.0%	120 26.8%
Internal bleeding	7 1.8%	4 7.4%	11 2.5%
Total	394 100.0%	54 100.0%	448 100.0%

Table 7 – Frequencies of cranium injuries in rerlation to the damage registered in the region of helmet

	Region of helmet		
	Top	**Left**	**Right**
AIS1	81.3	90.9	71.9
AIS2-AIS6	18.8	9.1	28.1
n	16	11	32

Table 8 – Relationship between injury severity, impact speed, accident configuration, injury pattern and body region: logistic regression model (n = 448)

		OR	IC 95%	P-value
Impact speed	< 50 km/h	1		
	≥ 50 km/h	3.62	1.39-9.41	0.008
Accident configuration	Head-on and side impact	1		
	Side	1.75	0.63-4.52	0.279
	Rear-end	0.85	0.31-2.32	0.751
	Single	0.71	0.23-2.25	0.566
	Other	2.08	0.37-11.72	0.408
Injury pattern	Contusions- abrasions	1		
	Fractures-haemorrhages	92.35	40.08-212.08	<0.001
Body region	Cranium	1		
	Trunk	6.00	2.17-16.57	<0.001
	Upper extremities	11.41	3.82-34.09	<0.001
	Lower extremities	5.93	2.38-14.75	<0.001

Pedestrian Reconstruction Tools Applied to Pedestrian Accidents in Portugal

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Abstract - Pedestrian accidents are one of the major concerns related with road accidents around the world. Portugal has one of the highest rates of pedestrian fatalities in Europe. In this paper an overview conditions were the pedestrian accidents occurred in Portugal is presented. In the last years, a project related with the pedestrian accidents has run in Portugal for the period 2004-2006 where 603 people died, 2097 have been severely injured and about 17000 slightly injured. Within this project all the pedestrian accidents in this period have been analysed providing global information about a wide range of aspects, since location, driver and pedestrian characteristics, weather and road conditions, among others. In addition, 50 in-depth accidents have been investigated and the data collected according the Pendant methodology. For this in-depth methodology detailed information about the accident has been collected, including injuries, vehicle damage, road conditions and road user's behaviour and actions. An accident reconstruction has been carried for each case including the determination of the speeds and driver actions, and the analysis of the contributing factors for the accident.

Depending of the accident complexity, different methodologies have been used to analyse these accident, from the classical analytical equations such as Simms and Woods, to the use of detailed computational pedestrian models as those included in the commercial software's PC-Crash® or Madymo®. Also one of the goals of our investigation is the development of multibody models and methodologies for the reconstruction of pedestrian accidents. Some of these tools integrated in the commercial software Cosmos Motion® are presented. The advantages of the different approaches are compared and discussed for some of the accidents investigated. With these tools the impact speed can be determined from the projection distance with analytical tools or PC-Crash®, but more complex tools should be used to determine speed from the injuries, what is especially important for fatal accidents. The influence of the vehicle geometry and stiffness characteristics is another aspect analysed, where the influence of the vehicle stiffness has been determined using a combined multibody-finite elements approach within the software Madymo®.

NOTATION

CARE	European Road Accident Database
SafetyNet	European Road Safety Observatory
ANSR	*Autoridade Nacional Segurança Rodoviária* (Portuguese Authority for Road Safety)
PARA	Project "*Peões, Atropelamentos e Reconstituição de Acidentes*" (car-to-pedestrian accident reconstruction)
V	Striking velocity
μ	Average coefficient of friction for pedestrian sliding on the ground
d_t	Throw distance
h	Pedestrian centre of mass's height
a	Acceleration
$\mathbf{M_{cp}}$	Vehicle and pedestrian mass relation
d_f	Distance travelled by the pedestrian during fall
d_s	Distance travelled by the pedestrian during slide
V_s	Impact velocity at the pedestrian rest position

INTRODUCTION

In 2006, according to the CARE Database [1], 42953 fatalities occurred on European road accidents (EU-27). The last accident data available, SafetyNet [2], shows that, in 2005, accidents related to pedestrians represents 17.5% in the total number of road traffic European fatalities (EU-18), Figure 1 shows the pedestrian fatalities as a percentage of total fatalities. Between 1991 and 2006, Portugal (comparing with the other European countries) achieved the best results with regard to reduce its fatalities on road accidents (81%), Figures 2 and 3. Contradicting this fact, Portugal is one of the countries where this problem is more serious, according to ANSR [3], in the year 2007, 974 (correcting for 30 days with 1.14 factor) people lost its lives in Portuguese roads and 3116 suffer severe injuries, that represents a slight increase in statistics, comparing to 2006. Pedestrian impacts represent 16% of those fatalities, more specifically, 157 fatal injuries (with correction factor) and 619 pedestrians severely injured. 64% of pedestrian fatalities and 86% of severe injuries occurred inside urban areas. The fatality reduction that Portugal achieved lead to the anticipation (in one year) of the main goal that the European Commission transport policy [4] established for 2010. In order to fulfil a more specific objective where a 60% reduction in the number of deaths of pedestrians (registered in the triennial 1998-2000) is established as a goal, the necessity of understanding the causes of road accidents becomes more important. Road accident reconstruction could answer this necessity by developing specific formulations and methodologies that are able to represent the accidents realistically.

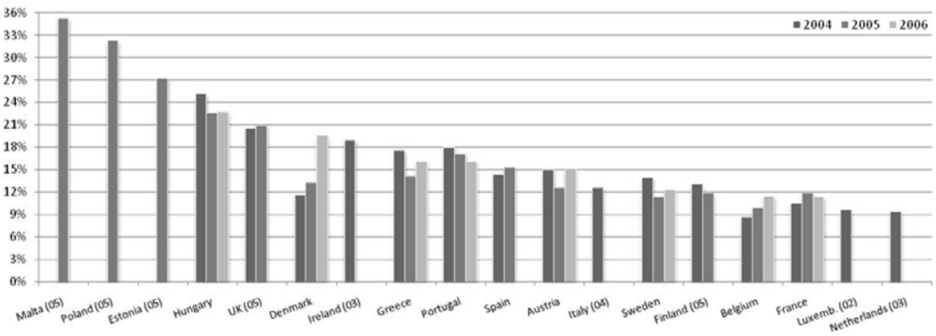

Figure 1. Pedestrian fatalities as a percentage of total fatalities: (02) data from 2002; (03) data from 2003; (04) data from 2004 and (05) data from 2005

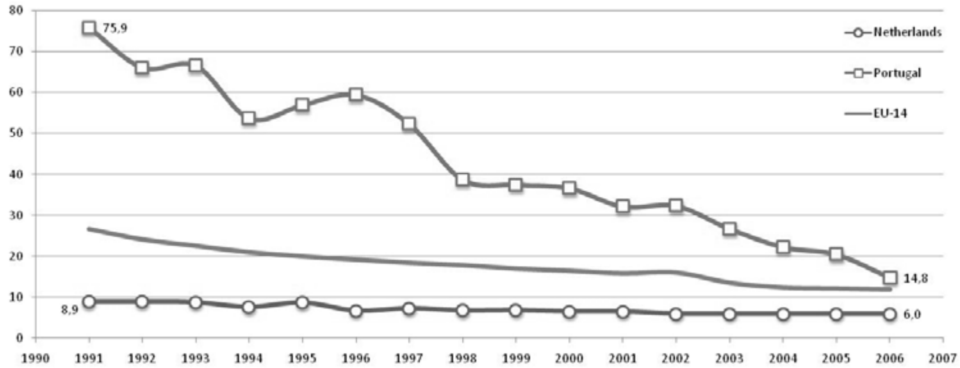

Figure 2. Fatalities per million inhabitants

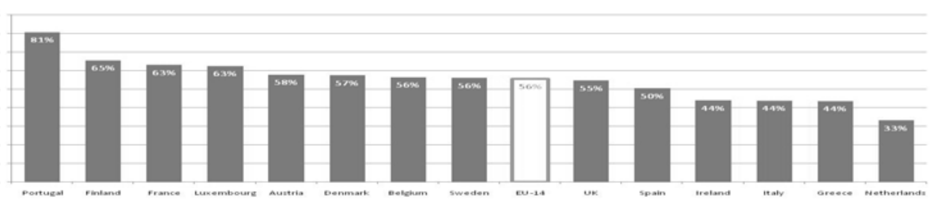

Figure 3. Pedestrian fatalities reduction, between 1991 and 2006, (EU-14)

Within the project PARA[1] the pedestrian accidents between 2004 and 2006 have been analysed providing global information about a wide range of aspects, since location, driver and pedestrian

[1] Peões, Atropelamentos e Reconstituição de Acidentes (Project Pedestrian accident reconstruction) www.dem.ist.utl.pt/acidentes/para

characteristics, weather and road conditions, among others. In addition, 50 in-depth accidents have been investigated and the data collected according the Pendant methodology. For this in-depth methodology detailed information about the accident has been collected, including injuries, vehicle damage, road conditions and road user's behaviour and actions. An accident reconstruction has been carried for each case including the determination of the speeds and driver actions, and the analysis of the contributing factors for the accident. One of the main conclusions of the PARA Project is the characterization of the typical car-to-pedestrian.

Portuguese car-to-pedestrian accident

The usual pedestrian collision occurs inside urban areas between 6 pm and 9 pm, normally on a straight road and with good weather conditions. The typical accident victim is typically an elderly male pedestrian, with 65 or more years old. In the majority of the cases, the pedestrian only suffers slight injuries and it is hit most often in places intended for crossing. The vehicle driver isn't under alcohol effect and drives a passenger car, usually speeding. Pedestrian behaviour has found to be the major cause of pedestrian accidents, but the speed of the impact vehicle represents has a primary role in about 70% of the fatalities. About 80% of the fatalities ate caused by a car, but heavy trucks are overrepresented in the sample, representing about 14% of the fatalities. Motorcycles represent the remaining 6% of the fatalities.

ACCIDENT RECONSTRUCTION METHODS

Accident reconstruction involving pedestrians can be complex and, in general, requires the use of three-dimensional biomechanical models of the human body [5]. Multibody dynamics has been used in the development of these models successfully [6-12]. The commercial software that allow biomechanical analysis are very expensive, for that reason the development of vehicle and pedestrian models and its use in computational tools based in multibody [13] systems dynamics are essential, [14-16].

Depending of the accident complexity, different methodologies have been used to analyse it, from the classical analytical equations, to the use of detailed computational pedestrian models as those including in commercial software PC-Crash® [17] or Madymo® [18]. The advantages of the different approaches are compared and discussed for some of the accidents investigated. With these tools the impact speed can be determined from the projection distance with analytical tools or PC-Crash®, but more complex tools should be used to determine speed from the injuries, what is especially important for fatal accidents. The influence of the vehicle geometry and stiffness characteristics is another aspect analysed, where the influence of the vehicle stiffness has been determined using a combined multibody-finite elements approach using Madymo®.

Analytical Methods

Car-to-pedestrian accidents are investigated for at least half a century. Several analytical methods are developed by many authors. Eubanks and Haight [19], in addition of addressing the typical sequence of events in a car-to-pedestrian accident and the relation between the striking velocity and the pedestrian trajectory, also resume several techniques to calculate vehicle impact velocities, some of these methods are summarized by
Table 1.

Wood *et al* [20] developed an analytical method considering three phases for pedestrian collision, both for wrap and forward projections. Brach and Han [21] also had developed a throw model for frontal pedestrian collisions that takes into account the road slope.

Computational Methods

As mentioned before, the analytical methods have limitations when the accident is more complex, or when the accident data as not been correctly collected or is some important data is unavailable, or even when these methods cannot be applied due to the complexity or parameters to be determined from accident reconstruction.

Schmidt and Nagel [22] [m/s]	$V = \sqrt{\mu^2 h + 2\mu g d_t} - \mu h$	V is the striking velocity μ is the average coefficient of friction for pedestrian sliding on the ground d_t is the throw distance h is the pedestrian centre of mass's height
Stcherbatcheff [23] [m]	$d_t = \frac{V^2}{2a} + \left(\frac{3}{100} Va\right)$	a is the acceleration
Collins [24] [m]	$d_t = \frac{V\sqrt{h}}{7.97} + \frac{V^2}{254\mu}$	
Searle [25] [m/s]	$V_{min} = \sqrt{\frac{2\mu g d_t}{1+\mu^2}}$ $V_{max} = \sqrt{2\mu g d_t}$	V_{min} is the minimum impact velocity V_{max} is the maximum impact velocity
Simms and Wood [26] [m/s]	$V = M_{cp} (A \times \sqrt{d_t} + B)$ $V = C\, M_{cp} (d_t - S_0)^D$	$M_{cp} = \frac{M_{car} + M_{pedestrian}}{M_{car}}$ If masses aren´t know use unitary M_{cp} A,B,C,D and S_0 are experimental parameters
Northwestern University [27] [fps]	$d_f = 2\mu h - 2h\sqrt{\mu^2 - \frac{\mu d_t}{h}}$ $d_s = d_t - d_f$ $V_f = d_f \sqrt{-\frac{g}{2h}}$; $V_s = \sqrt{2a\, d_s}$	d_f is the distance travelled by the pedestrian during fall d_s is the distance travelled by the pedestrian during slide V_s is the impact velocity at the pedestrian rest position
Eubanks (carry, fall and slide) [fps]	$V = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A}$	$A = (0.4 + \mu)^{-1}$ $B = \frac{d_{hood}}{V_{pedestrian} \sin\Phi} + \sqrt{\frac{h_{hood}}{16.1}}$ $C = -d_t$

Table 1. Analytical Methods to calculate vehicle striking speed on car-to-pedestrian accidents

Car-to-pedestrian collision with COSMOSMotion®

Lima *et al* [9] developed a simple pedestrian model using the CAD software Solid Works® an integrated with the add-in ***COSMOSMotion®***. Only the front shape of the vehicle is modelled, even so the model has the same mass and ground height of the real vehicles. Figure 4 shows the vehicle models, being vehicle 1 a small passenger car and the vehicle 2 is an SUV. Car-to-pedestrian collision was considered frontal, in the medium line of the vehicle, and consequently, the front traversal curvature of the vehicles is neglected.
The choice of those vehicles is due to the fact that it exemplifies different impact heights on pedestrian's leg. The simulations are performed at different collision speeds: 30, 50 and 70 km/h.

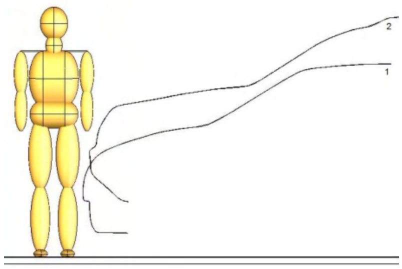

Figure 4. Vehicle front form representation: (1) small passenger car and (2) SUV.

Figures 3 and 4 shows the trajectory of the pedestrian from the impact to the rest position, for both simulations.

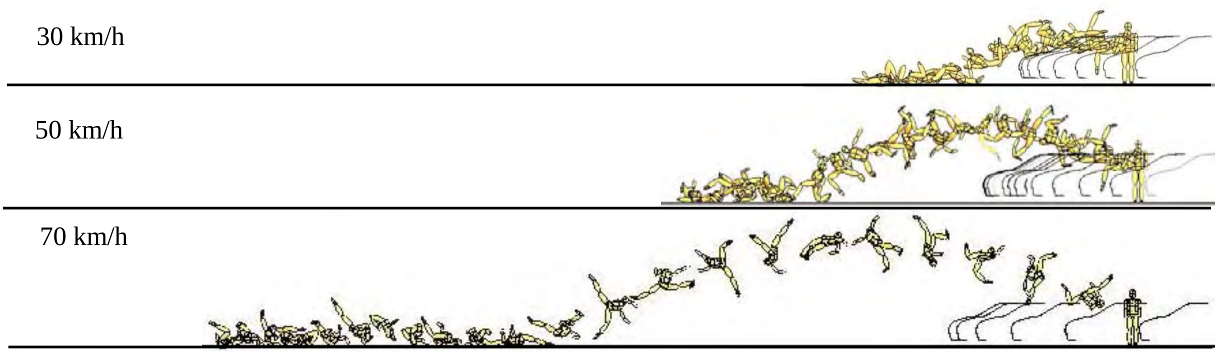

Figure 5. Small passenger car simulation

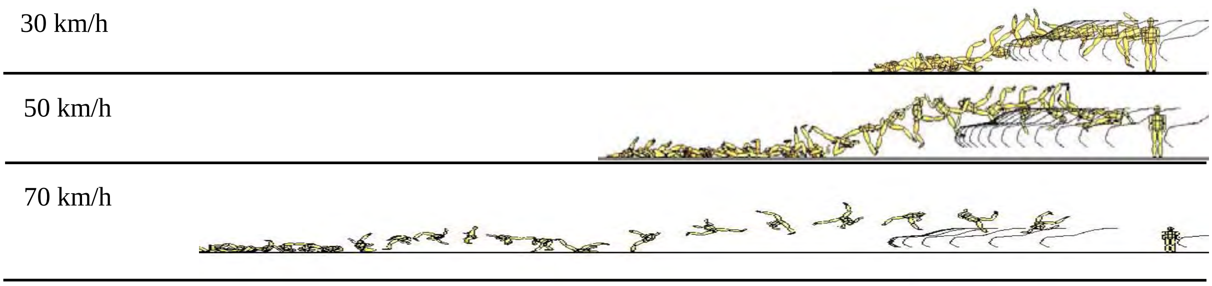

Figure 6. SUV vehicle simulation

	Projection Distance [m]			
	Impact Speed [km/h]	PC-Crash	COSMOS Motion	error [%]
Small passenger car	30	6.2	7.2	16.1
	50	14.4	13.5	6.3
	70	30.7	29.9	2.6
Off-road vehicle	30	7.9	8.6	8.9
	50	17.6	18.5	5.1
	70	28.9	33.6	16.3

Table 2. Pedestrian model results: PC-Crash® and COSMOSMotion®

As depicted on Table 2, results obtained are suitable to determine the impact speed in a car-to-pedestrian accident reconstruction. Concerning its limitations, this model should be used in the same conditions as analytical models, having the advantages of consider pedestrian characteristics and enabling an animated simulation.

Car-to-pedestrian collision with PC-Crash®

With PC-Crash® one can reconstruct more complex accidents, using multibody dynamics formulations. This model allows simulating complex pedestrian accidents [28]. It allows to perform car-to-pedestrian accident reconstructions, for instance, the accident depicted by Figure 7, has some capabilities for accident reconstruction that are not or are difficult to include in analytical methods present above, as the pedestrian hit position or the road slope. Multibody dynamics allows determining the impact speed (45 km/h) and several biomechanical indexes that permit the correlation between them and the medical report, and then to evaluate the pedestrian hit position that in this case has been proved to be on the pedestrian crossing.

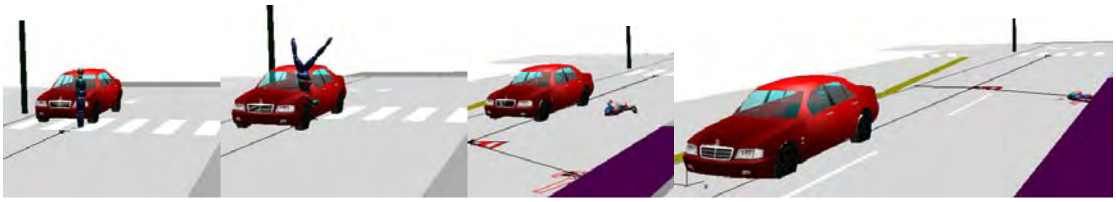

Figure 7. Car-to-pedestrian (1) real accident simulated on PC-Crash®

Other accident reconstruction performed with PC-Crash®, carried out by Paula [30] shows the correlation between vehicle deformation, pedestrian thrown distance and traces of blood registered by the police. In Figure 8 the wrap projection of the pedestrian is shown and in Figure 9 the pedestrian rest position is presented that correlates with the rest position of the body.

Figure 8. Car-to-pedestrian (2) real accident simulated on PC-Crash®

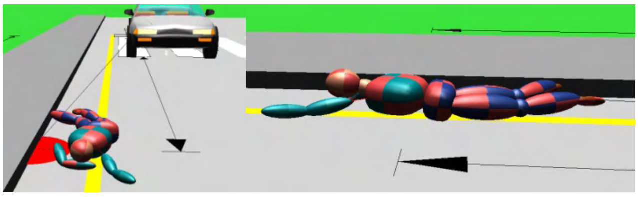

Figure 9. Car-to-pedestrian (2) pedestrian rest position

The software PC-Crash® can with good precision be used to determine hit position of pedestrians and impact speed of the vehicles specially for accidents involving cars and trucks.

Car-to-pedestrian collision with Madymo®

When the accident characteristics are too complex or what is to be evaluated requires high precision, more sophisticated models can be used. Therefore, a model that takes into account vehicle deformation and enables the rigorous determination of biomechanical indexes are necessary. One of such models is that developed by Freitas [31] and presented by Freitas *et al* [11], that uses a finite element – multibody dynamics approach implemented in Madymo® software. The vehicle' front has been developed using the finite elements method and is a simplification of the real vehicle, i.e., just the necessary components of the vehicle front are modelled. This method can be applied to a wide range of vehicles, known its exact shape, but for the structural characteristics such as the bonnet is not easy because, in general, this characteristics are not known.
Pedestrians' models are the anthropomorphic Pedestrian 50th percentile of Madymo® library, 6 YO child dummy, female and male dummies,
Figure 10. With these models there were performed car-to-pedestrian collision simulations and the results compared with PC-Crash®, with the scenario configuration as depicted by Figure 11, the vehicle striking velocity was 40 km/h.

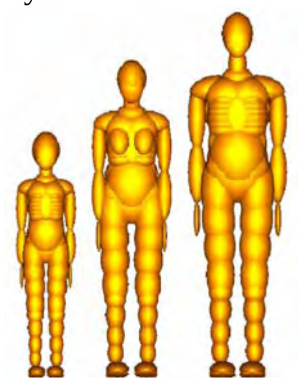

Figure 10. Madymo® anthropomorphic 50th percentile dummies

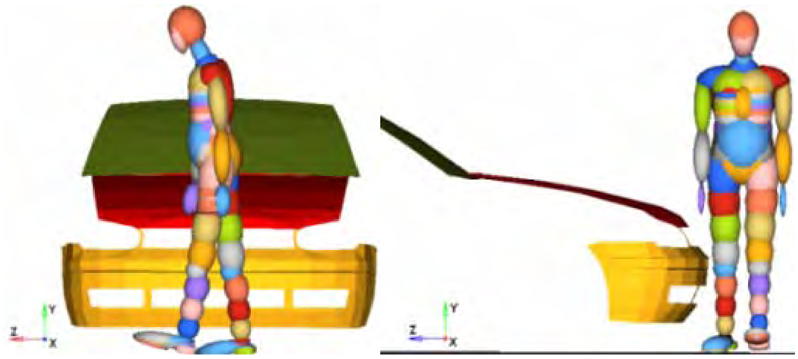

Figure 11. Madymo® car-to-pedestrian collision configuration

The results for these simulations are presented in **Fehler! Verweisquelle konnte nicht gefunden werden.**, illustrating the kinematic of the human body and the major impact zones. Results are compared with similar simulations performed on PC-Crash® and by Simms and Wood method [26], and gathered on Table 3. It can be observed that the projection distances obtained are shorter that that obtained with Pc-Crash, and within the limits obtained using the Simms and Wood method. The differences of the results concerning projection distance between Madymo models and Pc-Crash are coherent, because in Madymo models due to the deformation of the front components of the vehicle, the kinetic energy gathered by the pedestrian is lower and consequently the projection distances are lower.

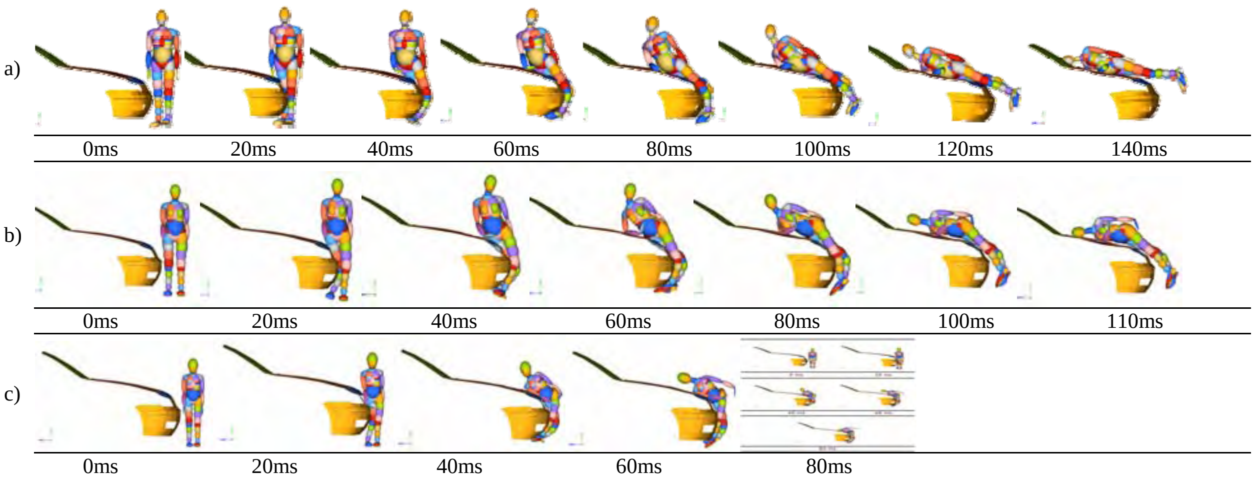

Figure 13. Madymo® car-to-pedestrian collision simulation: a) 50th percentile male dummy; b) 50th percentile female dummy and c) 50th percentile 6 YO child dummy.

Striking Velocity 40 km/h	**Madymo®**		**PC-Crash®**		**Simms & Wood**
	HIC	Throw Distance [m]	HIC	Throw Distance [m]	Velocity
Male	2430	10,7	1167	16,78	38,31 – 43,56
female	4741	11,56	1432	14,51	39,26 – 44,52
child	491,7	13,64	4584	17,19	40,14 – 45,30

Table 3. Car-to-pedestrian results

The details of the contact for Madymo models and Pc-Crash are presented in Figure 12.

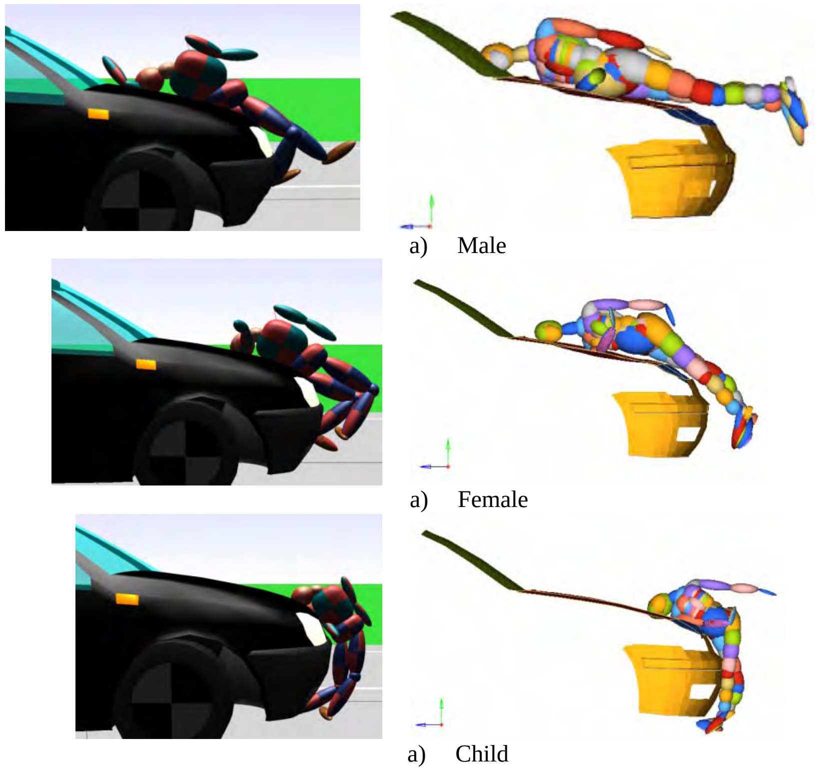

Figure 12. Illustration of the contact between the pedestrian and vehicle for *PC-Crash* (left) and *Madymo* (right).

Concerning the HIC values, with Madymo models lower values for the male and female models have been obtained, and for the child model the opposite is verified. This can be explained by two causes. One is the deformation of the vehicle and high rigidity of the vehicle near the bonnet extremity and windshield frame. For the child model the deformation of the bonnet during the head impact reduces substantially the accelerations and consequently the HIC index.

CONCLUSIONS

Pedestrian accident reconstruction can be performed with simplified models or with more complex ones, the choice that the reconstructionist must do relates with the accident complexity, the amount of information that he have and the predicted accident configuration.

Analytical methods prove to give accurate results for specific and simpler accident scenarios, mainly to determine impact speed and allow a fast way to determine a start value for the investigation. When the reconstructionist needs to solve more complex accidents, he has to use different formulations that enables the correlation between skid marks, vehicle and pedestrian rest positions, energy dissipation and evidences gathered at accident scene. In these cases, becomes mandatory that experts in accident reconstruction use software like PC-Crash® and/or Madymo®. In this work a Madymo model that includes the vehicle deformation during the impact as been presented. This model can be very useful for accident reconstructions were injury indexes have to be correlated with the injuries recorded in medical reports, or for the development and evaluation of the vehicle characteristics for pedestrian protection.

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Accident Involvement of Motorcycles – Description of the Current Situation in Germany Using Data from Federal Statistics and In-Depth-Studies

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Abstract – It is well known that motorcycle riding is fascinating but quite more dangerous than for example car driving. In 2006, 5,091 persons were killed as victims of crashes occurring on public roads in Germany. 52% (2,683) were car occupants, 16% (793) motorcycle riders, 14% (711) pedestrians, 10% (486) bicycle riders, 5% (235) commercial vehicle occupants, 2% (107) riders of smaller powered two-wheelers, called "Mofa, Moped and Mokick". This shows that motorcycle riders recently are the second largest group of killed traffic participants in Germany.

Latest information coming from the Federal Statistics predict for the year 2007 the figure of 4,958 killed road victims in total [1]. This would be again a successful reduction (-133 killed persons or –2.6% compared to the year 2006). But the news coming from the Federal Statistics during the year 2007 and at the begin of 2008 did not always tell the same positive story. It is questioned whether the positive trend of substantially reduced figures of killed road user year by year will longer continue for Germany. That means it could be impossible to reach the ambitious target, set by the European Commission, to cut in half the figure of killed road users until the year 2010 – compared to the figure for the year 2001.

It was reported that the group of 45 to 49 years old traffic participants (all traffic modes) is conspicuous with an increase of 30% up to 297 killed road users in total from January to August 2007. This increase can be ascribed in particular by an increase of killed motorcycle riders within this age group. Due to mild weather conditions in Germany in 2007 the season for motorcycle riding began relatively early and this may be a main reason for the increase of the figure of killed motorcycle riders by 16% from January to August 2007 [2].

With this background the accident occurrence of motorcycles became more and more essential. As part of the actual discussion about historical trends, recent emphases, causes and relevant structures of the events of motorcycle crashes it is evident, to have latest and carefully updated figures coming from both the Federal Statistics and In-depth studies. The paper will give a contribution to this using the German Federal Statistics and in-depth studies, for example GIDAS. Additional data coming from the DEKRA Motorcycle Accident Database as well as from literature are considered, too. The paper will help to describe the current situation of the accident involvement of motorcycles in Germany.

1 INTRODUCTION

Motorcycle riding on the one hand is fascinating and associated with pleasant experiences. On the other hand, the motorcycle rider is exposed to high accident risks. Out of 5,091 persons killed in traffic accidents in the year 2006 in Germany 793 (16%) were motorcycle riders. The most frequent group of killed crash victims are clearly the car occupants (2,683 fatalities, 52% of all crash victims). But the killed motorcycle riders recently follow as the second largest group. On rank 3 are the pedestrians (711 fatalities, 14%), followed by the bicyclists (486 fatalities, 10%), the occupants of commercial vehicles (235 fatalities, 5%) and the riders of Mofas, Mopeds and Mokicks (107 fatalities, 2%).

Latest provisional figures for the year 2007 show that the figure of killed motorcycle riders in Germany compared to the year 2006 rose by 36 (+4.5%) up to 829. For the same time period the figure of all traffic participants was reduced by 133 (-2.6%) to 4,958. With these figures the share of the killed motorcycle riders increased up to 17%. Whilst the figure of killed pedestrians was reduced by 18 (-2.5%) down to 693, their share of all road victims for the year 2007 remained constant (14%).

Not only against the background of the ambitious target set by the European Commission to cut in half the figure of killed road victims until the year 2010 (based on the 2001 figures), the motorcycle comes into the focus of operational and strategic considerations for further improvements of road safety. In contrast to the decreasing absolute figures of road victims which are striven in general and also realized during the years up to now (despite increasing figures for road users and miles travelled), the motorcycle is peculiar.

The assessment of the absolute figures and their relations must be based, amongst others, on careful analyses considering the registration figures for the fleet as well as for the mileage. Within the framework of ongoing developments and measures for the improvement of the safety of motorcycle riders the key aspects of the accident occurrence and the resulting potentials have to be taken into account. At this juncture it is of importance to judge recent trends also against the background of the historical evolution. Coevally permanent actualisations of the tabulations are necessary to recognise short-term changes, as the case may be.

The paper on hand will give a contribution to this matter. The data source used is predominantly the Federal German Statistics. It starts with a presentation of the historical development that is still remarkable. The recording of the long-term series reaches up to the data of the year 2006, which are recently available in all details. The current situation is also described using data from the official statistics. Supplementary insights into the accident occurrence of motorcycles are given using data and information coming from in-depth-studies and associated databases.

2 HISTORICAL DEVELOPMENTS

2.1 Vehicle-fleet

With the analyses and assessment of the accident participation of certain vehicles and vehicle groups it is functional, to put into account the vehicle-fleet population and the related mileages travelled. In general, the development of the vehicle-fleet population also can be seen in the involvement of the traffic accidents.

Given by the German Federal Motor Transport Authority, the so called “Kraftfahrtbundesamt” (KBA), the vehicle group of motorcycles which is mainly concerned with this article (that are motorcycles bearing an official registration number), contains light motorcycles (so called “Leichtkrafträder”), motorcycles, motor scooters and three-wheeled motorized vehicles, including light four-wheeled motorized vehicles. To simplify, even in official texts or statistics, often only the term “motorcycles” is used for this vehicle group. Some of the associated terms of definitions have changed several times during the last decades. Current definitions and associated driving licenses are shown with Table 1 [3].

The historical progression of the figures of theses vehicles within the time period from 1953 to 2008 is displayed with Figure 1. During the 1950ies the motorcycle was a vehicle used very often for daily participation on the individual motorized road traffic. The vehicle-fleet population of motorcycles and motor scooters reached a first maximum at 2.5 billion vehicles in the year 1956.

Afterwards, the motorcycles as means of mass transport have been substituted by cars rapidly. This resulted in a considerable reduction of the motorcycle fleet until the year 1969 down to almost a tenth (263,486). For the year 1970 the official statistics show for the first time separated figures of registered motorized two-wheelers bearing an official registration number: 141,047 motorcycles, 87,557 motor scooters and as a new sub group 150,000 light motorcycles.

During the 1970ies the motorcycle has been recovered as an individual motorized means of transportation. For under 18-years old people – according to their driving licence – the light motorcycle was still a vehicle for daily use during the entire year. But older traffic participants did not depend on the motorcycle and used it increasingly as an additional vehicle during their leisure times. Motor scooters played a very ancillary role in these years. In the year 1986 with 986,304 motorcycles, 56,895 motor scooters and 361,515 light motorcycles (1.4 billion vehicles in total) a new relative maximum of the fleet population was reached. However, this was far beneath the corresponding maximum of the 1950ies.

Subsequently the fleet population remained more or less constant until the year 1989. Already in the old German countries (figures until 1991) and later on also in the reunified Germany the figures of registered motorcycles again continuously increased. The old all-time high of 2.5 billion motorcycles was reached in the year 1997 (2,243,813 motorcycles, 152,222 motor scooters and 320,745 light motorcycles). This growth continued also for the following years.

Table 1. Sub groups of motorcycles bearing an official registration number and appropriated driving licenses (Source: KBA [3])

Type of vehicle	**Terms of technical regulations**	**Class of driving license**	**Minimal age of driver**
Light motorcycle	2-wheeler up to 125 cm³ up to 80 km/h up to 11 kW	A1 (former 1b) alternatively 1, 1a or 2, 3 or 4 if certificated before April 01, 1980	16 years
Light motorcycle	2-wheeler up to 125 cm³ no speed limit up to 11 kW	A1 (former 1b) alternatively 1, 1a or 2,3 or 4 if certificated before April 01, 1980	18 years
Motorcycle and motor scooter	2-wheeler (also with side car) up to 25 kW up to 0,16 kW/kg	A (former 1a) alternatively 1	18 years
Motorcycle and motor scooter	2-wheeler (also with side car) more than 50 cm³ more than 45 km/h (during the first 2 years: up to 25 kW up to 0,16 kW/kg)	A (former 1) since April 1, 1988 2 years driving licence class A (before 1a) and a minimum of 4.000 km driving experience, if the candidate is younger than 25 years old	20 years
3-wheeled light motorcycles and 4-wheeled motorized light vehicles	3-wheeler, 4-wheeler up to 50 ccm, up to 45 km/h up to 4 kW up to 350 kg	S (since February 1, 2005)	16 years

For the last time in the year 2001 separated figures for registered motorcycles (2,650,749), motor scooters (161,084) and light motorcycles (597,904) are published with the official statistics. For the following years up to 2005 only the sum of motorcycles and motor scooters is displayed. Since 2006, also the figure of registered light motorcycles is included into this sum. Starting with the year 2002, separated figures for three-wheelers and light four-wheelers are reported in the official statistics within the subgroups for motorcycles, too.

For the reference date January 1st, 2007 the Federal Statistics gives the total number of 3,969,103 registered motorcycles bearing an official licence number. This contains 3,885,572 two-wheeled motor vehicles, 6,280 three-wheeled motor vehicles and 77,251 light four-wheeled motor vehicles.

Up to the year 2007, the figures for the vehicle-fleet population did also contain vehicles that have been temporarily out of registration. This has changed with the new simplified vehicle registration procedures. Starting on March 1st, 2007 also the temporarily decommissioned vehicles (approx. 12%) are treated in the same way as the final shut-downs. Consequently, the fleet population reported with the German Federal Statistics contain only vehicles which participate in the traffic flow [4]. This has to be kept in mind for further updates and interpretation of this statistics.

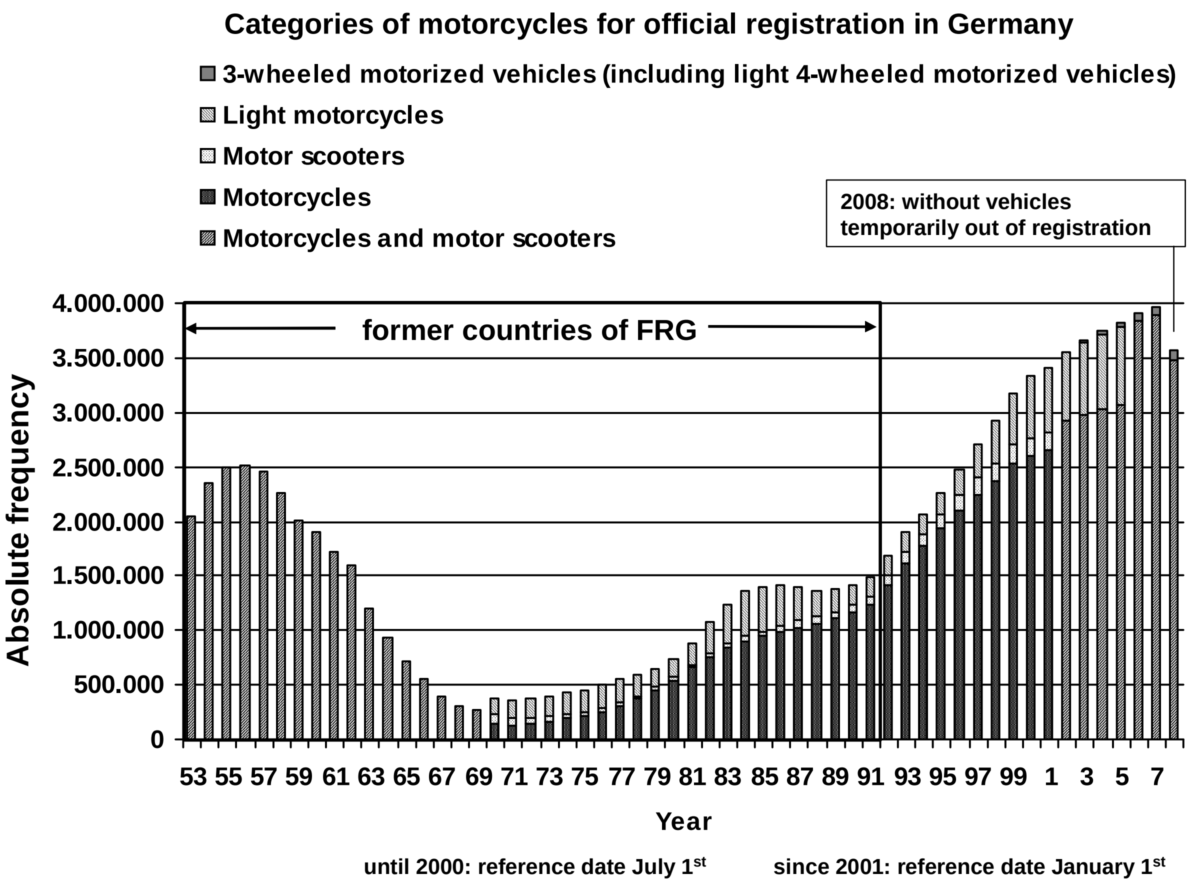


Figure 1: Historical time series of the figures for vehicle-fleet population of motorcycles bearing an official registration number in Germany (years 1953 to 2008; Sources: KBA, StBA)

2.2 Killed motorcycle riders

To analyse historical trends and developments of traffic accidents in Germany, a very useful data source is the series 8 traffic, part 7 traffic accidents, published by the Federal Institute for Statistics (Statistisches Bundesamt, StBA), [5]. Herein and with the annual volumes of the corresponding former series the long-term statistical series for the Federal Republic of Germany began with the year 1953. In the federal accident statistics the motorized vehicles dealt in this paper are defined corresponding to their kind of involvement in road traffic as motorcycles. These are powered two-wheelers bearing an official registration number wherein according to the current definitions contain: Light motorcycles, motor scooters and motorcycles and as well the compulsory approval three-wheelers (including light four-wheelers). Up to now the annual volumes available report until the Year 2006 [6]. Figure 2 illustrates the historical progression of the annual figures of killed riders of motorcycles bearing an official registration number inside and outside urban area compared to the development of the corresponding vehicle-fleet population.

It is noticeable, that up to the 1980ies the figures of the accident victims did follow more or less the figures of registered motorcycles. 4,135 killed motorcycle riders have been reported for the year 1954 with 1,965 fatalities inside and 2,170 fatalities outside urban area. Up recent years this was the absolute all-time high. Until the begin of the 1980ies corresponding to the figures of registered motorcycles subsequently the figures of killed motorcycle riders firstly decreased and then increased again. This can be seen in particular for fatalities outside urban area. A new relative maximum of these figures was then reached in 1982. For this year, 1,453 killed riders of motorcycles bearing an official registration number are reported (959 rural and 494 urban).

For the follow-up years a total decoupling of the figure of killed motorcycle riders from the figure of motorcycles registered occurred. Still in the former countries of the Federal Republic of Germany the figures of fatalities declined rural and urban, while the figures of registered motorcycles inclined or reminded more or less constant. After the German reunification the figure of killed motorcycle riders was again more or less constant inside and outside urban area until the year 2003. Afterwards, this figure continued to decrease rural but remained roughly constant urban.

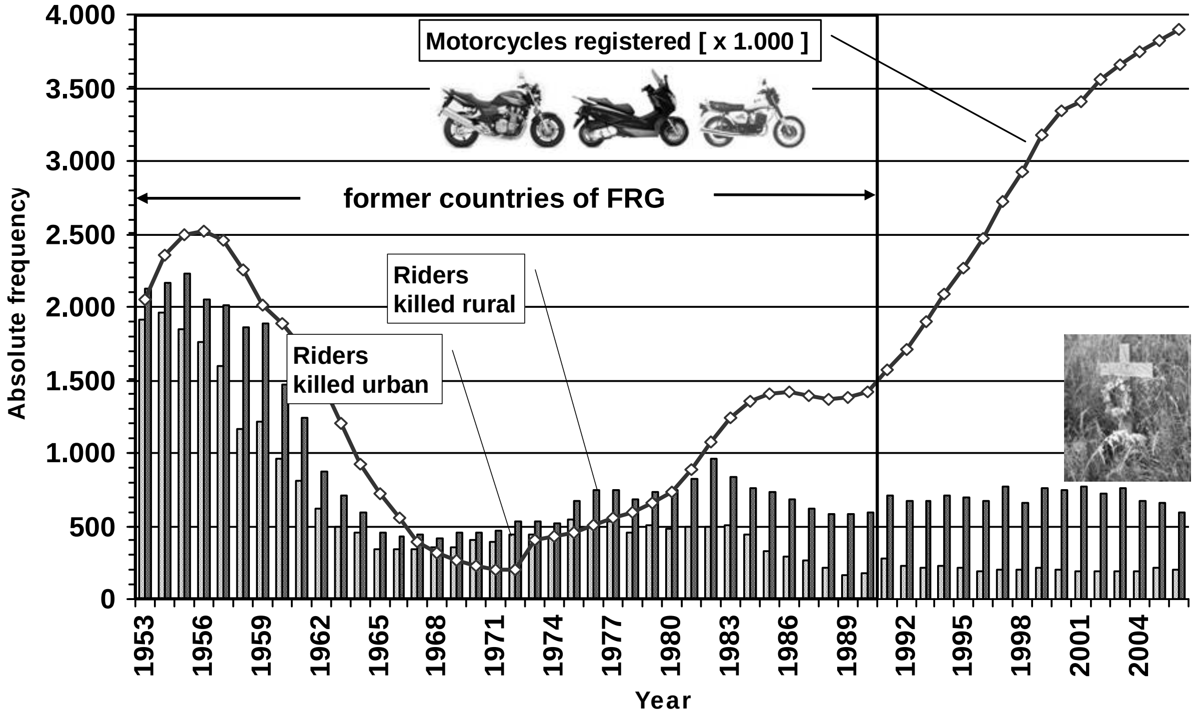


Figure 2: Historical time series of the figures of killed users of motorcycles bearing an official registration number in Germany from 1953 to 2006, subdivided by the locality of the accident (rural, urban) and compared to the corresponding vehicle-fleet population (Source: StBA)

With the interpretation of the accident figures of motorcycles there is a consistently remark to the weather conditions. Thereby motorcycle riders do not participate more often in accidents due to dirty weather. Quite the contrary: The better the weather, the more motorcyclists are en route and are endangered by the daily risks of road traffic. For example in the year 2004 the figure of fatal injured occupants of motorcycles bearing an official registration number declined considerably from 946 in the previous year 2003 by 88 (-9%) down to 858. As one of the reasons the comment to the official statistics mentioned weather conditions: During the summer of 2004 in Germany the weather was clearly less convenient than in the so called “summer of the century” of 2003 [7].

For the year 2006 the statistics report 793 killed motorcycle riders. 592 of them died in rural crashes and 201 urban.

From the monthly report of December 2007 it can be seen that in the entire year 2007 in total 829 drivers of motorcycles bearing an official registration number have been killed, 162 urban and 667 rural (these are preliminary figures). That points out a decrease of the figure of killed occupants of motorcycles bearing an official registration number, compared to the previous year, by 39 (19%) inside urban area. But outside urban area the corresponding figure increased by 75 (13%). In total the figure of killed motorcycle riders increased by 36 (4.5%). As one of the reasons it is mentioned, that in spring 2007 mild weather conditions began relatively early and caused by this the season for motorcycle riding did also start earlier.

As in previous years, also for the year 2007 the statistical figures which are available show considerably more fatal accidents of the motorcycles bearing an official registration number outside then inside urban area. This is an indication for the exceeding risk on rural accidents, which can be explained by the higher speeds normally driven by the traffic participants who are on the roads outside urban area.

2.3 Risks related to the vehicle-fleet population

One of the possible exposure data to indicate the accident risks of traffic participants is the relation between drivers and passengers and the corresponding vehicle-fleet population. On this, Figure 3 illustrates the figure of killed drivers and passengers of motorcycles bearing an official licence number per 100,000 of these vehicles registered in the fleet-population for the years 1953 to 2006. For the purpose of comparison the according courses of these risk figures for the riders of motorised two-wheelers bearing an identification mark (Mofa, Moped and Mokick) and for the occupants of cars are depicted, too. Caused by the definitions of the groups of traffic participants within the Federal Statistics the figures for Mofa, Moped and Mokick are first available in 1955 and for cars in 1957.

In the year 1957, for example, 89 drivers and passengers in cars, 68 riders of Mofas, Mopeds and Mokicks, and 149 occupants of motorcycles bearing an official registration number have been killed in traffic accidents per 100,000 of the corresponding vehicles registered in the fleet. The courses of the curves during the decades show a general trend to a steady and sustainable improvement of the safety of vehicles and traffic for the cars and for the smaller motorcycles without official registration. This was really not the case for the motorcycles bearing an official registration number within the time period from 1963 to 1969. For these vehicles the risk coefficient which is shown here was tripled from 100 for the year 1963 up to 308 for the year 1969. In the year 1969 a first success in breaking this fatal trend occurred. During these years an intensive debate happened on the mandatory wearing of protection helmets for motorcycle riders. Many motorcycle riders used the helmet already on a voluntary basis. The legal obligation of wearing a helmet for riders of motorcycles having a maximum speed of more than 40 km/h (without fine) was on January 1st, 1976. With this date, a sustainable trend to the reduction of the risk of a motorcycle rider to be killed in an accident began. It is remarkable, that the follow-up tightening with fines did not significantly enhance this already positive trend.

The steady and sustainable reduction of the risk of being killed for drivers and passengers of motorcycles bearing on official registration number was then also evident (as already before for the riders of Mofas, Mopeds and Mokicks as well as for the occupants in cars). These trends are still valid until recent years. Short-term increases did occur directly after the German reunification. But this have been only temporary events and also some irregularities during the consolidation of the statistics for the old and new countries could have been one of the related reasons.

Also in the reunified Germany the risk based on the vehicle-fleet populations to be killed in a traffic accident declined further on until today for the groups of traffic participation discussed herein. In particular the long-term evolutions show, that the corresponding curves decline more and more asymptotically flat during the last years. In other words: The marginal utility for further improvements of vehicle and traffic safety has gone smaller and smaller in the recent past.

For the improvements of traffic and vehicle safety seen here, amongst the causes are measures related to the vehicle technique, enhancements of the protection clothing for motorcycle riders, accompanying legal measures, progress in rescue services during first aid and medical care at the scene, transport and medical treatment for accident victims in a hospital, a general enhancement of the sense of responsibility and safety within the mobile population, and last but not least measures to improve road infrastructure. As mentioned before, in the course of time during the previous decades a considerably saturation took place. In only extrapolating the historical trends further improvements may be no longer expected. But this could be changed, whether fundamental new safety technologies with high efficiency, for example in the area of primary (active) safety to avoid accidents, could be made accessible.

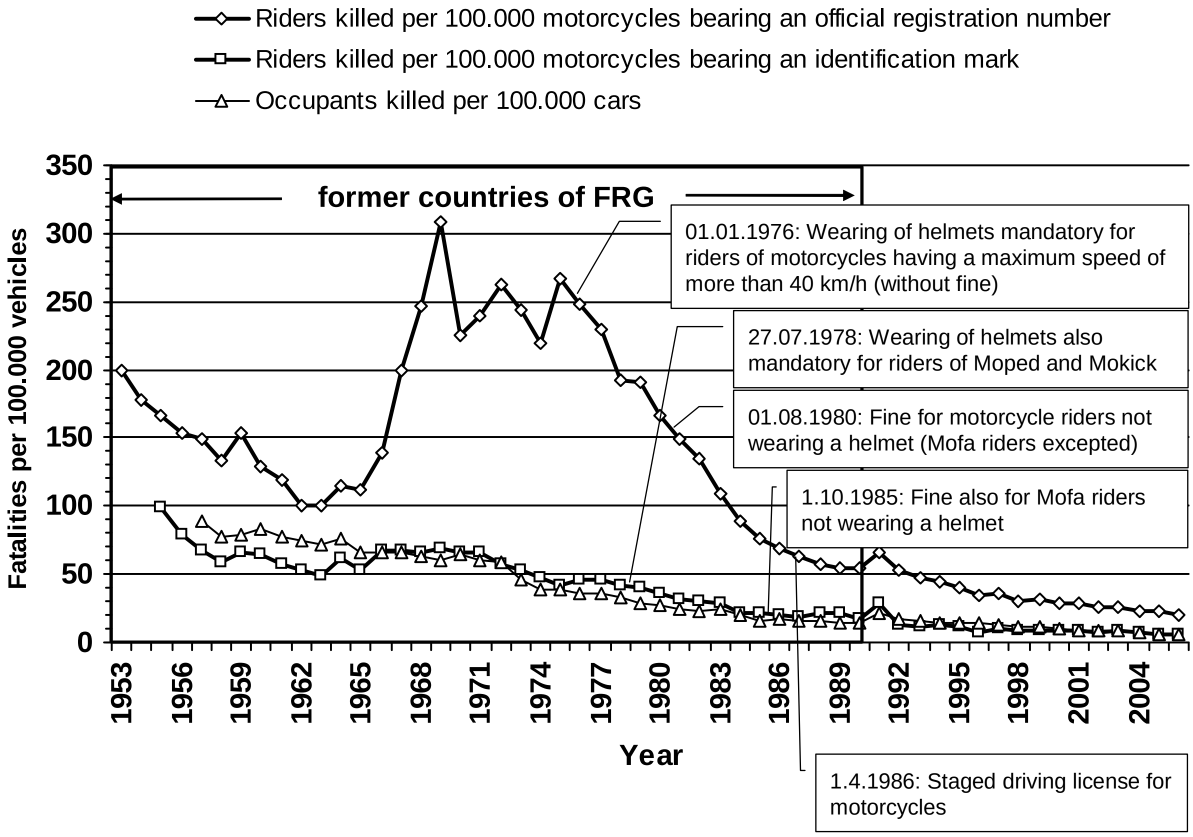


Figure 3: Killed occupants of motorcycles bearing an official licence number, of motorcycles bearing an identification mark (Mofa, Moped, Mokick) und in cars, each related to 100,000 corresponding vehicles in the fleet-population in Germany from 1953 to 2006 and corresponding legal measures (Sources: StBA, KBA)

20 occupants of motorcycles bearing an official registration number have been killed in traffic accidents per 100,000 of these vehicles in the fleet population in the year 2006. Compared to the corresponding risk-index of 308 for the year 1969 this is equivalent to a tremendous reduction of 208 (94%). Nevertheless, the risk of being killed in an accident based on the number of vehicles registered in the fleet population is considerably higher for motorcycle riders than for riders of Mofas, Mopeds and Mockicks and for car occupants. For these two vehicle groups in the year 2006 one can calculate in each case 6 fatalities per 100,000 vehicles. Compared to this figure the corresponding risk of motorcycle riders (20) is more than three times larger.

2.4 Miles travelled

Another reference to calculate the accident risks of a certain road-user group are their miles travelled. A cause of an increase or decrease of the risk based on the vehicle population may be an altering in the mileage corresponding to the duration of active traffic participation.

From the Federal Statistics data for the mileages of several vehicle groups are only available in sub ranges. Amendatory information is given by the German institute for economic research (Deutsches Institut für Wirtschaftsforschung, DIW) using a model-based calculation for different kinds of motorized vehicles [8]. With regard to the vehicle groups shown with Figure 3, Figure 4 illustrates the so called “native mileages” per vehicle (including vehicles temporarily out of registration) and per year for the time period 1953 to 2006. “Native mileage” means the driven distance of vehicles which are registered in Germany on roads inside and outside of Germany.

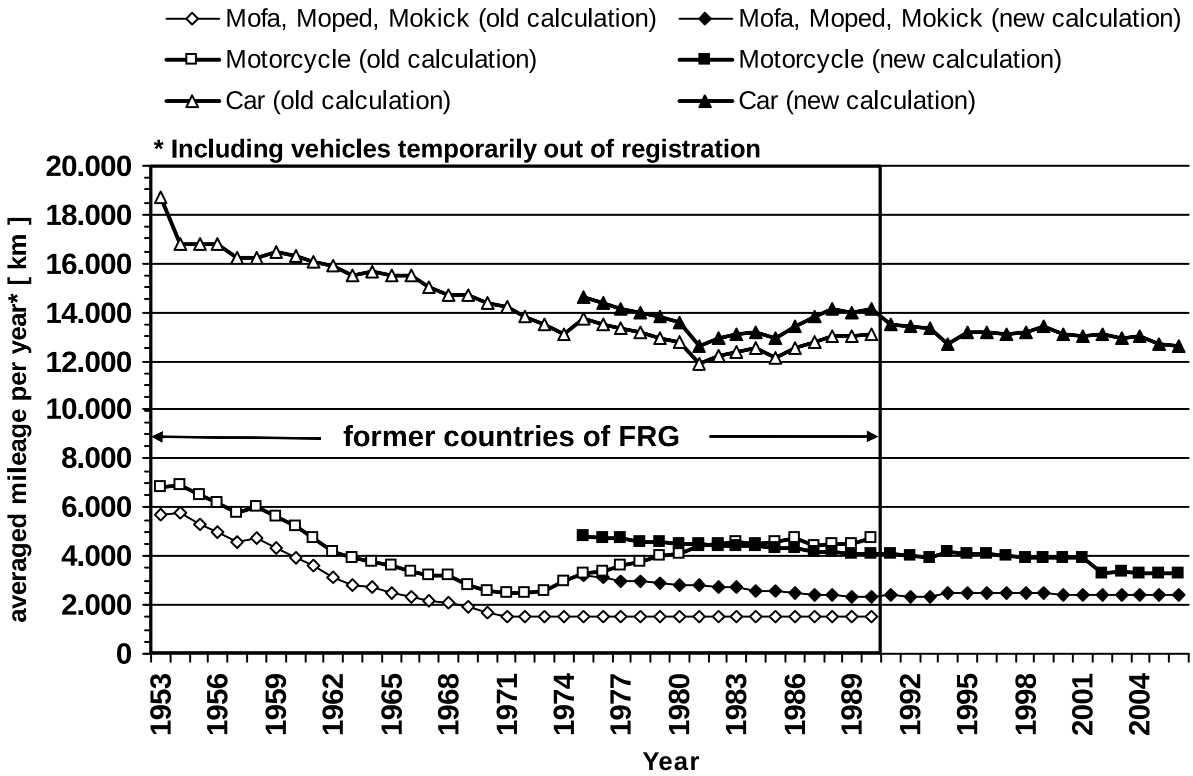


Figure 4: Mean value of the native annually mileages for Mofas, Mopeds und Mokicks (motorized two-wheelers bearing an identification mark), for motorcycles bearing an official registration number and for cars for the time period 1953 to 2006 (Source: DIW)

The calculated values are results from a model-based computation which is predicated on the total fuel consumption in Germany. Amongst others the vehicle-fleet population and the fuel consumption of different vehicle groups are taken as parameters for the model. Using the results of collections of real-world data for mileages and economics the results of the model-based computations are adjusted from time to time [9]. This is then also done for some of the years prior to the adjustment. Compared to cars with this procedure it is possible that for the motorized two-wheelers with its smaller mileages a relatively large variance of actualised mileages per vehicle and year is the result of such an update (see results of old and new calculation in Figure 4). This is the reason why for historical long-term illustrations of the course of risks based on the mileage of motorized two-wheelers these values seem to be suboptimal.

But it is evident, that till the begin of the 1970ies the mileages per vehicle and year for the several vehicle groups have been reduced. In principle this is convenient for the risks calculated on the basis of the vehicle-fleet only, because the vehicles do less participate in the road traffic and therefore they are fewer endangered by the corresponding accident risk.

The drastic growth of the fatality risk for motorcyclists based on the figure of registered vehicles only from 1963 to 1969 (see Figure 3) is not explainable by the course of their miles travelled, indeed. For the relevant time period the mileage of these vehicles did not increase, quite the contrary it decreased!

For the following years the results of the model-based calculation of miles travelled per vehicle and year show a slightly downwards drift, whereas for some years also constant mileages can be seen. Hence, the relative course of the fatality risk based on the figures of registered vehicles also shows roughly the relative course of the risk which is based on the mileage.

However, when considering the mileage, the absolute fatality risk of motorcycle riders is significantly higher because of their smaller distances travelled per year compared to cars. In Table 2, an overview on this matter is given for the years 1957, 1970, 1991 and 2006.

Table 2: Killed occupants of motorcycles bearing an official registration number, of motorcycles bearing an identification mark (Mofa, Moped, Mockick) and of cars, related to their vehicle-population and to their miles travelled in total per year (Sources: StBA, KBA, DIW)

Year		**1957**	**1970**	**1991**	**2006**
motorcycles bearing an official registration number	Killed drivers and passengers	3,604	853	992	793
	Vehicle population	2,419,000	378,604	1,491,694	3,902,512
	Mileage in total per year	14.1 billion km	0.6 billion. km	8.7 billion. km	13.2 billion km
	Killed per 100,000 vehicles	**149**	**225**	**67**	**20**
	Killed per 1 billion vehicle kilometres	**256**	**1.422**	**114**	**60**
motorcycles bearing an identification mark (Mofa, Moped, Mokick)	Killed drivers and passenger	1,116	700	243	107
	Vehicle population	1,650.000	1,052,543	867,875	1,793,209
	Mileage in total per year	7.6 billion km	2.0 billion km	4.9 billion km	4.6 billion km
	Killed per 100,000 vehicles	**68**	**67**	**28**	**6**
	Killed per 1 billion vehicle kilometres	**147**	**350**	**50**	**23**
Car	Killed drivers and passenger	2,293	8,989	6,801	2,683
	Vehicle population	2.583.656	13.941.079	32.087.560	45.668.108
	Mileage in total per year	41.3 billion km	201.1 billion km	496.4 billion km	586.3 billion km
	Killed per 100,000 vehicles	**89**	**65**	**21**	**6**
	Killed per 1 billion vehicle kilometres	**56**	**45**	**14**	**5**

Here too, for the cars a continuous and sustainable reduction of the risk from 56 occupants killed per 1 billion kilometres in the year 1957 to corresponding 5 occupants killed in the year 2006 is evident. For motorcycles bearing an identification mark (Mofas, Mopeds and Mokicks), caused by a reduction of the mileage with a roughly constant figure of 68 respectively 67 riders killed per 100,000 vehicles initially there was an increase from 147 riders killed per 1 billion kilometres in the year 1957 to corresponding 350 persons killed in the year 1970. Subsequently this was followed by a clear reduction down to accordingly 50 fatalities in the year 1991. In the year 2006 for this vehicle group the risk is calculated to 23 occupants killed per 1 billion kilometres.

For the drivers and passengers of motorcycles bearing an official registration number the risk ratio is 256 fatalities per 1 billion kilometres travelled in the year 1957. The year 1970 shows with corresponding 1,422 fatalities an extreme risk-ratio which is 4.6 times higher. For the year 2006 recently 60 drivers and passengers of motorcycles bearing an official registration number have been killed per 1 billion kilometres. Hence, related to the mileages in the year 2006 the risk of being killed in a traffic accident for the riders of motorcycles bearing an official licence number is 12-times higher than for car occupants and 2.6-times higher than for the riders of Mofas, Mopeds and Mokicks.

One main reason for the increased risk-ratios for riders of motorcycles bearing an official registration number per vehicle both regarding the fleet population and regarding the mileage travelled compared to that risk-ratio for car occupants surely is that the motorcycle rider is not protected by a surrounding safety cell which protects the occupants of cars combined with the protective effects of restraint systems and padding. Compared to Mofas, Mopeds and Mopeds the increased risk ratios for motorcycles bearing an official registration number can be mainly explained by the higher speeds of the motorcycles (and also of other traffic participants), especially on roads outside urban area.

In the year 2006 inside urban area 55 riders of Mofas, Mopeds and Mokicks have been killed in an accident. Outside urban area the corresponding figure of fatalities with 52 was nearly the same. For the motorcycle riders the figure of killed riders inside urban area was 201 and the corresponding figure of occupants killed in accidents outside urban area was 592, that means almost 3-times greater. One of the possible explanations is, that for motorcycles the distance travelled on rural roads is greater than that for Mofas, Mopeds and Mokicks. But there are no confirmed data available to verify this. On the other hand, in general the risk of being killed in an accident outside urban area increases with the speed especially for the so called “unprotected road users”. It is obvious that the protection clothing (helmet, overall, gloves, boots) normally used by the motorcycle riders is not sufficient to compensate this higher risk for appropriate severe impacts.

2.5 Shares of killed, severely injured and slightly injured motorcycle riders

In terms of the progression of the injury severity of the drivers and passengers of motorcycles bearing an official registration number the alterations of the shares of slightly injured, severely injured and fatally injured persons give revealing indications. This is displayed for the time period from 1953 to 2006 with Figure 6.

In 1953, in total 125,043 drivers and passengers of motorcycles bearing an official registration number have been victims of a traffic accident. Hereof 3.2% (4,046) have been killed, 39.0% (48,828) have been severely injured and 57.7% (72,169) slightly injured. During the following decades these shares did change only little. For the year 2006 the share of killed motorcycle riders was 2.4% (793 of 34,221 corresponding victims in total) and the share of severely injured was 32% (10,590). This is clearly different for example to the accordingly development for pedestrians involved in traffic accidents. For these pedestrians the share of killed and severely injured victims decreased from the year 1970 significantly and sustainably while at the same time the share of slightly injured pedestrians increased [10].

Per definition for the official Statistics of the Federal Republic of Germany as slightly injured all victims are counted who are injured after an accident and for example treated ambulant but not taken into hospital for inpatient treatment (of at least 24 hours). Increasing shares of slightly injured victims may for example indicate a reduced level of impact velocities as it was the case for pedestrians in speed-reduced urban areas (speed limit 30 km/h).

Severely injured are persons who were immediately taken to hospital for in-patient treatment (at least for 24 hours). Killed are victims who died immediately after the accident or within 30 days as a result of the accident. An increase of the share of severely injured in combination with a decrease of the share of killed victims may indicate improvements in the rescue chain and for the treatment of severely injured persons in the hospital. Appropriate indications are not recognizable for rides of motorcycles from the diagram shown with Figure 6.

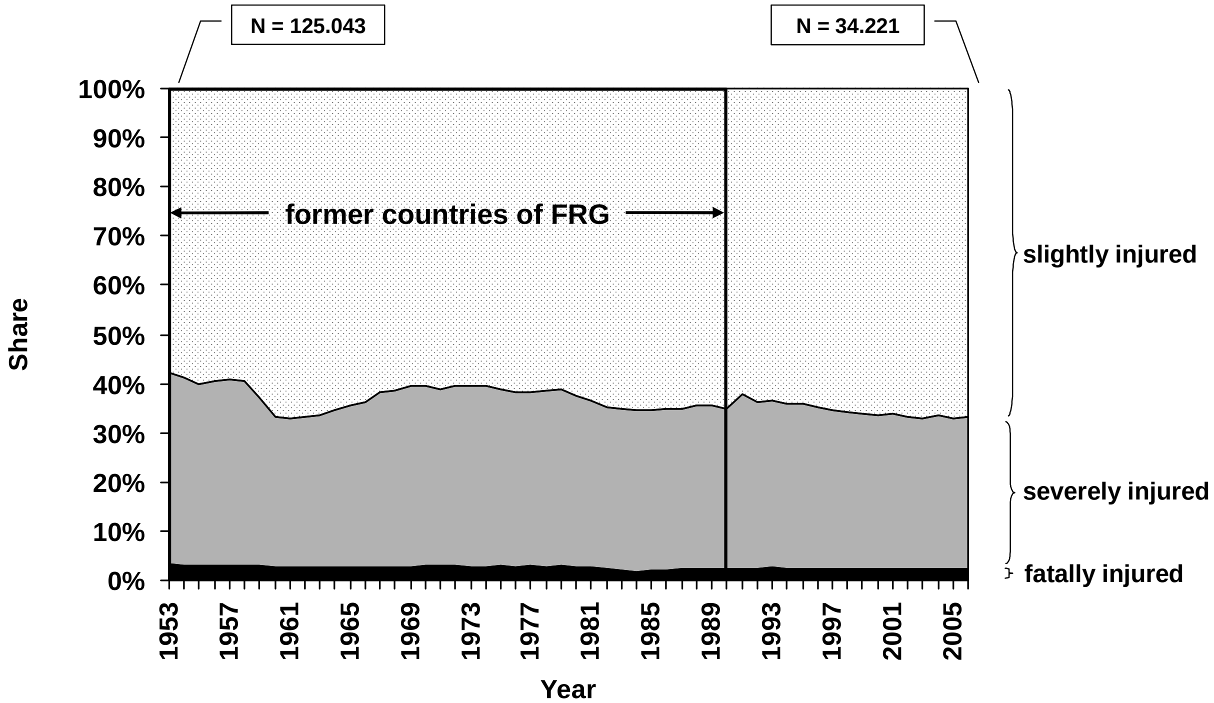


Figure 6: Shares of slightly injured, severely injured and killed occupants of motorcycles bearing an official registration number, in road-traffic-accidents in the Federal Republic of Germany at any year from 1956 to 2006 (Source: StBA)

2.6 Shares of killed motorcycle riders related to all fatalities

As shown with Figure 7, in the year 1953 the killed drivers and passengers of motorcycles and motor scooters with 36% formed the biggest share of all 11,449 killed road-accident victims in the Federal Republic of Germany. This was followed by the shares of pedestrians (30%) and of users of Mofas, Mopeds and Mokicks (17%). At that time the killed occupants of automobiles (cars, buses and coaches, agricultural tractors, commercial vehicles and remainders) with a share of 15% did follow only on rank four of all killed traffic accident victims.

This was changed drastically afterwards with increasing figures of automobiles coming into traffic. For the year 1970 the share of killed car occupants of all 19,193 victims killed in traffic accidents was 46%, followed by the share of killed pedestrians (32%). With a share of only 4% of all fatalities the killed motorcycle rides did play a relatively marginal role in these years.

The share of killed drivers and occupants of motorized two-wheelers bearing an official registration number was 9% out of 11,300 killed traffic accident victims in total in the year 1991. After the occupants in cars with a share of 60% and the pedestrians with a share of 17% the motorcycle riders have been in that year already on rank number three.

In 2006 the killed drivers and occupants of motorcycles bearing an official registration number formed the second frequent group of all killed victims of traffic accidents in that year. Their share was 16% out of 5,091 and herewith bigger than the share of killed pedestrians with 14%.

With smaller absolute figures of all persons killed in traffic accidents the relative importance of motorcycle riders did increase in the younger past. For further reductions of the figures of all traffic participants killed in accidents, the strategic and operational significance of the motorcycles increased correspondingly.

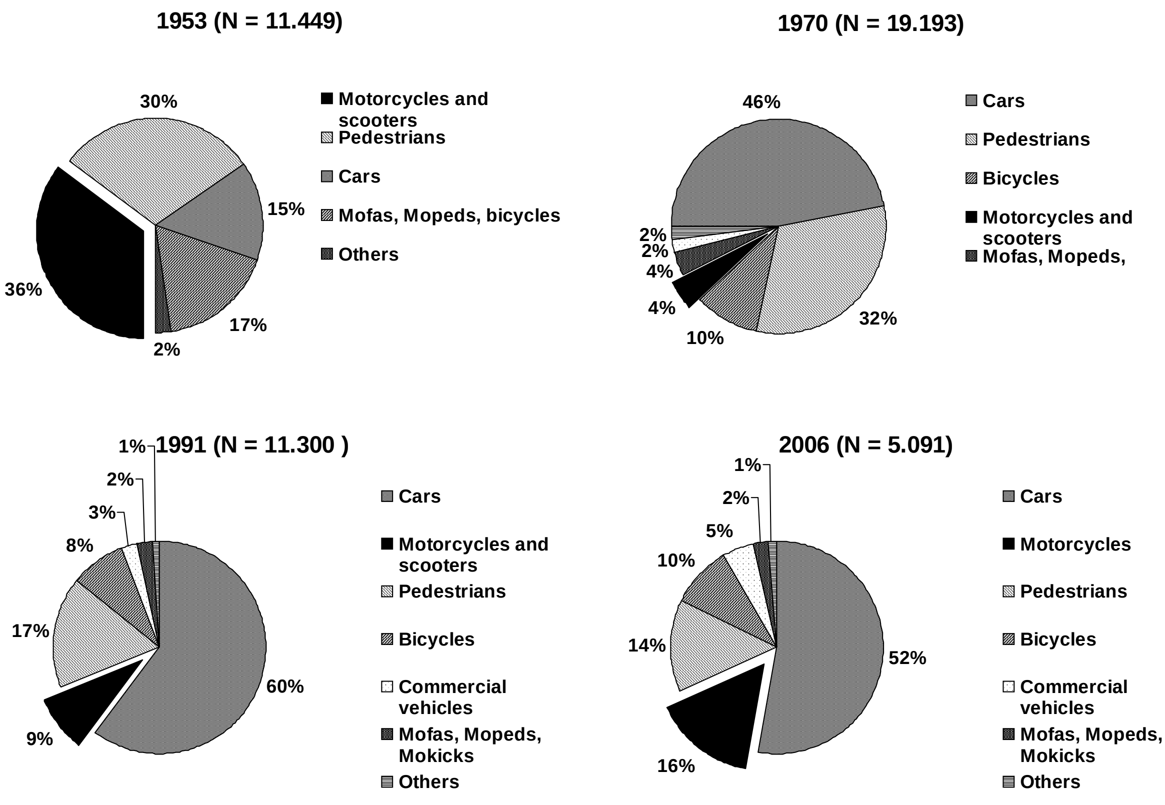


Figure 7: Shares of traffic participants killed in traffic accidents in Germany in the years 1953, 1970, 1991 und 2006 (Source: StBA)

This is also reflected by a multitude of recent research activities amongst others within the research programme of the European Union, some of them are still running.

An example is the project **MAIDS** (**M**otorcycle **A**ccident **I**n-**D**epth **S**tudy, see www.maids-study.eu). Herein for the years 1999 and 2000 a total of 921 accidents involving motorized two-wheelers in France, Germany, Italy, the Netherlands and in Spain have been collected to contribute in the further exploration of the causes and consequences of these accidents.

Settled within the ongoing projects running under the 6th Framework Programme is the integrated project **APROSYS** (**A**dvanced **Pro**tection **Sys**tems, duration from April 2004 until March 2009, see www.aprosys.com) by which in the sub project SP 4 motorcycle accidents are analysed. First results have been reported with [19].

Also currently in process are the projects **SIM** (**S**afety **I**n **M**otion, see www.sim-eu.org) und **PISa** (**P**owered Two-Wheeler **I**ntegrated **Sa**fety, see www.pisa-project.eu). Amongst the objectives of SIM is the identification of a feasible safety strategy for powered two wheelers. Thereto the primary (active) safety to avoid accidents as well as the secondary (passive) safety to reduce the consequences of an accident shall be enhanced. All aspects and findings shall be incorporated into the prototype of a new safety powered two-wheeler. As a result of PISa reliable and dependable integrated safety systems for a series of powered two wheelers are announced. As a result a considerable improvement of the primary safety of powered two-wheelers regarding the handling and driving stability should be reached. Herein also the benefits of secondary-safety systems are considered. As a result of the PISa project two prototypes will be developed to demonstrate the potential of integrated systems for a reduction of frequency and severity of accidents with powered two-wheelers involved.

3 CURRENT SITUATION AND TRENDS

3.1 Age groups of killed motorcycle riders

Amongst the phenomena worthy of mention for the current progression of the accident occurrence with motorcycles involved is the age distribution of the drivers. Figure 8 illustrates the shares of the different age groups for killed riders of motorcycles bearing an official registration number in accidents on German roads for the years 1991 to 2006. There in the year 1991 the share of the under 25 years old victims was laying just at 49% (485 from 992 in total). Until the year 2006 this share has been reduced almost by half down to 25% (196 from 793). Accordingly the shares of the older motorcycle riders did increase. For example in the year 1991 only 7% (69) of the killed drivers and passengers of motorcycles were 45 years old or older. The share of this age group was quadrupled until the year 2006 up to 28% (219). The share of the seniors with an age of 65 years or more did increase from 1.4% (14) in the year 1991 up to 4.5% (36) in the year 2006 and with this figures it was more than tripled.

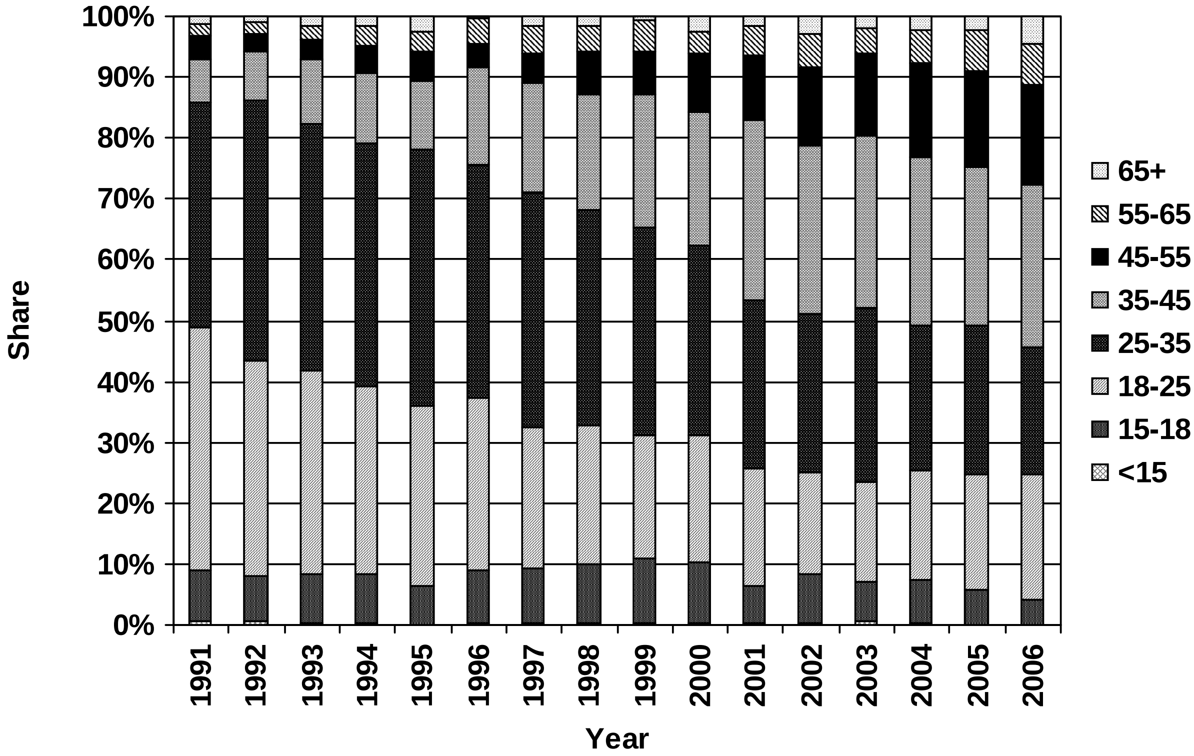


Figure 8: Shares of the age groups of riders of motorcycles bearing an official registration number killed in traffic accidents in Germany within the time period from 1991 to 2006 (Source: StBA)

As a result of these shifts of the ages of motorcycle riders involved as victims in traffic accidents additional actual challenges came up for the further development of the safety of motorcycles. It is in general well known, that the ability to withstand biomechanical loads is lesser for elderly people as for the younger. Correspondingly greater is the personal injury risk in road-traffic accidents, especially for the so called “unprotected road users” [11]. Some more restrictions follow as a consequence of the influence of age to the driving performance. Facts as increasing reaction times, weakening of sight and hearing abilities, restrictions with the motility and the sagging of muscular forces lead to limitations with the safe steering of motorized vehicles for elderly when participating in the “modern” road traffic. At this juncture the influence of drugs (medicine) shall also not be underestimated [12]. For this it follows that the system containing men, motorcycle and surrounding has to be further investigated to support the mobility of elderly motorcycle riders so that their road-traffic risk compared to younger riders will not increase excessively.

3.2 Regional scattering of risks

Not only international, but also for the national regions it is worthwhile to analyse and compare the accident occurrence. Also here, the figures published within the official statistics give a very useful basis. Corresponding to the figure of inhabitants the length of the road network and of the vehicle population in Germany, most of the motorcycle riders are involved in accidents occurring in the bigger states in Western Germany and the smallest figures are given for the small city states of Bremen and Hamburg, see Figure 9.

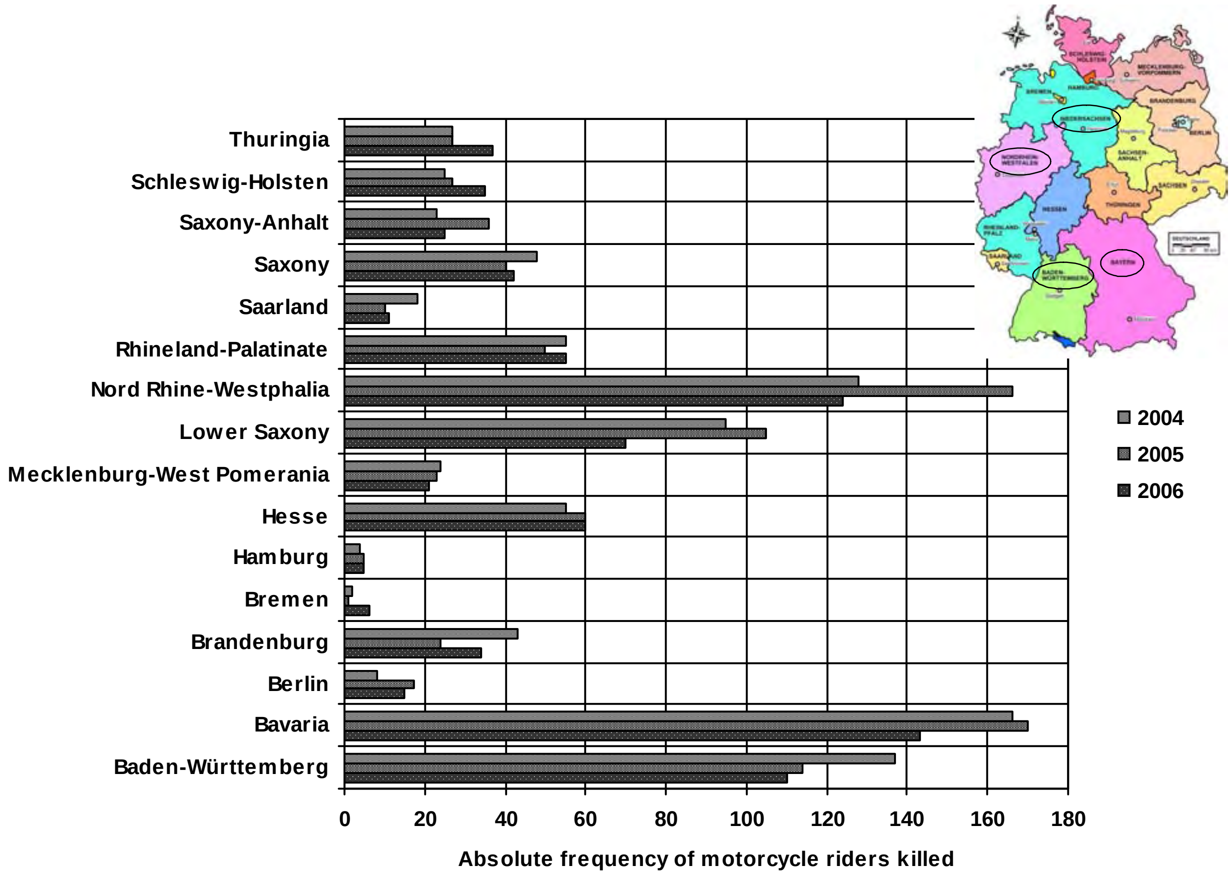


Figure 9: Absolute figures of drivers and passengers of motorcycles bearing an official licence number killed in traffic accidents occurring in the different states of Germany in the years 2004, 2005 and 2006 (Source: StBA)

In the year 2006 in Bavaria 143, in North Rhine-Westphalia 124 and in Baden-Württemberg 110 motorcycle riders have been killed in traffic accidents. At the other end of the absolute-frequency ranking of the year 2006 in Hamburg 5 and in Bremen 6 motorcycle riders have been killed.

With reference to the corresponding vehicle-fleet population the relations shown with Figure 10 exist. Herein for the year 2006 the fatality risk was highest in the Eastern German states Thuringia (45 killed per 100,000 motorcycles), Mecklenburg-Western Pomerania (39 killed per 100,000 motorcycles) and Brandenburg (36 killed per 100,000 motorcycles).

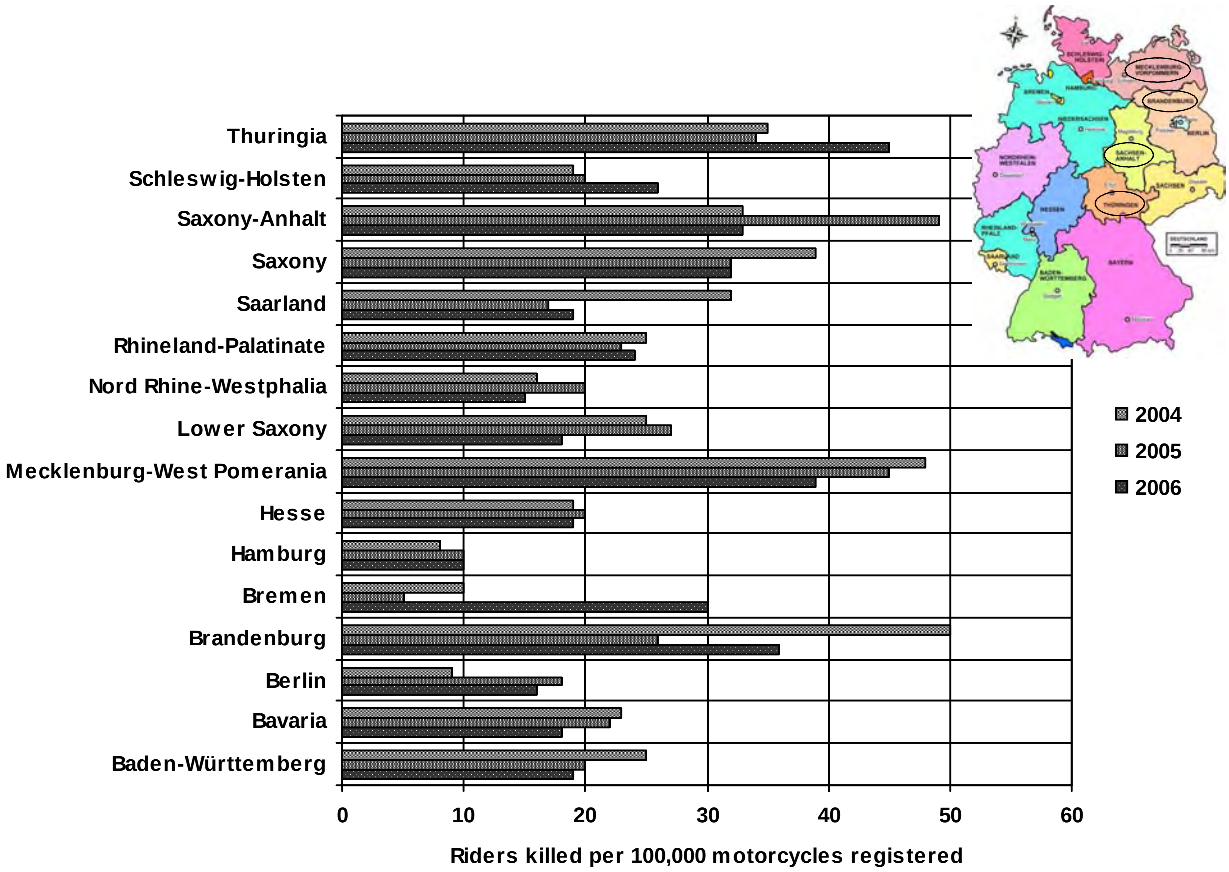


Figure 10: Drivers and passengers of motorcycles bearing an official licence number killed in traffic accidents occurring in the different countries of Germany per 100,000 corresponding vehicles registered in the years 2004, 2005 and 2006 (Source: StBA)

These values are not constant and may differ for several years with great variations. Therefore corresponding alterations are possible year by year for the chronological sequences of the several states as for the ranking of the states among each other.

Nevertheless, using these figures a potential for regional measures to improve the safety of motorcycle riders can be disclosed, see Table 3. In doing so it was assumed for the year 2006 that the risk based on the motorcycle fleet population for those countries laying over the average risk value for Germany was reduced exactly down to this value of 20 killed motorcycle riders per 100,000 motorcycles registered. Therewith in the states concerned the absolute figures of killed motorcycle riders would be reduced from 18% (Rhineland-Palatinate) to 54% (Thuringia). This means in absolute figures a reduction in all the states concerned (and therewith also for the entire German Federal territory) by 91 motorcycle riders. Based on the 793 killed motorcycle riders in Germany in the year 2006 this would be a relative reduction by 11% anyhow.

Why to, this calculation shows that the largest potential for reducing the absolute figures of killed motorcycle riders in Germany is given for those states where the most motorcycle riders are killed in traffic accidents. With the average of the years 2004 to 2006, the streets in the smaller city states Hamburg, Bremen and Berlin seem to be relatively safe for motorcycle riders. But for example the situation in Bremen does also point out, how smaller variations of the absolute figures already may result in extensive variations of the risk figures. The number of killed motorcycle riders relating to 100,000 motorcycles registered here was 10 in the year 2004, divided in half in the year 2005 down to 5 and sextupled in the year 2006 up to 30. For the risk ratio discussed here with only one killed motorcycle rider in the year 2005 (see Figure 9) the ideal "goal of zero" has temporarily almost been reached.

Since the risk for severe accidents is clearly greater on rural roads than inside urban area, for the assessment of the risk ratio based on the vehicle population in large-area states also the corresponding distribution of the roads has to be considered.

With this background a reduction of the average value of 20 killed motorcycle riders per 100,000 motorcycles registered down to 15 seems to be an optimistic projection. Why to, seeing the real-world risk figures in some countries, this could be educed as a “best-practice” approach. Out of this anyhow the figure of killed motorcycle riders would be reduced relatively by 25%. This would result into a reduction of the absolute figure of killed motorcycle riders in Germany for the year 2006 by 198 down to 595.

Table 3: Killed riders and passengers of motorcycles bearing an official licence number for the individual states of Germany in the year 2006 related to the corresponding vehicle-fleet population and assumption for regional reductions

State	**Killed motorcycle riders**	**motorcycle fleet population**	**killed riders per 100,000 motorcycles actual value**	**killed riders with the assumption of maximal 20 killed riders per 100,000 motorcycles**	**Killed riders difference**
Baden-Württemberg	110	578.529	19	110	0
Bavaria	143	775.278	18	143	0
Berlin	15	94.307	16	15	0
Brandenburg	34	94.375	36	19	-15 (-44%)
Bremen	6	20.243	30	4	-2 (-33%)
Hamburg	5	48.746	10	5	0
Hesse	60	312.189	19	60	0
Mecklenburg-West Pomerania	21	53.225	39	11	-10 (-48%)
Lower Saxony	70	387.554	18	70	0
North Rhine-Westphalia	124	825.714	15	124	0
Rhineland-Palatinate	55	225.174	24	45	-10 (-18%)
Saarland	11	58.626	19	11	0
Saxony	42	132.041	32	26	-16 (-38%)
Saxony-Anhalt	25	76.552	33	15	-10 (-40%)
Schleswig-Holstein	35	136.876	26	27	-8 (-23%)
Thuringia	37	82.832	45	17	-20 (54%)
Germany	**793**	**3.902.512**	**20**	**-**	**-91 (-11%)**

3.3 Allocation of the accidents over the months of a year

In particular because of the usage of a motorcycle as an additional vehicle for leisure times its traffic participation and therefore also its involvement in accidents depends considerably on seasonal effects. For many motorcycle riders adverse weather and worse road conditions may be reasons not to use their motorcycle in the road traffic. Often motorcycles are decommissioned during winter months.

Therefore most of the motorcycle accidents occur during nice weather in the warmer seasons. These are the months were also the regional trips and more extended motorcycle tours are organized more frequently. With this background it becomes clear that for those months with normally nice weather conditions in Germany the figures of killed motorcycle riders increases drastically especially on rural roads. Figure 11 illustrates the absolute figures of killed occupants of motorcycles bearing an official licence number in Germany over the specific months in the years 2004, 2005 and 2006.

Normally the motorcycle season begins in April and ends in October. Noticeably low was the figure of killed motorcycle riders outside urban area in August 2006. The official comment of the Federal Statistics mentioned that it could be explained by extremely foul weather conditions for this month [6].

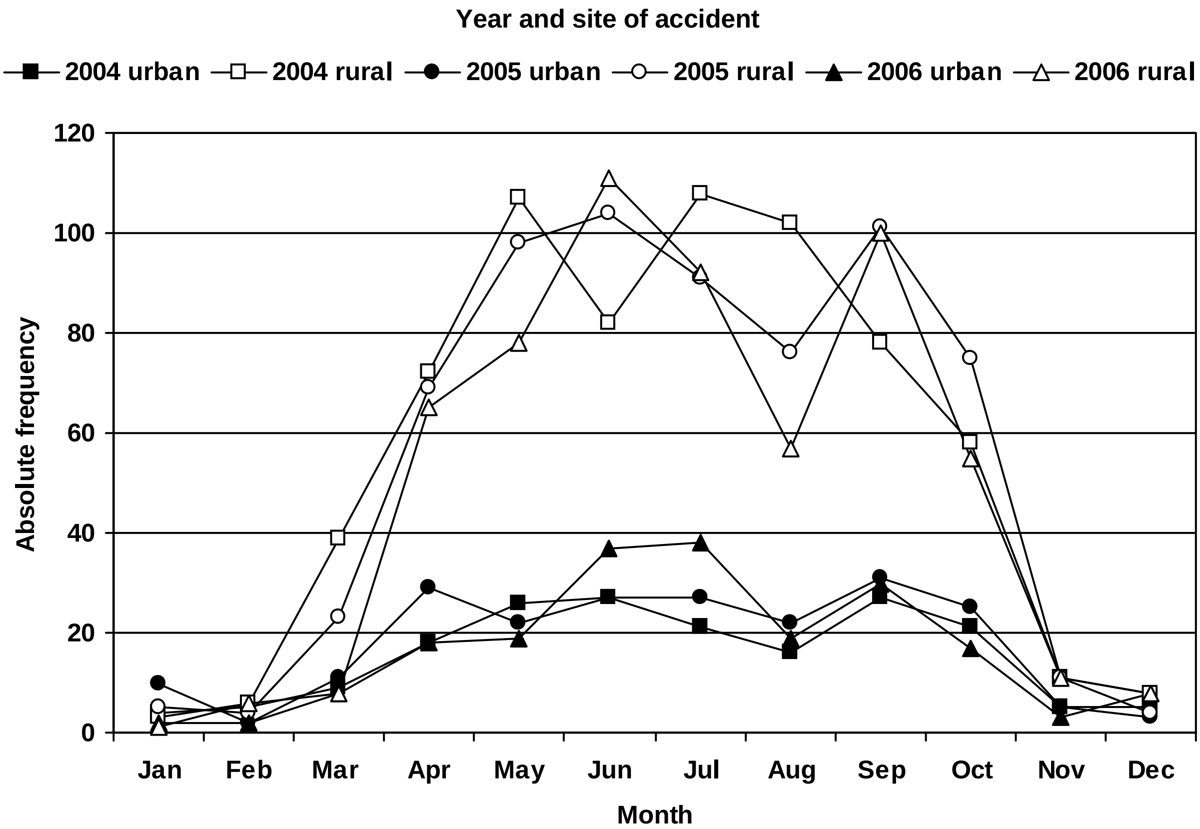


Figure 11: Monthly distributions for killed occupants of motorcycles bearing an official registration number outside and inside urban area in Germany for the years 2004, 2005 und 2006 (Source: StBA)

3.4 Personal-related misbehaviour of motorcycle riders

Proceeding from their personal judgement, the police officers recording the accident describe the causes of the accident in the survey form according to the list of possible causes which has been in force since 1975. A distinction is made between general causes (among other things road conditions, weather factors, obstacles), which are attributed to the accident and not to the individual road user involved, and personal-related misbehaviour (such as failure to give precedence, driving too fast, etc.), which is attributed to the individual driver, vehicle rider or pedestrian, i.e. the road user involved. This means that up to eight causes per accident can be registered.

Amongst others, the official statistics account for the personal-related misbehaviour per 1,000 road users involved in accidents. Correspondingly Figure 12 depicts the misbehaviour of the drivers of motorcycles bearing an official registration number involved in accidents with personal damage in Germany for the year 2006.

Driving too fast (that often means speeding) is the most frequent misbehaviour charged to motorcycle riders by the police officers recording the accident. In the year 2006 this was the case for 21% of all 33,782 motorcycle riders involved in an accident with personal damage.

A more detailed breakdown according to the driver´s age shows, that in all age groups driving too fast is the most frequent police-recorded misbehaviour.

It is remarkable that this occurred even for less then 15-years old motorcycle drivers (who obviously do not own the appropriate driving licence, see Table 1). For the year 2006, according to the statistics 21 motorcycle drivers in this age group have been involved in an accident with personal damage. For nine of these drivers (43%) the police officer assigned that driving too fast was their personal related accident causation.

For the age groups above 15 years the share of driving too fast within the police-recorded personal misbehaviour increases up to the 21-25 years old drivers. Here approximately 300 out of 1,000 motorcycle drivers are involved in accidents attributed by driving too fast. With increasing driver age this share decreases. However, even for the more than 65 years old drivers driving too fast is still the most frequently assigned personal accident causation. Also relatively frequent are personal failures to observe priority and to give precedence as well as mistakes when overtaking. This is the case for all age groups with an exception for the seniors who are 75 years old or older and the under 15 years olds.

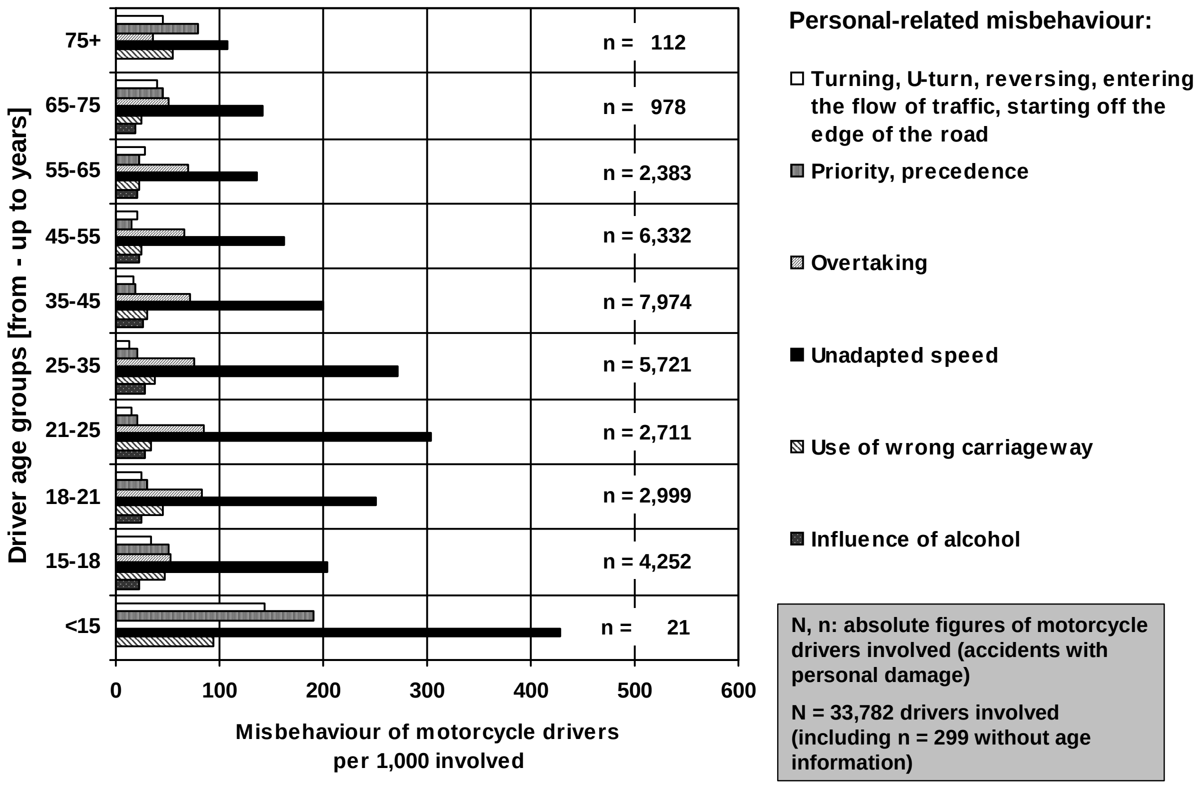


Figure 12: Misbehaviour of drivers of motorcycles bearing an official registration number per 1,000 involved in accidents with personal damage in the year 2006 in Germany subdivided for different age groups (Source: StBA)

In general, with increasing age of the motorcycle riders the percentage of personal-related misbehaviour per 1,000 drivers involved declines. This is caused primarily by the decrease of driving too fast as assigned personal accident causation and can be understood as an indication of a more carefully driving behaviour of the elderly motorcycle riders. Compared to the younger but already driving-experienced age groups and the middle-aged drivers conspicuous for elderly drivers is the relatively large share of misbehaviour related to disregarding of precedence and to turning, U-turning, reversing, entering the flow of traffic or starting off the edge of the road. For the more than 75 years old motorcycle drivers also the wrong carriageway plays a relatively significant role amongst the low absolute figures of personal-related misbehaviour in this age group. This may indicate problems for elderly people to cope with complex road traffic situations.

3.5 Type of Accident

For drivers of motorcycles bearing an official registration number who are categorized as mainly responsible party (that is the person who in the opinion of the police is chiefly to blame for the accident) the official statistics also contain tabulations showing figures and details for the so called "types of accident". The type of accident describes the conflict situation which resulted in the accident, i.e. a phase in the traffic situation where the further course could no longer be controlled because of improper action or some other cause. The following seven types of accidents are distinguished: Driving accident, accident caused by turning off the road, accident caused by turning into a road or by crossing it, accident caused by crossing the road (that is an accident caused by a conflict between a vehicle and a pedestrian), accident involving stationary vehicle, accident between vehicles moving along in carriageway and other accidents (which cannot be allocated to the other types of accidents mentioned before).

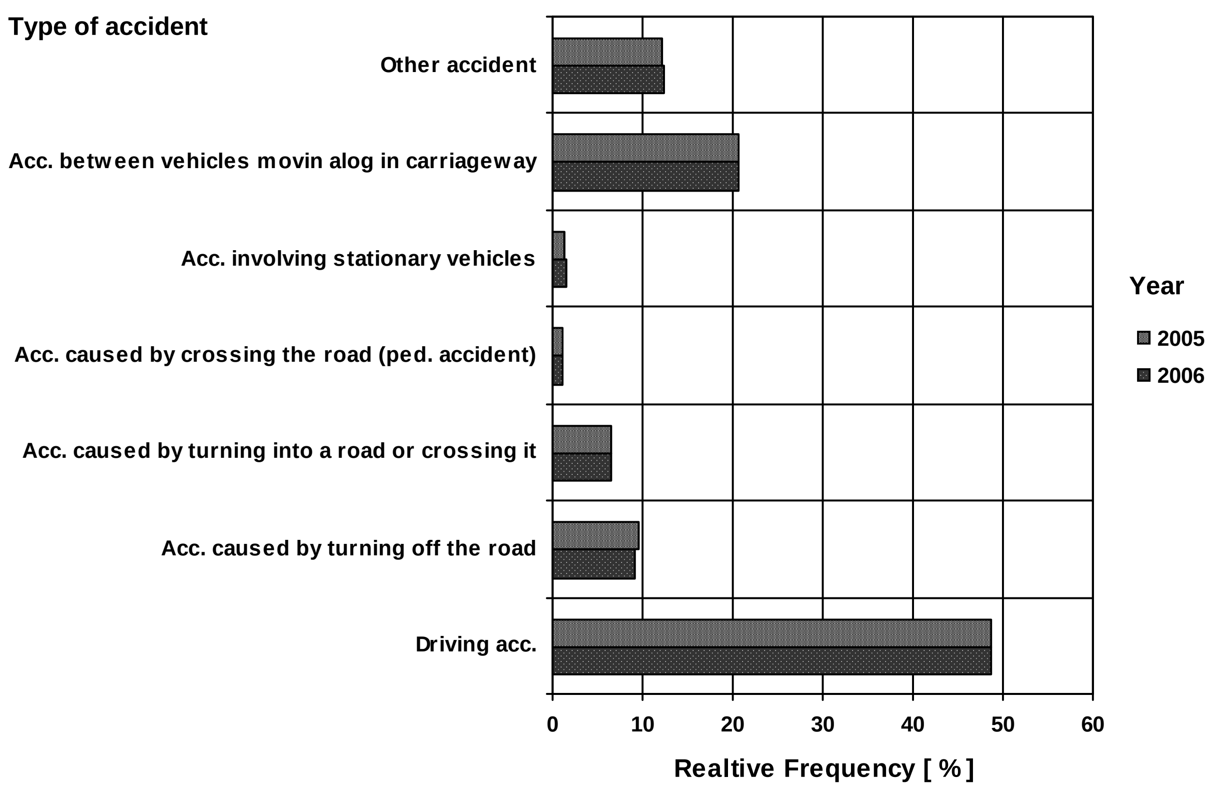


Figure 13: Relative frequency of the accident types in accidents involving personal injury and with drivers of motorcycles bearing an official registration number allocated as main responsible party for the years 2005 and 2006 in Germany (Source: StBA)

In the year 2006 in total 15,956 accidents with personal damage occurred with the rider of a motorcycle bearing an official registration number have been allocated as being the main responsible party of the accident. This is a share of 47.2 % of all 33,782 road users which have been involved in these accidents.

For 2005 the corresponding figure was 16,610 accidents involving personal damage and drivers of motorcycles allocated as the mainly responsible party (47.1% of all 35,242 road users involved in these accindets). As illustrated with Figure 13, the so called driving accident dominates these accidents.

The official definition is that “a driving accident is caused by the driver losing control of his vehicle without other road users having contributed to this. This could be due to unadapted speed or misjudgement of the course or condition of the road etc.. As a result of uncontrolled vehicle movements, however, a collision with other road users may have happen. A driving accident however does not include accidents in which the driver lost control of his vehicle due to a conflict with other road users, an animal or an obstacle on the carriageway, or because of sudden physical incapacity or a sudden defect of the vehicle. In the course of the driving accident, this vehicle may collide with other road users, so that this is not necessarily a single vehicle accident”.

With this background the dominance of the driving accident may again advise to a problem of unadapted speed for motorcycle riders killed in traffic accidents. When assessing this share it should also be kept in mind, that for motorcycle single accidents per definition for the official statistics always the motorcycle driver is the main responsible party. Accordingly a big share of single accidents is contained in the accidents of which the distribution of accident types are shown in Figure 13.

Second most frequent is the accident between vehicles moving along in carriageway. In the year 2006 with this type of accident 99 motorcycle drivers as the mainly responsible party have been killed. The corresponding figure for the year 2005 is 133. This is a share of 12.5% of all killed occupants of motorcycles bearing an official registration number in Germany for the year 2006, respectively a share of 15.2% for those killed in the year 2005. The accident between vehicle moving along in carriageway is described as an accident caused by a conflict between road users moving in the same or opposite direction, unless this conflict belongs to a different type of accident.

3.6 Opponents

Most of the riders and passengers of motorcycles bearing an official licence number killed in traffic accidents have been involved in crashes with a car as opponent, see Figure 14. In the year 2006 the corresponding absolute figure was 296 killed riders (37% of all 793 riders killed in this year). 96 of them had been fatally injured in urban-area accidents and 200 on rural roads. Second most frequent are killed riders in single accidents (264 respectively 33%). 57 were killed in accidents inside urban area and 207 outside urban area.

In single accidents and in accidents with two parties involved the sum of killed drivers and passengers of motorcycles bearing an official registration number in Germany for the year 2006 is 686. In accidents with more than two parties involved 107 riders (13.5% of the 793 riders killed in total) lost their lives.

The vast majority of accidents with two parties involved are crashes with only the motorcycle rider(s) and no opponent killed. In the year 2006 inside urban area in such crashes 119 motorcycle riders and 10 opponents (one car occupant and nine pedestrians) lost their lives. In corresponding accidents on rural roads 303 motorcycle riders and 26 opponents (two riders of Mofas, Moped or Mokicks, eight car occupants, one occupant in a commercial vehicle, six bicycle riders and nine pedestrians) have been killed. To understand this it has to be considered that the crash resulting into a fatality of a vehicle occupant is not always the first impact (with the motorcycle). It also may happen that after a (slight) first impact another severe impact with a rigid obstacle or a vehicle rollover follow. In this way it is possible, that even in an accident with a motorcycle and a heavy truck involved the occupant of the truck gets killed.

Altogether the analyses show that in accidents occurring inside urban area the greatest potential for a reduction of the figures of killed riders of motorcycles bearing an official registration number is evident for motorcycle/car crashes. Though the official statistics do not give any information on the speed of the vehicles involved, it can be assumed that the level of the travelling speeds as well as the level of the impact speeds is normally significantly lower in the accidents inside than outside urban area. With this background the relatively high share of single accidents with 57 killed riders on urban roads is remarkable.

For the accidents on rural roads the potential for reducing the absolute figures of killed riders on motorcycles bearing an official registration number is clear greater than for accidents inside urban area. Here again motorcycle/car crashes are on focus as well as motorcycle single accidents and on rank number three are accidents with motorcycles and commercial vehicles involved.

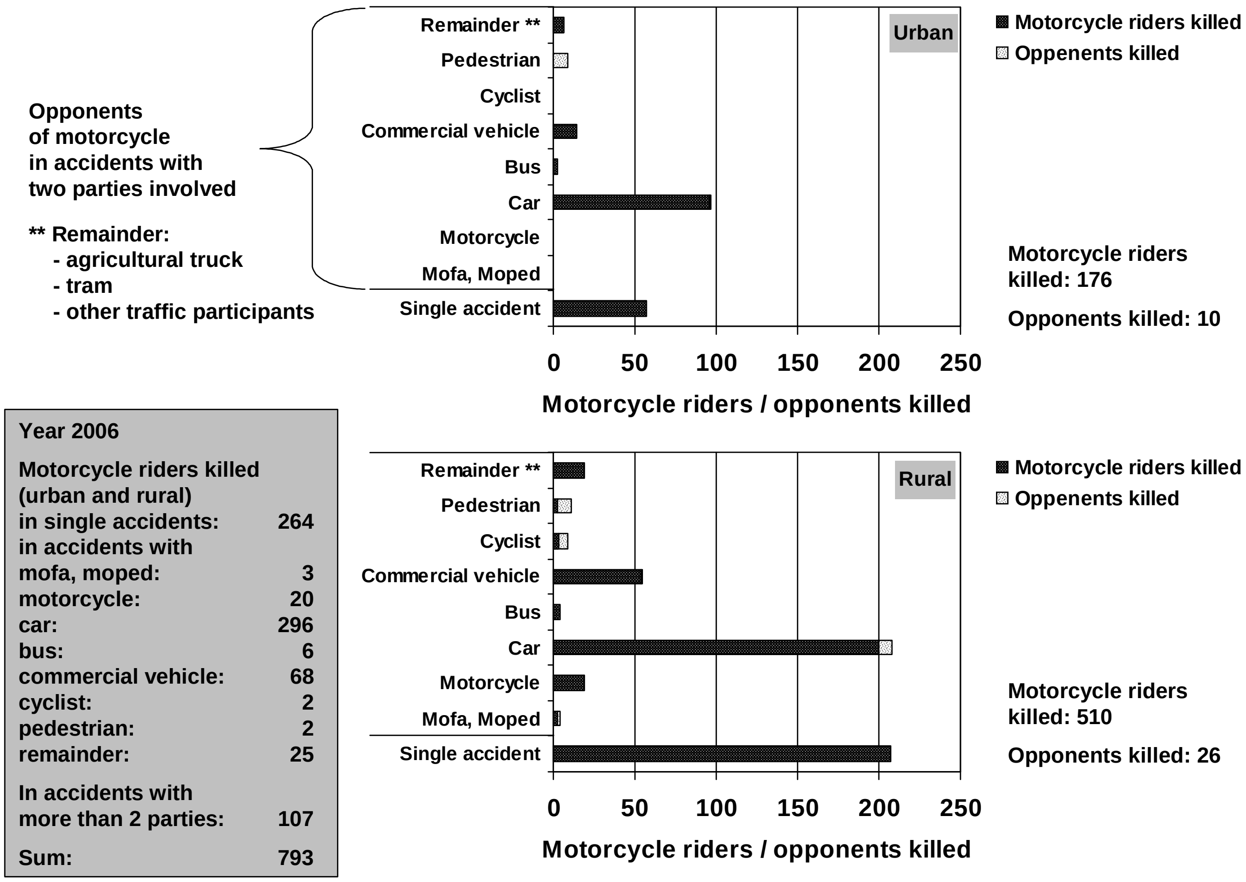


Figure 14: Killed drivers and passengers on motorcycles bearing an official registration number as well as opponents separated to motorcycle single accidents and motorcycle accidents with two parties involved in Germany for the year 2006 (Source: StBA)

All other accident scenarios, for example motorcycle accidents with pedestrians or with bicyclists involved are, from the statistically point of view, only very low significant. This is true for the killed motorcycle riders as well as for the killed opponents.

Special emphasis for the further research and development should be paid for improving the primary (active) safety of motorcycles to ovoid single accidents as well as for improving the secondary (passive) safety to reduce the consequences of crashes with cars (and at lower priority also to lower the consequences of crashes with commercial vehicles) [13]. When striving for improvements of the passive safety amongst others the protection clothing of the riders and, if applicable, protection measures at the motorcycle itself should be further analysed and developed. Measures to damp the forces of impacts of motorcycle riders against stationary obstacles, for example rigid posts of roadside barriers, should be considered, too [14, 15].

4 FINDINGS FROM IN-DEPTH-STUDIES

The official accident statistics for Germany do not comprise any information and parameters on the details of the collisions, for example impact speeds, impact locations at the vehicles involved or impact pulse directions with corresponding angles. Furthermore detailed information on the injured body parts and body regions of the accident victims corresponding to the international technical classifications which are in use for this are not covered by the official German statistics. Therefore, for more detailed descriptions and analyses of the occurrence and the outcomes of traffic accidents so called in-depth-analyses are running in the framework of research projects to permanently or temporarily collect information on real-world accidents to be stored in case collections and data banks. Hereunto the following descriptions give some insights that may be useful for a deeper understanding of the accident occurrence with motorcycles involved.

A problem of motorcycle accident research based on in-depth-studies are in general the relatively low case figures. Time and time again this becomes conspicuously with analyses of the great variations of the characteristics of motorcycle accidents. Variant are the degrees of freedom for the movement of the motorcycle and the rider(s) even before the first impact and as well during the follow-up movements and impact events. Manifold are the classes and types of motorcycles and scooters or the features and quality of the protection clothing of driver and passengers. Hence the results of in-depth analyses may often only be insufficiently statistically validated. But in particular combined with superordinated findings extracted from the official statistics, in-depth analyses can give precise insights into the real-world occurrence and important cognitions of potentials of possible measures for improvements of the safety and for lowering the risks of injuries of motorcycle riders.

4.1 Representative Scenarios

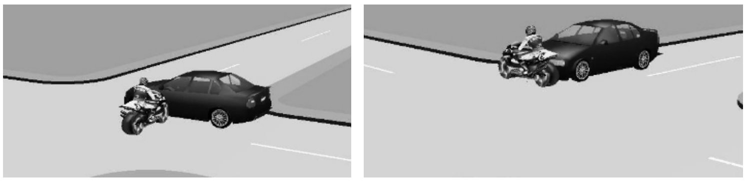
Latest findings regarding the most important accident scenarios of motorcycles come from the EU-funded research project TRACE (TRaffic Accident Causation in Europe, see http://www.trace-project.org). Amongst the objectives of TRACE is an update of knowledge about the accident causations. As a result of an analyses of descriptive accident databases in Germany, United Kingdom, France, Spain, Italy, Greece and the Czech Republic for motorcycles 4 representative accident scenarios were found for motorcycles, Figure 15.

It was found that the most important scenario is the motorcycle single accident on rural roads. With this accidents the motorcycle may run-off the carriageway, have a rollover on the carriageway or collisions with roadside restraint systems like steel barriers for example. The share of this configuration amongst the analysed fatal or serious motorcycle accidents is 27%. On rank number 2 with a share of 13% are front-side accidents in rural and urban junctions with a motorcycle and a car as the opponent. This is followed by a scenario with the motorcycle and a car impacting side by side in rural and urban non-junctions. This type of collision involves 5% of the fatal and serious motorcycle accidents analysed within the TRACE project. Another 5% share was found for scenarios with the motorcycle impacting the rear end of a car or a car impacting the rear end of a motorcycle both on rural and urban non-junctions. All in all these four scenarios cover 50% of the fatal or serious motorcycle accidents occurring on European roads in the years 2001 to 2004 and analysed within the TRACE project.

For these scenarios amongst the primary factors causing the accidents, as reported as first results of the TRACE project, are perception failures and decision failures of the motorcycle driver and/or car driver. As contributing factors for example for 16% of the single accidents (scenario 1) too fast/inadequate speed and/or unsafe acts of the motorcycle rider have been allocated. For scenario 2 a car-driver perception failure was assigned as a contributing factor for 70% of the accidents. This results have been generated by using in-depth case descriptions coming from the MAIDS database for the main motorcycle accident scenarios (see Figure 15) found in the previous European-wide statistical analysis. In General it was found that the main causes of the accidents are human failures. The most frequent human error was a failure perceiving the motorcycle by another vehicle driver (associated to the traffic environment, traffic-scanning error, lack of other vehicle driver attention, faulty traffic strategy or low conspicuity of the motorcycle driver).

1. Motorcycle single accident on a rural road: run-offs, rollover on the carriageway and collisions with road restrain systems: 27%

2. Front-side accidents in rural and urban junctions between motorcycles and passenger cars: 13%



3. Side-side accidents in rural and urban non-junctions between motorcycles and passenger cars: 5%

4. Rear-end accidents in rural and urban non-junctions between motorcycles and passenger cars: 5%

Figure 15: Representative accident scenarios for fatal and serious motorcycle accidents that are found as a result of the TRACE project

4.2 Impact constellations for accidents involving a car and a motorcycle

For the development of secondary (passive) safety measures to protect the motorcycle rider in accidents with a motorcycle and a car involved it is useful to know all corresponding impact configurations and their frequency in the real-world accident occurrence. Therefore in a first step of the accident analyses, cases have to be discriminated with the motorcycle and the rider driving upright at the begin of the first impact from other cases with the motorcycle already inclined or even fallen down to the road surface before the first impact with the opposing vehicle. In addition, for the cases with the motorcycle sliding with the side on the road surface, meaningful is a further classification depending on either motorcycle and rider(s) are moving still close together or are separated. Within the research project APROSYS the TNO-MAIDS database and the DEKRA motorcycle-accident database have been analysed in this way.

For all upright motorcycle impacts Figure 16 shows the distribution of the impact configurations coded using three digits as per ISO 13232 [13]. The first digit describes the impact location at the motorcycle, the second digit the impact location at the car and the third digit the heading angle between the longitudinal axes of the vehicles at the begin of the first impact.

Amongst the suitable motorcycle accidents in the DEKRA database (174 cases in total) configurations 115 and 114 are most frequent. Here the motorcycle impacts frontally onto the front of the car. With configuration 115 the angle between the longitudinal axis of the vehicles is near 180° (opposite-direction impact). In configuration 114 the motorcycle comes more inclined from ahead. It is remarkable that this scenario is not amongst the main motorcycle/car-accident scenarios found within the TRACE project.

In the DEKRA database the configuration 131 (a car impacts with its front the rear-end of a motorcycle, as part of the TRACE configuration 4) counts for 10 cases out of 174 according to a share of 5.7%. The configuration 711 with the motorcycle impacting frontally onto the rear-end of a car (the other part of TRACE configuration 4) counts for another 7 cases (4%) in the DEKRA database. So with a sum of 17 cases (9.8%) the TRACE configuration 4 could be treated as an important scenario also within the DEKRA database.

Corresponding to the TRACE scenario 2 are the impact constellations 413 with the motorcycle running perpendicularly into the side of the passenger compartment of the car and constellation 143 with the car hitting frontally the side of the motorcycle. Amongst the DEKRA cases constellation 413 counts for 6 cases and constellation 143 counts for 12 cases. The sum of 18 cases represents a share of 10.3% out of all 174 cases in the DEKRA data base which is somewhat smaller then the TRACE result (13%).

TRACE scenario 3 corresponds roughly to the impact scenarios 641 and 241 as coded corresponding to ISO 13232 whereas a total side by side collision (341, 441, 541) is not detected here. Constellation 641 with the motorcycle impacting sidewise the rear edge of a car counts for only 1 case and constellation 241 with the car impacting with its front edge the side of a motorcycle counts for 6 cases in the DEKRA database. So the sum of 7 cases represents a share of 4 % which is similar to the share of 5% for the scenario 3 as a result of the TRACE project.

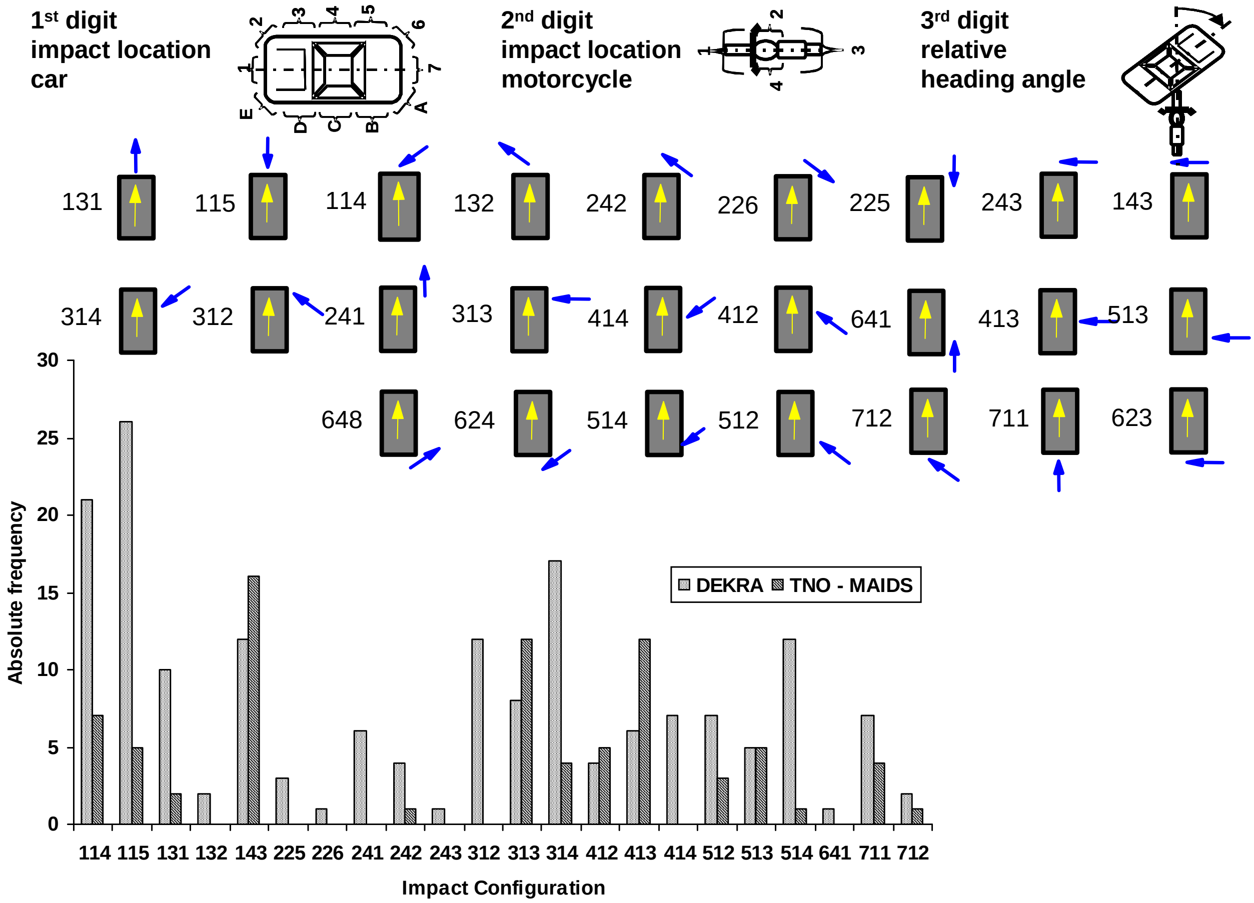


Figure 16: Definition von impact constellations in motorcycle/car collisions
as per ISO 13232 and corresponding distributions found in the motorcycle accident data bases
from TNO-MAIDS as well as from DEKRA

Most frequent in the TNO-MAIDS database is constellation 143. Here the car impacts perpendicularly onto the side of the motorcycle. Also relatively frequent in the TNO-MAIDS database are the constellations 313 and 413. In both constellations the motorcycle hits the side of the car perpendicularly. In constellation 313 the impact point at the car is located in front of the passenger compartment. For constellation 413 the motorcycle impacts directly into the compartment.

Constellation 413 is one of the most important impact constellations for the assessment of a motorcycle airbag [17]. In spite of wearing a protection helmet the face of the motorcycle driver may impact directly through the visor opening onto the stiff roof edge of the car. The consequences could be a severe or fatal head injury and fatal neck fractures.

Altogether Figure 16 illustrates the variety of real-world motorcycle impacts, which is in this juncture with the limitation to upright motorcycle impacts already reduced. Accordingly complex is the estimation of the benefit potential and the risk/benefit ratio for measures to improve the secondary (passive) safety of motorcycles, for example with a motorcycle airbag.

Regarding the severity of motorcycle-rider injuries, Figure 17 illustrates results coming from an analysis of GIDAS data within the research project SIM. The accidents happened on urban and rural roads in the GIDAS investigation areas inside and around the cities of Hanover and Dresden in the years 2002 and 2003. Corresponding to the case-collection criteria of GIDAS in the accidents at least one person was injured. In general the GIDAS database with approx. 2,000 accidents per year is in line with criteria for a database which is (if necessary combined with weighing factors) representative for all accidents in Germany (see www.gidas.org). Within the database used 56 accidents involving injured or killed riders of Mofas, Mopeds and Mokicks as well as 202 accidents involving injured or killed riders of motorcycles have been analysed.

The collision speeds of the Mofas, Mopeds and Mokicks were in the range of 0 to 55 km/h. For the motorcycles the collision speeds were 0 to 185 km/h.

Within GIDAS, the injuries for the individual body regions are coded as described with the Abbreviated Injury Scale AIS which is internationally accepted and in use. Herein MAIS stands for the MAximal Injury Severity of a person coded with the maximal AIS-value for a certain body region. AIS = 0 indicates uninjured, AIS = 1 minor injury, AIS = 2 moderate injury, AIS = 3 serious injury, AIS = 4 severe injury, AIS = 5 critical injury and AIS = 6 maximum injury, that means with the actual status of medicine not treatable. AIS = 6 often is also indicated as “unsurvivable”. But studies of the National Trauma Database in the USA have shown for example that for persons who sustained just one injury and this injury was coded by AIS = 6 there was a mean probability of survival by 21%. Relating to the probability of survival for the accident victims the figure of their (severe) injuries and their physical constitution as well as the possibilities for treatment in the certain hospital play also a role.

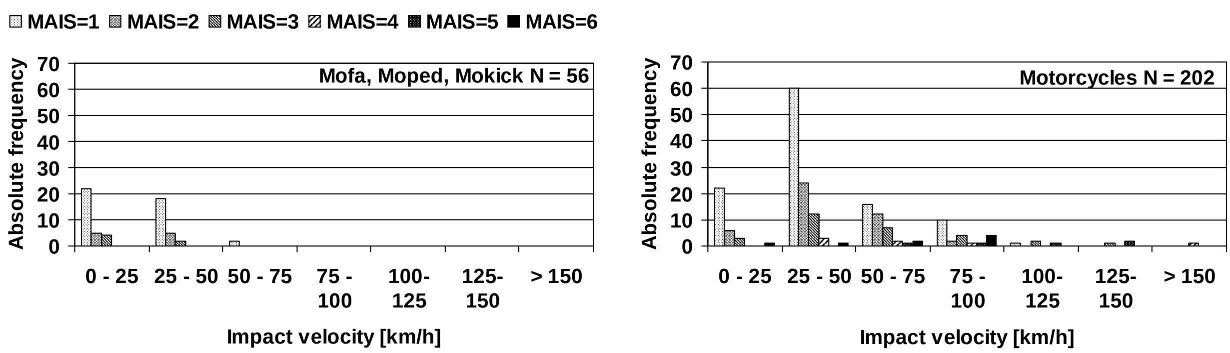


Figure 17: Injury severity of the occupants of Mofas, Mopeds und Mokicks as well as of motorcycles within different sub-groups for the impact velocities of the powered two-wheelers (Source: GIDAS, accident years 2002 and 2003)

For the riders of Mofas, Mopeds and Mokicks and for the riders of motorcycles in the classes of impact speeds of 0 up to 25 km/h and of more than 25 up to 50 km/h the minor injuries (MAIS = 1) are clearly most frequent. Amongst the cases studied, for the Mofas, Mopeds and Mokicks no rider injures have been found to be coded with AIS = 4+ (severe, critical or maximal injured). In contrast to this for the motorcycle riders in both of the low impact-velocity classes one person could be found who was maximal injured (MAIS = 6). This indicates, that not only the impact speed of a powered two-wheeler but also additional circumstances of the accident, for example the impact speed of the opponent, may influence significantly the injury severity of the powered-two-wheeler rider.

With greater impact velocities it can be seen for the riders of motorcycles that even in the sub groups of more than 50 km/h up to 75 km/h and of more than 75 km/h up to 100 km/h the minor injured (MAIS = 1) are most frequent. But accounting the smaller absolute figures of cases within these sub groups the relative shares of more severe injured motorcycle riders increases significantly.

In total amongst the 202 motorcycle riders only 8 persons have been injured by the degree MAIS = 6. The corresponding collision speeds of the motorcycle are 5 km/h, 30 km/h, 62 km/h, 67 km/h, 84 km/h, 2times 92 km/h and 95 km/h. This tends to a conformitation of the influence of higher speeds to the risk of a motorcycle rider of being killed in a traffic accident. But it is really a question whether on the basis of eight motorcycle riders suffering injuries classified with MAIS = 6 the accident occurrence of roughly 800 killed motorcycle riders could be described adequately.

In the year 2006 due to road accidents in Germany 10,590 occupants of motorcycles bearing an official registration number have been seriously injured and 793 have been killed (see clause 2.5). That indicates that 13 seriously injured counts for one killed motorcycle rider. So a representative sample of 200 seriously or killed Motorcycle riders would contain only 11 killed riders. This shows a basic dilemma for the statistical analyses of a sample of in-depth cases which is representative for the accident occurrence for the injured and killed motorcycle riders in a given region: Because only a relatively small number of cases can be sampled in a year using elaborate in-depth cases, to gather an appropriate figure of cases with killed accident victims it is necessary to combine several years. On the one hand this needs several years of time for the collection. On the other hand it could be that after completion of sampling the topicality of all cases in the whole sample is no longer up to date enough.

Insights into the accident occurrence of 289 motorcycles (> 125ccm) during the so called pre-crash phase as a result of further analyses of GIDAS data within the research project SIM are displayed with Figure 18. Thereby the powered two-wheeler did drive before the first collision far predominantly on a straight and dry road. In 185 cases (64 %) the driver of the motorized two-wheeler did brake.

Braking before the impact is one of the most important measures to reduce the severity of an accident in terms of reducing the kinetic energy of the motorcycle as much as possible for which the velocity counts squared. All the more this is essential for a motorcycle at higher speeds driven in the pre-crash phase. It is well known, that for a stable upright breaking of a motorcycle it is necessary that especially the front wheel is not locked. With a conventional brake system the motorcycle rider operates by hand the lever for the front-wheel brake and by foot the lever for the rear-wheel brake. In this way the brake forces are distributed independently to the wheels of a motorcycle. Therefore as a consequence of the dynamic alteration of the axle loading the highest brake force can be applied by the front wheel. To avoid a locking of the front wheel in order to avoid a downfall, many motorcycle riders do not capture the maximal possible brake force. As a consequence the deceleration respectively the reduction of the speed of a motorcycle in the pre-crash phase is not optimal. In this juncture an anti-lock brake (ABS) can help.

As also shown with Figure 18, amongst the 289 accident-involved powered two-wheelers only three (1%) have been equipped with ABS. This discloses an appropriate high potential for the improvement of the safety of motorized two-wheelers driving on our roads today.

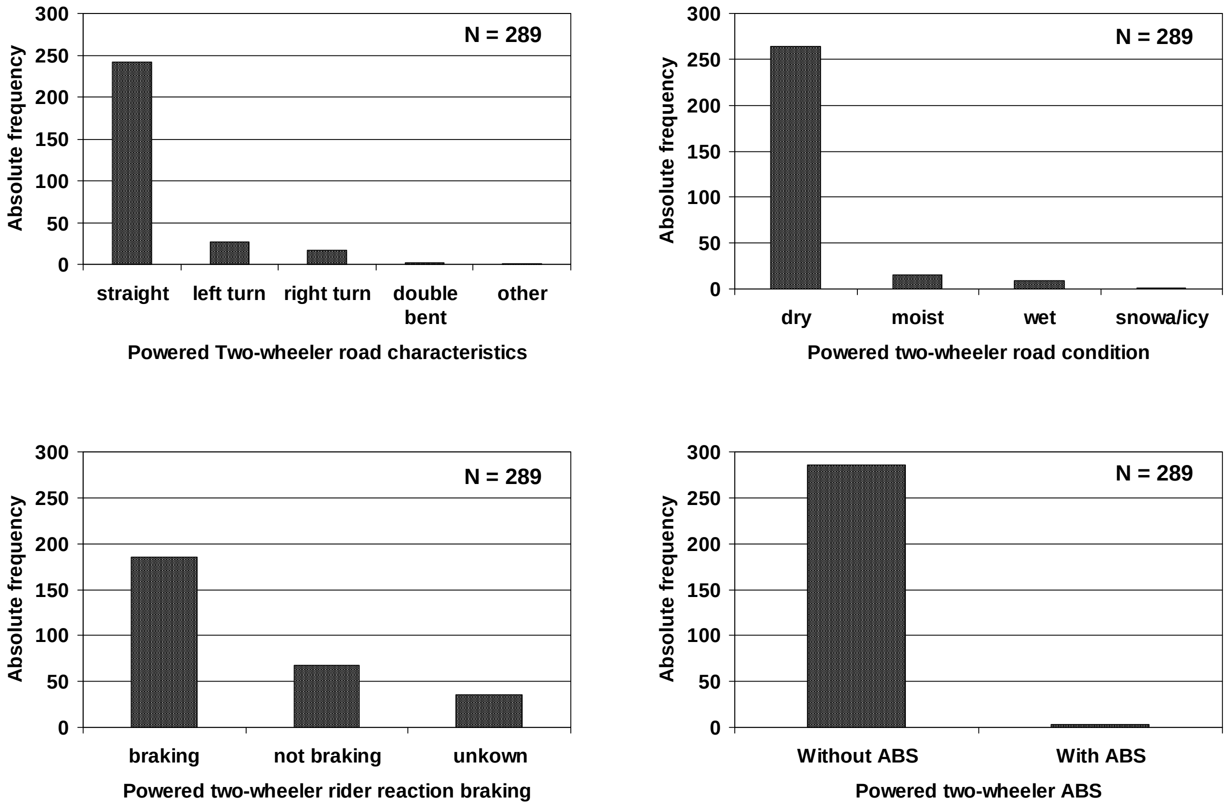


Figure 18: Results of the analyses of the pre-crash phases in 289 accidents involving motorcycles, (source: GIDAS, accident years 2002 and 2003)

5 SUMMARY OF RESULTS AND OUTLOOK

Despite enormous progress in safety that can also be assessed for the accident occurrence of motorcycles during decades now, there is still a big need for further improvements. Recently in Germany, for the occupants of a motorcycle bearing an official registration number the risk of being killed in a traffic accident based on the figure of corresponding vehicles in the fleet is more than three-times as high as for car occupants and the occupants of Mofas, Mopeds or Mokicks. Based on the mileage this risk is even twelve times higher than the appropriate risk for car occupants and 2.6 times higher than for the occupants of Mofas, Mopeds and Mokicks.

Whereas in Germany since the 1970ies the absolute figures of killed roads users did predominantly decrease significantly and sustainably, this was not always true for the motorcycle riders. Here, during the last years the absolute figures of killed road-accident victims remained more or less constant, whereas indeed the absolute figures of motorcycles registered in the fleet increased considerably. Within the smaller absolute figures of road-traffic accident victims of recent years the relative share of killed riders of motorcycles bearing an official registration number increased. In the year 2006 this share was 16% (out of 5,091 killed road users in total) and increased again to 17% (out of 4,958 killed road users) according to the preliminary figures for the year 2007. According to this, the strategic and operational importance of motorcycle accidents for further long-term reductions of the figure of killed road users in Germany is rising.

The emphasis of the occurrence of serious motorcycle accidents is placed on the streets outside urban area. Here – compared to accidents on urban roads – in general an increased potential of danger is evident for motorcycle riders due to higher speeds driven by the motorcycles as well by other traffic participants. Despite the protection clothing which is normally worn by the drivers of motorcycles bearing an official registration number, the motorcycle riders are amongst the unprotected vulnerable road users with an associated injury risk.

In serious accidents with motorcycles involved the vast majority of killed road users are the motorcycle riders itself. Herein the most important role play the motorcycle single accidents and the crashes with a motorcycle and a car involved.

As a result of the In-depth-analyses using GIDAS most of the motorcycle accidents occur on straight and dry roads.

Amongst the evolutions which are remarkable for the last year is the considerable enlargement of the share of elderly motorcycle riders. This is in line with the modified usage of a motorcycle as a vehicle in leisure times for an outstanding and fascinating feeling of motorized mobility. Herewith the accident occurrence of motorcycles depends also from the weather conditions. In particular nice weather with an increasing participation of motorcycles in the road traffic is recently one of the often mentioned causes for an increase of serious motorcycle accidents. Vice versa for a reduction of the frequency of killed motorcycle riders seasonally foul weather is often stated as a main reason.

It remains a very actual challenge for accident research to collect information and to describe the accident occurrence of motorcycle accidents for appropriate analyses and assessments. As shown with examples in the article this can be done with insightful results by using the Federal Statistics in combination with in-depth-studies. Despite of the brad variability of the motorcycle accident occurrence clear key aspects can be detected with promising courses of action.

In addition to measures for improving the secondary (passive) safety, for example a motorcycle airbag, especially measures for improving the primary (active) safety for example the ABS for motorcycles show a great potential for future enhancements of the safety of motorcycles. A precondition is, that such state-of-the-art safety systems are available not only for expensive luxury motorcycles.

Above all, the individual who is driving a motorcycle must be on focus. For him or for her the particular risks of driving a motorcycle have always and ever to be aware.

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In-Depth Human Functional Failure Analysis of Fatal Pedestrian Accidents in Bavaria

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Abstract
In the course of the EUROPEAN PROJECT TRACE all fatally injured pedestrians autopsied at the Institute for Legal Medicine in Munich in 2004 had been analysed by using the "Human Functional Failure (HFF) analysis" method [1]
It was possible to apply this method although some restrictions have to be taken into account. The results derived from this analysis comprise first the failures the pedestrians (most often "impairment of sensorimotor and cognitive abilities") and the opponents (most often " Non-detection in visibility constraints conditions") faced in the accident, second the conflicts and tasks (pedestrian crossing the street conflicting with a vehicle from the side (which was going ahead on a straight road), the degree of accident involvement (pedestrians often the primary active part), and further the contributing factors to the accident (pedestrians most often "alcohol (> 0.05% BAC)", opponents most often "visibility constraints").

NOTATION

n total amount/absolute frequency
n.e. not evaluable
HFF Human Functional Failure - P: Perception - T: Translation - D: Diagnosis - E: Effect - G: General

INTRODUCTION

Pedestrian fatalities have a share of about 17% of all traffic fatalities in the EU countries [2]. The interest in reducing the injury severity in case of an accident with these so-called vulnerable road users already also reached car manufacturers by introducing the EURONCAP ratings towards pedestrian protection. However, to prevent these kinds of accidents in the first the discussion ranges from improvement in pedestrians conspicuity [3] to educational measures, to constructional separation of different modes of traffic and accordant types of road users, and sometimes to calls for further curb parking restrictions and speed limit restrictions within city limits.
The analysis of fatal pedestrian accidents is often limited towards the documentation of facts and objective circumstances which provide of course valuable information about sites of accidents and characteristics of the involved parties in these accidents. But, a detection of the help the participants could have needed for avoiding the accident (all involved parties) is only possible by applying more sophisticated types of in-depth analysis methods.
The Human Functional Failure analysis method as developed and presented by van Elslande in 2007 [1] aims at detecting the failures and the contributing factors for these failures for each participant involved in the accident. During the "rupture phase" occurring during the stabilized driving phase of participating in road traffic ("where things start to go wrong") a failure in the information processing and aligned operations can occur on the stages detection (Perception–P), diagnosis/prognosis (Translation-T), decision (D) and action (Effect-E). By analysing these stages different needs to give the traffic participant a helping hand in avoiding the accident can be revealed. This method refrains from blaming someone as being a responsible causer for the accident but regards the Human in the context in its environmental interactions.
In Germany 838 pedestrians have been fatally injured in road traffic accidents in 2004. On behalf of the public prosecutions of Munich, Augsburg, Passau, Traunstein, Rosenheim, Memmingen, Landshut and Ingolstadt 51 pedestrians being killed in accidents were autopsied at the Institute for Legal Medicine in Munich. In the frame of Workpackage 1 (Types of Road Users, task 1.4 pedestrians and cyclists) of the EU-Project TRACE these cases served as basis for the application of the Human Functional Failure analysis [1,4] on fatal pedestrian accidents to derive new insights to accidents with vulnerable road users and to give answer to two questions. First: "is the method applicable to fatal pedestrian accidents?", and second: "can new insights be gained by this method concerning the prevention of fatal pedestrian accidents?".

MATERIAL AND METHODS

Study sample

For 48 fatally injured pedestrians (involved in 45 accidents) autopsied at the Institute for legal medicine at the LMU in 2004 the prosecution files were evaluated. Access to the files was granted for the EU-Project TRACE. The information available ranges from police reports, technical expertises, eye witness accounts to detailed medical, toxicological, and biomechanical expertises.
Out of the fatal accident cases in 2004 three files were not available; another three cases were excluded because of suicide of the pedestrian (one case) and accidents causing death of a pedestrian without any involvement of a vehicle driver (death of a worker of a construction site due to a rolling tag and one pedestrian being killed by a ripping tow rope).
One accident involved two fatally injured pedestrians, another one showed three fatalities.
The 48 pedestrians consist of 26 male persons and 22 females. 50% of the pedestrians killed in road traffic accidents belong to the age group of older than 60 years and 10% were children up until the age of 15; one child of 4 years, 4 children in the age group between 11 to 15
Nearly 87% of the opponent drivers involved in fatal pedestrian accidents are male. Only 6 of 45 drivers are female. The highest share with more than one third is represented by the age group between 30 and 40, being comparable to the normal driver population.
The opponents involved in the fatal pedestrian accidents are car, truck and van drivers in 40 cases (29 passenger cars). Another three opponents were trams, one motorcycle and one agricultural vehicle each.
The accidents happened within city limits in about 55%. In around 46% there had been daylight conditions, followed by darkness with streetlights in 31%. The majority of accidents took place between 12p.m. and 6p.m. in about 35%, followed by the first half of the night from 6 p.m. until 12 a.m. in 26%.
For further analysis 45 pedestrians and 45 opponents were taken into account. Accidents holding more than one killed pedestrian were screened if there had been different accident mechanisms or functional failures for the fatalities. But, as failures, tasks, conflicts, contributing factors, movement and mechanism of accident were homogenous for the fatalities relating to one case it was decided to select only one pedestrian being representative for all involved pedestrians per case.

HFF analysis

The method was developed on the basis of road traffic accidents where psychologists are able to interview the involved parties. In addition the method focuses not primarily on pedestrian accidents. Applying the method to fatal pedestrian accidents therefore had to be tested first. Two cases were prepared for validation, provided to experts of the institute having developed this method and feasibility could be attested.
Two investigators evaluated the files independently, afterwards comparing their results. In case of different concepts the original files were re-examined and one possible solution discussed. If no agreement could be gained a third person also trained in the method was consulted. Finally always one analysis result was decided upon and implemented in the database. In cases where no analysis was possible for single variables due to missing information giving too much space for individual interpretation it was either decided to take the most probable option, or to leave this variable as "n.e." (not evaluable). This (n.e.) might also be coded for seldom situations when evaluation scheme was not applicable.
Analysed variables comprise the Human Functional Failures, conflicts, tasks, degree of involvement and contributing factors as explained and presented in the Annex. For the evaluation of tasks a new category "crossing the street" was established which fits for almost half of the accidents (19 of 45). Included in this new category are all kinds of crossing the street by a pedestrian, including crossing either at a pedestrian crossing (with or without a traffic light) or not. An accumulation of a fixed combination of a Failure, task, conflict, degree of involvement and contributing factors is called a prototypical scenario.

Results of HFF analysis are presented for both, the pedestrians and the opponents, separately by frequency analysis and cross tabulations. Only for the most frequently occurring HFF the distribution of contributing factors is performed. Due to limited case number it is not to be expected to derive prototypical scenarios for fatal pedestrian accidents, but typical scenarios becoming apparent are presented as possible prototypical scenarios.

RESULTS

Pedestrians

HFF analysis

14 out of 45 pedestrians performed overall failures (G-failures) especially a G2-failure meaning an impairment of sensorimotor and cognitive abilities. Within this group the vast majority was detected to have had a high blood alcohol level while participating in traffic. 9 pedestrians underwent failures at the information detection stage (P-failures); by splitting up into HFF sub-groups the highest share is found for the P5-failure (neglecting the need to search for information, n=12). The failures D2 (deliberate violation of a safety rule) and T5 (expecting another user not to perform a manoeuvre) each contributed with 6 cases.
In 7 cases it was not possible to detect or define any failure, either due to unsatisfactory information (no witness of the accident, more than one failure possible) or encoding problems (rupture phase for the pedestrian unidentifiable). E.g. pedestrians were drawn into accident situation even if they did not take part in "usual" road traffic and thus caught by surprise (e.g. walking on pavement, standing at road banquet).
To get an overview over the most frequently occurring failures applying to pedestrians killed in traffic accidents the HFF groups' distribution is presented in Table1.

HFF group	explanation	n	HFF sub group	explanation	n
P	Failures at the information detection stage (PERCEPTION)	**9**	**P2**	Information acquisition focused on a partial component of the situation	**3**
			P5	Neglecting the need to search for information	**6**
T	Failures at the diagnostic stage (information processing stage 1) and on the prognostic stage (information processing stage 2) (TRANSLATION)	**8**	**T2**	Erroneous evaluation of the size of a gap	**1**
			T5	Expecting another user not to perform a manoeuvre	**6**
			T6	Actively expecting another user to take regulating action	**1**
D	Failures at the stage of deciding on the execution of a specific manoeuvre (DECISION)	**6**	**D2**	Deliberate violation of a safety rule	**6**
E	Failures at the psychomotor stage of taking action (EFFECT)	**1**	**E2**	Guidance problem	**1**
G	**Overall failure (GENERAL)**	**14**	**G1**	Loss of psycho-physiological capacities	**2**
			G2	**Alteration of sensorimotor and cognitive capacities**	**12**
n.e.	Not evaluable	**7**	**n.e.**	not evaluable	**7**
sum					**45**

Table 1: HFF groups and sub-groups, distribution for fatalities (pedestrians)

Task analysis

Most people tried to cross the street when the accident happened. However, 15 accidents could not be set into the evaluation scheme. "not evaluable" (n.e.) was applied to all pedestrians whose tasks are unknown to the investigators or performed a task not intended by the scheme (e.g. crossing tram

tracks, being stationary on a road like kneeling, laying on the ground, waiting in the middle of a road,…).
By cross tabulating HFF to tasks (see Table 2) it can be seen that the most frequently occurring combination is the general (G-) failure while crossing the street (n=6), and in all 6 cases it is a G2-failure (alteration of sensorimotor and cognitive capacities). It is followed by diagnostic and prognostic (T-) failures in combination with crossing the street (n=5) of which 4 apply to the T5 failure (expecting another user not to perform a manoeuvre). Another 4 pedestrian fatalities took place when sensorimotor and cognitive impaired pedestrians were walking along a straight road.

	HFF group						
Task	**P**	**T**	**D**	**E**	**G**	**n.e.**	**total**
Going ahead on a straight road	1	1	1	1	4		8
Going straight at "traffic signal" intersection					1		1
Going ahead on a left bend			1				1
Approaching pedestrian crossing	1						1
Crossing the street	**3**	**5**	**3**		**6**	**2**	**19**
n.e.	4	2	1		3	5	15
total	9	8	6	1	14	7	45

Table 2: HFF and task, distribution for fatalities (pedestrians)

Conflicts analysis

Conflicts can be described as the interaction with the opponent that the road user could be faced with during the pre-accident situation. An overwhelming majority had a conflict with a vehicle from the side. 11 out of 45 pedestrian fatalities conflicted with a following vehicle. For one pedestrian no conflict could be found as direction of crash impulse/walking direction are unknown.
By linking Human Functional Failures to conflicts (see Table 3) data show that most pedestrians performing an overall failure (G-failure) had a conflict with a vehicle from the side (n=10), especially due to impairment of sensorimotor and cognitive abilities (G2) (n=9). Nevertheless, 8 pedestrians with failures at the information detection stage, especially P5-failures (neglecting the need to search for information (n= 5), and 7 cases with failures at the diagnostic and prognostic stage especially T5-failures (not expecting by default manoeuvre by another user, n= 6) also crashed with vehicles from side.

	HFF groups						
Conflict	**P**	**T**	**D**	**E**	**G**	**n.e.**	**total**
Oncoming vehicle					1		1
Vehicle from side	**8**	**7**	**3**		**10**	**4**	**32**
Following vehicle	1	1	3	1	3	2	11
n.e.						1	1
total	9	8	6	1	14	7	45

Table 3: HFF and conflict, distribution for fatalities (pedestrians)

Degree of involvement

Most pedestrians were mainly seen to be "primary active" (n= 30) meaning these pedestrians initiated the situation in which the accident took place (see Table 4). 12 out of 45 pedestrians committed an overall-failure (G-failure) and were "primary active" according to evaluation scheme. 11 of these were meant to be impaired in their cognitive and sensorimotor abilities (G2-failure).

	HFF groups						
Degree of invovement	**P**	**T**	**D**	**E**	**G**	**n.e.**	**total**
Non-active			1			1	2
Passive					2	4	6
Primary active	**6**	**5**	**4**	**1**	**12**	**2**	**30**
Secondary active	3	3	1				7
total	9	8	6	1	14	7	45

Table 4: HFF and degree of involvement, distribution for fatalities (pedestrians)

Most frequent HFF subgroup in pedestrian fatalities

Most often G2-failures (impairment of sensorimotor and cognitive abilities) were seen in the pedestrians (n=12). Most often, these people tried to cross the street (n= 6) or were just walking along a road (n=4). Nine were confronted witch a vehicle from side and in three cases, a following vehicle was involved. The degree of involvement mainly was "primary active" (n=11) and one pedestrian was strictly “passive”.
Overall 21 contributing factors were applicable to the 12 pedestrians with G2-failures. In seven cases it was possible to assign one contributing factor, in two cases two, in two cases three and in one case four contributing factors. Most often they are found within the state of user, and the psycho-physiological condition, respectively. Eight pedestrian fatalities showed that alcohol had been taken "above legal limit". In these cases it was assumed that although a "legal" limit does not exist for pedestrians that these pedestrians were none the less impaired in acting properly. In two cases a "medical condition" of the pedestrian was found. For two cases "correctly used medication" or an "internal conditioning of performed task leading to identification of potential risk about only part of the situation" follow as third most frequently applied contributing factor. Other contributing factors were single events (see Table 5).

Contributing factors	Absolute frequency
Medical condition	2
Substances taken – alcohol above "legal" limit	8
Substances taken – alcohol below "legal" limit	1
Substances taken – illegal drugs	1
Substances taken – correctly used medication	2
Identification of potential risk about only part of the situation	2
Little/None experience - driving	1
Distraction within user – lost in thought	1
Risk taking – traffic control (signs/signals/markings disobeyed etc.)	1
Risk taking – "eccentric" motives (competing)	1
Visibility impaired – other vehicles	1

Table 5: G2-failures and contributing factors

Prototypical scenarios for pedestrians

On the basis of previously performed HFF analysis failures, task, conflicts, contributing factors and degree of involvement were sorted into groups in order to deduce scenarios being representative for a certain group of road users. Due to low case numbers only first hints for typical scenarios can be derived.
For pedestrians most often (six times) the combination was: G2-failure (impairment of sensorimotor and cognitive abilities), "crossing the street" (task), "vehicle from side" (conflict), "primary active" and as contributing factor in 5 out of 6 cases "substances taken – alcohol above "legal" limit.
Second most often two different combinations, each one tree times, occurred. G2-failure, "going ahead on a straight road" (task), "following vehicle" (conflict), "primary active" and in 2 out of 3 cases "medical condition" in contrary to T5-failure (not expecting - by default - manoeuvre by another user), "crossing the street" (task), "vehicle from side" (conflict), "primary active" with contributing factors "identification of potential risk about only part of the situation" and "risk taking – traffic control".

Opponents

HFF Analysis

Most frequently P-failures at the information detection stage are found (n=20). The highest share holds the P1 failure (Non-detection in visibility constraints conditions, n=9). Second most often (8 cases) the diagnostic and prognostic stage accounts for the failure (T-failure), and especially the T7 failure (Expecting no perturbation ahead, n=5). In 7 cases a D-failure (decision) is found, of which 6 are due to the "Deliberate violation of a safety rule" (D2-failure). In one case of a tram driver no failure could be assigned.

HFF group	Explanation	n		HFF sub groups – HFF groups	total
P	Failures at the information detection stage (PERCEPTION)	20	**P1**	Non-detection in visibility constraints conditions	9
			P2	Information acquisition focused on a partial component of the situation	4
			P3	Cursory or hurried information acquisition	1
			P4	Momentary interruption in information acquisition activity	1
			P5	Neglecting the need to search for information	5
T	Failures at the diagnostic stage (information processing stage 1) and on the prognostic stage (information processing stage 2) (TRANSLATION)	8	**T5**	Expecting another user not to perform a manoeuvre	2
			T6	Actively expecting another user to take regulating action	1
			T7	Expecting no perturbation ahead	5
D	Failures at the stage of deciding on the execution of a specific manoeuvre (DECISION)	7	**D1**	Violation directed by the characteristics of the situation	1
			D2	Deliberate violation of a safety rule	6
E	Failures at the psychomotor stage of taking action (EFFECT)	5	**E1**	Poor control of an external disruption	4
			E2	Guidance problem	1
G	Overall failure (GENERAL)	4	**G1**	Loss of psycho-physiological capacities	2
			G2	Alteration of sensorimotor and cognitive capacities	2
n.e.	Not evaluable	1	**n.e.**	Not evaluable	1
Total		45			45

Table 7: HFF sub-groups for opponents

Task analysis

"Going ahead on a straight road" is the most frequent task (n=22) and showing up in 10 cases in combination with a P-failure. It is followed by reversing (n=4) and "Turning across traffic out of private drive" and "Going straight at "traffic signal" intersection" each three times (Table 8).

	HFF group						
Task	**P**	**T**	**D**	**E**	**G**	**n.e.**	**total**
Going ahead on a straight road	**10**	**5**	**3**	**2**	**2**		**22**
Going ahead on a left bend					1		1
Going ahead on a right bend	1			1			2
Approaching intersection where road user has right of way		1					1
Going straight at "traffic signal" intersection	1		1		1		3
Turning across traffic at "traffic signal" intersection	1						1
Starting (not at junction)	1	1					2
Turning away from traffic from main road into private drive	1						1
Turning across traffic out of private drive	3						3
Reversing	2		2				4
Driving in wrong direction				1			1
Approaching pedestrian crossing				1			1
Approaching railway crossing		1					1
n.e.			1			1	2
total	20	8	7	5	4	1	45

Table 8: HFF and tasks, distribution for opponents

No task could be found applicable to the tram drivers in general. The 3 tram drivers in the opponents sample were going ahead on tracks and this option is not defined in evaluation schema. One tram driver was nevertheless able to be put into the evaluation scheme as he was approaching a railway crossing. Thus only two tasks remain encoded n.e.

Most of the drivers who were “going ahead on a straight road” underwent a P1-failure (n=6) or a T7-failure (Expecting no perturbation ahead, n=4).

Conflicts analysis

Considering conflicts (Table 9) drivers had to cope with while going ahead, one can find an overwhelming majority of the situation that a “pedestrian is crossing over the street” (n= 30 out of 45). Further seven drivers had to face a “pedestrian walking along the street”.

Among those whose conflict was a “pedestrian crossing over” P-failures are dominant above D- and T-failures (14 vs. 7 and 6 out of 30). In detail, especially P1-failures (non-detection in visibility constraints conditions, n=5) and D2-failures (deliberate violation of a safety rule, n=6) could be detected.

No conflicts could be defined for those who encountered a problem not listed in given schema e.g. pedestrian sleeping on road (can't be defined as "stationary obstacle"), fallen asleep while driving, medical problem, diverting from road due to high alcohol intoxication, losing control of the car.

	HFF groups						
Conflict	**P**	**T**	**D**	**E**	**G**	**n.e.**	**total**
None					2		2
Stationary vehicle ahead		1		1			2
Pedestrian crossing over	14	6	7	2		1	30
Pedestrian walking along road	4	1		1	1		7
n.e.	2			1	1		4
total	20	8	7	5	4	1	45

Table 9: HFF and conflict, distribution for opponents

Degree of involvement

Most opponents are "secondary active" (n=22), followed by "primary active" in 13 cases. Considering the combination of failures and degree of involvement 10 drivers dealing with P-failures (and especially P1 failures, n=9) were meant to be "secondary active" in taking action, another 6 were non active and another 6 drivers with T failures were also secondary active (Table 10).

	HFF groups						
Degree of involvement	**P**	**T**	**D**	**E**	**G**	**n.e.**	**total**
n.e.					1		1
Non-active	6	1	1			1	9
Primary active	4	1	2	3	3		13
Secondary active	10	6	4	2			22
total	20	8	7	5	4	1	45

Table 10: HFF and degree of involvement, distribution for opponents

Most frequent HFF subgroup in opponent analysis

Most frequently occurring failure in analysing opponents is the P1-failure (non-detection in visibility constraints condition, n=9), followed by D2-failure (deliberate violation of a safety rule, n=6), P5-failure (neglecting the need to search for information, n=5) and T7-failure (expecting no perturbation ahead, n=5), respectively.
Opponents committing P1-failure comprise eight car drivers and one truck driver.
Within P1-failure, most opponents were going ahead on a straight road (n=6) while being confronted with a pedestrian on road. Conflicts aroused when pedestrians tried to cross the street (n=5) or walked along road, not on pavement (n=2). In five times the opponent has to be regarded as "non-active" and four times as "secondary active".

24 contributing factors were applicable to those 9 opponents undergoing a P1-failure. In three cases four contributing factors were applicable, in two cases each one, two or three contributing factors. It has to be noted that particularly visibility impairment factors occur at large. Most often, opponents had to deal with a situation in which visibility was impaired, e.g. due to night, other vehicles or vehicle lighting (see Table 11). Risk taking speed also influenced accident development and progress.

Contributing factors	total
Visibility impaired: Night	**6**
Visibility impaired: Other vehicle(s)	**4**
Visibility impaired: Vehicle lighting	**3**
Visibility impaired: Weather	**3**
Risk taking: Speed	**2**
Identification of potential risk about only part of the situation	1
Risk taking: Traffic control	1
Road width	1
Visibility impaired: Road lighting	1
Maintenance: Windscreen/Glass	1
Maintenance: Exterior lights	1
	24

Table 11: P1-failure and contributing factors, distribution for opponents

Prototypical scenarios for opponents

For opponents three scenarios occur most often of which each holds three cases. First the combination of P1-failure (Failure to detect in visibility constraints), "going ahead on a straight road" (task), pedestrian crossing over" (conflict), "visibility impaired – other vehicle(s)" (contributing factor) and in two out of three cases "secondary active" (Degree of involvement).

Second: D2-failure (deliberate violation of a safety rule), "going ahead on a straight road"(task), "pedestrian crossing over" (conflict), "risk taking – speed" (contributing factor), "secondary active" (Degree of involvement) and in two out of three cases "visibility impaired – night"(contributing factor).
Third: P2-failure (Focalised acquisition of information), "turning across traffic out of private drive"(task) and "pedestrian crossing over" (conflict). In two out of three cases the opponents were regarded as "secondary active" (Degree of involvement). As contributing factors each two times "design – visibility" (contributing factor) and "distraction outside vehicle – searching for information/road construction/other perceived danger" (contributing factor) could be found.

DISCUSSION

By applying the method introduced by van Elslande in 2007 [1] for the in-depth analysis in the EU-Project TRACE to the fatalities database for pedestrians at LMU a kind of feasibility study was successfully performed on the one hand. On the other hand some reasonable insights could be gained.

The pedestrians killed in road traffic accidents were nearly evenly distributed for sex, and the majority was more than 60 years old. The pedestrians most often underwent G2-failures, meaning they were impaired in their sensorimotor and cognitive abilities. The task they performed was "crossing the street" when the conflict with a vehicle from the side occurred. In most cases the pedestrians had to be regarded as "primary active". The most frequently found contributing factor for this failure*task*conflict combination was alcohol above the legal limit (as would have been applied to drivers with a value of 0.05% BAC).
A study conducted in France in the early 90ies [5] proposes four different groups of pedestrians being involved in fatal accidents. Elderly traffic participants crossing the road and the problem of alcohol are found in this sample comparably. That alcohol and pedestrians is a risky combination not only for fatal accidents in some of the European countries is known for the UK and Germany [6].
Pedestrians' factors most often were found within the state of user and the psycho-physiological condition. It has to be noted that for opponents particularly visibility impairment factors occur at large
For the opponents as being the drivers involved in the fatal pedestrian accident the distribution of sex is shifted towards males, and show an age distribution comparable to the driver population in general. For the drivers most often a P1-failure (Non-detection in visibility constraints conditions) could be detected. The task they were performing was going ahead on a straight road most frequently when conflicting with a pedestrian crossing the street. In most cases the drivers have to be regarded as "secondary active" as the pedestrian initiated the situation, although in police records most often the opponent is seen as the "causer" of the accident. The contributing factors found for the drivers comprise visibility constraints like night, other vehicles, weather, and vehicle lighting.
Whereas Langham [7] cannot show clear evidence for improving pedestrian visibility for preventing accidents in a review because of the included studies methodological differences, still conspicuity and visibility are regarded as main factors for pedestrian and bicycle accidents. "Visibility aids have the potential to increase visibility and enable drivers to detect pedestrians and cyclists earlier. Public acceptability of these strategies would merit further development. However, the effect of visibility aids on pedestrian and cyclist safety remains unknown. Studies which collect data on simple, meaningful outcomes are required." is the authors' conclusion of an updated review from 2006 [3]. In this sample it can be found that the drivers were faced with visibility constraints when crashing with the pedestrian. The conspicuity of the pedestrian doesn't show up as a contributing factor. In addition often the drivers neglected the need to search for information in the first (not expecting any pedestrian to be around or crossing the street because of site, time or weather conditions).

A first set of three prototypical scenarios for fatal pedestrian accidents are possible to propose for the pedestrians' point of view:
Fatal pedestrian scenario No 1 (Ped: Pedestrian): a pedestrian impaired in sensorimotor and cognitive abilities due to alcohol crosses the street, initiates as primary active participant the conflict situation and is hit by a vehicle from the side.

Fatal pedestrian scenario No 2 (Ped): a pedestrian impaired in sensorimotor and cognitive abilities due to medical conditions was going ahead on a straight road and initiates as primary active participant the conflict situation with a following vehicle.
Fatal pedestrian scenario No 3 (Ped): a pedestrian wants to cross the street and before doing so identifies a potential risk of crossing the street only on a part of the whole situation or shows risk taking behaviour regarding traffic control and due to the failure of not expecting a manoeuvre of the vehicle crosses the street and is hit by the vehicle from the side.
The translation of the scenarios to prevention suggestions is difficult for overall failures. People showing impairment in sensorimotor and cognitive abilities constantly should not take part in traffic by themselves at all. However, overall failures in these abilities can occur suddenly (medical condition) or e.g. after consumption of alcohol and/or falling asleep. People commonly able to take part in traffic as pedestrians face situations when the overall failure occurs and as a consequence are fatally injured in an accident. For the first two scenarios for pedestrians the human role has a main influence, therefore only education, information (take a taxi – don't walk when drunk", use apt lane when no sidewalk present (on-coming traffic side), and wear visible clothing) can be recommended. Also for the third pedestrian scenario the knowledge and behaviour when crossing the street which should have been trained in pre-school age would have helped to avoid the accidents (no risk taking but crossing only on facilities, not crossing on red). As all scenarios show crossing the street as planned task, thus especially the suggestions of separating pedestrians and other traffic by infrastructural and environmental modifications to prevent pedestrian fatalities like done by Retting [8] might apply here as well.

A first set of three prototypical scenarios for fatal pedestrian accidents are possible to propose for the opponents' point of view:
Fatal pedestrian scenario No 1 (Opp: Opponent): A driver is going ahead on a straight road when due to impaired visibility because of other vehicles the driver fails to detect the pedestrian crossing the street.
Fatal pedestrian scenario No 2 (Opp): A driver going ahead on a straight road deliberately decides to violate against safety rules with risk taking behaviour of speeding (at night) when the pedestrian crosses the street.
Fatal pedestrian scenario No 3 (Opp): A driver turns against traffic out of a private drive and fails to detect the pedestrian crossing the street because of focalised acquisition of information due to distraction outside the vehicle or the vehicle design restricting visibility.
The first scenario can be prevented by reduced curb parking density. In addition vehicle systems with better perception sensors compared to humans for detecting earlier also hidden objects could give the missing but necessary information to the driver about pedestrians and other possible obstacles. The second scenario can be overcome by more education, information, law enforcement, and mandatory intelligent speed adaption systems as active safety systems in vehicles, to reduce speeding. In addition as the second scenario occurred mainly at night also night vision would have helped to detect the pedestrian earlier and enable an active speed reduction in time. The third scenario is also based on a detection failure therefore vehicle systems providing information to the driver of the pedestrian being in the way would have helped here as well.
If all suggested prevention measures were not able to avoid the accident in the first then only further structural improvements of the vehicle front (bonnet functions, bumper and front design) might help to at least reduce the injury severity of the pedestrian.
Still, the primary prevention attempts by active and passive safety measures of cars might have helped to avoid a majority of the analysed accidents. According to Molinero [9] the suggested systems range from driver visual aids such as night vision, to autonomous emergency braking systems. Further, some of the more traditional vehicle systems such as brake assist and traction control can also work to reduce braking distances or prevent vehicles from leaving road surfaces, both of which could aid the prevention of an impact with pedestrians.

Limitations:
All fatal pedestrian accidents of which the prosecution files were available for evaluation at LMU Institute for Legal Medicine, within the catchment area in 2004 have been analysed in-depth.

Autopsies might be requested primarily for unclear situations raising legal interest The sample might be biased towards fatal pedestrian accidents where death happened on site and where information about the accident circumstances are lacking on a first view so that the police orders a legal investigation. The advantage of this selection can be seen in the fact that focus is laid on traffic accidents where tertiary prevention might not influence the outcome. Death might have occurred to the pedestrians independent of time and mode of first aid, transport, intensive medical treatment and factors like age and co-morbidities. Despite this estimated selection bias the urban accidents which are assumed to happen at lower velocities with a higher chance for surviving at least up to 30 days are over-represented. However, the results are comparable to published facts concerning pedestrian accidents. Opponents and age distribution is comparable to a German study on pedestrian accidents [10]. The pedestrians are primarily of older age and by taking the total number of fatalities in traffic for females into account, the higher risk for females is also found in the CARE- database for the EU [2]. The number for Germany is also given with 47% of pedestrian fatalities being in the age group of 65+ [9].

The method was not developed for fatal accidents, as no interview can be performed with a fatally injured traffic accident victim. Thus, a lack of information in the files used has to be accepted for this study. Especially for the Human Functional Failures and the contributing factors the lack of information is striking. For the HFF of the opponents most often also eye-witness reports had to be taken into account in addition to their own statements towards the police and the prosecution. As from the pedestrian no information can be expected, the opponents might be tempted to lying or refrain from statements at all, in order not to be convicted. Especially confessing to having been in thoughts, being in a hurry, or being sleepy might be easily avoided, as no objective proof afterwards is possible. In contrast the speed driven or alcohol limit can still be assessed afterwards by expertises.

The evaluation scheme is primarily focusing on vehicle accidents and their drivers. Tasks and conflicts sometimes lack possibilities for coding apt items. In addition three times trams had been involved, where tasks are also not meant to be applied to. In general the method allows defining new items for each variable. A suggestion for new categories within the tasks would e.g. comprise: - "walking on pavement", - "standing beside the traffic lane (banquette)", - "pedestrian crossing at a pedestrian crossing with pedestrian lights".

The case number of 45 is too low to give general statements on prototypical scenarios consisting of typical failure*task*conflict*involvement*contributing factors combinations. But, first hints for typical scenarios out of a multitude of single events were possible to detect. More analysis of this type would be necessary to show if the most often occurring scenarios in this sample will hold the highest shares also in larger samples. This is necessary for giving useful advice concerning efficient countermeasures.

Although psychological interviews on site would be preferable this study shows that the method can nevertheless add new insights also to fatal pedestrian accidents.

CONCLUSION

Applying the human functional failure analysis method as developed by van Elslande [1,11] on fatal pedestrian accidents was successfully performed on the database of fatal pedestrian accidents in 2004 of the Institute of Legal Medicine, Munich. Some emerging prototypical scenarios were possible to derive for pedestrians and opponents. The combination of drunken pedestrians and reduced visibility conditions for opponent drivers shows up as a typical deadly mixture. Corresponding countermeasures for prevention can be suggested comprising educational, infrastructural, and vehicle measures.

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Appendix: all annexes derived from vanElslande, 2007 [1] and 2008 [11] and Naing, 2007 [4]

Annex 1: Human Functional Failures

Failure type	HFF-label	HFF- sub-type
Perception	Perception - P	P1 Failure to detect in visibility constraints
		P2 Focalised acquisition of information
		P3 Cursory information acquisition
		P4 Interruption in information acquisition
		P5 Neglecting information acquisition demands
Diagnosis	Translation - T	T1 Incorrect evaluation of a road difficulty
		T2 Incorrect evaluation of a gap
		T3 Incorrect understanding of how site functions
		T4 Incorrect understanding of manoeuvre undertaken by another user
Prognosis		T5 Not expecting (by default) manoeuvre by another user
		T6 Expecting adjustment by another user
		T7 Expecting no perturbation ahead
Decision	Decision - D	D1 Directed violation
		D2 Deliberate violation
		D3 Violation-error
Action	Effect - E	E1 Poor control of a difficulty
		E2 Guidance problem
Overall	General - G	G1 Loss of psycho-physiological ability
		G2 Impairment of sensorimotor and cognitive abilities
		G3 Exceeding cognitive abilities

Annex 2: Tasks

Level 1	Level 2
A. Stabilised Situation	
Going ahead	Going ahead on a straight road
	Going ahead on a left bend
	Going ahead on a right bend
B Intersection	
On approach	Approaching a 'give way' intersection
	Approaching a 'stop' intersection
	Approaching a 'traffic signal' intersection
	Approaching intersection where road user has right of way
Stopped	Stopped at a 'give way' intersection
	Stopped at a 'stop' intersection
	Stopped at a 'traffic signal' intersection
	Stopped in road/ turning lane waiting to turn
Going ahead	Going straight on at a 'give-way' intersection
	Going straight on at a 'stop' intersection
	Going straight on at a 'traffic signal' intersection
	Crossing intersection where road user has right of way
	Travelling on roundabout (not turning on/off)
	Travelling on slip-road (not turning on/off)
Turning	Turning across traffic at a 'give-way' intersection
	Turning across traffic at a 'stop' intersection
	Turning across traffic at a 'traffic signal' intersection
	Turning across traffic from main road into side road
	Turning away from traffic at a 'give-way' intersection
	Turning away from traffic at a 'stop' intersection
	Turning away from traffic at a 'traffic signal' intersection
	Turning away from traffic from main road into side road
C. Manoeuvre	
Overtaking	Overtaking stationary vehicle on left
	Overtaking stationary vehicle on right
	Overtaking moving vehicle on left
	Overtaking moving vehicle on right
Changing lane	Moved into lane on left (NOT overtaking)
	Moved into lane on right (NOT overtaking)
Slowing	Stopping (not at junction)
	Parking (roadside)
Starting	Starting (not at junction)
	Leaving parking space (roadside)
Turning (not at intersection)	Turning across traffic from main road into private drive
	Turning away from traffic from main road into private drive
	Turning across traffic out of private drive
	Turning away from traffic out of private drive
Reversing	Reversing
U-turn	U-turn
In wrong direction	Driving in wrong direction (e.g. down a one-way road)
D. Other	
Parked	Parked
Stopped in traffic queue	Stopped in traffic queue
Pedestrian crossing	Approaching pedestrian crossing
	Stopped at pedestrian crossing
Railway crossing	Approaching railway crossing
	Stopped at railway crossing

Annex 3: Conflicts

Level 1	Level 2
None	None
Oncoming vehicle(s)	Oncoming vehicle(s) in correct lane
	Oncoming vehicle(s) in wrong lane
Vehicle ahead (moving in same direction or stationary)	Moving vehicle(s) ahead
	Stationary vehicle(s) ahead (congestion or accident)
	Stationary vehicle(s) ahead (parked)
	Car door open on stationary vehicle
Following vehicle(s)	Following vehicle(s)
Vehicle from side	Vehicle(s) from side road/path
	Vehicle in lateral lane travelling in same direction
Obstacle(s) ahead (non-vehicle)	Moving obstacle(s) ahead
	Stationary obstacle(s) ahead
Pedestrian in road ahead	Pedestrian crossing over
	Pedestrian walking along road
	Pedestrian playing/ running on road

Annex 4: Grid of factors which could lead to Human Functional Failures

Descriptive (user related factors)			
		Generic	**In-depth examples**
A. User State	1. Physical/ Physiological	Medical condition	Heart condition/Epilepsy/Other brain condition/Respiratory condition/Blood condition/Other condition
		Pre-existing impairment	Hearing/Visual/Physical disability/Other impairment
	2. Psycho-physiological condition	Substances taken - alcohol	Above 'legal' limit/Below 'legal' limit
		Substances taken - drugs	Illegal drugs/Correctly used medication/Misused medication
		Emotional	Upset/Angry/Anxious/Happy/Other emotion
		Fatigue	Physical/Mental
		In a hurry	In a hurry
	3. Internal conditioning of performed task	Right of way status	Rigid attachment to the right of way status
		Excessive confidence	Excessive confidence in signs given to others
		Identification of potential risk	Identification of potential risk about only part of the situation
B. Experience	1. Little/None	Driving	Learner/New driver/Infrequent driver/Other
		Route	New route/Road type/New road/Road feature/Driving on the left/Driving on the right/Other
		Vehicle	New vehicle/ Transmission type/ Left hand drive vehicle/ Right hand drive vehicle/ Other vehicle feature
		Environment	Night driving/City driving/Country driving/Driving in snow/Driving in fog/Driving in wet or flood/Driving in ice/Other
	2. Over-Experienced	Driving	Change in driving rules/Other
		Route	Route in general/Road type/New road/Road feature/Other
		Vehicle	New vehicle/ Transmission type/Other vehicle feature
		Environment	Night driving/City driving/Country driving/Driving in snow/Driving in fog/Driving in wet or flood/Driving in ice/other
C. Behaviour	1. Conflicting (Distraction)	Distraction outside vehicle*	Police/Animal in road/ Sunlight or sunset/ People in roadway/ Crash scene/Other perceived danger/Road construction/ Searching for directional information/ Unspecified outside distraction
		Distraction within vehicle*	Adjusting radio/ Adjusting cassette/ Adjusting CD/ Other occupant/ Moving object in vehicle/Using or viewing device integral to vehicle/ Using other device brought into vehicle/Adjusting climate controls/Eating/Drinking/Cell phone/Smoking/Looking inside vehicle/Reaching for object/Unspecified inside distraction
		Distraction within user*	Lost in thought/Medical problem
	2. Risk taking	Speed	Illegal/Legal but inappropriate/Erratic/Other
		Vehicle positioning	In front/Lateral/Other
		Traffic control	Signs disobeyed/Signals disobeyed /Markings disobeyed/Other
		'Eccentric' motives	Testing a vehicle/Thrill-seeking/Competing/'Stunt'/Unspecified eccentric motives

Descriptive (environment related factors)		
	Generic	**In-depth Examples**
A. Road Condition	Contaminants: Wet/Flood/Snow	Wet/Flood/Snow
	Contaminants: Ice/Frost	Ice/Frost
	Contaminants: Oil/Diesel	Oil/Diesel
	Contaminants: Sand/Gravel/Mud	Sand/Gravel/Mud
	Surface defects	Potholes/Cracks/Bumps
	Surface type	Asphalt/Concrete/Untreated/Cobbles /Brick/Other
B. Road Geometry	Bend(s)	Left/Right/Wide/Tight/Multiple bends
	Slope(s)	Decline/Incline/Multiple slopes
	Road width	Wide/Narrow/Single lane/Multiple lanes/Change in width
	Adverse camber	Left/Right
	Traffic calming	Road hump/Speed table/Throttle/Chicane
	Temporary road layout	Roadworks/Other
	Misleading/complex road layout	Misleading/Complex
	Speed-inciting layout	Bend in road/Straight road/Gradient/Wide road/Continuity effect
C. Traffic Condition	Flow	Smooth/Erratic
	Speed	High/Low/Stationary
	Density	Low/High
	Other road user(s) : Absence of clues to manoeuvre	Absence of clues to manoeuvre
	Other road user(s) : Ambiguity of clues to manoeuvre	Ambiguity of clues to manoeuvre
	Other road user(s) : Atypical manoeuvres	Atypical manoeuvres
	Being drawn into manoeuvre	Passenger/Vehicle ahead/Vehicle behind/Pedestrian/Cyclist
D. Visibility Impaired	Road lighting	Type/Colour/Intensity/No lighting
	Vehicle lighting	Type/Colour/Beam type/No lighting
	Day/night	Daylight/Darkness/Dusk/Dawn
	Sun glare	Direct from sun/Reflection from wet road
	Weather	Rain/Fog or mist/Snow/Hail
	Smoke	Vehicle/Nearby fire/Other
	Terrain profile	Bend/Slope/Side slope(s)/Other
	Other vehicle(s)	High vehicle/Wide vehicle/Parked vehicle/Vehicle stopped in traffic/Other
	Roadside objects	Overhanging tree(s)/ Overhanging shrubbery/Sign(s)/Bridge structures/Barrier(s)/Wall(s)/Boundary fence(s)/Other
E. Traffic Guidance	Traffic signs/signals - Insufficient	Signs present but insuffincient/Signals present but insufficient/Signs absent/Signals absent/Other
	Traffic signs/signals – Maintenance	Signs damaged/Signals damaged/Signs poorly maintained/Signals poorly maintained/Signs positioned incorrectly/Signals positioned incorrectly/Other
	Traffic signs/signals – Unexpected	Signs replaced/Signals replaced/Signs new/Signals new/Other
	Traffic signs/signals – Inappropriate	Signs inappropriate/Signals inappropriate/Signs confusing/Signals confusing /Other
	Road markings (visual/tactile) - Insufficient	Visual markings present but insufficient/Tactile markings present but insufficient/Visual markings absent/Tactile markings absent
	Road markings (visual/tactile) - Maintenance	Visual markings damaged/ Tactile markings damaged/ Visual markings poorly maintained/ Tactile markings poorly maintained/ Visual markings positioned incorrectly/ Tactile markings positioned incorrectly/Other
	Road markings (visual/tactile) – Unexpected	Visual markings replaced/ Tactile markings replaced/ Visual markings new/ Tactile markings new/Other
	Road markings (visual/tactile) - Inappropriate	Visual markings inappropriate/ Tactile markings inappropriate/ Visual markings confusing/ Tactile markings confusing /Other
F. Other Environmental Factors	Earlier collision	Vehicle(s)/Debris/Other
	Pedestrian in road	Adult/Child/Other
	Fire in road/roadside	Car in Road/Car in Roadside/Other in Road/Other in roadside
	Level crossing	Controlled/Uncontrolled
	Animal in road	Dog/Cat/Horse/Cow(s)/Pig(s)/Sheep/ Deer/Rabbit/Badger(s)/Fox(es)/Bird(s)/ Reptile(s)/Other animal(s)
	Other obstacle(s) in road	Vehicle part/Dead animal/Discarded vehicle load/Other
	Road works	Major/Minor/Other
	High wind	Gale force/Storm Force/Hurricane force/Other

Descriptive (vehicle related factors)		
	Generic	**In-depth Examples**
A. Electro-Mechanical	Steering	Partial failure/Total failure
	Brakes	Partial failure/Total failure
	Engine	Partial failure/Total failure
	Suspension	Partial failure/Total failure
	Electrical/electronics	Partial failure/Total failure
B. Maintenance	Windscreen/Glass	Front chipped/ Front cracked/ Front misted/ Front dirty/ Front scratched/ Rear chipped/ Rear cracked/ Rear misted/ Rear dirty/ Rear scratched/ Side chipped/ Side cracked/ Side misted/ Side dirty/ Side scratched/ Other
	Tyre(s)	Incorrect type/Air pressure/ Tread/ Blow-out/Other
	Exterior lights	Headlight type/Headlight bulb needs replacing/Headlight cracked/Headlight broken cover/ Rear light type/ Rear light bulb needs replacing/ Rear light cracked/ Rear light broken cover/ Brake light type/ Brake light bulb needs replacing/ Brake light cracked/ Brake light broken cover/ Indicator type/ Indicator bulb needs replacing/ Indicator cracked/ Indicator broken cover/ Fog light type/ Fog light bulb needs replacing/ Fog light cracked/ Fog light broken cover/Other
	Interior lights	Fuel light/Oil light/Water light/Parking brake light/Other dashboard light/Other interior lighting
C. Design	Visibility	A-pillar(s)/B-pillar(s)/C-pillar(s)/Steering wheel blocking view/Rear view mirror/Wing mirror(s)/Seating/Other
	Auditory	Auditory warnings confusing
	Displays	Colour/Size/Confusing information/Other
	Controls	Colour/Size/Confusing information/Reach/Other
D. Load	Heavy	On vehicle/Within vehicle/Other
	Uneven	On vehicle/Within vehicle/Other
	Visibility obstructed	On vehicle/Within vehicle/Other

Annex 5: Degree of involvement

This variable defines the role played by the pedestrian/opponent in the genesis of the accident. Close to the notion of 'responsibility', it differs from this latter by the reference not to a legal code but by the recourse to a strictly behavioural reference ('code').

- Primary active

This modality designates the pedestrian/opponent who "provoke the disturbance". They have a determining functional involvement in the genesis of the accident: they are directly at the origin of the destabilization of the situation.

- Secondary active

These pedestrians/opponents are not at the origin of the disturbance which precipitates the conflict, but they are however part of the genesis of the accident by not trying to resolve this conflict.

- Non-active

These pedestrians/opponents are confronted with an atypical manoeuvre of others that is hardly predictable, whether it is or not in contradiction with the legislation.

- Passive

These pedestrians/opponents are not involved in the destabilization of the situation but they are nevertheless an integral part of the system. Their only role consists in being present and they cannot be considered as an engaging part in the disturbance.

Comparison of injury severity between AIS 2005 and AIS 1990 in a large injury database

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Abstract - The aim of this study is to investigate the differences in car occupant injury severity recorded in AIS 2005 compared to AIS 1990 and to outline the likely effects on future data analysis findings. Occupant injury data in the UK Co-operative Crash Injury Study Database (CCIS) were coded for the period February 2006 to November 2007 using both AIS 1990 and AIS 2005.

Data for 1,994 occupants with over 6000 coded injuries were reviewed at the AIS and MAIS level of severities and body regions to determine changes between the two coding methodologies.

Overall there was an apparent general trend for fewer injuries to be coded at the AIS 4+ severity and more injuries to be coded at the AIS 2 severity. When these injury trends were reviewed in more detail it was found that the body regions which contributed the most to these changes in severity were the head, thorax and extremities.

This is one of the first studies to examine the implications for large databases when changing to an updated method for coding injuries.

INTRODUCTION

The UK's Co-operative Crash Injury Study (CCIS) is one of Europe's largest car occupant injury causation studies (www.ukccis.org). The programme of research started in 1983 and is now in its eighth phase. In the study multi-disciplinary teams examine crashed vehicles and correlate vehicle damage with the injuries sustained to determine how car occupants are injured. The main objective of the study is to improve vehicle safety performance by continuing to develop a scientific knowledge base, which can be used to identify the future priorities for vehicle safety design as technology develops. The study carefully selects a sample of accidents which are representative of the UK.

Since the inception of CCIS all injuries sustained in the accidents have been coded to allow for their use in data analysis. The injuries are coded and always have been according to the Abbreviated Injury Scale (AAAM). The Abbreviated Injury Scale (AIS) dictionary itself has been used for thirty years since the first edition was introduced in 1976 [1], although it was originally published in 1971. The AIS is an ordinal scale which is used to rank the severity of injuries from 1 to 6, (Minor through to Currently Untreatable). It describes injuries anatomically and judges the threat to life based on each single injury occurring in a healthy adult. The AIS has continued to evolve with each dictionary publication; the original dictionary consisted of a list of 500 injuries which were then expanded upon in 1980 and 1985 providing users with better injury descriptors [2]. By 1990 the dictionary had undergone a major overhaul to include 1,331 injury descriptors with more refined choices to address child injuries [3]. This version of the dictionary also included guidelines for coders to promote uniformity in injury coding across the globe. Although there was an update in 1998 of the dictionary this did not introduce major changes [4]. The recent introduction of the AIS 2005 dictionary has expanded the contents to 2,104 injury descriptors [5]. This has resulted in an expanded list of injuries in an attempt to incorporate all trauma. This new data dictionary reflects injuries that occur in different circumstances (e.g. road crashes, explosions etc). The new scale is reflective of advances in medical interventions and is designed to be compatible with other injury scaling systems.

For any database a change at any level has to be reviewed particularly where the change can have a direct impact on the results from old and new data. The aim of this study is to review the changes between the 'old' AIS 1990 and the 'new' AIS 2005 data dictionaries on a large dataset to determine what likely effects a new coding methodology has on injury severity for future data analysis.

METHODS

In-depth crash injury data from the UK Co-operative Crash Injury Study (CCIS) were used to explore the study objectives. CCIS selects cases for investigation using a stratified sampling procedure based on car occupants' injury severity, with a weighting and hence a bias towards fatal and seriously injured casualties. Cases were selected from the CCIS database from February 2006 to November 2007. All injuries were coded to AIS 1990 [3] and AIS 2005 [5] from medical notes or post mortem reports where appropriate. Trained coders were used to code all injuries. Detailed injury information was available for each occupant in the study including the AIS, maximum AIS (MAIS) by body region and Injury Severity Score (ISS).

This double coding has been labour intensive and illustrated the complexity of the AIS 2005 coding system. For example in AIS 1990 there is one code for a fractured clavicle but in AIS 2005 this injury has 18 coding options depending on the type and position of the fracture.

The data were analysed to review the changes between the two coding methodologies (AIS 1990 and AIS 2005) for the overall AIS and MAIS severity and body region AIS and MAIS severity. The percentage differences in the injuries for each coding methodology were used to highlight the changes in AIS severity between AIS 1990 and AIS 2005. This analysis examines all occupants who were involved in a road traffic crash during the study period. Not all occupants were injured and not all injuries were known.

The assessment of multiple injuries is an important area to consider when analysing crash data as it is likely that two or more injuries occur as opposed to single isolated injuries. The methods used for assessing occupants with multiple injuries are the MAIS and ISS. The MAIS will be considered here where the overall MAIS represents the injured occupants' highest AIS score for the whole body and the body region MAIS represents the highest AIS score in each specified body region.

RESULTS

A total of 1,994 occupants were included in the CCIS database for the time period covered and a maximum number of actual coded injuries was 6,373 (AIS 1990) and 6,410 (AIS 2005). There were 1,426 car occupants with a recorded injury in both AIS 1990 and AIS 2005. Thus 329 car occupants were uninjured (AIS 0) and 239 car occupants were recorded to have unknown injuries or injuries that could not be assigned a severity code (AIS 9). Figures 1 and 2 show the distribution of the number of injuries in each AIS severity and includes the AIS 0 (no injury) and AIS 9 (unknown injuries) for both coding methodologies and the direction of general trend for those differences.

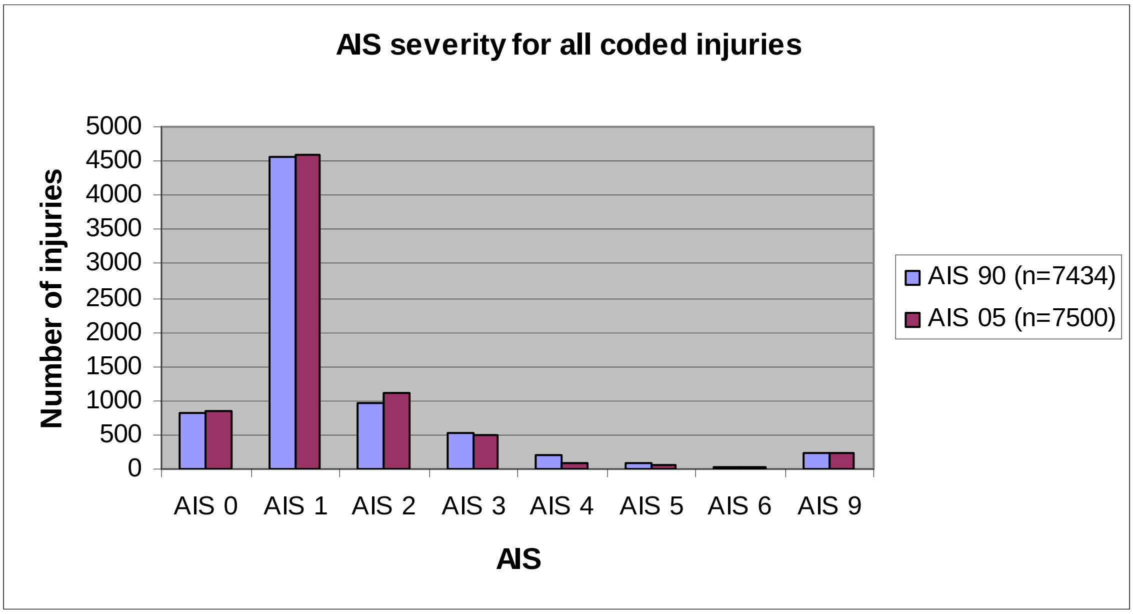

Figure 1: AIS severity for all injuries sustained by car occupants

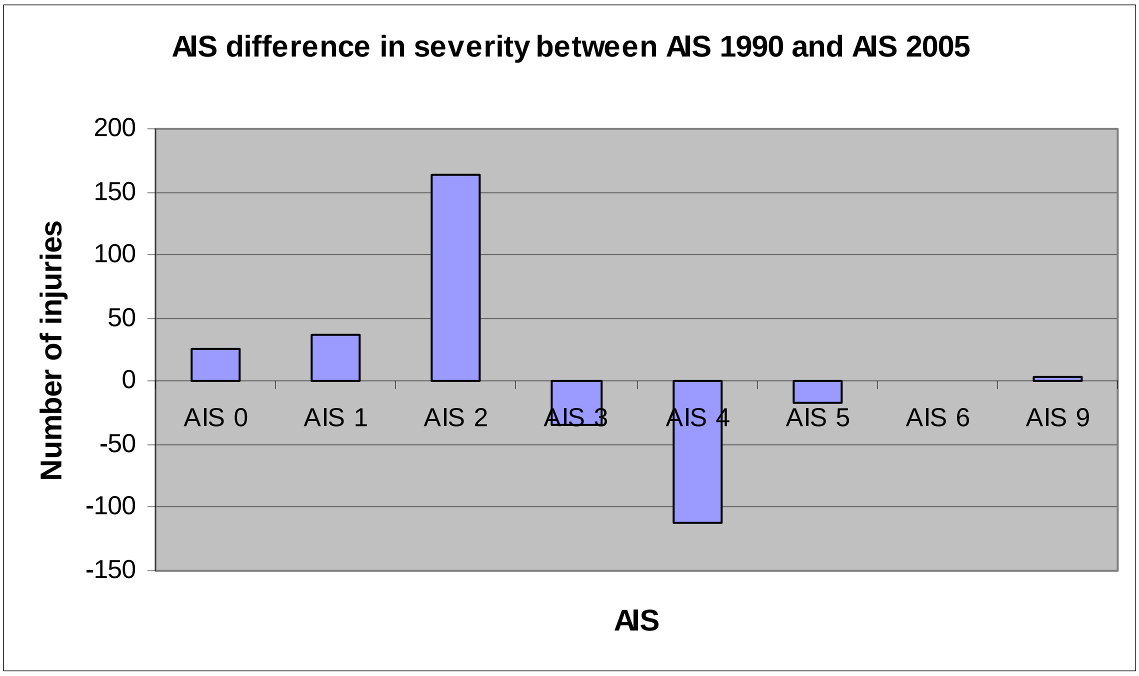

Figure 2: Distribution of changes in severity in AIS 2005 from AIS 1990

As can be seen from figure 2 there appears to be an apparent increase in moderate (AIS 2) injuries of 2% and a decrease in the more severe injuries AIS 4 of 1.5%. There were also changes noticeable in the AIS 1, AIS 3 and AIS 5 severities but these were not as pronounced. There was also an increased number of AIS 0 injuries in AIS 2005. However the overall view does not show what injuries are causing the changes in AIS severity, thus injuries to body regions were reviewed.

Body region changes

The nine body regions in the AIS dictionary were examined in detail to determine where changes between the two coding methodologies occur. These body regions are head, face, neck, thorax, abdomen, upper and lower extremities, spine and external injury. The four body regions identified as having a major effect on the injury data were the head, thorax, upper and lower extremities.

Head Injuries

Analysis of head injuries identified changes in AIS severities between the two coding methodologies (Figure 3). For AIS 1 (minor) injuries there was an increase of 2% and also 3% for AIS 2 (moderate) injuries. There was a 3.5% decrease in AIS 3 (serious) injuries a 4% decrease in AIS 4 (severe) injuries and a slight 0.5% decrease for AIS 5 (critical) injuries in AIS 2005. A 4% increase in AIS 0 'non injuries' was also recorded.

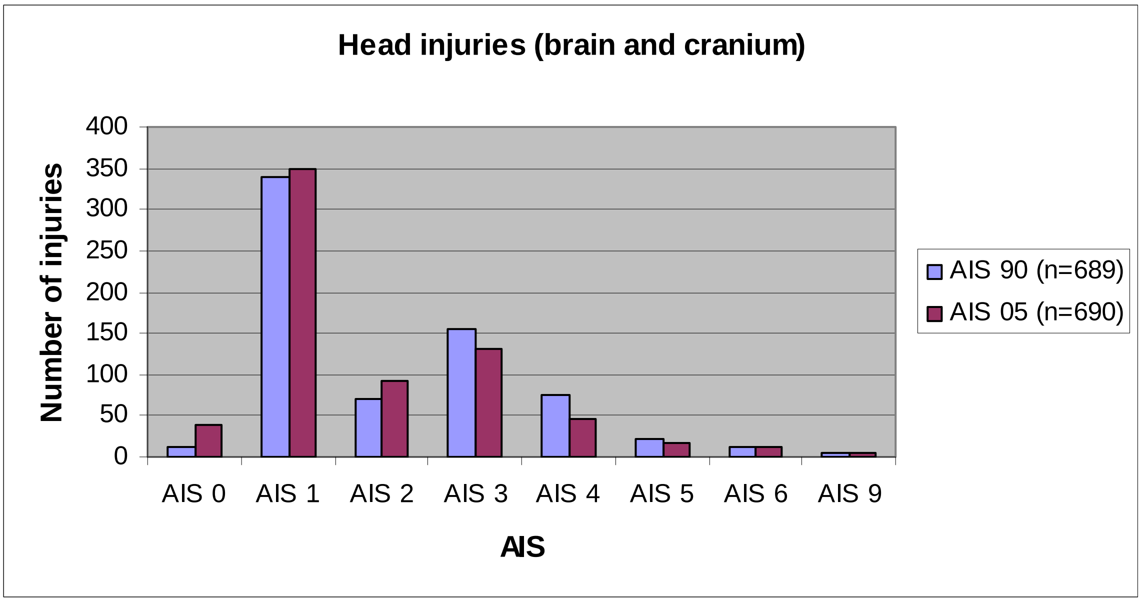

Figure 3: AIS severity for brain and cranium injuries

The shift in AIS severity would suggest that injuries at the 'serious' and 'severe' severities (AIS 3 & 4) have reduced whilst in contrast 'minor' injuries at AIS 1 and 'moderate' injuries at AIS 2 have increased. Of note are the number of AIS 6 injuries which have remained constant between the two coding methodologies. The increase in AIS 0 recorded 'no injuries' could be accounted for by changes in the AIS 2005 dictionary which do not allow for coding such as 'amnesia' to be recorded compared to the AIS 1990 dictionary.

Thoracic injury

The distribution of AIS for all thoracic injuries identified a 2% increase in AIS 1 (minor) injuries and a 6% increase in both AIS 2 (moderate) and AIS 3 (serious) injuries. However in the AIS 4 severity an 8% decrease occurred whilst there was a 1% decrease in 'critical' AIS 5 injuries (figure 4).

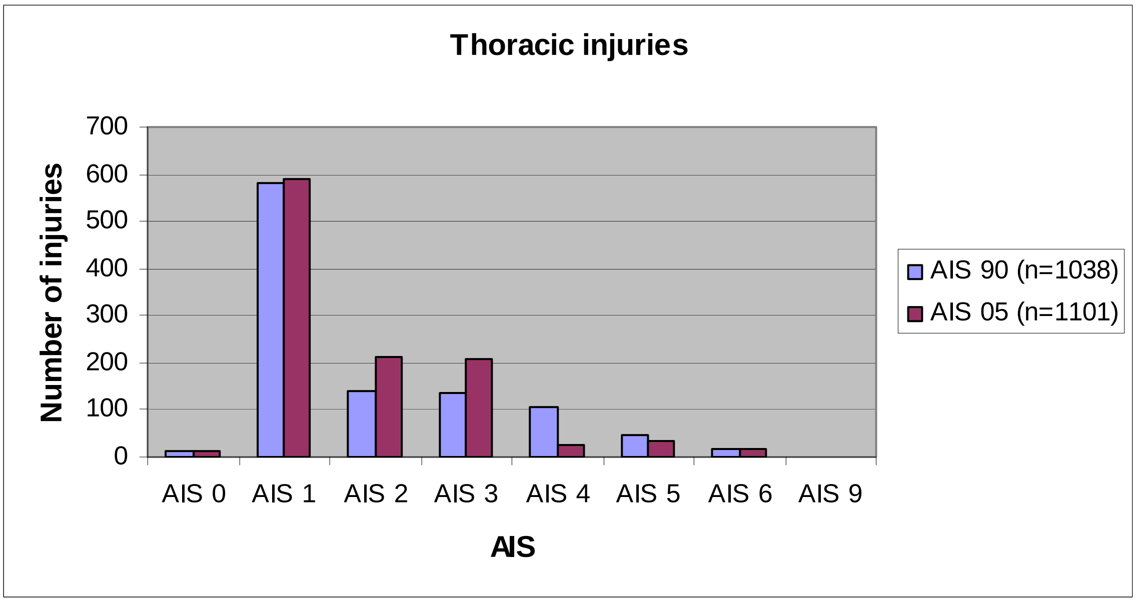

Figure 4: AIS severity for all thoracic injuries

The thorax was considered to have a number of substantial changes in injury codes in the AIS 2005 data dictionary. These changes included actual coding rules for certain injuries and also severity changes for both skeletal and internal organ / vessel injuries. The thoracic injuries were further explored to establish what types of injury accounted for the variation between the two coding methodologies. From figure 5 it can be seen that there is a substantial reduction in AIS 4 (severe) skeletal injuries in AIS 2005 of 18% and a 6% reduction in AIS 5 (critical) injuries. A corresponding 22% increase in AIS 3 (serious) injuries was also noted with less notable increases in AIS 1 (minor) and AIS 2 (moderate) injuries.

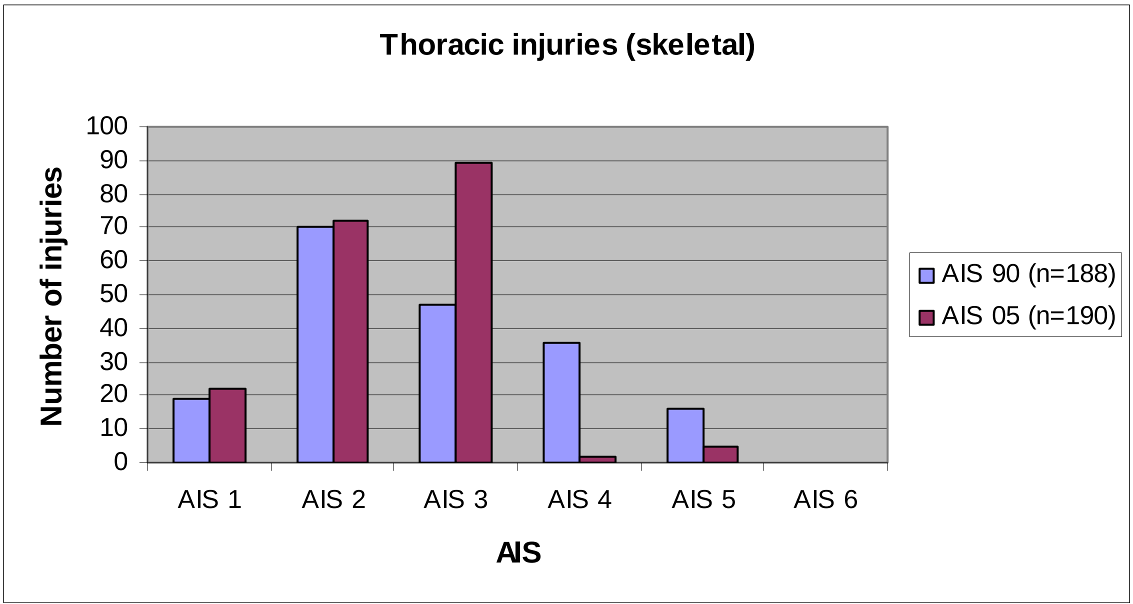

Figure 5: AIS severity for thoracic skeletal injuries

Figure 6 shows the changes in AIS severity between the two coding methodologies for internal organ / vessel injuries. It again shows substantial shifts in AIS severities for AIS 4 (severe) injuries a 24% decrease is observed whilst a 19% increase in AIS 2 (moderate) injuries is seen. It is evident that the internal thoracic injuries in AIS 2005 are considered to be of a lesser severity than in AIS 1990. Again the number of AIS 6 injuries remained constant between the two coding methodologies. Also of note are the higher number of thoracic internal injuries recorded in AIS 2005 compared to AIS 1990. This is a product of the change in coding rules for particular injuries which in AIS 1990 were coded together but in AIS 2005 have now become two separate injuries.

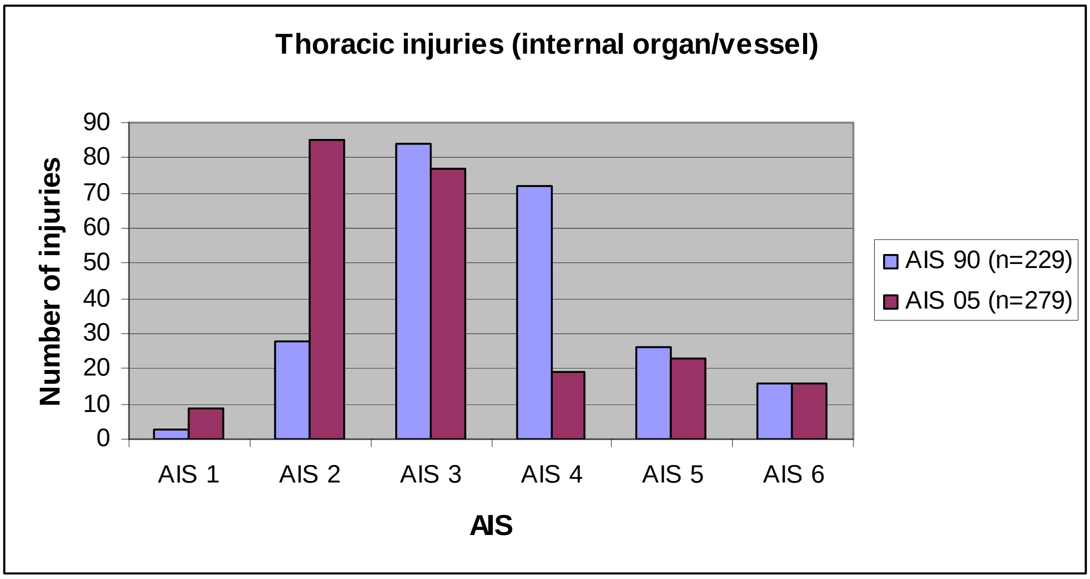

Figure 6: AIS severity for internal organ / vessel thoracic injuries

Extremity injuries

The upper and lower extremity injuries only varied in the AIS 2 and AIS 3 severities with a 2% increase in AIS 2 severity and a 3% decrease in AIS 3 severity injuries (figure 7) The majority of extremity injuries are at their highest severity at the AIS 3 (serious) level apart from a small number of codes to describe crush, some amputations and severe pelvic fractures. Although the changes in severity for the extremity regions were not as remarkable as the thorax, the upper and lower limbs were further reviewed in isolation.

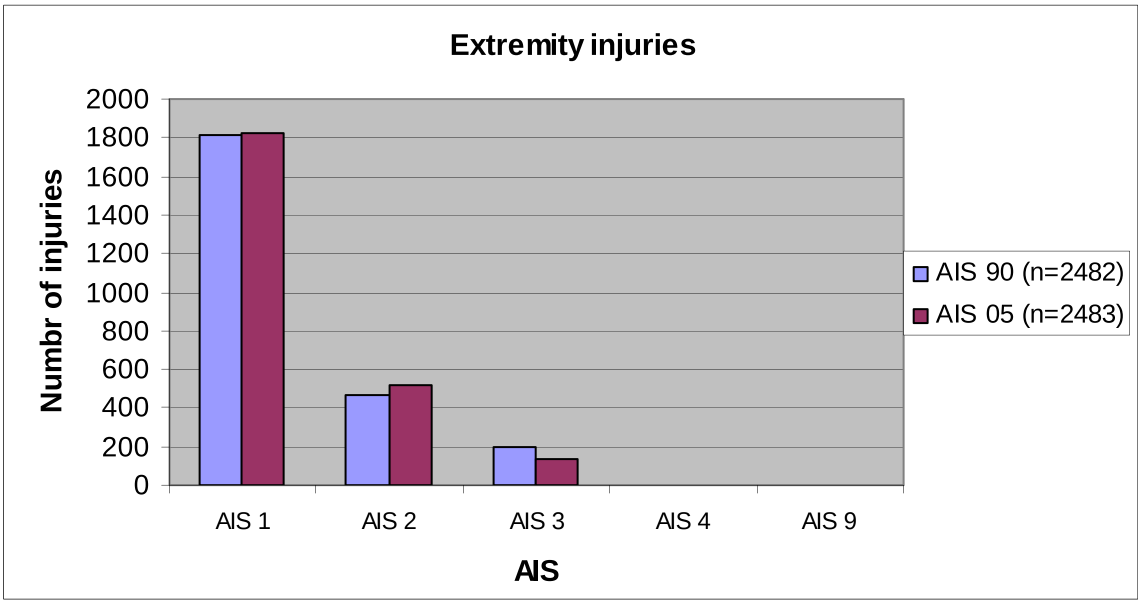

Figure 7: AIS severity for all extremity injuries

The major changes in AIS severity in the extremities were accounted for by upper extremity and pelvis injuries with the lower limb (femur to foot) recording minor changes only.

The most notable of changes in the upper extremity was the reduction of all but one injury at the AIS 3 severity to AIS 2 (figure 8). This accounted for a 4.6% reduction in AIS 3 (serious) injuries and a 4% increase at AIS 2 (moderate) injuries and also a slight increase at the AIS 1 level of severity.

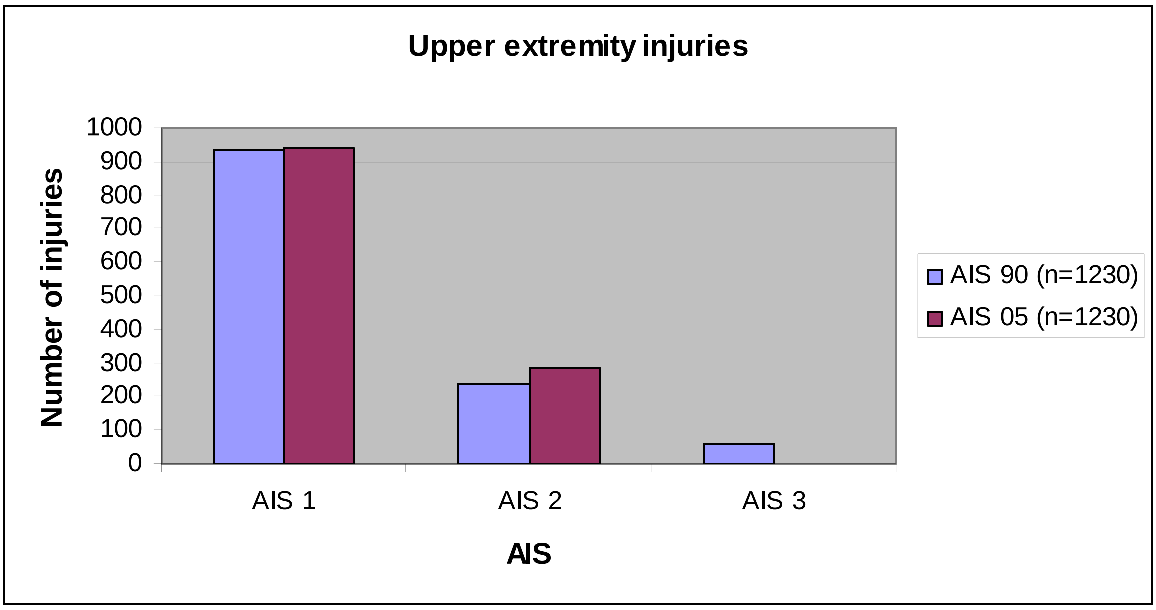

Figure 8: AIS severity for upper extremity injuries

Analysis of pelvic injuries revealed shifts in AIS severity to lesser severities in AIS 2005 (figure 9). There was an increase in AIS 2 (moderate) injuries of 10% with a decrease of 11% for AIS 3 (serious) injuries. This suggests that there has been a general reduction of injury severity for the pelvis in AIS 2005.

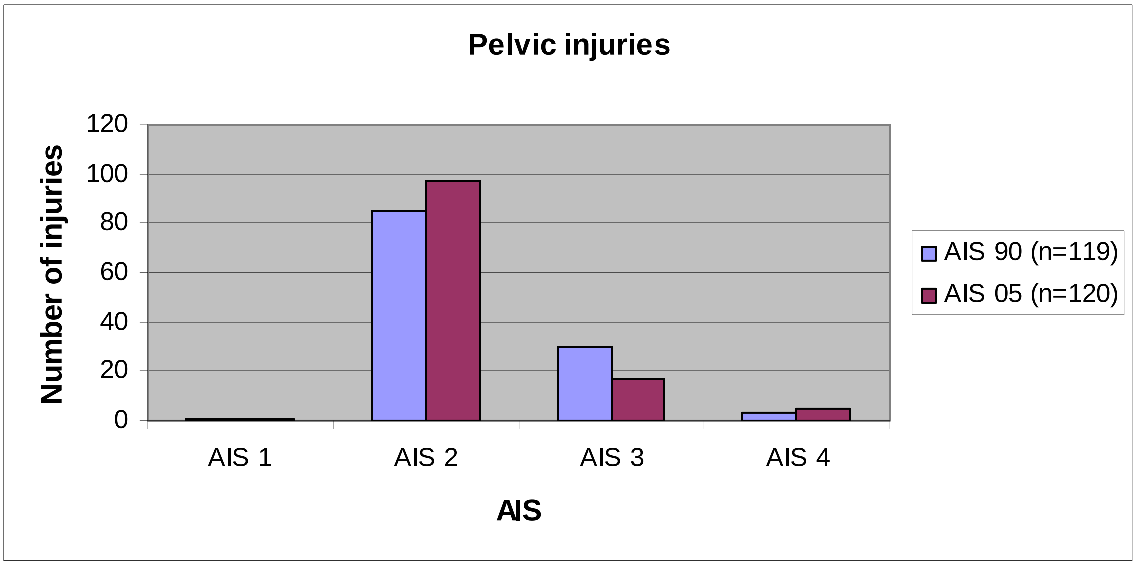

Figure 9: AIS severity for pelvic injuries

Maximum Abbreviated Injury Scale Score (MAIS score)

The overall MAIS in the CCIS represents the occupants' highest severity injury out of all of the injuries sustained during the crash (figure 10). There were noted changes with 2% more injuries at the MAIS 1 level and 2.5% fewer injuries at the MAIS 4 level (figure 11). These differences were found to be statistically significant ($p<0.001$ Wilcoxon rank sum test). There were no changes in the MAIS

6 occupants which is as expected as no AIS 6 injuries changed in severity between the two coding methodologies.

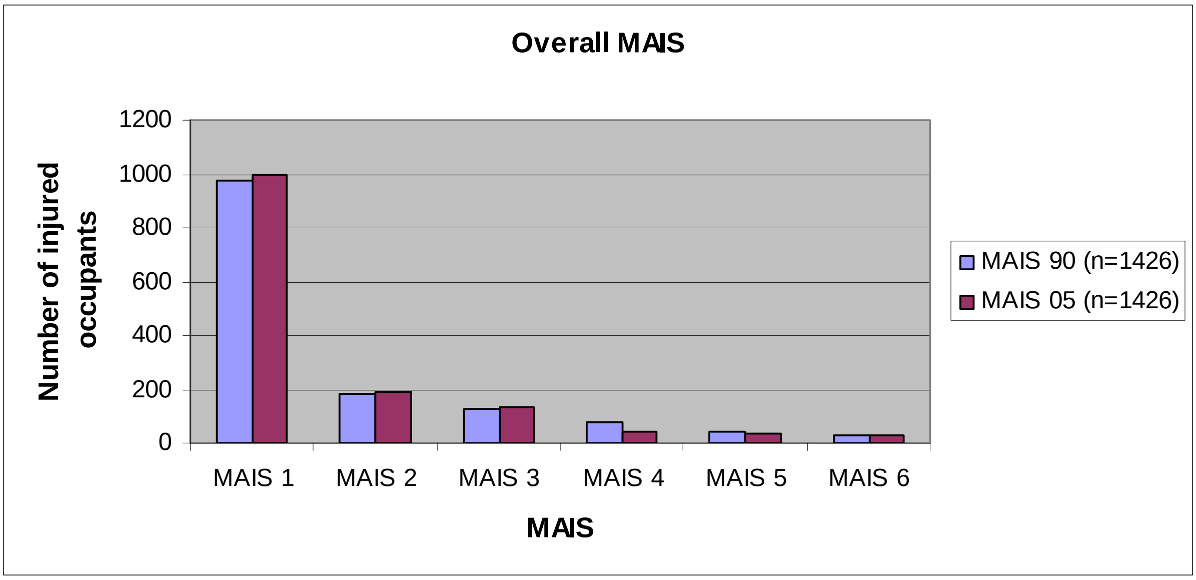

Figure 10: Overall MAIS for occupants with an actual injury

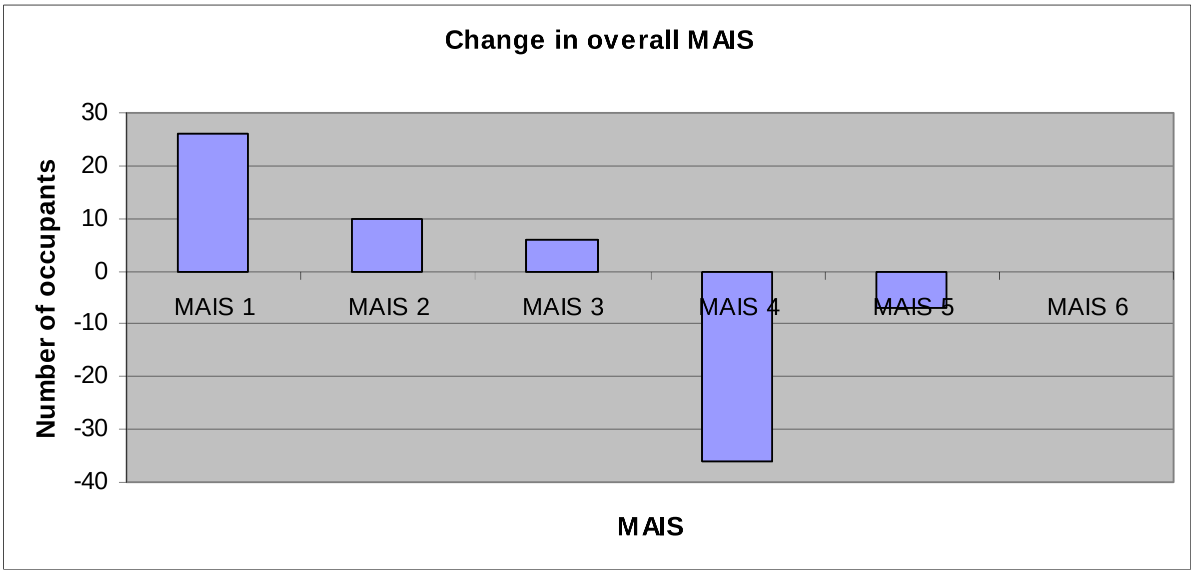

Figure 11: Difference in Overall MAIS for injured occupants

Body region MAIS

Body region MAIS is used to identify specific changes in overall injury severity in body specific regions and can be used to show improvements in vehicle safety measures before and after their introduction.

To determine the effect of the AIS 2005 changes on the assessment of multiple injuries the MAIS was calculated for each of the six ISS body regions (head & neck, face, thorax, abdomen, extremities, external) for all injured occupants. The MAIS was significantly different between AIS 1990 and AIS 2005 for the head and neck, thorax and extremities ($p<0.001$ Wilcoxon rank sum test) (figures 12-14).

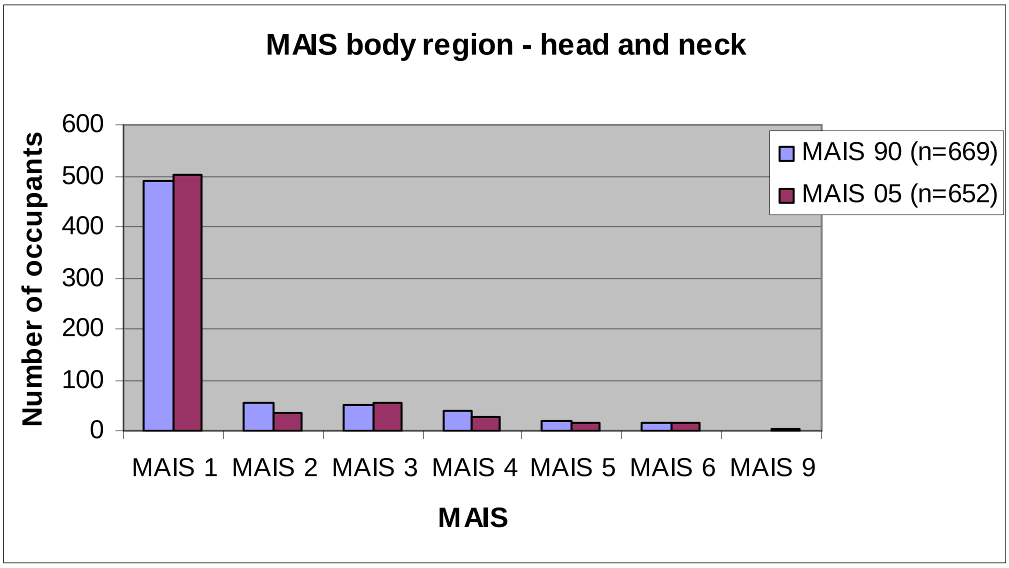

Figure 12: Body region MAIS for head and neck injuries

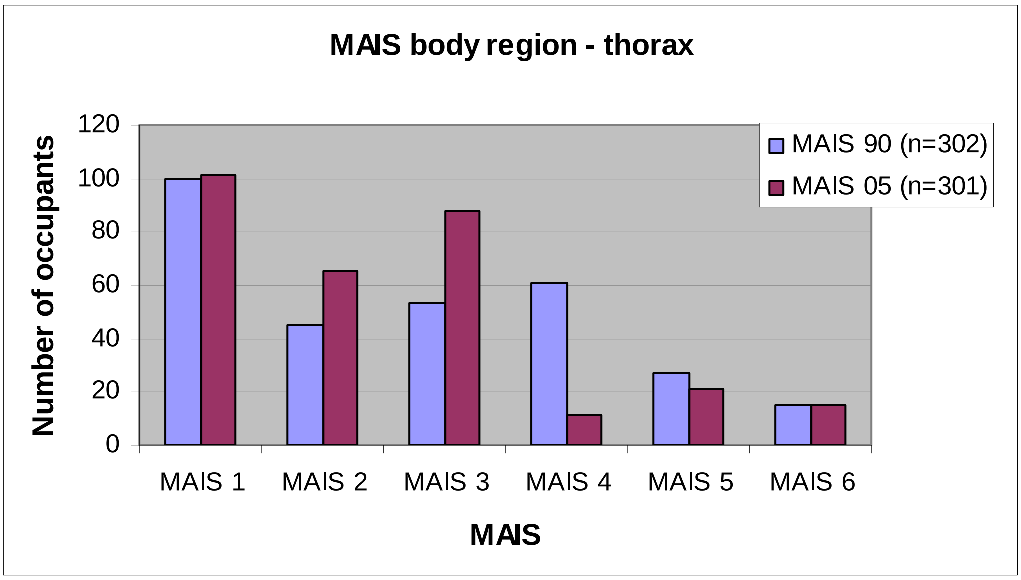

Figure 13: Body region MAIS for thorax injuries

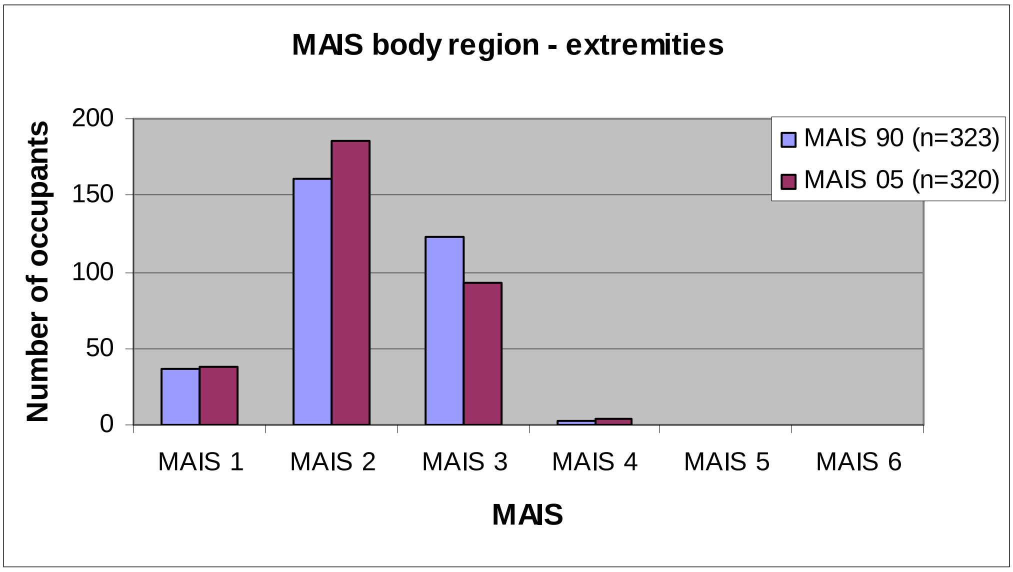

Figure 14: Body region MAIS for extremity injuries

DISCUSSION

The analysis of the data has shown that there is an effect on the AIS severity between the two AIS coding methodologies with AIS 2005 evidently recording lower severity injuries. These reductions in injury severity were found most notably in the head (brain & cranium), thorax and extremities (upper extremity and pelvis).
The AIS severity changes in the "Head" chapter of the AIS 2005 dictionary have focussed mainly on the brain and vessel injuries. The reduction in injury severity for the head can be attributed to a few common injuries in the database; for example sub-arachnoid haemorrhage without clarification of any coma has an AIS severity of 2 in AIS 2005 compared to an AIS severity of 3 in AIS 1990. For brain contusions an added code at a lower severity has been included in AIS 2005 to allow for coding of 'tiny' contusions at AIS 2 severity compared to the AIS 3 severity option for 'small' contusions in AIS 1990. The other notable change is the code for loss of consciousness which in AIS 1990 has an AIS severity of 2 but in AIS 2005 has a severity of 1. One other change of note includes the injury described as 'amnesia' which could be coded at AIS 2 in AIS 1990 whereas in AIS 2005 there is no allowance to code this injury. This difference in the coding methodologies for 'amnesia' may account for the higher number of AIS 0 injuries recorded in AIS 2005 compared to AIS 1990 for the head (brain and cranium) injuries. However this recording of AIS 0 and AIS 9 'injuries' will need further in-depth analysis between the two coding methodologies, to gain a better understanding of their definitions in the CCIS database. AIS 9 is used to code 'unknown injuries' as well as recording an injury which is 'not further specified' as to type or severity in the two AIS dictionaries.

Analysis of thoracic injuries reveals the biggest changes between AIS 1990 and AIS 2005 with definite reductions in severity. The injuries that have predominantly contributed to these changes are rib fractures accompanied with the presence of a haemothorax or pneumothorax, multiple rib fractures and lung contusions. In AIS 1990 rib fractures with a pneumothorax are assigned one code, however in AIS 2005 two codes are assigned; one for the rib fractures and one for the pneumothorax. In combination in AIS 1990 the AIS severity was higher but as separate injuries in AIS 2005 the severities are lower particularly if no details are given for the extent of the pneumothorax. Thus this creates a higher number of injuries sustained by occupants using AIS 2005 but also a corresponding reduction in AIS severity even though in reality no change in the injury itself has occurred. In general lung contusions have reduced in severity for all but the most extensive contusions in AIS 2005 also explaining some of the changes in AIS severity between AIS 1990 and AIS 2005.

The changes in severity in the extremities were found to be associated with the upper extremity and pelvis. The reduction of all but one AIS 3 severities in the arm was accountable to the down grading

in the severity of a number of compound fractures particularly in the radius and ulna in the AIS 2005 dictionary.
Analysis of the pelvis identified reductions in severity however the coding of actual pelvic injuries has caused the greatest problems particularly in the field tests in the new AIS 2005 dictionary [5]. In AIS 1990, the sacro-iliac joint and pubis symphisis are coded separately. However in AIS 2005 these two injuries are contained within the pelvic fracture codes and have an effect on the overall severity of the pelvic fractures. Also the coding of the acetabulum has changed and is a separate code in AIS 2005 compared to AIS 1990 (when it was implicit in the pelvic fracture codes). Thus the changes in the severity of pelvic fractures between the two coding methodologies are complex when attempting to identify the causes in the variation in severities. The inclusion of the sacro-iliac joint and pubis symphisis in the pelvic fracture codes can alter the severity as a result of the coding rules and orthopaedic knowledge of the coder.
The other body regions did not have any significant changes in the AIS severity of injuries between the two coding methodologies.
The changes in the MAIS were not as pronounced as the individual AIS codes but were still noticeable and could have an effect on data analysis particularly in the assessment of vehicle safety measures. For example analysis of data on thoracic injuries would show that MAIS decreases in AIS 2005 compared to AIS 1990. If data on (for example) side impact performance were analysed using the two coding methodologies it could conceivably indicate major improvements although this would be an erroneous and misleading observation brought about by the changes in coding methodologies.

CONCLUSION

This review of the changes between the AIS 1990 and AIS 2005 coding methodologies has been laborious but has highlighted the differences between the two coding methodologies for car occupants and has allowed for the user to examine in detail the effect that the changes have on the same dataset. This review has shown that certain injuries with exactly the same general descriptions can be coded differently in AIS 2005 compared to AIS 1990. These differences in AIS 2005 on one hand are to be expected but on the other hand can impact on analytical outputs. The changes may indicate that the same injuries are more survivable now than previously due to advances in medical care.
For those assessing vehicle safety measures there is a need for caution as these inherent changes in severity may not necessarily equate to 'safer' vehicles as the injuries themselves are still the same and caused in the same way but more survivable. There are also potential implications for consistency between old and new data in the CCIS for AIS 1990 and AIS 2005 coding methodologies. As CCIS is primarily aimed at identifying improvements in the protection vehicles offer to occupants, the study will not transfer to AIS 2005 wholesale, it will continue to code injuries using AIS 1990 and AIS 2005 so as not to potentially mask changes in vehicle crashworthiness. The full extent of the effects of the changes will continue to be assessed over time as more data are collected further comparisons will be made between the AIS 1990 and AIS 2005 coding methodologies.
There is always potential for inconsistencies in the coding and to some extent the pelvic injuries have highlighted the complexity added to the AIS 2005 dictionary for coding these specific injuries. Inter-rater reliability of the coders will also be incorporated in further reviews of the data.

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Data was collected by teams from the Birmingham Automotive Safety Centre of the University of Birmingham; the Vehicle Safety Research Centre at Loughborough University; TRL Limited and the Vehicle & Operator Services Agency (VOSA) of the DfT
Further information on CCIS can be found at http://www.ukccis.org

Severe Injuries in Passenger Cars – Development of a Software Tool for Emergency Diagnostics

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Abstract

In Germany averagely two million traffic accidents happen each year and emergency medical services are called to more than 400 000 patients. Even though this number is decreasing continuously (due to improvements in the fields of vehicle safety, road construction, and accident prevention) every case is yet a challenge for the rescuers and requires improvements in emergency medicine as well. Especially during diagnostics right at the accident scene, there are only limited instruments available to gain the necessary knowledge of the injuries suffered, to come to essential decisions about treatment or transport. To provide an additional diagnostic aid by scouting and estimating the situation, a software-tool calculating the likeliness of the most frequent severe injuries (AIS 3-6) of front occupants in passenger cars has been developed to deliver this necessary information about particular accident scenarios. To achieve this, logistic likelihood functions have been calculated in a multivariate regression analysis analysing all AIS 3+ injuries in the GIDAS database of the years 1999-2006 that happened more than four times.

Introduction

Especially after traffic accidents, that make up 25% and thus the largest portion of all trauma fatalities [18], it is often difficult to comprehend all injuries immediately and weight them regarding their urgency of treatment. On one side there is often the problem that the patient is not easily accessible right away and on the other side slighter superficial injuries may distract from severe inner trauma. In addition to that the confrontation with a severely injured crash victim always embodies a critical situation, especially for less experienced emergency physicians. It is then particularly essential to use all hints and information available for the diagnostic investigation. Due to the fact that the treatment of crash victims requires crucial decisions regarding necessary forces, on-spot treatment, transportation and appropriate hospitals, a thorough comprehension of all threatening single injuries is absolutely vital.

Using a software-based calculation of the most likely injuries on the basis of a few easily accessible parameters at the accident scene, these analyses offer an aid for thorough diagnostics. The tool can point out expected injuries and already call attention to important diagnostic steps before the actual examination. Beside the analysis of injuries that are only obvious if the patient is freely accessible, both inner traumata that can even slip the attention of a thorough initial examination, and brain injuries that can always lead to “talk and die” situations due to delayed manifestation, are considered.

Used Data

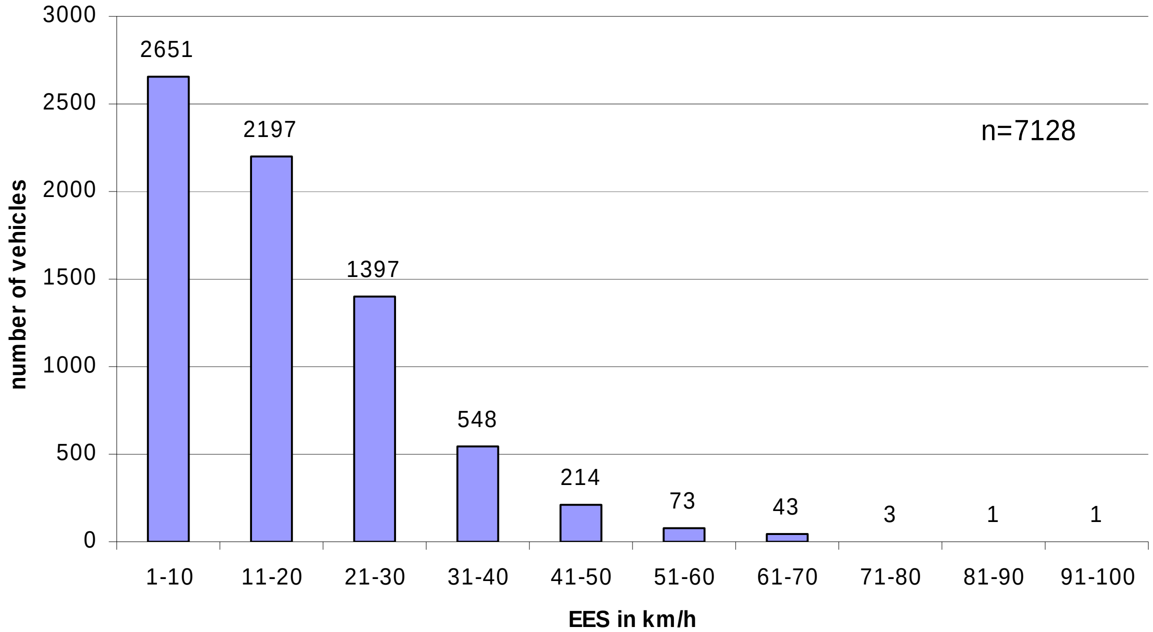
For this study the GIDAS database of the years 1999-2006 was used, using data from Dresden as well as Hanover. The used data base copy from 15 May 2006 included 8839 reconstructed cases with 22768 involved persons. Since only passenger car occupants are considered in this study, only automobiles and limousines were included. In addition to that only front occupants were considered, because from experience [10] there are only enough cases for those. Accidents with a rollover were also excluded.

The master dataset does now include 5010 accidents involving 7128 vehicles and 9106 drivers or front-seat passengers. In these accidents 342 people suffered 768 AIS 3+ injuries and injuries of unknown severity. These injuries were available for the analyses.

Descriptive Analyses

EES Distribution in the Dataset

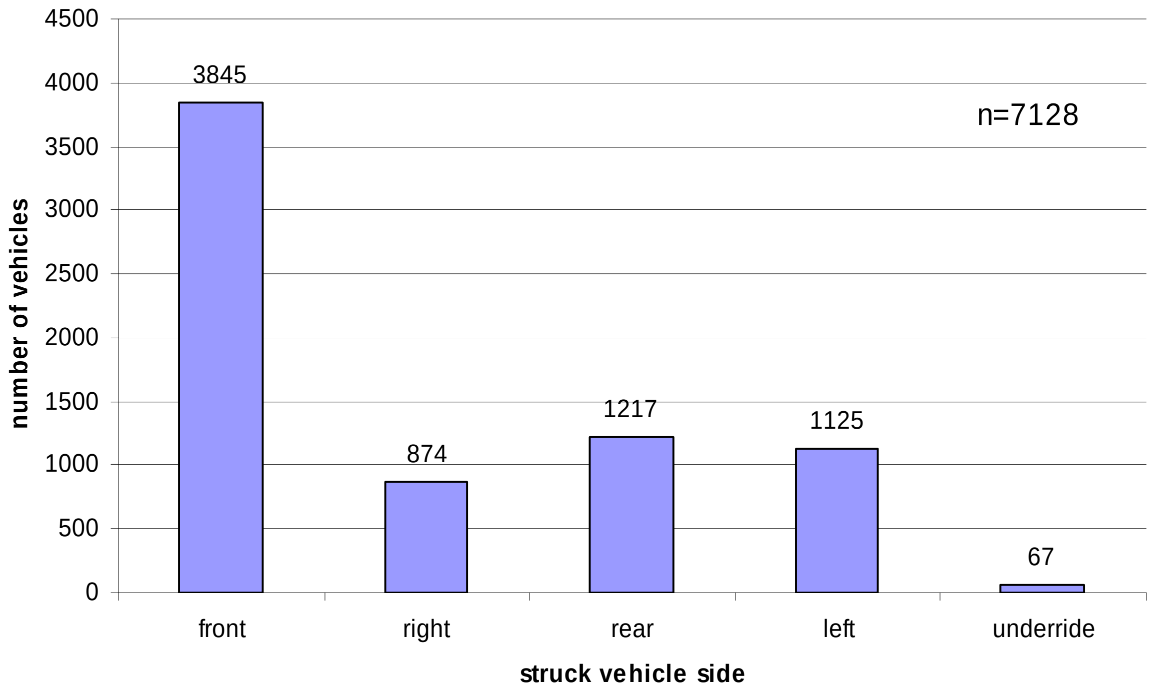
Since slight accidents do of course happen more often than severe collisions at high speeds, the number of GIDAS cases reduces considerably for higher EES values [picture 1]. Due to that fact a statistical evaluation with a univariate analysis can be rather difficult, because after a classification there are only smallest sample sized left.



Picture 1 - EES Distribution in Dataset [Source: GIDAS]

Struck Side Distribution in the Dataset

The distribution of the struck vehicle side [picture 2] shows that collisions on the vehicle front are expectedly most frequent. This fact has been shown in several studies before [6,16,22] and can partly be derived from the usual forward driving direction. Collisions on the left vehicle side were 1.3 times more frequent than collisions on the right vehicle side.



Picture 2 – Struck Side Distribution in Dataset [Source: GIDAS]

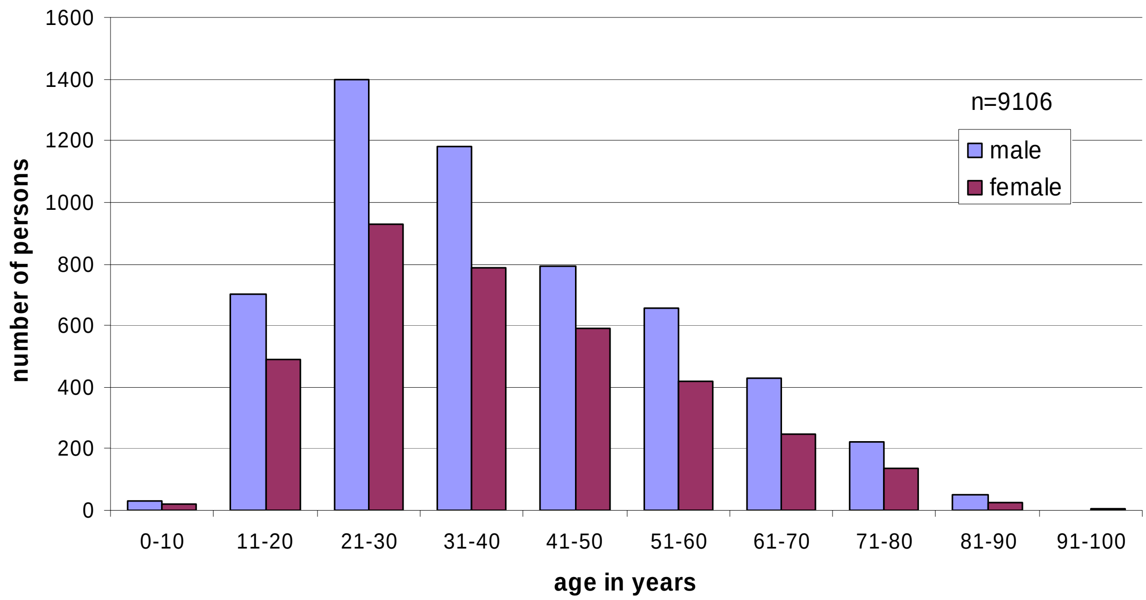
Seat Belt Usage Rate in the Dataset

The analysis of the seat belt usage rate showed that 96% of all front occupants used their seatbelts during the collision. This portion is consistent with the official belt usage rates of the German federal road research institute. Here the total belt usage rates of adult passenger car occupants indicates 97% average in 2006, 96% in 2005, and 93%-95% for the years 1999-2004. [5]

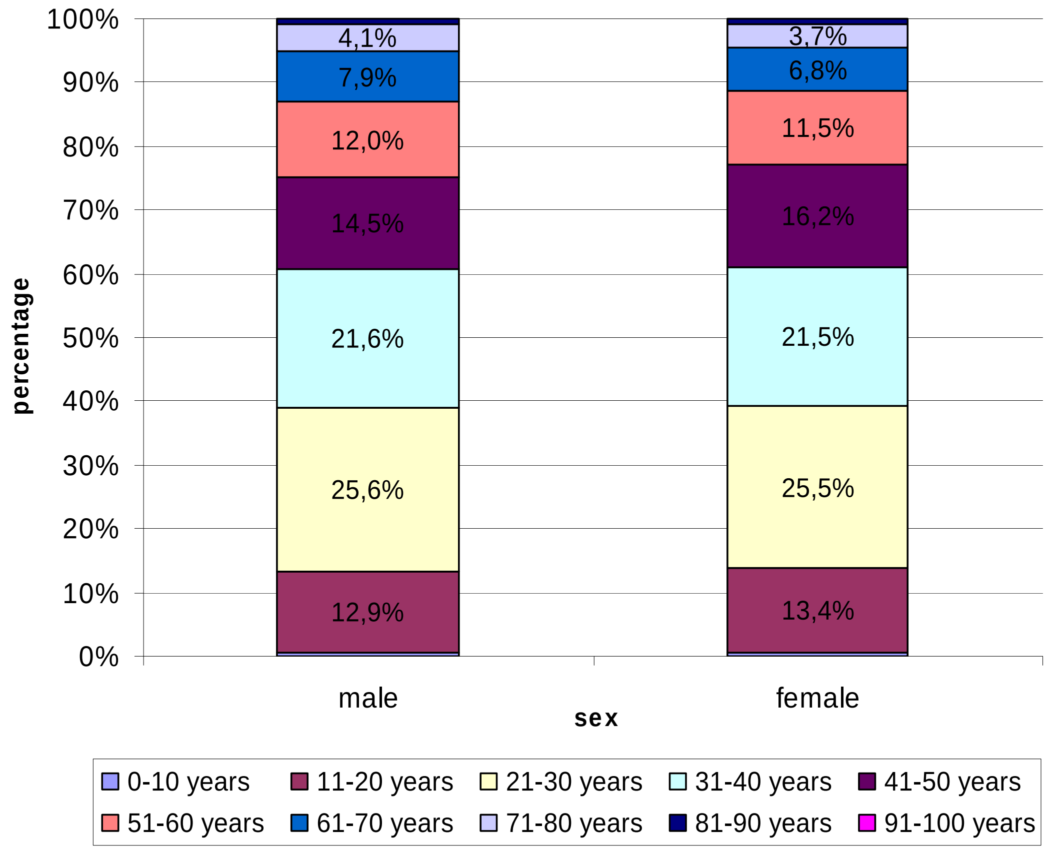
Age and Sex Distribution in the Dataset

The age distribution of the occupants showed that twenty to thirty year old occupants made up the largest group in the dataset [picture 3]. Younger occupants were by far less often involved. This could be due to the age of acquiring a driver's licence and also to the fact that children are often sitting in the rear passenger compartment [21] because of the assumed lower injury risk [4,9,23].

Considering the occupant sex distribution it can be shown that male occupants are overrepresented (59.9%) while no difference in the age distribution appeared here [picture 4].



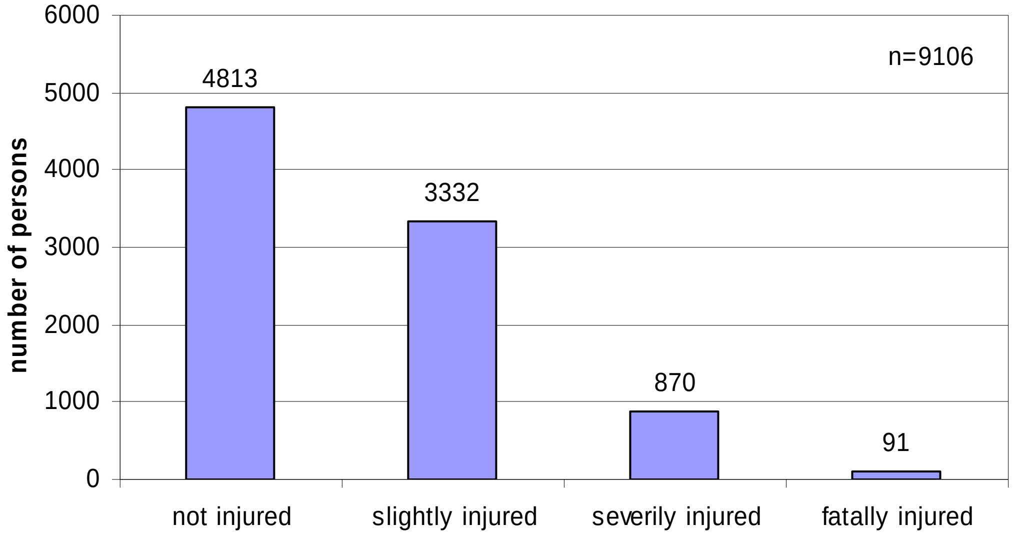
Picture 3 – Occupant Age and Sex Distribution [Source: GIDAS]



Picture 4 – Age and Sex Distribution (normalized) (n=9106) **[Source: GIDAS]**

Injury Severity Distribution in the Dataset

As expected the distribution of the injury severity showed that the greatest part of occupants (89.4%) was not or only slightly injured [picture 5]. It has to be considered though, that this is only representative for accidents where at least one involved person got injured indeed, because of the statistical sample scheme for the GIDAS data collection.



Picture 5 – Injury Severity Distribution [Source: GIDAS]

Overview Most Frequent Single Injuries in the Dataset

In the following table [table 1] all injuries with an AIS severity of three or higher are listed (if they could be found at least four times in the dataset):

injury	AIS value	number in dataset	injury	AIS value	number in dataset
brain injury	3+	132	severe spleen injury	3-5	16
femoral fracture	3	87	lung rupture	3+	11
multiple rib fractures	3-5	81	humeral fracture open/displaced/comminuted	3	10
pulmonary contusion	4	44	intimal injury/rupture thoracic aorta	4+	9
skull base fracture	3	38	contusion/laceration spinal cord	3+	9
hemo- and/or pneumothorax	3-5	34	midfacial fracture Le Fort III	3	8
pelvic fracture	3-5	34	jejunum/ileum rupture	3+	8
cervical spine fracture	3	26	complex fracture calvaria	3+	6
tibial fracture open/displaced/comminuted	3	25	extended contusion/rupture kidney	3-5	5
forearm fracture open/displaced/comminuted	3	22	thoracic spine fracture	3	5
severe liver injury	3+	18	rupture abdominal vessel	3-5	5
severe heart injury	3+	16	ankle joint fracture	3	5

Table 1 - AIS 3+ Injuries in GIDAS

As an examples the following injury will be explained:

Brain Injury

According to the AIS catalogue brain injuries AIS 3+ include the following traumata: all intracranial vessel ruptures, brain stem / cerebellum / cerebrum lesions confirmed by diagnostic imaging, or unconsciousness with neurological involvement or duration of more than one hour. [1]

Methods

Description Energy Equivalent Speed

The energy equivalent speed is a measure of the kinetic energy that was converted into deformation work during the collision of the relevant vehicle [3]. It represents the speed that displays the deformation work for the vehicle in one single value. It equals the speed of the vehicle that would have been necessary to cause the same damage in a collision with a rigid, not deformable barrier. Physical basis of the EES reconstruction are the energy conservation law, the linear momentum conservation law, and the angular momentum conservation law.

For the exact calculation of the EES there are several possible approaches, such as the methods of Cambell and Rau [14]. These do, however, need a lot of mathematical effort and are thus not applicable for a rough EES evaluation at the accident scene. It is hence customary in accident research to estimate the value according to catalogues that show deformations of the same vehicle type. Since this method is also difficult to use at the accident scene, a rough estimation with limited information about type specifications is used.

For an estimation of the EES value the overlapping ratio, the intrusion and the deformation of supporting elements are particularly important. The overlapping ratio characterizes the contact area of the vehicle and the collision opponent or object. This area correlates directly with the intrusion, because the force can affect a larger or a smaller region. Consequently the amount of energy transformed in a small overlapping area (e.g. in a tree or a pole collision) is comparatively high, leading to a deeper intrusion than in a collision with a high overlapping ratio (e.g. in a collision with a wall).

The greatest advantage of the EES for this analysis is the possibility for trained emergency personnel to use it for a rough evaluation of the accident severity right at the accident scene, even though an exact calculation is of course reserved to accident specialists. For this rough evaluation of the accident severity a detailed manual with sketches and photos has been developed to go with the software-tool.

Statistical Analysis

For the evaluation of a covariate regarding a resulting event there are univariate and multivariate methods available. The influencing factors may, however, have different impact in univariat and multivariate analyses. Koch states [12] that this leads to the conclusion, that univariate analyses can be falsified by bias that may be detectable in multivariate models. As this study aimed to calculate the influence of given parameters the analysis was performed with a multivariate model only. This way affected influences and concealed influences in the univariate analysis and correlations between the parameters were considered in the calculations.

As analyses using logistic regression offer the possibility to examine different influencing factors regarding an empirically obtained complementary result, the method is often used for medical questions such as disease risks, survival chances, or injury risk. The logistic regression model can calculate the chance of belonging to a specific group (or category of the dependent variable) depending on one or more independent variables. Since logistic functions are used for the estimation, logistic regression models belong to the non-linear algorithms. This characteristic is necessary because a linear regression model would allow negative values as possible results.

Like all structure checking algorithms the logistic regression analysis requires the user to logically decide about the possible categories of the dependent variable and the influencing factors that define the likeliness [2]. For this study, the considerations about these influencing factors had to mind different criteria. Only variables that are recorded in GIDAS and encoded in the database could be used. Furthermore these parameters had to be obvious and easily acquirable at the accident scene for a fast and functional utilization. The third restriction was the user himself. As especially medical personnel makes up the target group, only parameters that get along with basic technical knowledge instead of engineering know-how could be used. In different studies and works the chosen parameters were proven to be among the most important factors [7,8,13,15,17,19,24] which were hence used for the analysis: a rough EES estimation, the struck vehicle side regarding the main deformation, the seat belt status, and the age and sex of the patient.

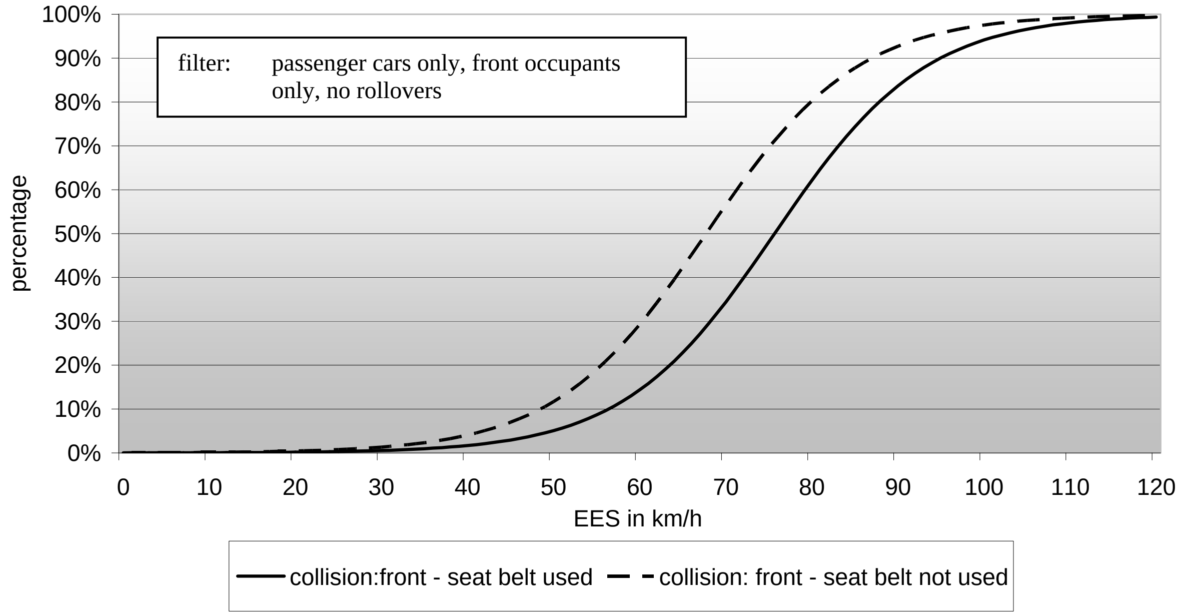
The logistic regression analysis uses the maximum likelihood method to estimate the model parameters. The aspired aim is to maximize the likelihood that the observed results are obtained by optimizing the assumption for the different parameters. In SPSS this maximization of the likelihood function is processed using the Newton-Raphson-Algorithm. This algorithm iteratively changes the estimated parameters until the resulting values of the independent variable maximize the likelihood of one specific event. [2] According to the p-value the single parameters are included or excluded in the analysis. The p-value itself specifies the likelihood that (accepting the null hypothesis) the obtained values or values diverging the null hypothesis are obtained. If this p-value is smaller than the default risk α for a false decline of the true null hypothesis, a statistically significant result is obtained [11]. In this study the default value for α was set to 0.1 (10%) to include as many parameters as possible.

The likelihood for the appropriate event can finally be calculated using the regression coefficients and the logistic function. Therefore the regression coefficients of the specific parameters and the constant $ß_0$ are included in one equation to calculate the combined influence z to estimate the likelihood of a specific injury depending on the chosen parameters. To verify the models the ROC-curve, the AUC-value and the Hosmer-Lemeshow-Test were used.

Analysis

Example: Brain Injuries

There were 132 brain injuries available for the analysis. After excluding all unknown injuries 9100 cases were included in the analysis. In the iterative regression analysis the EES, the struck vehicle side and the seat belt status were included according to their p-value. The different likelihoods for a brain injury AIS 3+ suffered by a specified patient were calculated. An example for frontal collision is given in picture 6.



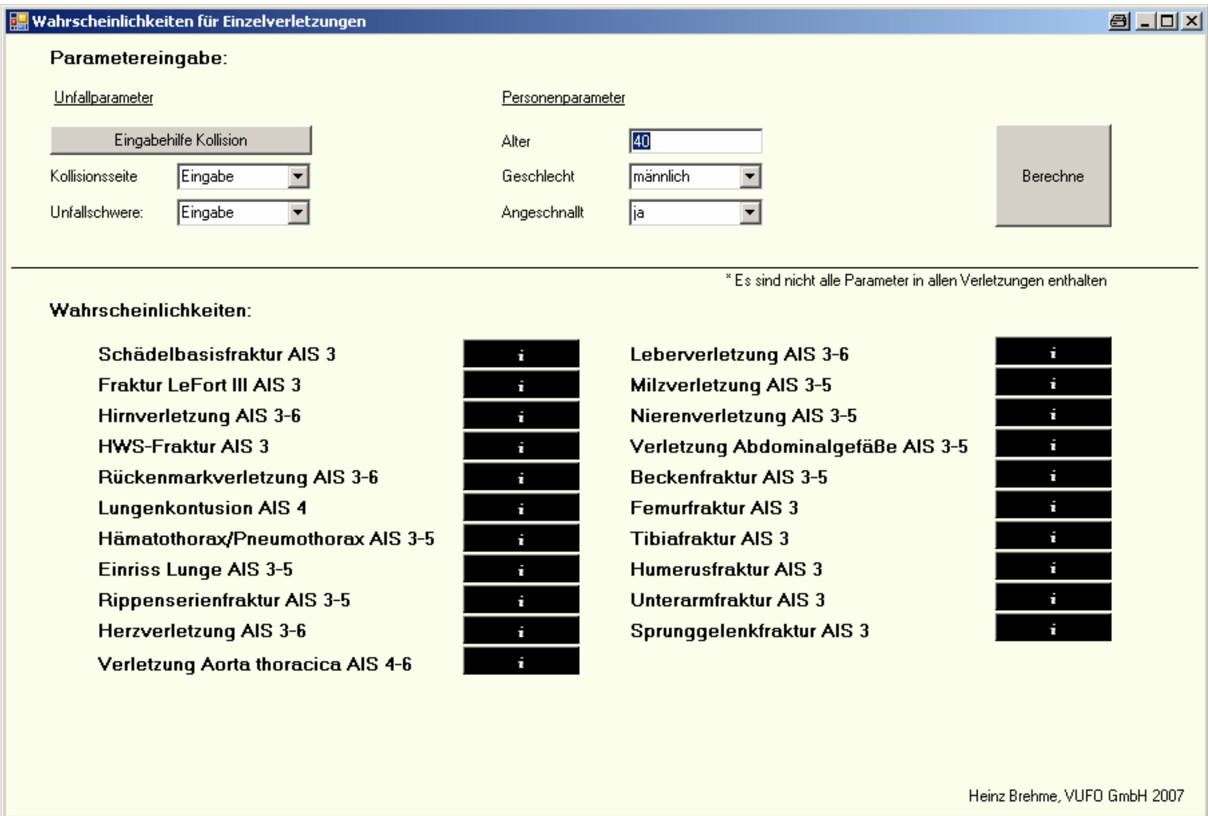
Picture 6 – Brain Injury – Collision: Front

The analysis showed that the highest risk to suffer a brain injury AIS 3+ exists for accidents with an underride collision, followed by collisions to the side of the vehicle. The differences between left and right are only marginal. In frontal and rear end collisions there is the lowest risk. Additionally all collision sides show that the injury risk is notably higher if the patient did not use a seatbelt. For the other parameters (age, sex) statistically significant differences to these values could not be shown.
To verify the quality of the model the ROC-curve and the AUC-value were calculated. With an area under the curve of 0.936 the model adjustment lies far above the null hypothesis of 0.5. The Hosmer-Lemeshow test showed a p-value of 0.310 and verified the good model fit as well.

Utilization of the Results in the Software-tool

To make the results available at the accident scene a software-tool was developed that calculates the likelihood for a specific injury in three gradations according to the input of the necessary parameters.

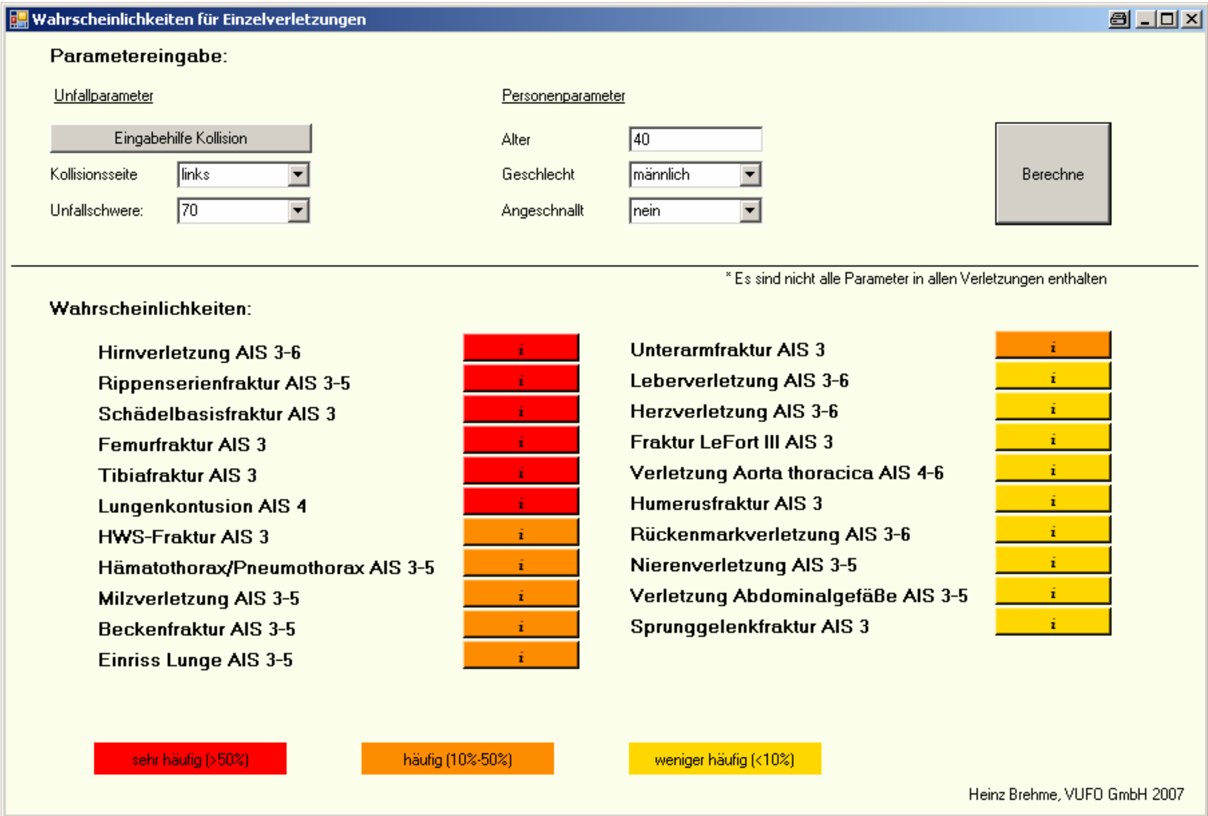
In the upper part of the initial screen [picture 7] the parameters collision side, accident severity, age, sex and seat belt status can be entered. For the collision parameters "collision side" and "accident severity" there is an additional help menu given. The collision parameters are mandatory while there are default values pre-set for the person parameters.



Picture 7 – Initial Screen Software-tool

Using the help button for the collision parameters the menu for the collision side is started where a choice of the side leads to another help menu for the accident severity estimation. Here the accident severity is explained with different short texts and sketches. When the particular picture is selected the values are automatically transferred to the initial screen.

As soon as the “start-button” is selected the likelihood for each injury is calculated and the injuries are given in the correct order. Values below 10% are given in yellow, values between 10% and 50% are depicted in orange and very likely injuries with values above 50% are shown in red [picture 8].



Picture 8 – Output Screen Software-tool

Behind the injuries there are info-buttons. After a short click the exact definition of the injury is given and the parameters that were included in the calculation are listed.

If the parameters are changed, the tool can be restarted and the new likelihoods for the injuries will be calculated.

Conclusions

In Germany averagely two million traffic accidents happen each year and emergency medical services are called to more than 400 000 patients [20]. Even though this number is decreasing continuously (due to improvements in the fields of vehicle safety, road construction, and accident prevention) every case is yet a challenge for the rescuers and requires improvements in emergency medicine as well. Especially during diagnostics right at the accident scene there are only limited instruments available to gain the necessary knowledge of the injuries suffered, to come to essential decisions about treatment or transport. To provide an additional diagnostic aid by scouting and estimating the situation, a software-tool calculating the likeliness of the most frequent severe injuries (AIS 3-6) of front occupants in passenger cars has been developed to deliver this necessary information about particular accident scenarios.

In a multivariate regression analysis using the parameters EES, collision side, age and sex of the patient and the seat belt status, logistic risk functions have been calculated for all AIS 3+ injuries that happened more than three times in the GIDAS data of the years 1999-2006. That way statistical models were developed for twenty different injuries that provide information about the likelihood of these traumata for a front occupant of a passenger car involved in a traffic accident. With the development of a comprehensive instruction for the estimation of the accident severity that has been verified in another study, the calculated models were utilized in a software-tool. Having knowledge about the likelihood of the severe injuries given in a comprehensible chart, a faster start of diagnostics of not easily accessible patients can be achieved and the attention of the rescue staff can be drawn to less obvious injuries or injuries that are concealed by impressive superficial traumata, immediately.

Finally the given software-tool shall by no means replace or hold up any part of a physical examination but rather extend and expedite the restricted diagnostic possibilities at the scene of an accident to ease necessary decisions about emergency treatment, calling additional rescue forces, transport and appropriate hospitals.

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Injury situation of novice drivers in road traffic
-A medical and technical analysis-

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ABSTRACT

Background Novice drivers are at high risk for crash involvement. We performed an analysis of causations, injury patterns and distributions of novice drivers in cars and on motorcycles in road traffic as a basis for proper measurements.
Method Data of accident and hospital records of novice drivers (licence < 2 years) were analysed focusing the following parameters: injury type, localisation and mechanism, Abbreviated Injury Scale (AIS), maximum AIS (MAIS), delta-v, collision speed and other technical parameters and have been compared to those of experienced drivers.
Results In 18352 accidents in the area of Hannover (years1985–2004), 2602 novice drivers and 18214 experienced drivers were recorded having an accident. Novice car drivers were more often and severe injured than experienced and on motorcycles the experienced riders were at higher risk. Novice drivers of both groups sustained more often extremity injuries. 4.5 % novice car drivers were not restraint compared to 3.7 % of the experienced drivers and 6.1 % novice motorcycle drivers did not wear a proper helmet (versus 6.5 %). Severe injuries sustained at a rate of 20 % at collision speeds below 30 km/h and in 80% at collision speeds above 50 km/h. Novice car drivers drove significant older cars. The risk profile of novice drivers is similar to those of drivers older than 65 years.
Conclusions Structural protection and special lectures like skidding courses could be proper remedial action next to harder punishment of violations.

Key words
Car accident, injury mechanism, motorcycle, prevention

INTRODUCTION

According to annual accident reports novice drivers are at a higher risk in road traffic [1]. This thesis is proven every year in Germany and a discussion in different reporting media could be observed. Plenty of initiatives were run to reduce risk. When looking at the literature the definition is very heterogeneous.
In recent years, not only the severity of road accidents has been reduced, but also the frequency and sustained injuries [2, 3]. This trend reflects progress in crash safety protection design of automobiles [4]. Compared to 1973 with 18424 fatal accidents in Germany in 2006 only 5091 could be observed indicating a new historic base line [3]. Nevertheless, in 2006 1011 young people between 18 and 24 years were killed in road traffic accidents (– 6,0% compared to the preceding year) and 83292 injured (– 3,7%) [3]. When calculating those numbers compared to the portion of population of 8.2%, risk of accident in road traffic is doubled. The safety of car occupants was enhanced by mandatory belt use, the interior design – especially the restrain systems and airbags –, and on the other hand structural changes focusing the exterior design and enhancing stiffness of car frames tremendously [5].
Although there are previous studies that outline distinct characteristics and risk profiles with a special view on psychological markers and background, there is a lack of in-depth technical evaluation of the potential influence of external factors and real-world prevalence. Most previous studies utilized medical, police and/or insurance records to obtain both accident and medical data [6]. In consideration of the results of previous studies with alternative aims, we strongly believe that a specific technical in-depth crash investigation in combination with a medical data analysis is the most inclusive basis for the improvement of safety of novice drivers. A special focus was given upon the usage of safety devices like belts and helmets and, if those provide as sufficient protective measurement. Furthermore we wanted to identify special characteristics in novice driver's accidents. The purpose of this study was therefore to estimate the prevalence of knee injuries in real world car crashes in Germany and to identify any change in prevalence with time.

METHOD

Based on a non-standardized definition of the term „novice driver“ we defined this subpopulation in analogy to the pending driver’s licence as those holding one less than 2 years. The local traffic accident research unit collected prospective data in regard to all reported traffic crashes within the area. 18352 traffic accidents were documented between 1985 and 2004. Specially trained documentation personnel are notified by police dispatchers and arrive on scene, often simultaneously with the rescue personnel. Thus, investigation of the crash (including stereotactic photographs for measurement of distance), and clinical injury documentation is performed on site. The report is then completed at the medical institution providing care for the victims, with documentation of x-ray films, injury type and severity. The monitoring includes demographic data, type of road user (car/truck occupant, motorcyclist, cyclist, pedestrian), delta-v (km/h; change of velocity at the collision time as a basic force indicator) of motorized vehicle user; vehicle collision speed (km/h) of motorbikes, Abbreviated Injury Scale (AIS), Maximum AIS (MAIS), Injury Severity Score (ISS) and incidence of serious and/or severe multiple injuries (polytrauma, ISS $\geq$ 16) [2, 7, 8, 9]. 1000 accidents are recorded annually.
The Abbreviated Injury Scale (AIS), developed by the Association for the Advancement of Automotive Medicine is the most widely used anatomic injury severity scale in the world [10]. A six-point severity scale is used to rank threat to life. For injuries of the limbs most regions are described by the first three steps as those are rarely life-threatening. This information was used along with the impact vector and the resulting relative motion of the car and differentiated according to frontal and side impact.
Traffic crash reports from 1985 to 2004 produced by the process described above, were carefully analyzed for the involvement of novice drivers. A liability curve was generated using the ratio guilty/not guilty related to the delinquents age and supported by a polynomic trend line.
For statistical analysis t-, Pearson- or Linear-Trend-tests were used. A p>0,001 was considered to be significant.

RESULTS

Epidemiology
Between 1985 and 2004 (20 years) 18352 traffic accidents including injured persons were collected. 20816 of those were motorbike or car drivers (tab. 1). Of all drivers 2602 (12.5 %) obtained less than two years prior the accident and were considered as novice drivers. Those were divided to 1614 car- and 233 motorbike novice driver and compared to 11750 car- and 729 motorbike-drivers that had a driver licence longer than 2 years at the time of the accident. The average age of all accident victims was 37.2 (15–97) years. The average age of novice driver at the time of the accident was 23.7 years versus 39.1 within the subpopulation of experienced drivers. The significant younger novice driver sustained significant more often in the earlier years (1993.8 versus 1995.4). In total young (<25 years) and old drivers (>65) were identified for being at higher risk in a liability curve (fig. 1). For novice car drivers (tab.1) a mean age of 23.7 +/- 9.0 was calculated. 69.0% were male. The experienced car drivers were in mean 39.5 +/- 15.1 years old. 67.7 % were male. Gender difference was between novice and experienced drivers not significant for all car drivers. Significant more male drivers had accidents in experienced motorbike riders. For novice motorbike riders a mean age of 23.7 +/- 8.3 was calculated and 79.1% were male. The experienced motorbike drivers were in mean 31.7 +/- 9.8 years old and 90.1% were male.

Car-drivers
Accident circumstances
Novice drivers had significant more often accidents on rural roads than inside cities compared to experienced car drivers besides that more than 2/3 of all accidents occurred out of town (tab. 1). Only every twentieth accident happened on highways. Non significant less often novice drivers were guilty (5.7 vs. 6.7 %). About 2/3 of all accidents were during daylight time, but nonetheless even here novice car driver were significant over represented during dusk or dawn. Novice drivers had accidents during all week days when experienced ones had significant more often accidents during working days. Cars of

novice drivers were significant older than those of experienced car drivers (mean values: tab.1). When examining the accidents causations significant more often skidding, excessive speed or overtaking were identified in novice drivers. In all novice drivers liability was significant more often identified, especially in solo accidents without participation of any other road user (471 Novice driver (16.9 %) vs. 1616 experienced drivers (7.4 %); tab.1, fig.1)). Safety devices like belts were significant less often used (4.5 % vs. 3.7 %) and alcohol affected the accident events more often than in experienced drivers (7.0 % vs. 4.9 %).

Injury severity
59 % (n=1263) of all novice car drivers were unhurt compared to the group of experienced drivers of 64.8 % (n=10572) (tab.2). Slightly injured (MAIS 1) were 33.9 % compared to 29.0 % experienced car drivers. Severely injured (MAIS 2–4) were 6.1 % versus 5.3 % of experienced drivers and worst injured (MAIS 5 und 6) were 0.6 % versus 0.4 %. Novice driver were overall significant more often and severe injured than the experienced ones. Of all car drivers head injuries were observed in 574 (19.3 %) novice drivers versus 3071 (14.0 %) and neck injuries 389 (15.7 %) versus 2790 (15.8 %) experienced drivers (fig. 2). Thorax injuries were seen in 381 (12.8 %) versus 2674 (12.4 %) and abdomen 110 (3.4 %) versus 707 (3.0 %) experienced drivers. Pelvic injuries were recorded in 115 (3.5 %) versus 558 (2.2 %) experienced drivers. Extremity injuries were for the upper counted with 380 (13.7 %) injured novice drivers versus 1948 (9.0 %) and lower 359 (12.3 %) versus 2073 (9.3 %) experienced drivers. For head, pelvis, upper and lower extremity significant differences were demonstrated.

Motorbike-riders
Accident circumstances
Novice drivers crashed more often on rural roads than inside cities compared to experienced car drivers but not significant and near 80 % of all accidents happened on residential or urban streets (tab. 1). More accidents were recorded during daylight, but the difference was not significant. During the week accidents were recorded on an equal level, while a non-significant peak was observed for experienced drivers on weekends (Fr-Su).
After analyzing accidents causations there were no significant differences. In novice driver a significant higher liability was demonstrated (tab 1). A helmet protection was not worn by every 20th victim. Alcohol influenced less often the crash incidence than in car drivers without significant differences in both subgroups.

Injury severity
59 % (n=1263) of all novice motorbike riders were not injured compared to 64.8 % of the experienced (n=10572) (tab. 2). Lightly injured (MAIS 1) were 62.9 % versus 63.2 % of all experienced motorbike drivers. Severe injured (MAIS 2–4) were 23.4 % of novice drivers compared to 28.7 % of the experienced. Worst injured (MAIS 5 and 6) were 1.1 % of all riders in both groups. In this group experienced riders were significant more often and severe injured than novice riders. When analyzing body regions 68 (15.1 %) versus 222 (15.2 %) of all experienced riders had head and neck injuries in 24 (5.5 %) compared to 100 (9.1 %) (fig. 3). Thorax injuries were observed in 77 (20.8 %) novice drivers versus 334 (28.7 %) and abdominal injuries were in 22 victims (47.7 %) compared to 106 (8.0 %). Pelvic injuries were demonstrated in 53 (17.2 %) of novice drivers versus 176 (17.2 %). Extremity injuries were more often seen in novice drivers: upper 138 (47.7 %) versus 470 (44.9 %) experienced motorbike riders and lower 218 (73.7 %) compared to 712 (68.7 %). A significant difference could not be demonstrated for any body region in the subgroups.

Technical parameters
In the group of car drivers a remarkable portion of severe injuries (MAIS 2-4) were observed only above a delta-v of 30 km/h (fig. 4). Up to a delta-v of 50 km/h car accidents could be experienced without any injury. Above a delta-v of 70 km/h worst injuries could be expected. In motorbike riders severe injuries could be seen even below a low collision speed less than 30 km/h in 20% of all accidents (fig. 5). An

increase of 30 km/h in relative speed showed no significant severer injuries. The risk to be severely injured was higher in older cars. In new cars (<3 years) 66.9 % of drivers were not injured, 27.5 % light injured (MAIS 1) and 4.8 % severe injured (MAIS 2-4). In old cars (> 9 years) 63.0 % of all drivers were not injured, 30.3 % light injuries (MAIS 1) and 5.8 % severe injuries (MAIS 2-4). The injury severity increased in relation to the age of the car continuously.

DISCUSSION

Already in the 1970s a higher risk for novice drivers in road traffic was identified [10]. Young adults involvement in car accidents are above the average in Germany [3]. In the literature a high risk acceptance especially in young male in addition to overestimating their own driving abilities and low driving experience is discussed [11]. A lot of protective measurements were initiated to lower accident rates. Attended driving or the driver's licences on trial are actual examples. The age to obtain a car licence was reduced to 17 after promising results of a trial [12].

In this study it was possible to generate a liability curve (fig. 1), in which young and old drivers were identified to be at higher risk. For novice drivers being inexperienced and overestimation were factors, while the older showed longer reaction times and lower perception indicating a higher risk in fatality analyses [13]. Despite not investigating psychological factors in this study, those are important factors in accidents [14]. For older drivers a not significant elevated risk could be demonstrated in the literature above a designated annual driving distance (more than 14000 km) [15]. Furthermore it is known that this subpopulation has the lowest accident rate per licence, but otherwise show the lowest rate of use as well. Overtaking, skidding and high speed could be identified in this study to be significant parameters in novice car drivers' accidents. That is the reason why a good education of traffic participants is mandatory for prevention [16]. Higher punishment for novice drivers or general speed limits until a sufficient experience could be preventive measurements. When analyzing day and week times a focus could be identified for novice drivers during night time and weekends. Because of an unknown exposition profile the cause of the higher risk could only be estimated [1]. But during that time so called „disco drivers" are on the road. Novice drivers are driving significant often older cars. Those cars are in general types of the compact class and are often not equipped with modern safety devices like ABS, ESP or other electronic stability programs. An additional measurement could be not exposing novice drivers to technical low equipped cars. The modification of the interior and exterior design was already identified to be effective protection in cars [2, 17, 18]. The injury severity in cars is basically determined by the collision circumstances like impact angle and delta-v which is the change of velocity at the collision time as a basic force indicator. Car occupants are moving in relative vectors inside the cars. In case of a collision the car is slowing down and the people inside are restrained by belts for car parts, which could induce injuries. In frontal collisions and additional use of belts higher delta-vs are necessary for injuries than for side collisions. Next to injury foci like the head, extremity injuries are pointed out in novice drivers. In contrast motorbike riders showed fewer injuries but a relative higher extremity injury rate. A lack of discipline using elementary safety devices like protection suites or helmets is present, too. In contrast the effectiveness was demonstrated often and needs not to be discussed [19, 20, 21]. The safety belt advantage is accepted to be best of all passive safety devices. Due to this knowledge a mandatory usage is required by law since 1983 for all car drivers.

Measurements like attended driving and higher punishments for driving under alcohol or drug influence and special education courses could be successful. The high risk profile above a designated age must be outlined. Next to speed, skidding and overtaking could be identified being risky situations. A psychological training against overestimation and special skidding courses (ADAC) could be preventive measurements. Such an education could be useful to become more experienced in border line situations. But those should only be conducted to learn special rescue manoeuvres. Some behaviour seems to be only influenced on a low level despite a broader education nowadays. Integrative concepts could be useful to lower accident rates in road traffic.

Novice drivers are still at a high risk. Safety devices are often unused despite the technological advantages of the modern systems. The car's age seems to be important in reference to the victim's injuries. This study has highlighted some new and old facts about road traffic-related accidents of novice drivers. Advanced strategies must be developed to provide effective injury prevention. Despite the fact that we have shown a reduction in injury prevalence, the medical and socio-economic consequences of novice driver's accidents is high. It is therefore of paramount importance to continue to push for advances in car safety design.

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Table 1: Epidemiology and accident circumstances in cars and motorbikes

n (%)		Novice car driver	Others car	Significance (p>0,001)	Novice motorbike rider	Others motorbike	Significance (p>0,001)
Accidents, injured drivers		2312	17193		290	1021	
Sex	male	1614 (69.0 %)	11750 (67.7 %)	n.s.	233 (79.1 %)	925 (90.1 %)	s.
Age		23,7 +/- 9,0	39,5 +/- 15,1	s.	23,7 +/- 8,3	31,7 +/- 9,8	s.
Accident site	Urban	1419 (69.2 %)	11344 (73.8 %)	s.	208 (79.7 %)	729 (78.8 %)	n.s.
	Rural	740 (25.2 %)	4369 (19.5 %)	s.	78 (18.8 %)	234 (17.1 %)	n.s.
	Autobahn	153 (5.7 %)	1480 (6.7 %)	n.s.	4 (1.5 %)	58 (4.2 %)	n.s.
Time	Day	1417 (63.7 %)	12084 (72.2 %)	s.	210 (73.4 %)	789 (79.5 %)	n.s.
	Night	728 (29.2 %)	3901 (21.2 %)	s.	59 (20.2 %)	163 (14.0 %)	n.s.
	Dusk/Dawn	166 (7.1 %)	1195 (6.5 %)	s.	18 (6.0 %)	67 (6.1 %)	n.s.
Day	Mo-Thu	1260 (55.5 %)	10493 (61.3 %)	s.	172 (61.1 %)	557 (55.5 %)	n.s.
	Fr-Su	1052 (44.5 %)	6700 (38.7 %)	s.	118 (38.9 %)	464 (44.5 %)	n.s.
Vehicle age	0-3	268 (11.4 %)	3574 (21.0 %)	s.	80 (26.9 %)	243 (23.8 %)	n.s.
	4-6	286 (12.4 %)	3323 (19.3 %)	s.	61 (20.7 %)	175 (18.1 %)	n.s.
	7-9	457 (20.4 %)	3024 (17.5 %)	s.	35 (12.2 %)	105 (10.6 %)	n.s.
	9+	958 (41.0 %)	4528 (26.5 %)	s.	37 (13.0 %)	175 (18.2 %)	n.s.
Accidentcausation (yes/no)	Skidding	510 (19.2 %)	1801 (8.5 %)	s.	63 (20.3 %)	190 (17.7 %)	s.
	Speed	767 (30.0 %)	3853 (19.9 %)	s.	102 (29.8 %)	347 (30.0 %)	n.s.
	Distance	100 (5.2 %)	728 (4.8 %)	n.s.	17 (7.7 %)	58 (5.8 %)	n.s.
	Overtaking	110 (3.6 %)	544 (2.8 %)	s.	30 (10.5 %)	101 (9.2%)	n.s.
Liability	Yes, alone	471 (16.9 %)	1616 (7.4 %)	s.	52 (16.6 %)	186 (15.2 %)	n.s.
	Yes	889 (41.4 %)	6482 (39.9 %)	s.	63 (22.4 %)	157 (15.1 %)	n.s.
	No	948 (41.5 %)	9056 (52.4 %)	s.	174 (60.9 %)	675 (69.5 %)	n.s.
	Unknown	4 (0.2 %)	39 (0.3 %)	n.s.	1 (0.1 %)	3 (0.2 %)	n.s.
Usage of restraint devices	no belt/helmet	115 (4.5 %)	674 (3.7 %)	s.	17 (6.1 %)	62 (6.5 %)	n.s.
Influence alcohol/drugs		196 (7.0 %)	976 (4.9 %)	s.	15 (3.8 %)	57 (4.2 %)	n.s.

Table 2: Injury severity of car drivers and motorbike riders

n (%)	Novice car driver	Others car	Significance (p>0,001)	Novice motorbike rider	Others motorbike	Significance (p>0,001)
not injured	1263 (59.0 %)	10572 (64.8 %)	s.	27 (11. 8%)	65 (6.4 %)	s.
MAIS 1	742 (33.9 %)	4756 (29.0 %)	s.	146 (62.9 %)	517 (63.2 %)	n.s.
MAIS 2	192 (4.8 %)	1146 (4.2 %)	n.s.	69 (18.0 %)	271 (21.6 %)	n.s.
MAIS 3	53 (1.0 %)	305 (0.8 %)	n.s.	28 (4.5 %)	111 (6.0 %)	n.s.
MAIS 4	14 (0.3 %)	105 (0.3 %)	n.s.	6 (0.9 %)	22 (1.1 %)	n.s.
MAIS 5	17 (0.3 %)	90 (0.2 %)	n.s.	7 (0.9 %)	14 (0.6 %)	n.s.
MAIS 6	20 (0.3 %)	96 (0.2 %)	n.s.	4 (0.5 %)	11 (0.4 %)	n.s.
unknown	11 (0.5 %)	121 (0.5 %)	n.s.	3 (0.6 %)	10 (0.7 %)	n.s.
Head injury	574 (19.3 %)	3071 (14.0 %)	s.	68 (15.1 %)	222 (15.2 %)	n.s.
Neck injury	389 (15.7 %)	2790 (15.8 %)	n.s.	24 (5.5 %)	100 (9.1 %)	n.s.
Thorax injury	381 (12.8 %)	2674 (12.4 %)	n.s.	77 (20.8 %)	334 (28.7 %)	n.s.
Upper extremity injury	380 (13.7 %)	1948 (9.0 %)	s.	138 (47.7 %)	470 (44.9 %)	n.s.
Abdomen injury	110 (3.4 %)	707 (3.0 %)	n.s.	22 (47.7 %)	106 (8.0 %)	n.s.
Pelvic injury	115 (3.5 %)	558 (2.2 %)	s.	53 (17.2 %)	176 (17.2 %)	n.s.
Lower extremity injury	359 (12.3 %)	2073 (9.3 %)	s.	218 (73.7 %)	712 (68.7 %)	n.s.

Figure 1: Liability curve in relation to the age of traffic participants with polymeric trend line

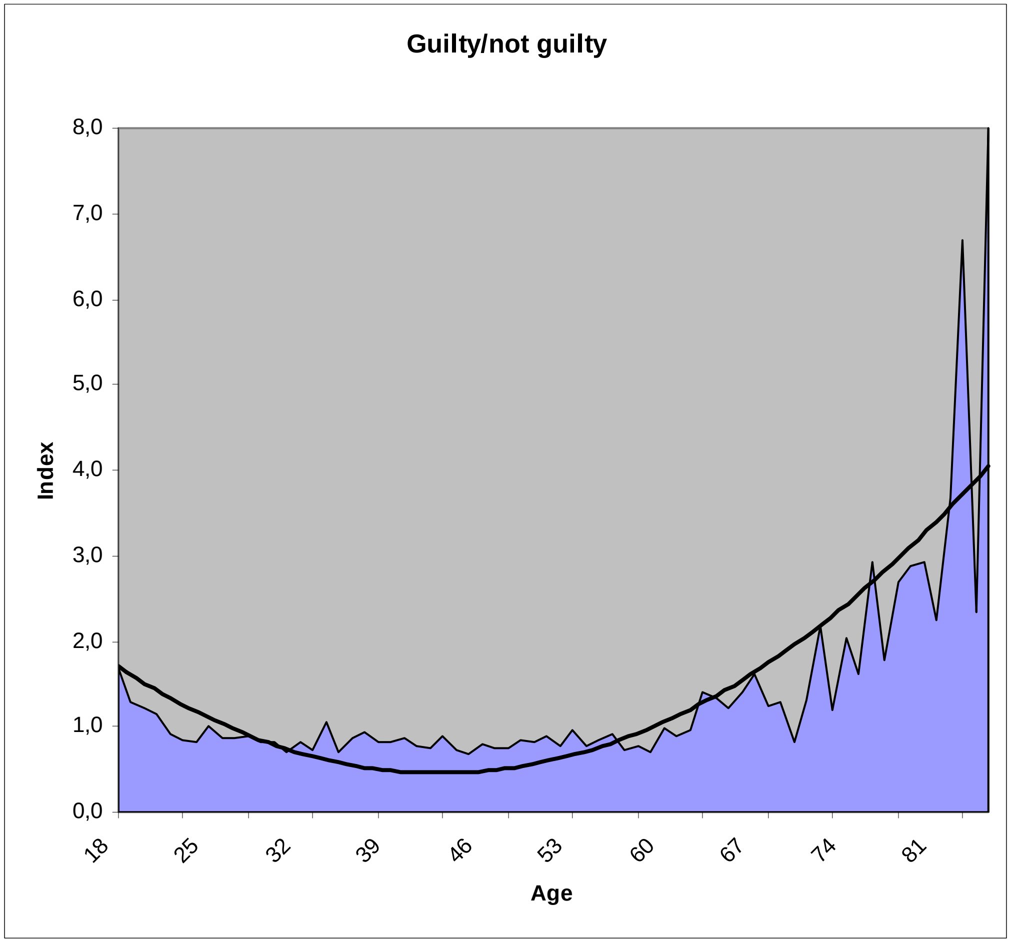


Figure 2:

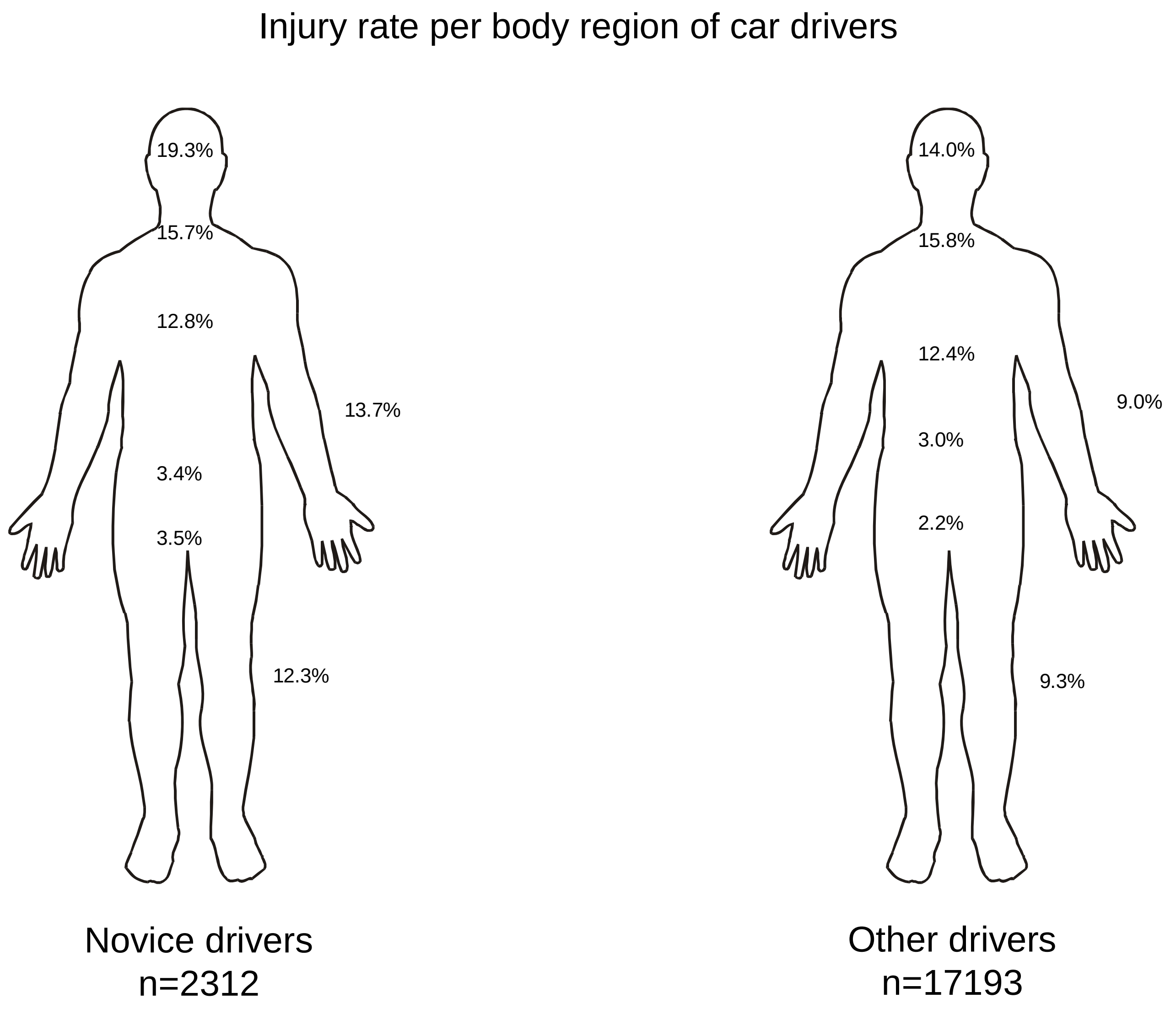
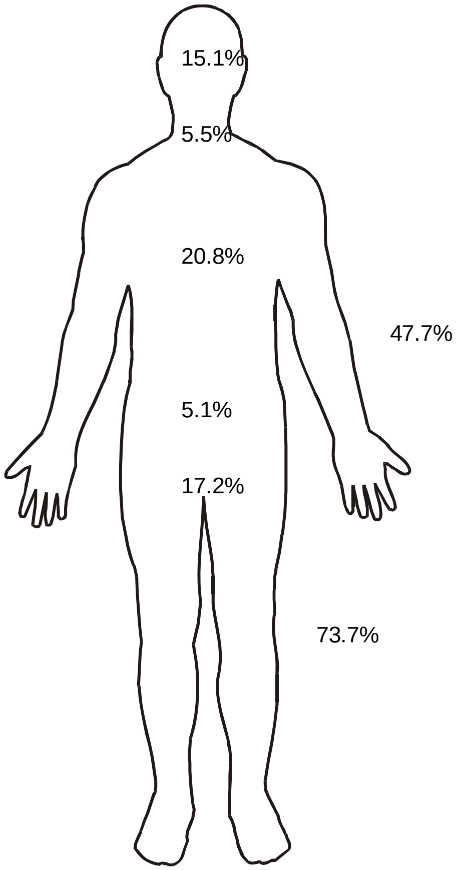
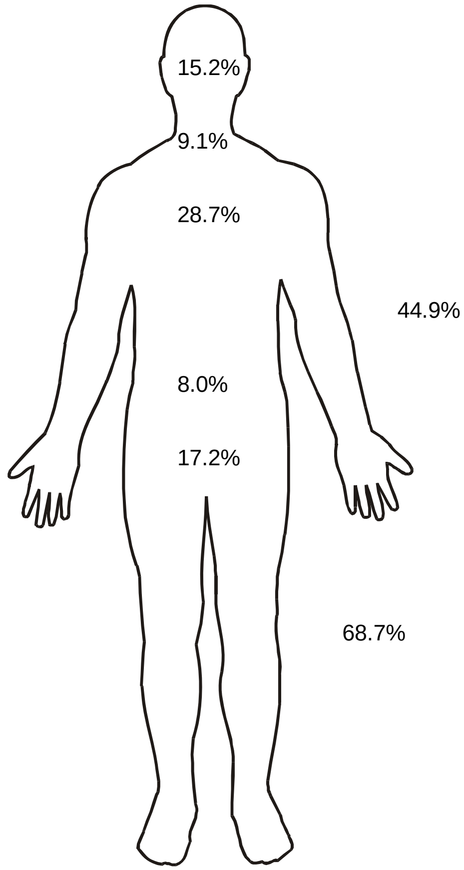


Figure 3:

Injury rate per body region of car drivers

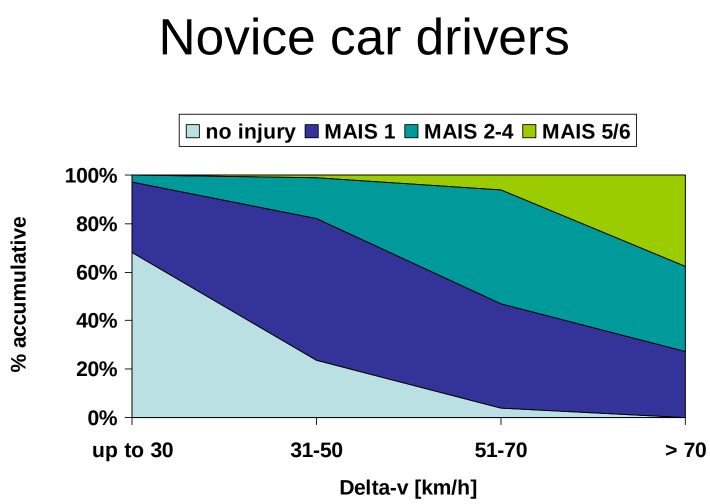


Novice riders
n=290



Others
n=1021

Figure 4:


Novice car drivers
no injury
MAIS 1
MAIS 2-4
MAIS 5/6
100%
80%
60%
40%
20%
0%
% accumulative
up to 30
31-50
51-70
> 70
Delta-v [km/h]

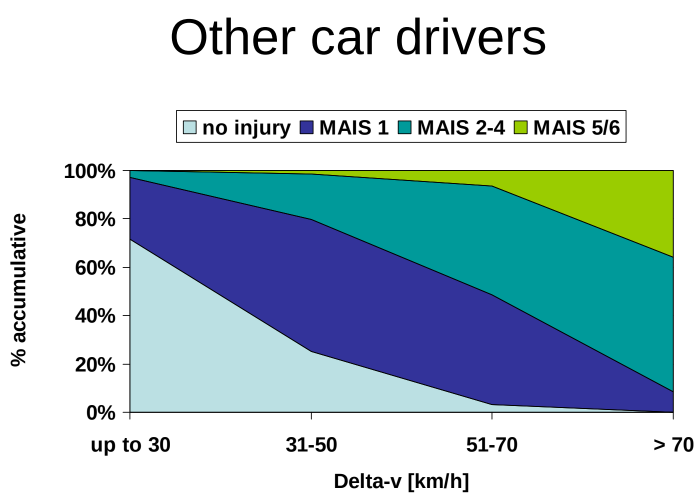
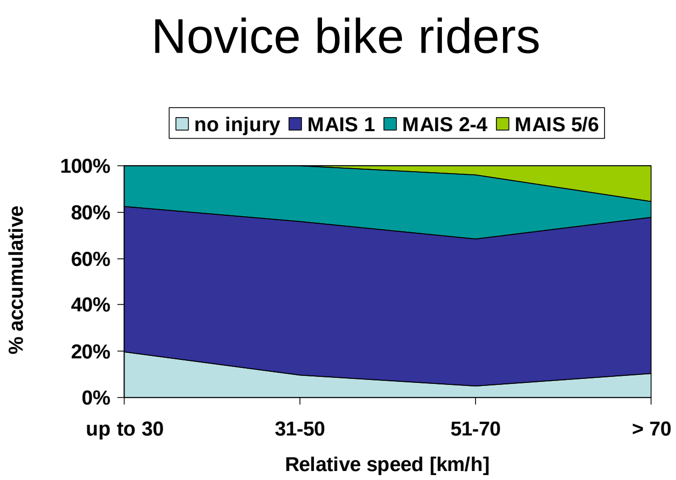
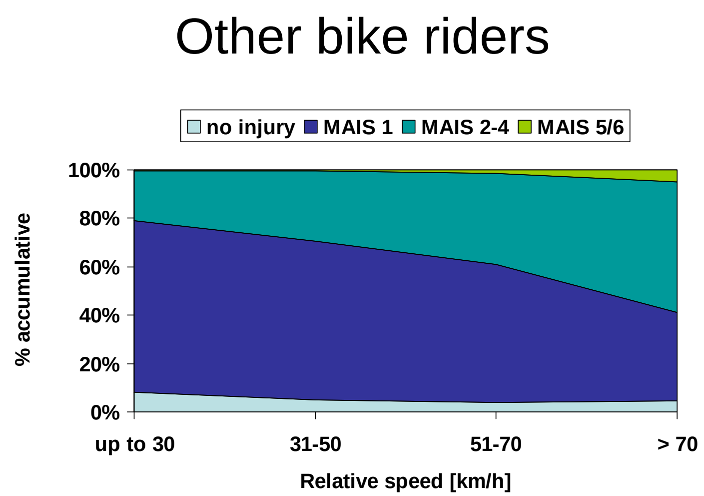

Other car drivers
no injury
MAIS 1
MAIS 2-4
MAIS 5/6
100%
80%
60%
40%
20%
0%
% accumulative
up to 30
31-50
51-70
> 70
Delta-v [km/h]

Figure 5:


Novice bike riders
no injury
MAIS 1
MAIS 2-4
MAIS 5/6
100%
80%
60%
40%
20%
0%
% accumulative
up to 30
31-50
51-70
> 70
Relative speed [km/h]


Other bike riders
no injury
MAIS 1
MAIS 2-4
MAIS 5/6
100%
80%
60%
40%
20%
0%
% accumulative
up to 30
31-50
51-70
> 70
Relative speed [km/h]

Emergency Medical Care in case of traffic accidents in Bavaria: Actual process analysis in reference to clinical and rescue service structures

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Abstract
A change emerges in hospital landscape due to health political measures, which in consequence also influences the pre-clinical medical care of emergencies. The main focus of this study was to gather information about emergency medical care after traffic accidents on the basis of data of Bavarian emergency medical services. In Bavaria, in 2006 it was necessary to call an emergency doctor in the case of 14.261 traffic accidents. Predominantly the patients were provided by land-based life saving appliances, air rescue services were only applied in 19.1 % of the cases. 47.6 % of patients being involved in a traffic accident were transported into a primary health care hospital. A prehospital interval of more than 60 minutes was calculated in 20 % of emergency care. 96.2 % of the patients were transported to hospitals of tertiary or maximum supply by air rescue services. The life saving appliances' readiness for action is however restricted to daylight. A further limitation appeared for routine office hours in hospitals: Only 36.7 % of accidents occurred in this time frame. An increase of hospitalizations in clinics of maximum supply appeared from 2002 until 2006 while simultaneously the prehospital period was extended. To assure a sufficient medical care of seriously injured persons further on, a fulltime and area-wide expostulation of efficient facilities is necessary. For this purpose it is necessary to establish regional trauma networks as well as emergency medical service at night time. Beyond that, a cost efficient compensation of the structural, personnel and logistic expenses has to be assured.

BACKGROUND

In the Federal Republic of Germany 422.337 persons, injured in consequence of a traffic accident, were registered in 2006. In most instances car owners were affected. The survival rate for traffic accidents could be increased as result of medical progress, due to improvements of emergency medical services and also because the active and passive protection systems in cars could be raised continuously. Many patients, who earlier would have died at the place of accident, now reach the clinic as seriously injured persons. It is crucial for the medical treatment result to be successful in taking the patients quickly to an adequately equipped hospital preferably within the first 60 minutes after the accident. In this context the terminus "golden hour disease" is used.
By the introduction of DRG-based payment for hospital services, a process of change in the hospital landscape was initiated. Publications mention the reduction of hospital locations as well as the privatization of hospitals and the tendency to establish centres of excellence as possible consequences. In addition, a specialization in most profitable hospital services as well as a negligence of emergency medical care and a reduction of stand-by duty, bed capacity and length of stay. Furthermore, an insufficient coverage of the treatment expenses caused by severely injured persons, by persons with a long residence time, by emergencies, as well as by relocated patients can be stated.
In regard to the pre-clinical medical care, the following changes can be expected due to close-downs of hospitals and emphases on centres of excellence: a reduction of emergency headquarters, an extension of length of transport, an increased deployment of vehicles and of emergency physicians and their assistants and also an accumulation of the secondary transports. Sufficient medical care of emergencies close to their residence is made difficult because many small-sized hospitals are not able to maintain emergency medical care to the full extent as costs are not covered adequately.
So far there is no analytical study which determines emergency medical care after traffic accidents in reference to clinical and rescue service structures. This study was performed to determine emergency medical care in case of severe traffic accidents in Bavaria.

METHODS

Statistical database of this review were data of all emergency medical care services carried out by all 26 Bavarian rescue coordination centres. The analysis of the actual emergency services after severe traffic accidents resulted from data of 2002 until 2006. For the analysis of process of change data material from

2002 until 2006 was taken as a basis. For the registration of the processing parameters starting from the incoming emergency call until the return of the life saving appliances to their headquarters, Bavarian rescue coordination centres apply disposition programmes like ARLISplus and ELDIS. The Institute for Emergency Medicine and Management in Medicine, INM (attached to the clinical centre of the university of Munich), prepares, analyses and combines the correspondent data with further data (data from the central clearing house for emergency medical services in Bavaria, from private health care providers and from providers for acute transports and air rescue services). The data as a whole allow a complete illustration of the entire emergency medical care events.
All traffic accidents were extracted from the complete data pool. The next step of the present study was a restriction on traffic accidents, which made at least one emergency doctor necessary. In the analysed period (01.01.2002 until 31.12.2006) 77.458 traffic accidents with the need of an emergency doctor and 120.835 traffic accidents without that were documented. The present study classifies the first group as “severe”, the second group as “light” accidents. The analysis of the study is based on the database management system Access TM and on the statistic and analytic software SPSS. The further data preparation was done by the spreadsheet program Excel as well as by the geographical information system ArcGIS, produced by ESRI.

RESULTS

Geographical and temporal spreading of severe traffic accidents in 2006

In 2006, 14.261 severe traffic accidents with the need of emergency care occurred in Bavaria.
Within the 25 cities in Bavaria enjoying county status, 2.834 (19.9 %) accidents were documented, within the 71 administrative districts, 11.427 accidents (80.1 %) were documented. The capital cities Munich (462), Nuremberg (422), Augsburg (283) and Regensburg (226) as well as the administrative districts Passau (340) and Traunstein had a comparatively high accident volume. A relatively small number of severe traffic accidents were documented in the administrative districts Kronach (79) and Lichtenfels (77) as well as in the city Memmingen (36). As expected, the quantity of severe traffic accidents correlated significantly positive with the population figure of the respective regional corporation (r=0,708; p 0,001).
In Weiden, (1.92) and Regensburg (1.75), both cities enjoying county status, as well as in the administrative districts Berchtesgadener Land (2.18), Bad Tölz – Wolfratshausen (1,96) and Traunstein (1,90), the number of severe traffic accidents per 1.000 habitants was comparatively high. Most of the traffic accidents happened indeed in Munich, but related to the population figure, the statistical value of 0.37 pro 1.000 inhabitants had though the lowermost level. Analogically, the administrative district of Munich with a population of 306.182 inhabitants and a number of 171 severe traffic accidents had a relatively low statistical value of 0.56 accidents pro 1.000 inhabitants. The administrative districts Fürstenfeldbruck and Miltenberg also showed a low statistical value of 0.71, respectively 0.73 pro 1.000 inhabitants.
A concentration of the administrative districts and towns of county status, which had high statistical values, predominantly appeared in the more rural regions in the South and East of Bavaria. In densely populated areas like Munich, Nuremberg and Neu-Ulm as well as in such areas in Unterfranken, the number of severe traffic accidents pro 1.000 inhabitants was on a lower level (cp. map 1).
A further step in 2006 was to analyse the severe traffic accidents, documented in the Bavarian rescue coordination centres, in regard to their temporal disposition (illustration 1).

Map 1: number of severe traffic accidents pro 1.000 inhabitants based on data of Bavarian administrative districts and independent cities in 2006 (N = 14.261 inhabitants)

A further step in 2006 was to analyse severe traffic accidents, documented in the Bavarian rescue coordination centres, with regard to their temporal disposition (illustration 1).

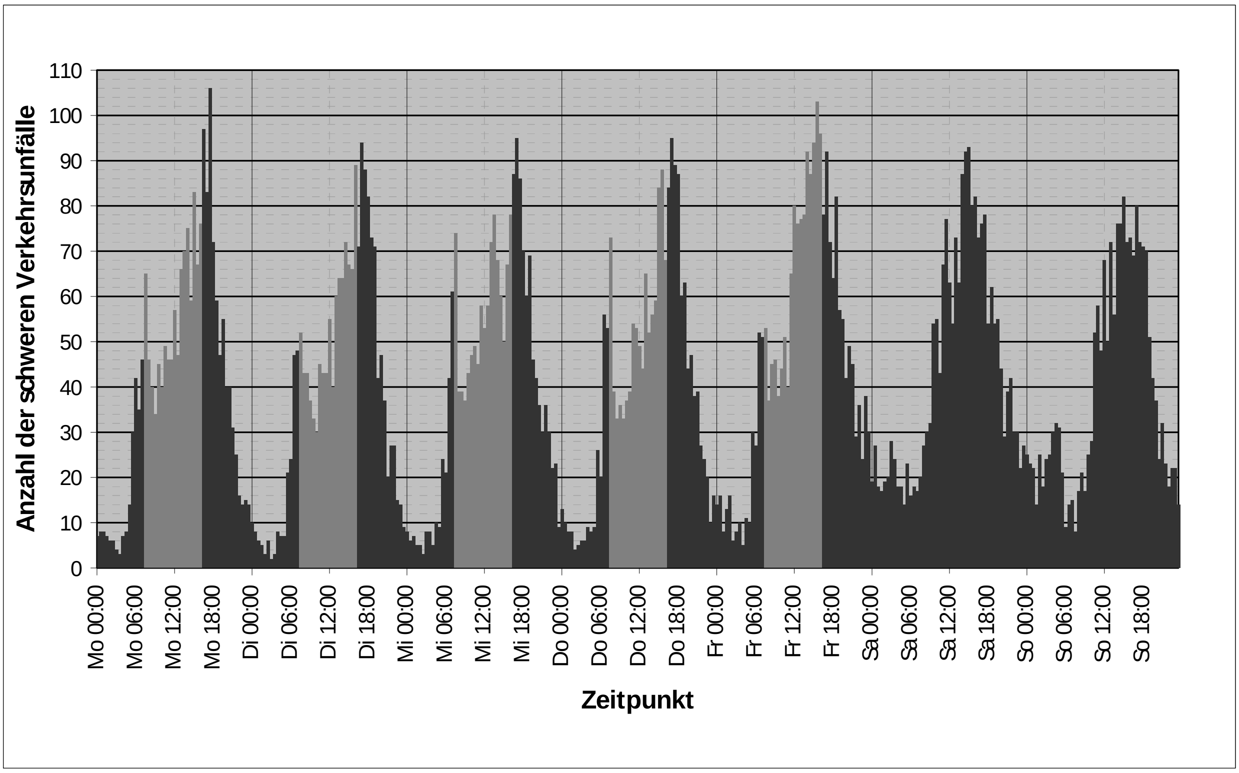


Illustration 1: Temporal disposition of accidents during the course of day and week in Bavaria in 2006 (N=14.003 events; N=258 events without sufficient documentation of time)

Illustration 1 shows a maximum in the course of the day between 05.00 and 06.00 p.m.
All days of the week compared with each other show that most traffic accidents happen on a Friday. Furthermore, an increase of severe traffic accidents during night-time can be proved for the nights from Friday to Saturday and from Saturday to Sunday.
In addition, a categorization was made to the effect whether severe traffic accidents occurred within routine office hours or off-peak. The period between 7.30 a.m. and 5.30 p.m. from Monday until Friday was defined as routine office hours (cp. illustration 2).

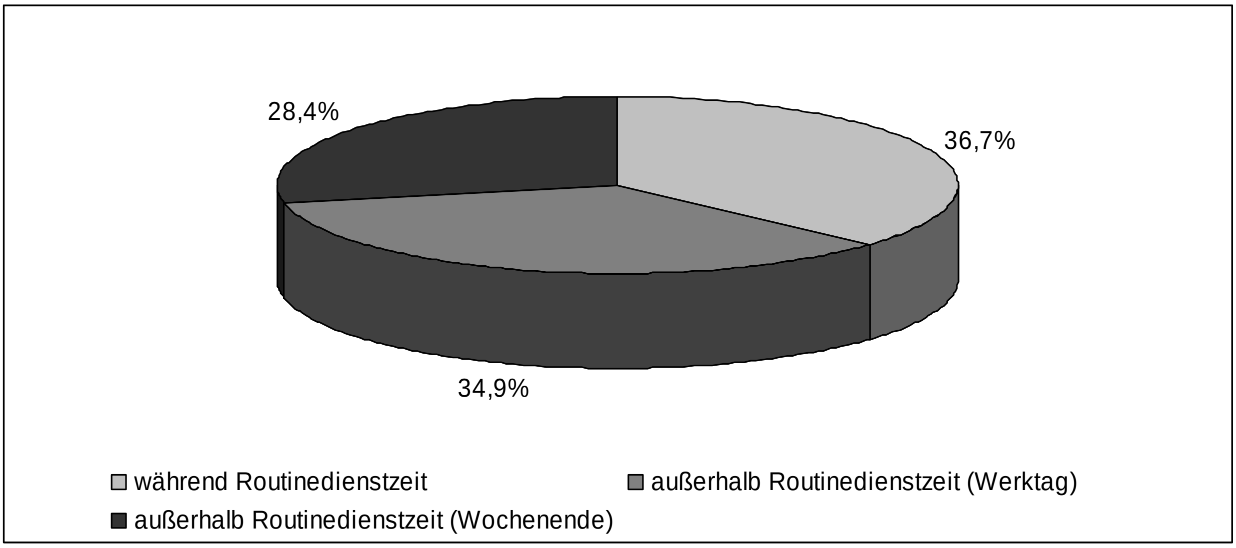


Illustration 2: percentage of events during and beyond routine office hours in hospitals in Bavaria in 2006 (N=14.003 events; N=258 events without any documentation of time)

36.7 % of all severe accidents in Bavaria happened during routine office hours, when all special departments in the clinics were well-staffed. Outside routine office hours, special departments are normally not occupied, which means that the clinic staff, which is on call, has to be ordered to the hospital in case of emergency. On weekdays from Monday until Friday 34.9 % of the accidents occurred during leisure and night time, off routine office hours. Further 28.4 % were registered on the weekends. Altogether 63.3 % of severe traffic accidents occurred during availability time of the clinics.

Target hospitals

The Bavarian rescue service had to hospitalize 17.146 patients being injured in 14.261 traffic accidents documented in 2006. If these patient transports are differentiated with reference to the care level of the targeted hospital, it appears that the majority of the patients (47.6 %) after a severe traffic accident were taken to a hospital of basic medical care. 31.6 % of patients were hospitalized in tertiary care clinics and further 20.4 % were taken to hospitals of maximum care level. The decision to pick a hospital of a higher care level proved to be independent of the time of the accident (p=0,284).

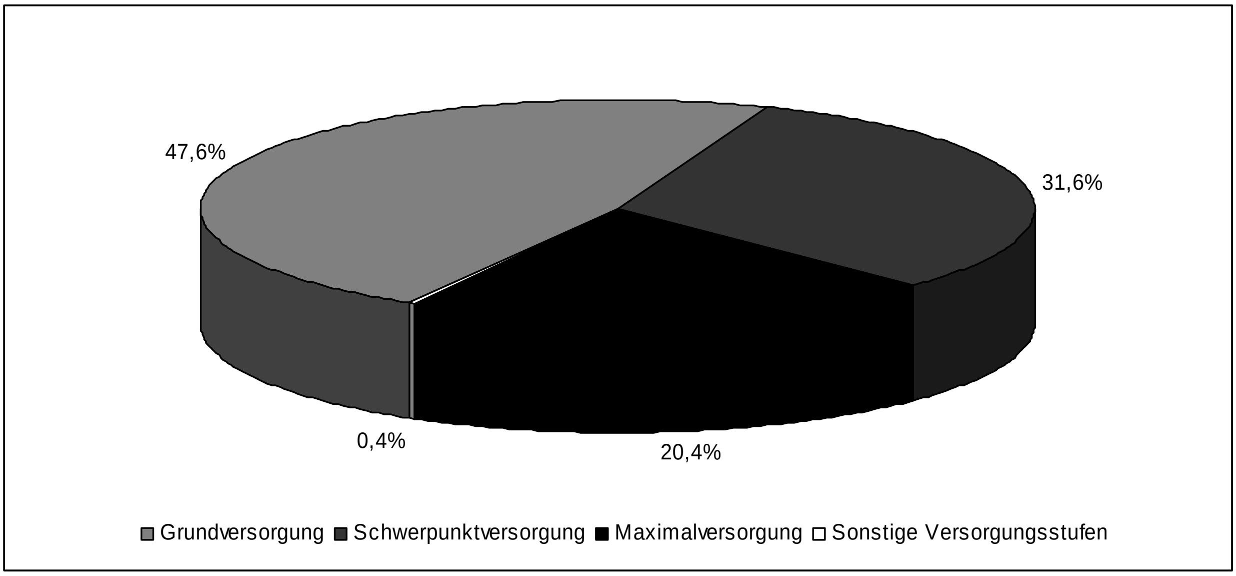
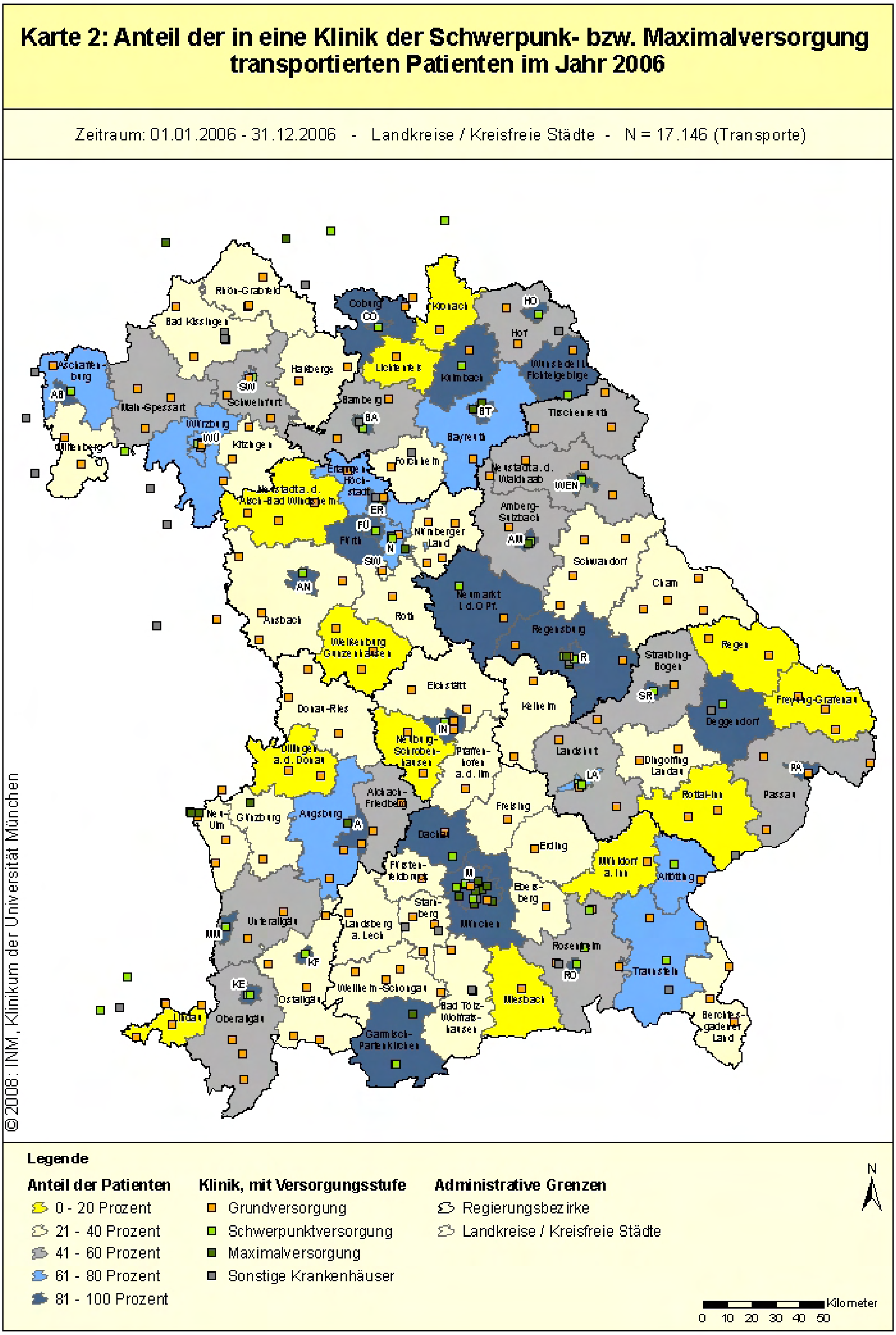


Illustration 3: Medical care levels of selected target hospitals in case of severe traffic accidents in Bavaria in 2006 (N=17.146 transports)

Hospitals with less than 100 hospital admissions were at a rate of 64.3 % facilities of basic medical care. In contrast, clinics with at least 100 hospital admissions after severe traffic accidents were tertiary care clinics or maximum care providers. Hospitals of a superior medical care level normally had a higher quantity of hospital admissions ($p<0.001$).

Map 2 illustrates the rate of patients per administrative district and per independent city, who were transported in a clinic of tertiary of maximum care. As an average value it could be proved that in independent cities 85.4 % of tertiary or maximum medical care hospitals were chosen, for the administrative districts a value of only 44.7 %.arises



Map 2: Number of patients being transported to a hospital of tertiary or maximum care in 2006

Involved life saving appliances

In Bavaria in 2006 averaged 3.1 operating resources and life saving appliances were disposed in case of a severe traffic accident. These were primarily land-based life saving appliances: in 97.6 % of the cases at least one ambulance vehicle (RTW) was involved in emergency care, in 84.2 % a rapid response unit (NEF) was needed. Air rescue services (RTH/ITH), which were applied in 19.1 % of the cases followed by far. The least share of 3.8 % could be determined for the emergency ambulance (NAW).
Clear differences appear when air rescue services are compared to land based services concerning their designated hospitals and their medical care level (cp. illustration 4).

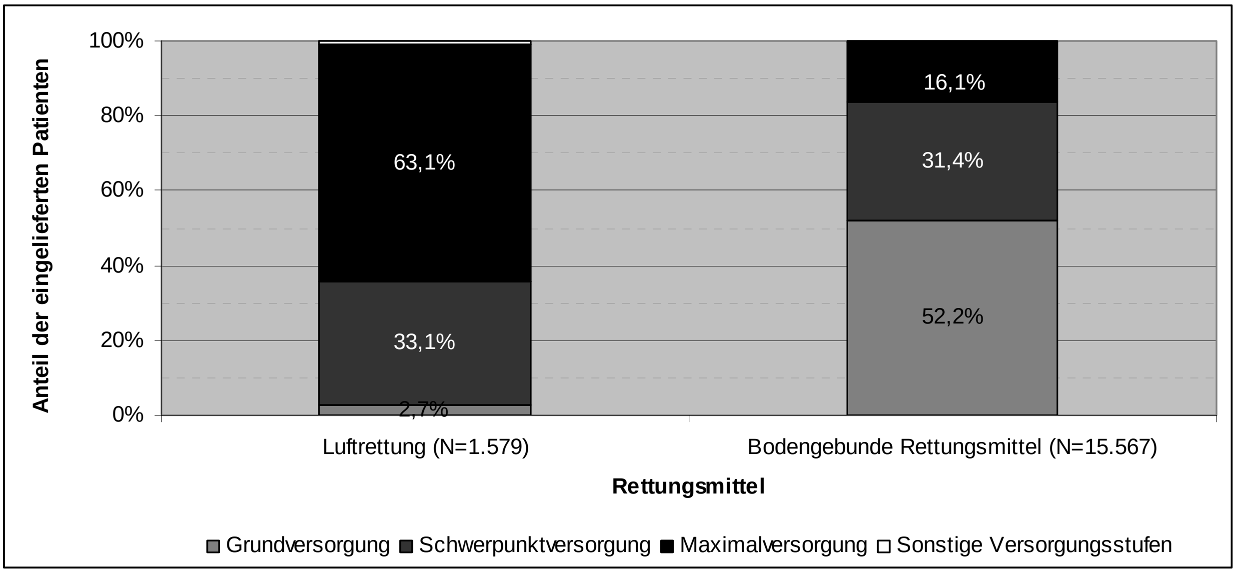
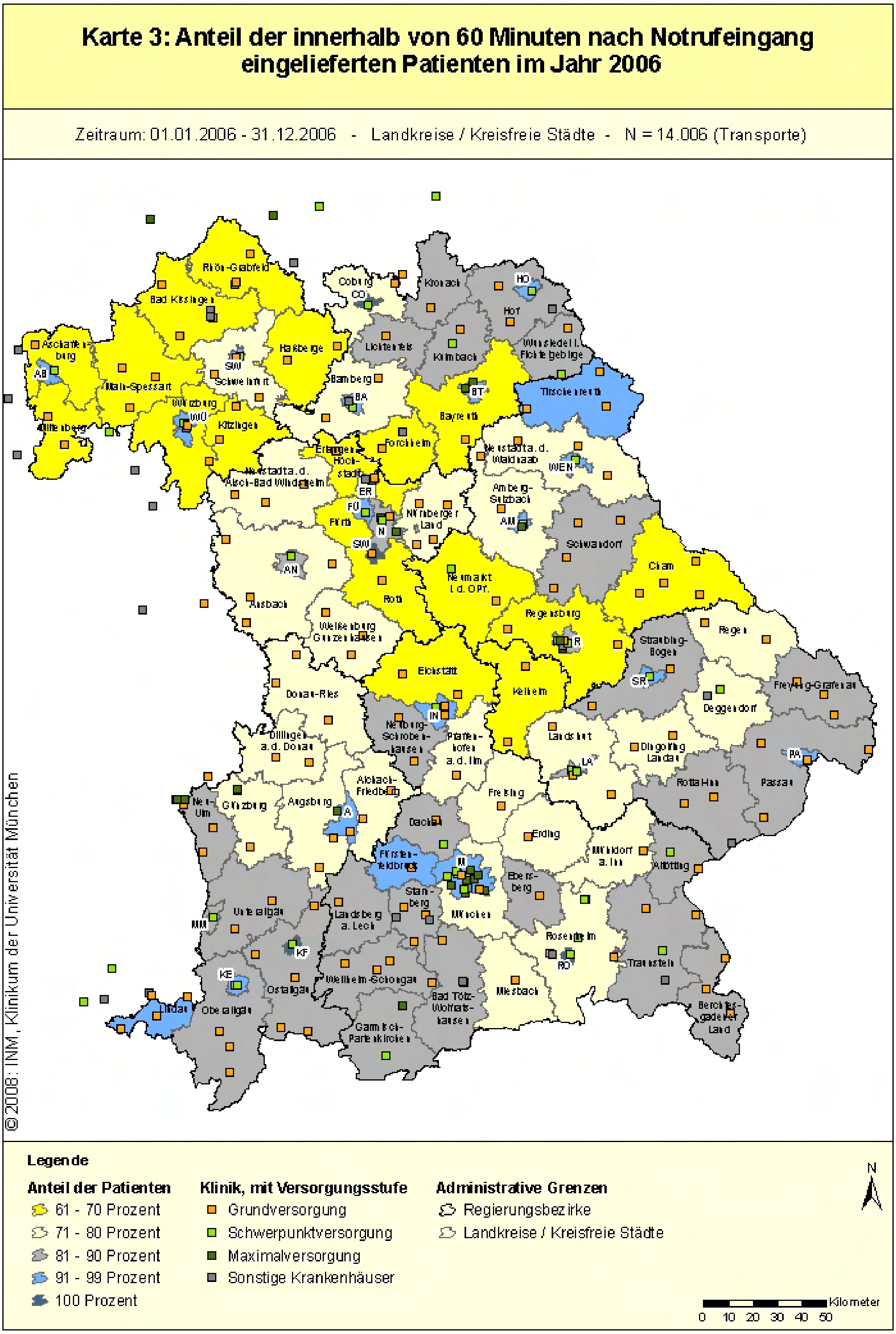


Illustration 4: medical care levels of target hospitals by transports with land based life saving appliances and air rescue services in Bavaria in 2006

96.2 % of patients were transported to hospitals of tertiary or maximum care by air rescue services. Only 2.7 % of the patients were hospitalized in clinics of primary care. 47.5 % of patients were taken to clinics of both superior levels, tertiary and maximum care. By land-based life saving appliances only 47.5 % of patients were taken to hospitals of superior levels, while 52.2 % were hospitalized in primary health care clinics. According to the analysis, air rescue services had a clear preference for hospitals of superior levels ($p<0,001$).

Pre-clinical time – compliance with the golden hour

Averaged pre-clinical time based on Bavarian rescue services data, was in 2006 at an average of 46 minutes and 22 seconds. The result for the independent cities was an average value of 38 minutes and 18 seconds, for the administrative districts a value of 48 minutes and 22 seconds ($p<0.001$).
The request for compliance with the “golden hour” is only fulfilled in 80.0 % of the cases. In 20 % of the cases, patients were hospitalized more than 60 minutes after emergency call. The independent cities had an average value of 91.7 %, the administrative districts of 77.1 % (map 3).



Map 3: number of patients being hospitalized in 2006 within 60 minutes after emergency call

Development from 2002 until 2006

In the period from 2002 until 2006, the total number of traffic accidents provided by Bavarian rescue services, was reduced from 42.130 events in 2002 to 37.715 events in 2006 (rate of 10.5%). The number of light road traffic accidents decreased in this period about 5.0 %, the number of severe traffic accidents decreased about 18.3 %. Thereby the relation changed for the benefit of easy traffic accidents from 58.6 % in 2002 to 62.2 % in 2006. For the independent cities and the administrative districts a decrease of severe traffic accidents in 90 regional corporations and an increase in 6 regional corporations occurred.
In 2002, altogether 22.607 patients were transported to 299 different hospitals after severe traffic accident. In 2006, 17.146 patient transports after traffic accidents to 278 different hospitals were documented.
The number of patients being transported to hospitals of superior care levels has increased continuously since 2002 (cp. illustration 5). In comparison with 2002, maximum care hospitals have documented an increase of 4.3 %, tertiary care clinics an increase of 1.3 %.

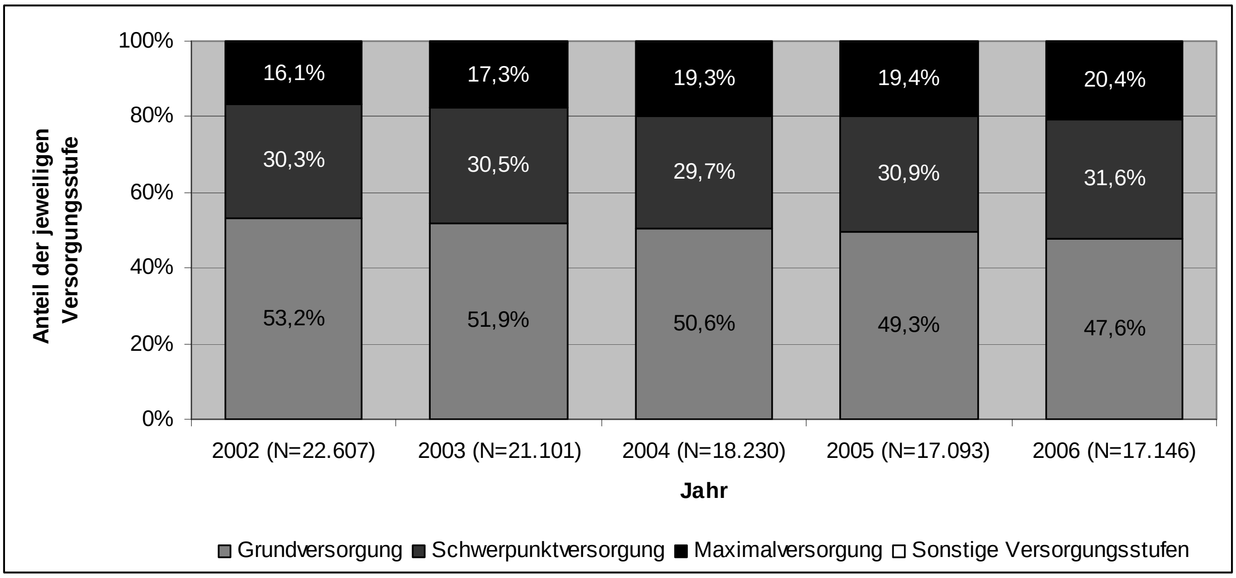


Illustration 5: Change of shares of care levels in target hospitals from 2002 until 2006

In 2006, a transport from place of accident to a target hospital after traffic accident in Bavaria took on average 12 minutes and 36 seconds, which means that this period is 50 seconds longer than in 2002. In the independent cities of Bavaria, duration of transport had an increase of 37 seconds, in the administrative districts an increase of 53 seconds.
In the same period, the prehospital interval starting from the incoming emergency call until the arrival at the target hospital was extended for 2 minutes and 14 seconds in the independent cities, in the administrative districts of Bavaria for averaged 1 minute and 55 seconds**.**

Discussion

Extensive effects on clinical structures and as a consequence also on the rescue services are induced by the implementation of the health care reform as well as by the gradual initiation of a case-based payment system for hospital services since 2003. The reorganization of the hospital landscape takes also a considerable influence on trauma management system in Germany. Concerning area-wide presence, it can be assumed that regulatory and financial framework induces a reduction of about one third of the facilities being involved in trauma management. These developments mean a special challenge for prehospital care, because –nevertheless- the system has to cope with the postulation for compliance with the “golden hour” rule. The efficiency analysis of the described effects on hospital landscape and pre-clinical care resulted in this study on the basis of data of the Bavarian emergency medical services from 2002 until 2006. The evaluations consider the collective of severe traffic accidents and are not conferrable to other emergency situations.
The available study was focused on traffic accidents with the need of emergency care. One has to bear in mind, however, that emergency doctors sometimes are being called because of an imprecise emergency call, although the patient’s state of health doesn’t require medical care.

These false assignments couldn't be excluded from the analysis. The individual disposition behaviour of the staff of the rescue coordination centre can also be a decisive factor for an emergency doctor's call. Although the Bavarian indication checklist regulates in which cases the rescue service team has to be supported by an emergency physician, this decision is nevertheless determined by experience, medical and tactical considerations and by subjective interpretation of the emergency call.

Geographical and temporal spreading of the road traffic accidents

In 2006, 11.427 severe traffic accidents were registered in the Bavarian administrative counties (population of 9.0 million people). This signifies 1.28 severe traffic accidents pro 1.000 habitants. In the independent cities with a population of 3.5 million habitants and 2.834 severe traffic accidents, we have 0.81 events per 1.000 inhabitants. For this reason 80.1 % of severe traffic accidents occurred in the administrative districts and only 19.9 % occurred in the independent cities of Bavaria. These results are in accordance with data of the Bavarian State Office for statistics and data handling [17], which prove that severe traffic accidents occur frequently on country roads. Reasons for that are a stringent traffic regulation and a slowing down of maximum speed within the cities as well as a disproportionate traffic volume. Furthermore different types of roads as well as touristy influences have to be considered. As expected, the number of severe traffic accidents correlated in the present study positively with the number of inhabitants per Regional Corporation. Here, the independent cities Munich and Nuremberg were an exception, because for these cities a far higher number of severe accidents could have been expected.

The evaluation of the temporal spreading proved that the daily maxima on weekdays from Monday until Thursday came along with usual working time, were thus related to rush-hour traffic. The absolute maximum was registered between 5:00 p.m. and 6:00 p.m. and lies therefore beyond routine office hours of hospitals, which are also called standardized working hours and contain the period from Monday until Friday from 07:30 a.m. until 5:30 p.m.

During that period, only 36.7 % of severe traffic accidents occurred, while 63.3 % occurred beyond these standardized working hours. Furthermore, one has to bear in mind, that approximately one third of all accidents and hospitalizations took place at the weekend which lies to the full extent beyond standardized working hours. It is possible that severely injured patients, who are taken to hospital beyond routine office hours, suffer damages because specialized units are not staffed and further clinical therapy is not possible because the doctors on duty had to been ordered to the hospital at first [18]. An efficient pre-clinical medical care which has to be continued seamlessly in the clinic is essential for the prognosis of the patients. The committal of the patient from emergency physician to the clinic should be flawless and induce a rapid admission diagnose and assignment to the adequate specialized unit [19]. An extension of the standardized working hours would be desirable, but seems to be almost impossible because of economic factors. Therefore the establishment of interdisciplinary full-time emergency units would be a reasonable and adequate alternative. The implementation would cause a permanent organizational performance structure with a permanent staff of doctors, carers and nurses from anaesthetics, surgery and internal medicine as well as from neurology if necessary. To guarantee an area-wide supply all over Bavaria, 300 interdisciplinary emergency units would be necessary. These emergency units should be regarded as independent units within the clinic [19]. By these central hand-over points delays could be avoided and the availability of the resources of the rescue service could be re-established in very short time [20].

Life saving appliances and target hospitals

For the increase of survival chances and a minimization of the effects of the injury, it is ideal if patients are transported into a local clinic of tertiary or maximum care with sufficient capacity for definitive medical treatment [5, 21-24]. Because of the dominating clinic structures this is not always possible. The evaluations proved that 47.6 % of patients in 2006 were transported to a primary health care clinic, 31.6 % to a hospital of tertiary care and 20.4 % to a hospital of maximum care. An adequate medical treatment of most severely injured persons was possibly therefore not given, because nearly half of the patients were not hospitalized in a clinic of the two superior care levels. There were also significant differences between the independent cities and the administrative districts of Bavaria: persons being injured within the district of an independent city were transported to a hospital of tertiary or maximum care in 85.4 % of the cases, within the administrative districts this value is 44.7 %. Furthermore, the analysis demonstrated that in 82.6 % of the cases, clinics with less than 100 hospitalizations in 2006 were clinics of primary health care or of other medical care levels. In contrast, clinics with more than 100 hospitalizations were tertiary or maximum care providers at a rate of 66.7 %. That means that primary health care hospitals frequently had a slightly falling number of injured patients and as an after-effect had less experience and also a shortfall in medical equipment.

In the administrative districts rescue services are more frequently forced to decide between a longer duration of transport to a suitable clinic and a shorter duration of transport to a primary health care hospital. In this context enormous differences could be proved between air rescue services and land-based appliances: In 96.2 % of the cases the injured patients were taken to a tertiary or maximum care hospital by rescue helicopters, while only 47.5 % of the patients being transported by land-based rescue service appliances were taken to those facilities. Therefore, this study could also confirm the clear advantages of air rescue services on the choice of the designated hospital [22, 25]. In this context it has to be considered that regular flight disposition of air rescue services is limited to daylight interval at the moment. Analyses of the nationwide trauma register published by the German College of Trauma Surgery (DGU) proved however that the accident severity does not differ essentially during day- and night time. Even if the commitment of a flying ambulance would be reasonable from the medical point of view, severely injured patients have to be transported by land-based life saving appliances at night because air rescue services were not available. The available collected data showed that for the medical care of the patients primarily land-based life saving appliances had to be chosen. Air rescue service was only ordered in 19.1 % of severe traffic accidents. Besides the use of appropriate life saving appliances, an adequate medical treatment of the patients and the choice of the suitable clinic, the compliance with the “golden hour”, is a further essential factor to influence the outcome of severely injured patients [3, 19]. Invasive therapy measures in the first 30 to 60 minutes after the trauma can contribute to an important decrease of the lethality- and morbidity rate, so it should be aspired to hospitalize the patients within one hour after the accident has happened. The longer the pre-clinical interval extends, the more one has to assume a prolongation of the period a patient has to remain in the intensive care unit. Furthermore there is danger of an extended rehabilitation period or of permanent secondary damages.

The analysis of the individual patient transports could prove deficiencies in the medical emergency care with respect to compliance with the “golden hour” norm. 20 % of the transported patients couldn’t be taken to hospital within the demanded 60 minutes. These drawbacks could mainly be proved for the regional corporations which border directly to independent cities which in turn have facilities of maximum care. In this context, a possible drawback because of an extended pre-clinical time was subordinated to the advantages of a hospital of superior care level. Altogether, 91.7 % of patients being injured within the district of independent cities were transported to a hospital within a maximum period of 60 minutes; analogous value in Bavarian administrative districts was 77.1 %.

Changes of clinical structures

The German Hospital Federation anticipates nationwide a closure of 330 hospitals (about 15 % of all hospitals) [5]. Besides that, the introduction of the DRG-system induces an increasing specialization of the clinics in preferably profitable areas. Based on the DRG-system, numerous studies show that it can not be worked therapeutically with especially severe injured patients in a cost-covering way [26]. Cost calculations based on G-DRG Version 2005 show a shortfall between 3.500 and 5.000 € per severe injured patient in dependence on the annual rate of treatment per facility [5]. Thereby primarily smaller clinics won't have the possibility in future to maintain the acute medical care to a full extent. Emerging localization and specialization tendencies on centres of excellence will have an impact on local emergency care [8, 11, and 20]. On the other hand, these specializations are also an advantage if increased quality in medical care can be achieved. The establishment of centres of excellence and the localization of complex performances are seen as a target of health policy. The number of smaller and less efficient hospitals shall be dramatically reduced by this [9]. The present analysis proves that first effects can already be pictured empirically. By the analysis of the care levels of all target hospitals between 2002 and 2006 an increase of hospitalizations in clinics of tertiary and maximum care could be proved. It must be considered, however, that in 2006 nearly every second patient was taken to a primary health care hospital after a severe traffic accident. Especially in rural regions which do not own a hospital of maximum care, it has to be decided frequently between the quickest possible transport to a nearby hospital of a lower care level or a longer transport to a hospital of superior care level. This problem is being complicated additionally by changes in the hospital landscape, because the rescue services in the concerned areas are forced to cover longer distances to reach more suitable clinics [20]. Thereby resulting transport times have the effect that patients are exposed to greater dangers and emergency physicians are bounded to rescue missions for a longer period because they normally have to accompany the transport. The search for a suitable transport target is going to be more difficult in future because hospitals near to living areas will cease to exist ([8, 10, and 11]. This study could prove an increase of pre-clinical time of averaged 2 minutes and 15 seconds in the district of independent cities and about 1 minute and 52 seconds in the Bavarian administrative districts. This increase also signifies an extended deployment to rescue mission. 80 % of the injured patients were hospitalized in the designated hospital within one hour after the emergency call was answered in the rescue coordination centre. To avoid life-threatening consequences by the accident, there is only a very limited time slot for seriously injured patients. Therefore, the demand for compliance with the "golden hour" rule is compulsory. To recognize and balance possible structural deficiencies, there is a need of continual scientific evaluation of the present changes.

Conclusion

To guarantee medical care of seriously injured patients at the highest level in future and within the framework of Trauma networks D, a close interaction between facilities of different medical care levels becomes more important [8, 27]. For an efficient coordination and the ideal use of available resources, an intensive cooperation between facilities of primary, tertiary and maximum care becomes much more significant. Furthermore, a cost-suitable compensation of the structural and logistic expenses as well as of personnel costs resulting from treatment of seriously injured persons has to be assured [5]. This implicates also the remuneration of emergency doctors. A further strategic concept concerns the extension of the office hours of air rescue services, which, especially in regions lacking in infrastructure, offer advantages because of higher speed and because they come along with a larger deployable radius. The advantage of air rescue services is the free choice of the target hospital. The transformation process of public health system, initiated in the last years, has a gradual impact on pre-clinical medicine and requires continuous scientific support.

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A Prospective and Interdisciplinary Study on Polytraumata in Traffic Accidents

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ABSTRACT

While many medical studies have dealt with the incidence, nature and treatment of polytrauma the injury-causing accident mechanisms are rarely discussed in detail, mostly due to the lack of documentation of the technical aspects. The present prospective study was started in late 2007 and collects data from traffic accidents with most severely injured in six south-German counties and two larger cities for the duration of one year. It is aimed at identifying and documenting all polytrauma cases (ISS $\geq$ 16) caused by traffic accidents and their crash circumstances. The data collection is based on an interdisciplinary concept to include both the police, emergency dispatch centers, hospitals and fire departments in the region and is completely anonymous. Potentially relevant cases where an emergency physician was called to the scene of a traffic accident are provided by the dispatch center. All three hospitals in the region suited for the treatment of polytraumatised patients record injuries, major diagnostic and surgery data. Data and images from the accident scene are provided by the police and by fire departments. The latter provide information which is usually not available from the police, like deployed airbags, vehicle extrication measures and detailed views of car interiors. The main objective of the study is to determine the structure of road users who sustain a polytrauma, their crash opponents and the injury patterns found in relation to the collision configuration and the protection by seat belts, air bags and other devices. With detailed documentation of vehicle damage and extrication measures the study is also intended to support the development of injury predictors for pre-hospital treatment and provide field data regarding further improvement of technical rescue.

INTRODUCTION

In 2004, the German Highway Research Institute (Bundesanstalt für Straßenwesen BASt) presented the results of a pilot study that looked at the incidence rate of most severe injuries in traffic accidents [1]. The German statistics on road accidents do not use this term since only slightly injured (out-patient treatment of accident victims), severly injured (in-patient treatment for at least 24 hours) and fatalities (accident victims who deceased within 30 days after the accident) are defined. BASt described most severely injured as being those accident victims who – due to the severity and kind of their injury – bear a high risk of long-term or even permanent disability. Official statistics of the most severely injured from road traffic accidents do not exist in Germany, they are included in the number of seriously injured, according to the authority's definition. For the purpose of the pilot study, hospital diagnosis statistics, national statistics for the disabled and the trauma registry of the German Society for Trauma Surgery (Deutsche Gesellschaft für Unfallchirurgie DGU) were analysed. Based on these figures, BASt could not find a decrease in the number of cases over a 9-year period. An earlier study by Busch [2] on the number of disabled as a result of traffic accidents was based on an analysis of German data from compulsory health and accident insurers. It was estimated that most severe, but survived injuries have a share of approximately 10 % among the seriously injured as defined by national accident statistics.

Often, such kinds of injuries occur in connection with a polytrauma. The annual number of most severely injured or polytraumata is not known, likewise their distribution among the different kinds of road users (pedestrians, cyclists, motor-cyclists, passenger car and heavy vehicle occupants) and the circumstances of the accident, like the kind of collision and seating position in motor vehicles are unknown. This could be a starting point to develop counter measures targeted at polytrauma.

EPIDEMIOLOGY OF POLYTRAUMA IN GERMANY

The incidence rate of polytraumata in Germany was estimated by Kühne et al. [3]. The number of polytrauma patients treated in 2005 in hospitals participating in the DGU trauma registry was extrapolated to all hospitals in Germany which provide maximum level trauma treatment. They concluded that Germany would see approximately 35,000 new polytraumatised patients annually, caused by work accidents, falls, traffic accidents or other injury mechanisms. Haas et al. [4] estimated this rate to be 32,500 annually. The white book for care of severely injured [5] quotes the annual report of the German Ministry of Labor [6] with the estimate that the number of most severely injured has declined during the past 10 years by 5 % in average. Liener et al. [7] determined the incidence of severe multiple injuries in the city of Ulm and the neighbouring county of Alb-Donau-Kreis in Germany in a retrospective study for the period from 1996 until 2000. Their sampling tried to collect all cases, no matter which mechanism caused the polytrauma. Based on the number of inhabitants in the study area the extrapolated rate for Germany yielded 18,700 polytraumatised patients which is significantly lower than the figures in other studies. Therefore, it was concluded that the accident rate in the study region was below average. The largest share among the causes for life-threatening multiple injuries were traffic accidents accounting for 59 % of the cases. Otte et al. reported in their comparative study of traffic accidents in the period of 1973 until 1978 and 1994 until 1999 that life-threatening injuries were present in almost all body regions in the earlier study period, but could be found mainly in the head and thorax region in the later period [8]. It was hypothesized that this change in injury pattern was caused by the progresses in the passive safety of modern vehicles. This would allow significantly higher collision energies to be survived than in the 1970's. However, immediate death at the accident scene would be more likely once these thresholds were exceeded.

Causes of most severe injuries in traffic accidents

As injuries and treatments in conjunction with a polytrauma are mostly well documented their incidence rate can be determined, especially when using the trauma registry of the German Society for Trauma Surgery (DGU) [9]. The outcomes of severe injury patterns are described by research in accident and rehabilitation medicine [10, 11]. Yet, for road traffic accidents, the detailed circumstances and the collision mechanism causing these injuries remain mostly unknown because it is difficult to determine and document these influential factors during the pre-hospital phase. Even completely filled-out emergency physician's protocols will usually not include detailed data on seating position, impact direction etc. The question to which degree modern occupant protection systems with air bags, belt pretensioner and force limiter or measures of pedestrian protection in a car can prevent such injuries are even harder to answer. Assessment of passive vehicle safety, on the other hand, relies mostly on standardised crash tests that utilize anthropomorphic test devices which represent the average adult in size and weight. Prediction of the incidence of certain injury patterns in real occupants is limited with the physical loadings measured on a crash test dummy. Due to the lack of suitable anthropomorphic test devices and a considerable test effort only little can be said about the injury risk for occupants in heavy vehicles and riders of motor-cycles and bicycles or pedestrians.

Interdisciplinary In-Depth Accident Research in Germany

Research at the scene of an accident which covers medical and technical issues is performed in Germany in the course of the German In-Depth Accident Study (GIDAS) by the Medical University of Hanover (MHH) and by the Technical University of Dresden in their surrounding areas [12, 13] and, to a smaller degree, at major German car manufacturers. The sampling in Hanover and Dresden includes all injury severities in principle, but shows some regional particularities like most accident research projects. For instance, the accident statistics for these regions reveal that severe collisions with involvement of motor-cycles or with heavy vehicles are underrepresented in comparison with other parts of Germany [14]. Investigations by car manufacturers usually take place in an area close to their R&D headquarters and focus on the newest car models of their own production. Often, the results are used only internally for the improvement of the crashworthiness of future models.

OBJECTIVE OF PRESENT STUDY

This research effort is designed as a multi-center, interdisciplinary study based on a prospective documentation of all polytrauma cases caused by traffic accidents in a defined geographical region. Accidents are recruited for the study when they occur in public space and when at least one of the accident victims sustained life-threatening multiple injuries. This could be any kind of traffic participant if some sort of vehicle is involved, too. This is in line with the definition used for the German accident statistics.

Beside the most important descriptors of the polytrauma patients like age, sex etc. and their injuries the technical parameters (e.g., equipment and type of air bag and seat belt, vehicle mass) and the circumstances of the collision (e.g., kind of road user, impact direction, collision opponent, depth of occupant compartment deformation) and the use of restraints and protective gear (e.g., seat belt, motorcycle helmet) should also be documented. The study does not record which party was primarily at fault or which misconduct contributed to the collision.

Injuries and their treatment are described and classified on the basis of the hospital documentation and the emergency physician’s protocol. Single injuries should be coded according to the International Classification of Diseases ICD-10 [15], their severity according to the Abbreviated Injury Scale AIS-98. The total injury severity is described by the Injury Severity Score ISS.

In addition to these parameters, the following data are targeted for inclusion in the documentation from different sources:

- Time and place of accident
- Time needed for the medical staff and ambulance to reach the accident scene, duration of stay at the accident scene and transport to the hospital
- Target hospital, possible transfer to other medical facility and discharge of the patient
- Body mass and size of patient
- Pre-existing diseases
- Patient deceased in hospital
- Duration of treatment in intensive care unit (ICU) and in regular hospital care
- Vital parameters, especially those required for the calculation of the Trauma Injury Severity Score (TRISS) [16]
- Manufacturer and model designation, model year and body type of vehicles involved in collision
- Code of seat belt type for belted car or heavy vehicle occupants

STUDY POPULATION AND AREA

The data are collected in six counties and two larger cities in the southern part of Germany which form one coherent study region (see Fig. 1):

- County of Alb-Donau (-Kreis)
- City of Ulm

in the German state of Baden-Wurttemberg and

- County (Landkreis) of Günzburg
- County (Landkreis) of Neu-Ulm
- County (Landkreis) of Dillingen/Donau
- County (Landkreis) of Aichach-Friedberg
- County (Landkreis) of Augsburg
- City of Augsburg

in the German state of Bavaria.

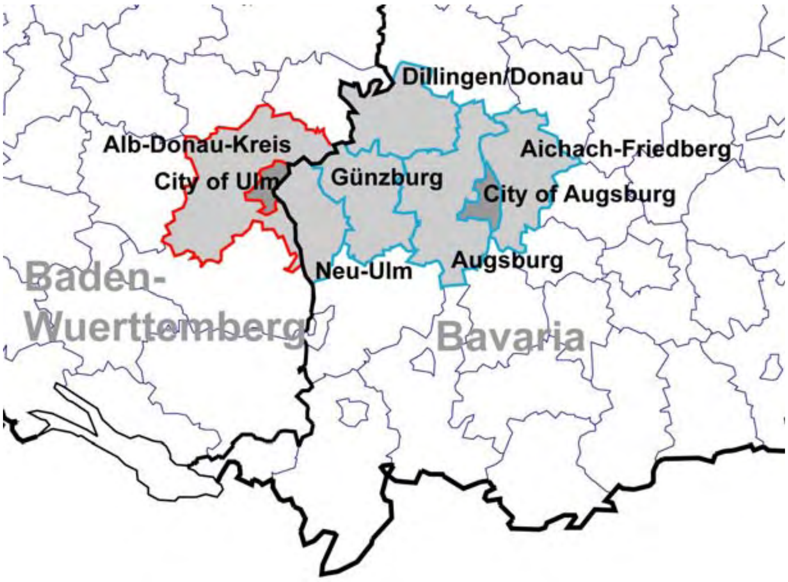

Figure 1. Counties and cities of the study region in southern Germany

The study region covers an area of 5545 km^2 with approximately 1.32 million inhabitants [17, 18] and ranges from urban areas to very rural regions with a low population density. Apart from all kinds of inner-city and country roads the study region features several major highways and two motorways (Autobahn) crossing it in the east-west and north-south direction. With a considerable amount of traffic volume on these roads it can be expected that all relevant kinds of traffic participation will be included in accident data from the study region.

Three regional emergency dispatch centers cover these eight administrative areas to answer medical emergency calls and to dispatch ambulances, emergency physicians and other means of medical rescue. They are located at the

- German Red Cross (DRK) dispatch center in Ulm (for the area of the city of Ulm and the county of Alb-Donau-Kreis)
- Bavarian Red Cross (BRK) dispatch center in Krumbach (for the area of the counties of Günzburg and Neu-Ulm)
- Dispatch center at the Augsburg Fire Department (for the counties of Dillingen/Donau, Aichach-Friedberg, Augsburg and the city of Augsburg)

Three large hospitals in the area are trauma centers suited for the treatment of polytrauma patients:

- University Hospital of Ulm (Universitätsklinikum Ulm)
- Hospital of the German Armed Forces in Ulm (Bundeswehrkrankenhaus Ulm)
- Augsburg Hospital (Klinikum Augsburg)

All other hospitals in the study region provide basic medical care [19] and are not equipped to handle severe multiple injuries. The Günzburg Regional Hospital, however, has a large neurological and neurosurgical department to treat isolated traumatic brain and spine injuries.

Therefore, it can be expected that the large majority of polytrauma patients from traffic accidents will be transported to one of the three aforementioned hospitals and treated in their emergency rooms. Data about patients’ injuries are collected from these three and the Günzburg Regional Hospital. However, a small number of victims may be brought to more remote trauma centers, especially by rescue helicopter. It is planned to collect these singular cases later in the project where persons sustained a polytrauma in a traffic accident within the study region, but were treated outside of it.

Pre-hospital care is provided by ground ambulance with an emergency physician joining the scene by car (so-called “rendez-vous” system) if the emergency call suggests so. A rescue helicopter is stationed at the Hospital of the German Armed Forces, Ulm, staffed by an emergency physician from the hospital, that is dispatched to urgent medical calls in an area of ca. 50 km radius around Ulm during daylight conditions. The region around Augsburg forms an area which is just touched by the response areas of this and three other rescue helicopters stationed in Ingolstadt, Munich and Murnau. The data collection started on November 1, 2007, and will continue at least until October 31, 2008. Based on the number of casualties from accident statistics for the respective counties and cities [20, 21, 22] and the factor determined by Busch approximately 110 most severely injured survivors can be estimated for the region annually.

Representativeness of study region

Based on statistical data for the counties and cities and for Germany as a whole, the study region was analysed regarding its representativeness. The average population density is 238.5 inhabitants per km^2 for the region and almost equals that of Germany (230.4 inhabitants per km^2) [17, 18, 23]. The density of the road network outside of built-up areas averages 0.64 km per km^2 for the region and 0.62 km per km^2 for Germany [24]. The shares of different road categories, ranging from motorways (Autobahn) to secondary roads, are also very similar to those in Germany although they sometimes differ significantly between individual counties.
The number of casualties (fatally, seriously and slightly injured) was determined from regional accident statistics for 2005 and 2006 for the respective administrative areas and compared with the German national statistics. Specific values were calculated for this purpose. Fatalities had a share of 1.8 to 1.9 % among the casualties in the study region (2005 and 2006) which was 0.3 % higher than the national level. The percentages of seriously injured and slightly injured were also very similar to those for entire Germany. A differentiation of these figures by urban and country roads and motorways provides a similar picture. The share of fatal injuries on urban roads in the study region was almost identical to that in Germany. The incidence of fatalities among all casualties was 0.4 % more frequent on country roads and approximately 0.6 % fewer on motorways compared to the national statistics. However, the small absolute number of victims killed on motorways in the study region (eight in 2005 and five in 2006) is not suited for a detailed statistical evaluation of accidents on this kind of road. When comparing the number of casualties per 1000 inhabitants it appears that the number of fatalities in the study region overestimates the situation for Germany (0.076 for the study region vs. 0.062 for Germany in 2006) and that for seriously injured the incidence is slightly underestimated (0.851 for the study region vs. 0.905 for Germany in 2006) (Fig. 2 and 3).

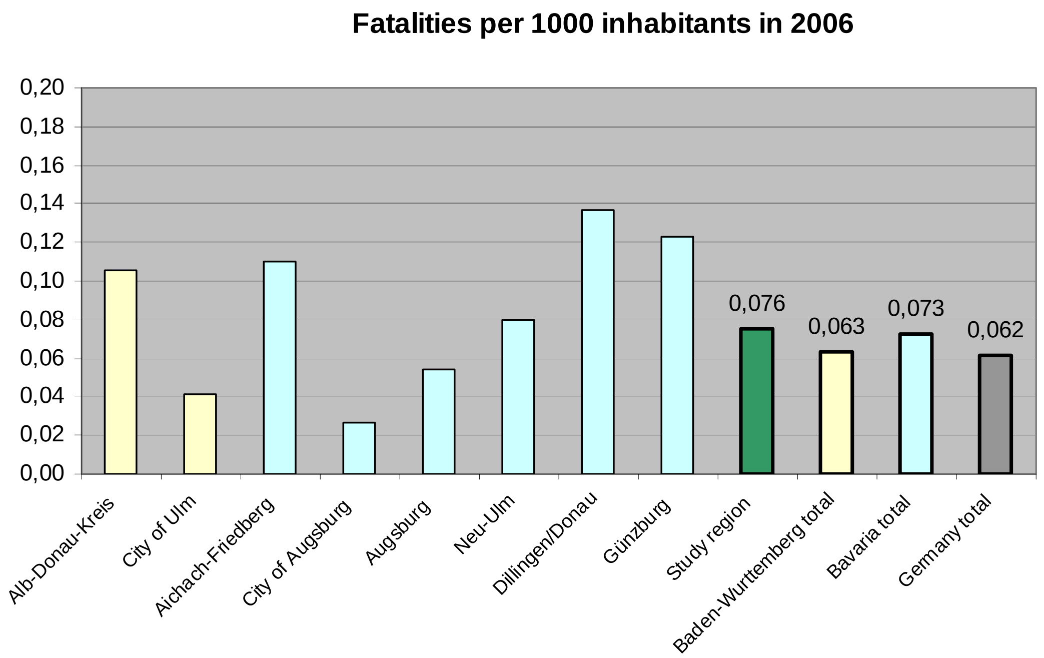

Figure 2. Incidence of fatalities per 1000 inhabitants

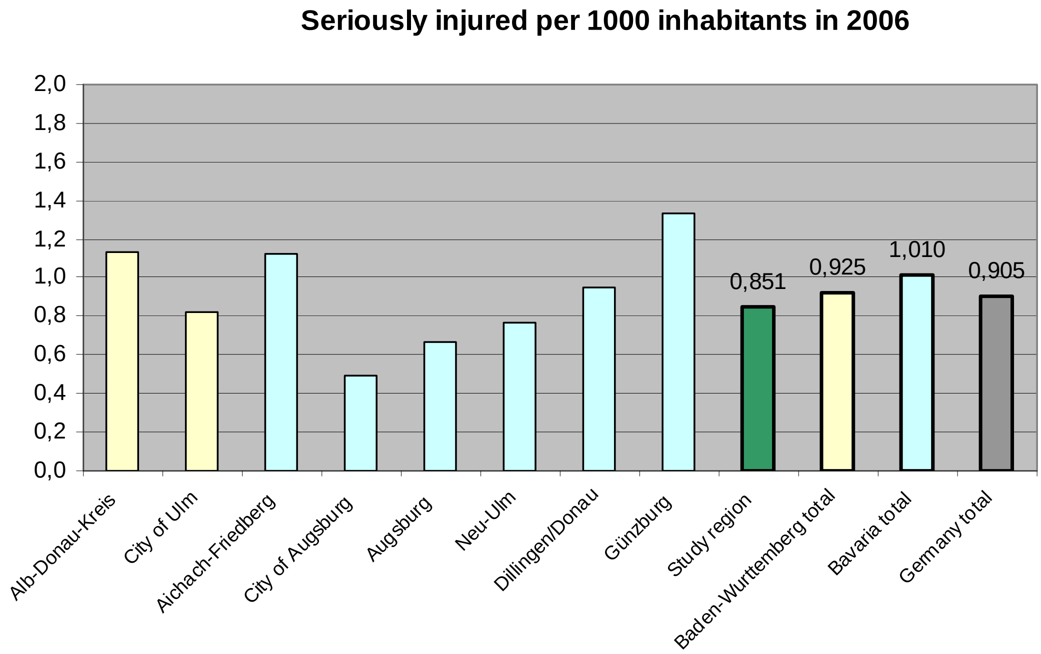

Figure 3. Incidence of seriously injured per 1000 inhabitants

Altogether, the demographic, infrastructural and traffic accident data suggest that the study region can be regarded as a good representation of the situation in Germany when analysing accidents with most severely injured.

METHODOLOGY FOR CASE IDENTIFICATION AND DATA RETRIEVAL

A complete on-the-spot accident research was not possible for the planned duration and due to the size of the study region. A different method was therefore pursued to obtain detail data on the collisions, vehicle damages and injuries. The concept to identify potential polytrauma cases from traffic accidents was carried over partially from the methodology applied by Liener et al. [3] in their study of polytrauma incidence in the Ulm region and refined for the present purpose. All three emergency dispatch centers in the study region provide data sets of calls to traffic accidents which required the presence of an emergency physician. The dispatch centers in Bavaria (Krumbach and Augsburg) index cases in their electronic alarm protocols if the dispatcher considers them to be potentially relevant. The dispatch center in Baden-Wurttemberg (Ulm) uses a different software to protocol their alarms which allows to filter by the cue words “traffic accident” and “emergency room admission”. All centers then provide the relevant data sets for the study which include the date and time of the in-coming emergency call, the approximate location of the accident, the dispatched type of ground ambulance, emergency physician’s car or rescue helicopter and the hospital the patient was taken to. Two of the centers can provide additional data on the time of rescue vehicles responding, reaching the accident site, leaving with the patient and arrival at the hospital. Furthermore, information on the communication path of the emergency call (whether reaching the dispatch center directly or via police etc.) and the rough type of collision (whether involving motorists, cyclists or pedestrians) is available in a number of cases. All data sets are sanitized from any patient or other personal data before they are provided to the project coordinator (see Fig.4).

The data are transferred into a common format for further evaluation by the project coordinator. Collisions that occurred outside of the study region are removed as well as cases that indicate that the accident did not classify as a traffic accident because it happened in a non-public location (e.g., on the premises of a company or facility). Cases where the patient was taken to a hospital of basic care are also deemed to be of less severe nature and are excluded from the analysis in the first step. Reports of

the regional police and media available through the internet are constantly monitored, documented and evaluated by UDV to obtain more early information on severe accident occurrences. This facilitates the interpretation of the very concise data from the dispatch centers and sometimes provides a few photos from accident sites.
With the enhanced data of potentially relevant accident events medical staff at the trauma centers review their patient data to identify the matching cases. Once a patient is identified, his or her injuries, vital parameters and treatment at the accident scene and at the hospital and the duration of stay in care are documented in an electronic form that is provided by the project coordinator. The form includes more than possible 200 fields for data entry, most of them being identical to those in the documentation sheets ("Erhebungsbogen Schwerverletzte") A to D of the German Society for Trauma Surgery (DGU) [25]. Personal data are limited to information about gender, month and year of birth, and – where possible – body height and weight. The amount of patient data and the collection method for this study was reviewed and accepted by the ethics committee at the University of Ulm.
After the sustained injuries have been documented and coded according to AIS-98 the injury severity score is calculated and the injury pattern categorized as a polytrauma with ISS ≥ 16, as a severe monotrauma or as an injury pattern of lower severity. Polytrauma or severe monotrauma cases define accidents which are followed up at the police. In both the federal state of Baden-Wurttemberg and Bavaria the police provide sanitized data from police accident reports. In Baden-Wurttemberg, they are requested to fill out a special form for these kinds of accidents to determine the year of first registration, deployed airbags and the exact seating position of occupants for vehicles involved in the collision. In case of children in cars the use and type child restraint systems should be specifically reported and for injured motor-cyclists the use and type of helmets should be documented. In addition, photos from the accident scene and damaged areas of the involved vehicles from the police files are requested.

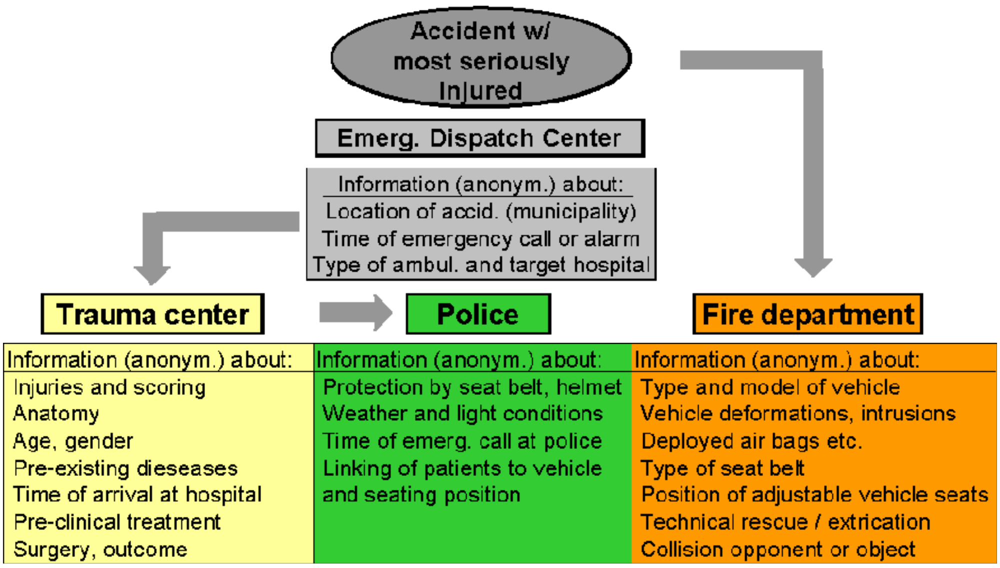

Figure 4. Process of data retrieval after severe road accident

Pilot study on documentation by fire departments

Depending on the accident situation only a limited number of photos and technical data may be available since one of the main purposes of documentation by the police is to determine the accident cause and the party at fault. In accidents where this is obvious, e.g., in single vehicle accidents with only one injured driver, there may be no need for an extensive documentation. A lack of photos of the vehicle interior and the absence of a reference to evaluate vehicle damage and intrusion was found to be a special hindrance for the analysis of injury causes in car or truck occupants. Since many local fire

departments in Germany maintain internet homepages which sometimes include pictures of special alarms a concept was developed to include these organisations in the documentation for the study, too.
A pilot study with seven German volunteer fire departments was run in 2006 over six months to try-out and improve the concept [26]. The fire chiefs or other representatives of the fire department were approached and educated about the study purpose and the most important parameters when documenting severe accidents at the scene. Each department received a clipboard, a set of paper forms to provide information about crashed vehicles, a check list with photo examples to illustrate which views at the accident scene would be most important and a folding yardstick to be used as a dimensional reference in photos of vehicle deformations. The test phase showed that the fire departments could provide valuable information and photos to complement police documentation. Concerning measures taken for technical rescue or vehicle extrication, fire departments are the only reliable source. On the other hand, it turned out that a complete documentation could not be expected under all circumstances. Sometimes not all desirable photos could be taken due to limited technical resources or personnel. In some cases during the pilot study the documentation had simply been forgotten due to the fact that no relevant traffic accident alarm had occurred for several months.
With the lessons learned from this pilot the concept to involve the local fire departments was enhanced for the polytrauma study. The fire chiefs responsible for the six counties and two larger cities were approached and organised meetings with representatives of the largest departments in their area. The meetings served to explain the motivation for the study, the required information from the accident scene and how to use the documentation equipment. It was stressed that the information and pictures taken of a traffic accident serve scientific purposes and is made anonymous (license plate numbers removed from photos etc.) either directly by the fire department or immediately after being received by the project coordinator. Each of the more than 100 participating departments received a backpack containing the items for documentation and the presentation material in electronic and paper form. The backpack is intended to be stored on one of the emergency vehicles which respond to traffic collisions. In addition, adhesive stickers were provided to be placed on the dashboard to remind rescue staff of the study on their way to the accident site. They also list the criteria under which an accident should be documented. Departments participating in the study receive irregular newsletters via e-mail from the coordinator to update them on the state of the project and discuss questions and challenges that may arise during actual accident documentation.
Returned documentation from the fire departments confirms that their photos and data can improve the quality of information particularly about the vehicles and damages (see Fig. 5). Whenever extrication of occupants is necessary the circumstances, rescue equipment used and possible difficulties are researched at the fire department. However, it turns out that fire departments are not necessarily called to accident scenes if the police and medical rescue staff can handle the situation alone. Fire fighters may be required only to mop up spilled liquids, to illuminate the accident site at night or may not be alerted at all. Accordingly, the pictures and information contributed to this study by fire departments pertain mostly to severe auto accidents and rarely to collisions with pedestrians, cyclists or motor-cyclists.

Figure 5. Example of documentation by fire department using yard stick for reference (source: Kreisbrandinspektion Günzburg)

Data collection and analysis

All relevant data are entered into an ACCESS data base. Data fields provide pre-defined entry options and only rarely free text in order to avoid spelling errors or use of synonyms and to facilitate later data analysis. Some 500 data fields are available to describe the accident site, light and weather conditions, involved vehicles and their technical specifications as well as casualties with their detailed injury descriptions, use of restraint system or protective gear and the key data from the emergency call, the pre-hospitalisation phase and technical rescue.

In 2007, the concept for the case identification of polytrauma patients was tested in the Augsburg area for the duration of one month [27]. The emergency dispatch center at the Augsburg city fire department indexed all alarm protocols where emergency physicians responded to traffic accidents. In parallel, local media articles and police reports on traffic accidents were studied over the internet and information collected. 26 patients were reported for the month of April who were involved in traffic accidents, had been treated by an emergency physician at the scene and transported to the Augsburg Hospital. All of these patients could be identified at the hospital. Twelve of them had a confirmed polytrauma, the remaining had injuries of lower severity. The trauma surgery department reviewed all of their data for the respective month and found no other polytrauma cases caused by traffic accidents. However, three patients were taken to trauma centers outside of the region by rescue helicopter which would have required follow-up.

The Schwaben precinct of the Bavarian Police checked their files and identified accident reports for all cases provided by the rescue dispatch center, except five accidents. Two of those cases did not meet the criteria for an traffic accident, two others were cyclist falls without a polytrauma and one was a reported accident on a motorway which may have occurred outside of this police precinct's boundaries.

The cases were also researched through the county fire chiefs, with the exception of the Augsburg city fire department, whether local fire departments had been called to the scene. Only in eight out of 22 accidents, the presence of fire fighters could be confirmed, too. These were mainly severe car collisions and only few of them required technical rescue.

In summary, this pilot indicated that all polytrauma patients from traffic accidents were captured with the criteria used at the dispatch centers and that their information enabled hospitals and the police to identify the relevant cases. The majority of polytrauma patients were treated in one of the trauma centers of the study region. Documentation by fire departments is limited largely to severe crashes involving cars or heavy vehicles and cannot be expected to take place under all circumstances. However, the information provided, then, is valuable and supplements accident data from other sources.

DISCUSSION

The data collection in the course of this study combines a prospective and retrospective approach in order to document the traffic accidents involving polytrauma as completely as possible. This pertains particularly to the number of polytrauma patients in a given geographical area and key descriptors of the collision. The chosen study region was determined by the necessity to have a sufficient frequency of severe accidents in order to obtain data in a relatively short period of time (12 to 24 months) and to level possible distortions due to local peculiarities. The presence of a limited number of trauma centers and the absence of hospitals above basic care level was the pre-requisite for easier identification of patients while all patient data remained anonymous to the project coordinator. On the other hand, this represents a specific situation of medical care which may not be representative for Germany. Due to the given structure of pre-hospital care, e.g., regarding organisation of medical rescue or emergency dispatch centers in southern Germany, a bias may exist, too. Currently, it has not been analysed whether the chosen region is representative for the medical care situation of polytraumatised in Germany. Regarding population, frequency and structure of accidents and road network the study region mirrors the national situation quite well. A comparison of the economical situation and the motor vehicle fleet with data on national level has not been carried out, yet.

Ideally, on-the-spot research teams would document and analyse collision events that involve polytraumata with standard data quality and quantity for each accident. However, this would have required a vast amount of human and technical resources to cover the area and respond to accidents in an acceptable time frame. The chosen methodology uses existing data that are available from police, emergency dispatch centers and hospitals and tries to enhance them with additional information for the purpose of the study. The local fire departments are requested to document collision-involved vehicles and technical rescue specifically according to the criteria of this research. Almost all organisations and responsible authorities which were contacted have agreed to support the study and engage strongly in the provision and processing of relevant information. Careful and time-consuming preparation of the data collection phase and a clear definition which patients and related accident events should be documented were necessary to ensure that the work load for individuals remains acceptable. The fact that a few local organisations in the region denied their participation in the study has not caused a major lack of information and could be compensated in another way.

The study is limited with regards to the detail information that can be retrieved from the accident site and the rescue chain and sometimes depends on the available resources at the supporting organisations. Regardless of these potential shortcomings, the contributing organisations and their staff have provided a wealth of information in a short time frame already which would not have been possible with a conventional accident research approach. Nevertheless, the follow-up of cases during the data collection requires intensive efforts to coordinate the study, to transfer all data into a common format and to close gaps where information is missing in individual cases.

SUMMARY AND OUTLOOK

The presented study is intended to determine the incidence and characteristics of polytraumata from traffic accidents in a large geographical region in Germany. It was started in late 2007 and data collection is continuing. The method is based largely on the provision of information and pictures by public authorities and organisations involved in medical and technical rescue of victims after a vehicle collision. It combines the retrospective retrieval of information from standard protocols of the police, emergency dispatch centers and trauma centers with the prospective data collection of parameters specifically related to polytrauma and vehicle damage resulting from such accidents. The latter are provided by the police and hospitals, too, but also by local fire departments. All patient data are anonymous when they are delivered to the project coordinator.

Relevant accident events with potential polytrauma patients are identified from data sets of regional emergency dispatch centers. With information about the approximate time and place of accident and the medical facility that a severely injured person is taken to the patients are identified at the hospital by medical staff. If a polytrauma is confirmed, the project coordinator follows-up the case at the police to obtain further information and photos from police accident reports. Local fire departments are requested to take pictures of the damaged vehicles and possible collision objects at the accident scene to complement information from the police and to report measures taken for technical rescue.

Injuries and vital parameters are documented in close conformity with the data sheets for most severely injured patients as recommended by the German Society for Trauma Surgery. ISS values of 16 and over define a polytrauma and represent the criterion for the inclusion of patients and related accidents in the study. In contrast to earlier plans, it is intended to document also collisions where traffic victims deceased at the scene of the accident. However, the definitive fatal injury may often remain unknown as autopsies are rarely conducted after accidents in Germany.

The study will deliver further insight into the structure of polytrauma patients and their injuries and the circumstances of the traffic accident which caused them. Particularly, their kind of traffic participation, whether as a vehicle occupant, cyclist or motor-cyclist or pedestrian and their protection by seat belt, airbags or helmets will be evaluated. A general description of the collision and impact direction for crash opponents will also be available in most cases. Depending on the individual detail level, an analysis of the rescue chain including emergency call handling, response times and time spent at the accident site will be possible.

An electronic data base has been set-up to enter all relevant and accessible information. Besides medical information, it includes a general description of the conditions about the place and time of accident and technical specifications as well as the extent of damage of the involved vehicles.

Comparisons of the incidence rate of accidents and key descriptors for the chosen study region suggest good conformity with the corresponding data for entire Germany. If an evaluation with respect to other important parameters confirmed this finding the study results could be extrapolated to a national level. Whether the chosen study region is also comparable with other German areas where accident research takes place has yet to be evaluated.
For the future, analysis of typical injury patterns of polytraumatised and their relevance among different kinds of road users can be addressed with this data base as well as the collision mechanisms causing them. Furthermore, as the average time of medical rescue reaching the accident scene has been rising in Germany during the last years [28] the data from this project could help to analyse the timeline of the rescue chain or estimate the impact of automatic vehicle crash notification systems, for instance.

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Adult front car occupant thorax injury experience following frontal impacts

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ABSTRACT

The following paper presents the nature and mechanism of injuries sustained in frontal impacts, focusing on car to car impacts. It was found that the body regions most frequently sustaining severe to fatal injuries were the legs and the thorax. The nature and mechanism of the injury sustained was investigated only for the thorax injuries, due to their potentially life threatening nature. The analysis revealed that the most frequent cause of the injury recorded was the seatbelt for low severity injuries and the front structure of the vehicle for higher severity injuries. An analysis of the effect of load limiter technology in the restraint system showed that the proportion of occupants who sustained 'no thorax injury' did not increase when a load limiter was fitted to the restraint system. However, a decrease in the 'organ' and 'organ and skeletal' injuries was observed in the load limiter sample. Sample size and variation mean that these findings are not conclusive.

INTRODUCTION

Following the introduction of the European frontal and side impact directives and EuroNCAP, significant improvements have been made to car secondary safety. Even so, there are still about 1,600 car occupants killed and 15,000 seriously injured in Great Britain (GB) annually (Road Casualties Great Britain 2006)[1]. Approximately 50 to 60 percent of these occur in frontal impacts. One of the next steps to improve frontal impact protection further is to improve compatibility in vehicle-to-vehicle impacts.

To this end, the European Enhanced Vehicle-safety Committee (EEVC) Working Group 15 (Compatibility and Frontal Impact) is working to develop an integrated set of test procedures to assess a vehicle's frontal impact performance, including its compatibility. The assessment of the likely benefit for improved vehicle compatibility was undertaken as part of a 5th framework European Commission project called VC-COMPAT[2] published in 2006.

The benefit analysis (GB only) performed in the VC-COMPAT project predicted that, even with improved compatibility, thorax injury would still be a substantial problem in frontal car impacts. Further work is needed to understand whether changes in vehicle design have affected the mechanism of thorax injury sustained in car frontal impacts and how, if at all, the mechanism has changed. This understanding is needed to accurately direct future research and test procedures. For example, one possible reason could be that, because EuroNCAP has encouraged cars to have stronger compartments, the thorax injury mechanism in car frontal impacts is no longer predominantly related to compartment intrusion but to the car's deceleration and the performance of the restraint system. If this were the case, it would have a major effect on the direction of future work as currently the focus is on the development of test procedures to improve a car's structural performance to reduce compartment intrusion.

BACKGROUND

Much research has been performed to understand compatibility, with three main influencing factors being identified: structural interaction, frontal force matching and compartment strength.

Structural interaction is relevant for all frontal impacts and describes how well vehicles interact with their impact partner, either another vehicle or a road-side obstacle[3]. If the structural interaction is poor, the energy absorbing front structures of the vehicle may not function as efficiently as designed, leading to an increased risk of compartment intrusion at lower than designed impact severities and a less optimum compartment deceleration pulse.

Also, 'triggering' of the restraint system may be sub-optimal due to a less predictable crash pulse. Examples of poor structural interaction are override (where a vehicle rides up over its impact partner) and the fork effect (where the longitudinals of a vehicle misalign in a horizontal plane).

A vehicle's frontal force levels are related to its mass. In general, heavier vehicles have higher force levels as a result of the current test procedures and manufacturers' desire to keep crush space to a minimum[4]. As a consequence, in a collision between a light vehicle and a heavy vehicle, the light vehicle absorbs more than its share of the impact energy as it is unable to deform the heavier vehicle at the higher force level required. Matched frontal force levels would ensure that both vehicles absorb their share of the kinetic energy, which would reduce the risk of injury for the occupant in the lighter vehicle.

Compartment strength is an important factor for self-protection, especially for light vehicles. In an event where vehicle front structures do not absorb the impact energy as designed, the compartment strength needs to be sufficiently high to ensure minimal compartment intrusion. Beyond this, there is scope for better optimisation of the car's deceleration pulse to minimise restraint induced deceleration injuries.

METHODOLOGY

The analyses described in this report have been performed using data from the Co-operative Crash Injury Study (CCIS). CCIS is an ongoing project, which has collected real world car occupant crash data since 1983 and conducts approximately 1,000 car injury crash investigations per year. Occupant injuries are coded in accordance with the Abbreviated Injury Scale (AIS)[5]. AIS is a threat-to-life scale and every injury is assigned a score, ranging from 1 (minor cuts, bruises etc) to 6 (currently untreatable). The Maximum AIS score a casualty sustains is termed MAIS.

A comprehensive overview of the methodology involved in the CCIS can be found at www.ukccis.org.

The CCIS dataset used in this analysis contained information about 17,314 occupants involved in 8,395 accidents that occurred between 1998 and 2007.

The original VC-COMPAT project conducted its analysis on vehicles registered after 1995 and up to 2005. A criticism of the original VC-COMPAT benefit analysis, was that cars designed and manufactured before and after the introduction of the frontal impact directive and EuroNCAP were grouped together in the sample, so that the improvements introduced in more recent generations of cars were not taken into account, and therefore the predictions overestimated the likely benefits associated with improved compatibility. To gain a greater understanding of how thorax injury and the corresponding mechanisms of injury have changed with vehicle and restraint design improvements in recent years, the dataset has been split into two subsets: occupants in cars registered from 1992-1997 ('old'), and occupants of cars registered in 2000 to 2007 ('new'). These subsets, with a clear separation between newer and older vehicles, were used to assess how improved vehicle structures and improved occupant restraints of newer cars have affected the predicted benefits of compatibility, particularly for thorax injuries.

Within these subsets, the samples analysed were chosen based on the following criteria:

- Only front outboard occupants were included.
- The most severe impact that was experienced was to the front of the vehicle.
- The vehicle did not roll over before the most severe impact.
- The injury severity, measured by MAIS (Maximum AIS severity score), was known for the occupant.
- The occupant was belted at the time of the accident.

The sample sizes, unless otherwise stated, were 1,786 occupants for the ‘new’ dataset and 1,854 occupants for the ‘old’ dataset.

To ensure that the datasets were roughly equivalent, a comparison exercise, looking for any confounding factors, was conducted. The following variables within the CCIS dataset were compared:

- The age distribution of the occupants in each sample
- The ETS for the impact
- The Delta-V for the impact
- The Police severity assigned to the impact (used as an initial notification for case selection)
- The object that was hit in the collision
- The kerb mass of the vehicles

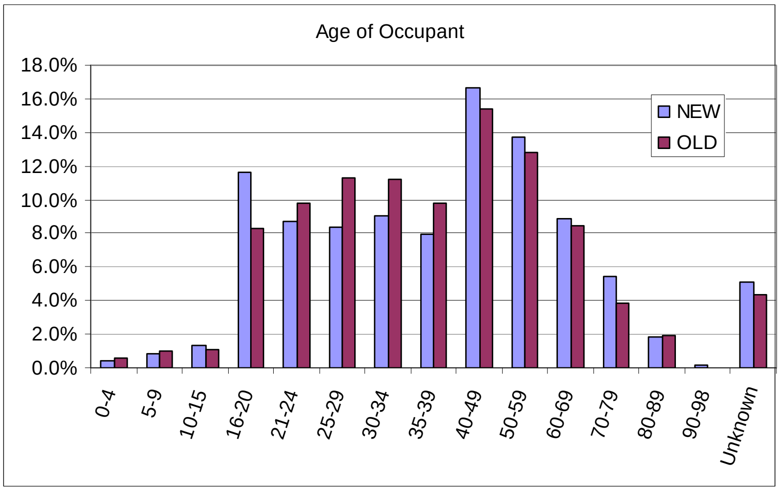

Figure 1 Age distribution of the occupants

It was found that the ‘old’ and ‘new’ datasets were significantly different with respect to the age profile of the injured casualties. The occupants of cars in the two datasets have a different age range distribution profile; although shows that the distributions are of broadly similar shape.

Both the collision severity (measured in terms of Equivalent Test Speed, ETS) and injury severity are typically greater for the old dataset compared to the new. However, car front structures are becoming stiffer and this directly affects the calculation of the ETS. Increases in stiffness reduce the amount of residual structural deformation, which is the basis for calculating ETS for CCIS investigated cars Therefore, the ETS may be underestimated for new cars compared to old, and the CCIS project’s technical management team are currently investigating this phenomenon. Based on the data currently available from CCIS, it is considered that the differences in the ETS values observed between the new and old cars at the thorax AIS 3+ injury level are greater than might be explained by a calculation error based on inappropriate (too low) stiffness parameters being used in the collision severity algorithm alone. Additional explanatory factors are therefore required, and the most likely is felt to be that the increased stiffness of vehicles is contributing to new car occupants experiencing more deceleration based injury through greater seat belt webbing loading.

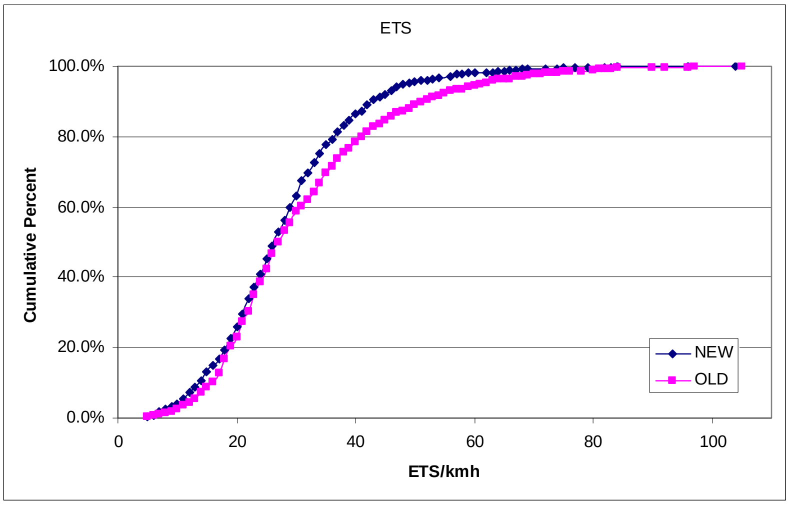

Figure 2 ETS for the single most severe impact

CCIS preferentially samples newer cars; an older car can only be included if it collided with a newer car. This leads to another difference between the two datasets, with proportionally more car-to-car impacts in the old car sample, and more single-vehicle accidents in the new car sample.

RESULTS

Repeat of the VC-COMPAT analysis

The analysis conducted for the VC-COMPAT project was repeated, using the same methodology, on the 'old' and 'new' datasets.

Model 1 removes all injuries caused by an intruding internal front structure. Model 2 removes all injuries caused by contact with any internal front structure, regardless of intrusion.

Table 1 Summary of casualty benefits estimated by compatibility models

Dataset	Impact partner	% casualty reduction			
		Model 1: intrusion		Model 2: contact	
		Fatal	Serious	Fatal	Serious
Old cars	Car-car (n=1323)	16.9	10.2	23.1	26.3
	Car-large vehicle (n=257)	5.8	3.2	17.7	9.6
	Car-object (n=232)	2.9	8.0	4.5	16.1
New cars	Car-car (n=1221)	12.7	7.1	21.8	26.0
	Car-large vehicle (n=228)	5.5	3.2	8.4	15.1
	Car-object (n=325)	10.1	13.0	15.8	29.4
VC-COMPAT	Car-car (n=2031)	14.0	10.1	23.9	27.3
	Car-large vehicle (n=434)	0.9	4.0	12.9	13.8
	Car-object (n=572)	13.8	10.3	21.7	22.6

In general, the results from the ‘new’ car and the ‘old’ car dataset are broadly similar to the results of the VC-COMPAT dataset. This would be expected because there is a large overlap in the year of manufacture of the cars involved: the VC-COMPAT dataset included cars built in 1996 or later, and this overlaps with both ‘old’ and ‘new’ datasets used in the current analysis. The lower percentages seen in the ‘new’ car dataset when compared to the VC-COMPAT dataset for car-car impacts are due to the differences in the proportion of impact types contained in the two datasets. The percentage of fatalities mitigated in car-large vehicle accidents differs between the ‘new’ car dataset and the VC-COMPAT dataset, but this change is exaggerated because of the low number of fatalities involved. The same can be said of the differences in the percentage of fatalities mitigated in the car-object group.

A larger benefit is estimated for the car-car impacts in the ‘old’ car dataset compared to the ‘new’ car dataset. This suggests that the newer cars have improved in terms of safety in this type of impact compared to the older cars, although there are still improvements to be made.

Further to the validation of the original VC-COMPAT results indicated in **Table 1**, additional repeated analysis, not presented in this paper, again shows that thorax injuries are not significantly mitigated by the compatibility models in either old or new cars.

Analysis of the body region injured

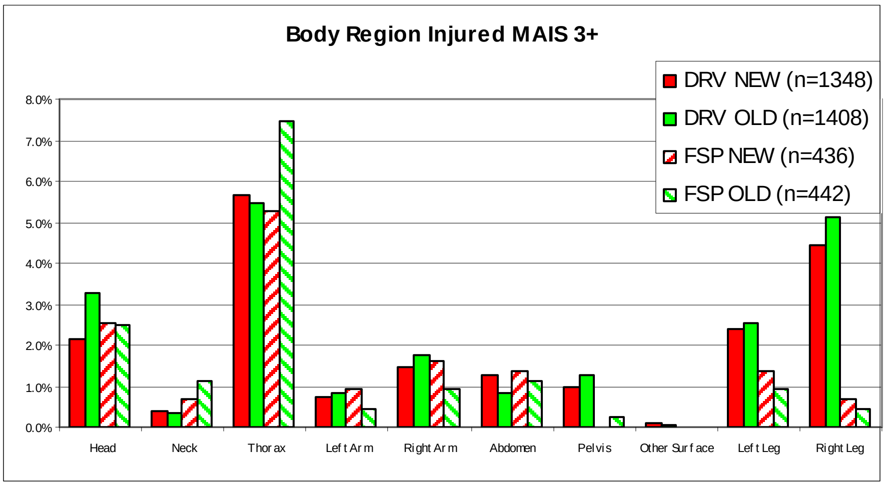

Figure 3 Body region injured at MAIS 3+, by occupant position

Figure 3 shows the percentage of injuries sustained at the MAIS 3+ level, that is, serious and life threatening injuries. At this level it can be seen that the main regions injured are the thorax and the legs. Although possible, life threatening injuries to the legs are relatively infrequent, so the thorax can be said to be the most life threatening area injured in frontal impacts at the MAIS 3+ level. The remainder of this paper will therefore concentrate on injuries sustained to the thorax and investigate the mechanism of injury and any confounding factors that may alter the injury severity sustained by the occupant. In the figure, DRV indicates the Driver and FSP indicates the front passenger.

Figure 4 presents the distribution of anatomic structures of the thorax that are injured at two different injury severities. The bars represent the percentage of the total sample size of the dataset. When an occupant sustains a significant injury to the thorax it mostly involves the internal and/or skeletal structures, apart from the thoracic spine. Because we are considering only a single body region, the term HAIS (Highest AIS score) is used instead of MAIS.

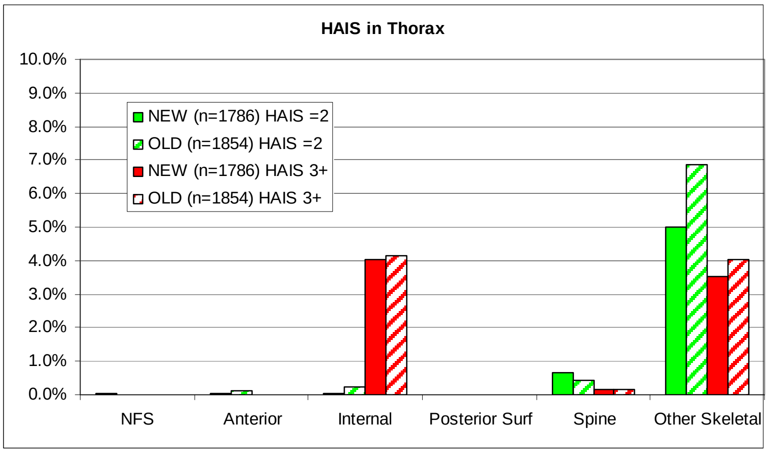

Figure 4 Highest AIS score in the thorax

Further investigation into the relationship between thorax injury severity and age, not presented here, showed that, for both drivers and front passengers, the number of severe thorax injuries as a proportion of the total number of injuries sustained by occupants in that age range, increases as the age of the occupant increases. This is in line with the results of cadaver tests, where it was found that deflection-based injury to the thorax was dependant on age, with risk of injury increasing with age[6].

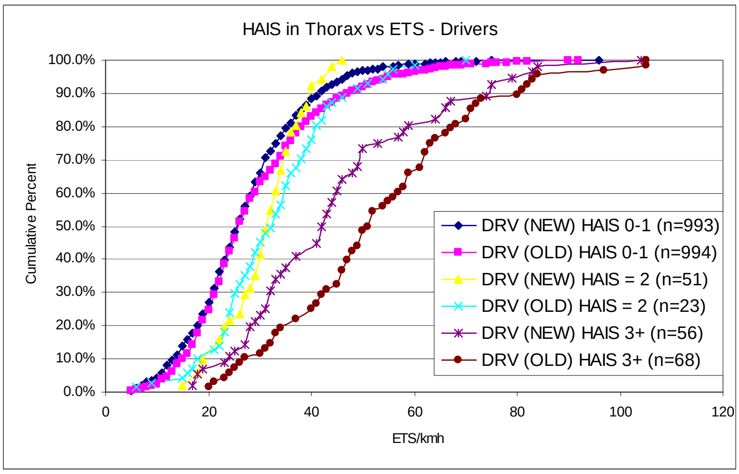

Figure 5 The highest AIS score in the thorax vs the ETS of impact - Drivers only

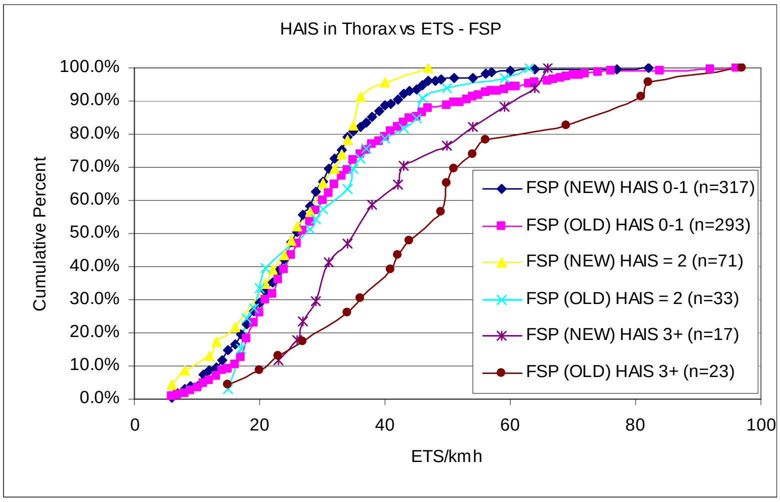

Figure 6 The highest AIS score in the thorax vs the ETS of impact - front passengers only

Figure 5 and Figure 6 present, for occupants injured at different severity levels, the distribution of ETS values at which those injuries were sustained. The figures show that, both for the driver and front passenger the severity of the injury sustained to the thorax increases as the ETS increases. The higher average ETS for the HAIS 3+ occupants in the old car dataset can be clearly seen here, but caution should be exercised when making conclusions, due to the low sample size.

As well as the differences outlined above regarding the ETS distributions of the datasets for HAIS 3+ thorax injuries, there are also other differences in the characteristics of the datasets for this subset of occupants, and these are shown in Table 2.

Table 2 Characteristics of Occupants with AIS 3+ Thorax injury

		New (n=1786)	**Old (n=1854)**
Gender	% Male	63.6%	53.2%
Age(years)	25%ile	37	34
	50%ile	56	54
	75%ile	69	66
Object hit	% Car	57.5%	67.6%
ETS (km/h)	% Unknown	26.2%	18.0%
	25%ile	30	37
	50%ile	42	50
	75%ile	53	63

This table shows that, although comparable, there are differences between the samples when considering those occupants that have sustained a serious injury to the thorax. There are more males in the ‘new’ car sample, but when the age distribution of the sample is assessed the ‘new’ car sample contains older occupants; this could be due to demographics but further work is needed to understand the reason.

The differences in the ETS distributions of the vehicles between the new and old datasets have been discussed above. Similarly, the over-representation of car to car impacts in the ‘old’ dataset is seen to apply to the HAIS 3+ thorax subset as well. To address any possible bias introduced by this, further analysis will focus on car to car impacts only. Taking account of other types of object hit (large vehicle, two-wheeler, wide object, narrow object etc) would be fruitless, since the sample sizes would be too small.

Analysis of the mechanism of Thorax injury

The analysis presented thus far has focused on the severity and location of the injuries sustained. The next section of the results further investigates these injuries and focuses on their nature and causation mechanisms.

Wherever possible, injuries in the CCIS database are attributed to causation agents. Figure 7 shows the distribution of AIS scores for the injuries associated with each causation agent, in the two vehicle subsets. Note that, since it is possible for an occupant to have multiple injuries, the sample size quoted for any injury level analysis will be higher than the number of occupants that are in the sample.

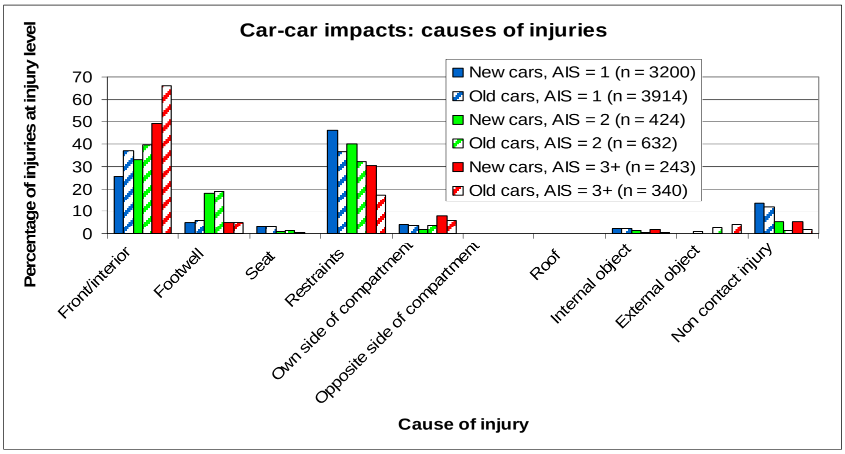

Figure 7 Causes of injury for car to car impacts

The main recorded causes of the injuries in car to car impacts were the front/interior structure and the restraint system. It should be noted that the non-contact injuries are mainly AIS 1 injuries: these are predominantly ‘whiplash’ or strain injuries. Overall, the number of injuries that are caused by the front/interior structure are higher than the number caused by the restraint, but when severity is taken into account, it is noted that there is a shift in the main mechanism of injury; low severity (AIS < 3) injuries are predominantly caused by the restraint system and high severity (AIS = 3+), by the front structures of the vehicle. In addition to this, as the injury severity rises, the restraint system is responsible for a greater proportion of injuries in new cars compared to old.

Another trend shown is a shift between the proportion of injuries that occur due to restraint and front/interior loading in new cars compared to old cars. The new cars have more injury causation assigned to the restraint loading (regardless of injury severity) and conversely the old vehicles have more injuries assigned to the front/interior structure. This could be due to the post EuroNCAP drive, by legislation and vehicle manufacturers, to reduce the level of compartment intrusion that vehicles suffer in frontal impacts.

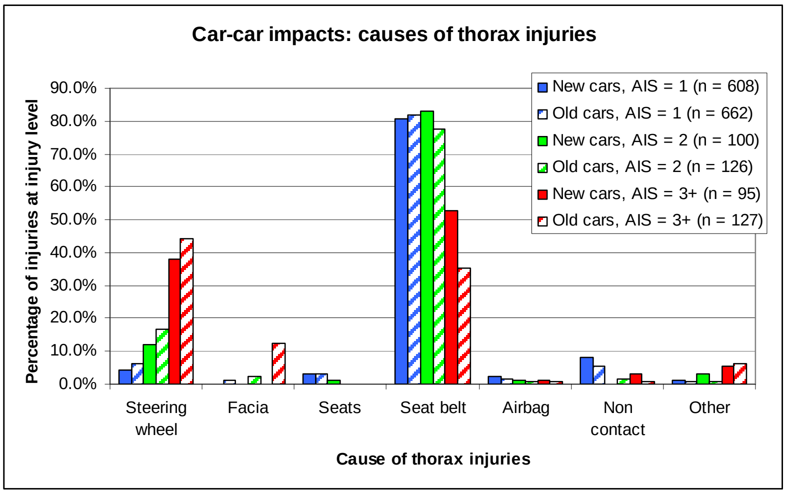

Figure 8 Causes of thorax injuries in car-car impacts

As previously shown, the main regions injured in frontal impacts were the thorax and lower extremities. The focus was deemed to be thorax injury due to the potentially life threatening nature of thorax injuries. It can be seen (Figure 8) that the majority of AIS 1 and AIS 2 thorax injuries are caused by the restraint system. When the more serious, AIS 3+, thorax injuries are considered the steering wheel is also a significant cause. However, the most obvious difference between old and new cars is that a larger percentage of AIS 3+ thorax injuries are caused by the restraint system in new cars compared to old cars.

Finally, the nature of the injury sustained to the thorax was assessed and compared to the functions of the restraint system present in the vehicle that the occupant was injured in. The analysis again only focuses on car-car impacts.

The different types of thorax injury sustained were grouped into skeletal only, organ only, skeletal and organ, and other injuries. Injuries classed in the vessels, thoracic spine and whole area in the AIS 1990 coding manual were included in the analysis, but grouped in the 'other' section. There were very few cases where the occupant had only a vessel injury and in the majority of cases they had either a skeletal or organ injury in addition; as such these vessel injuries have been included in the later categories where possible.

The type of restraint was defined by the level of functions fitted to the system. A 'normal' seat belt was defined as one where no load limiter or pretensioner device was fitted to the restraint system.

In addition to an analysis of the nature of the thorax injury and the restraint system, the age of the occupants and severity of the accident (measured by ETS) were also analysed; these are known to affect the injury severity score sustained and were also earlier identified as being slightly different when comparing the two datasets.

Occupants of 'old' and 'new' cars that had sustained AIS 2+ injuries to the thorax were compared.

Table 3 Occupants with AIS 2+ thorax injuries, comparison of old and new cars

	Old cars	**New cars**
Number of occupants	164	127
Only a skeletal thorax injury	67.7 %	65.4 %
Only an organ thorax injury	11.0 %	8.7 %
Skeletal and organ	20.1 %	24.4 %
Other thorax injury	1.2 %	1.6 %
Occs with clavicle fracture	12.2 %	12.6 %
Occs with AIS 2+ abdomen injury	19.5 %	18.1 %
Occs with pelvis fracture	7.3 %	8.7 %
Normal belt	9.8 %	1.6 %
Pretensioner	9.1 %	3.1 %
Load limiter & pretensioner	0.0 %	3.9 %
Airbag and normal belt	2.4 %	4.7 %
Airbag & pretensioner	11.6 %	17.3 %
Airbag & pretensioner & load limiter	0.0 %	51.2 %
Other / not known	67.1 %*	18.1 %

**Note the Other/Not Known for old car occupants is high due to a change in CCIS protocols for recording of restraint system type.*

The most frequent injury type for both the new and old car data sets was 'skeletal only', followed by 'skeletal and organ' and then 'organ only' injuries. However, there were slight differences in the proportions of these injury types for each data set. These differences are not believed to be significant based on this comparison alone, given the previously mentioned difference in age distribution between the two datasets.

Previous analysis has shown that injuries are commonly caused by the restraint (seat belt). The design of the vehicles in the 'old' car dataset largely pre-dates the introduction of EuroNCAP in 1997 and the European Union (EU) frontal impact legislation in 1998, although some of them will have been designed to anticipate the legislation and improved safety criteria. These vehicles will therefore have a range of structures with associated differing performance during an impact situation. It is not possible to analyse the performance of a restraint system within the vehicle without being able to control for the structural improvements which are believed to have had a significant influence on the injury outcome of the occupant. Therefore, to evaluate the performance of the restraint system alone, injuries in the 'new' vehicle dataset only were assessed. The new vehicles were registered post 2000 and nearly all had been designed to meet the EU frontal impact directive. Their structural performance is believed to be less of a confounding issue with respect to how the restraint system has performed than is the case for the 'old' cars. The new vehicles were all sampled equally and there is less bias with respect to the occupant characteristics (age and gender) and collision severity (ETS) when this group is divided by restraint system specification

Table 4, Figure 9 and Figure 10 compare the types of thoracic injury sustained by MAIS 2+ occupants in new vehicles with and without load limiters fitted. There were 146 occupants in the former group (129 with known ETS) and 51 in the latter (47 with known ETS). This is in line with the current trend for the vast majority of modern cars to be equipped with front seat belt load limiter technology.

Table 4 New cars, car-car impacts, occupants with MAIS 2+ injuries: comparison of restraint systems

	Airbag + pretensioner	**Airbag + pretensioner + load limiter**
Number of occupants	51	146
Only a skeletal thorax injury	23.53%	32.88%
Only an organ thorax injury	5.88%	2.74%
Skeletal and organ thorax injury	13.73%	10.27%
Occs with other thorax injury	29.41%	28.08%
No thorax injury	27.45%	26.03%
Occs with clavicle fracture	7.84%	11.64%
Occs with AIS 2+ abdomen injury	9.80%	13.01%
Occs with pelvis fracture	5.88%	6.85%

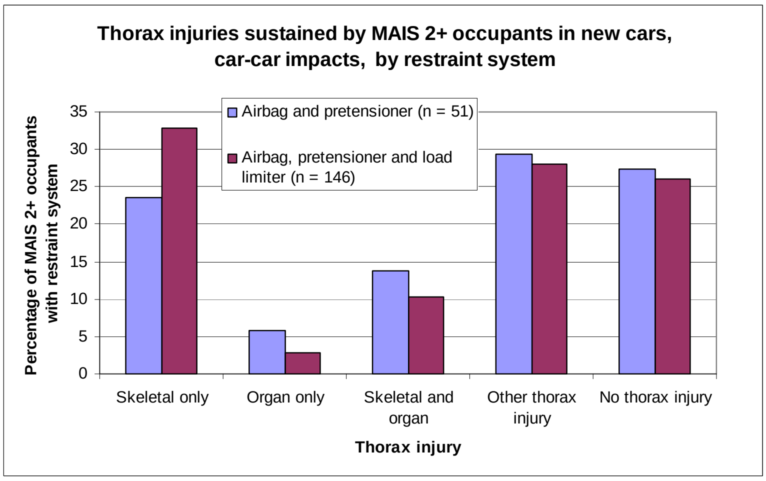

Figure 9 Thorax injuries sustained by MAIS 2+ occupants in new cars by type of restraint system

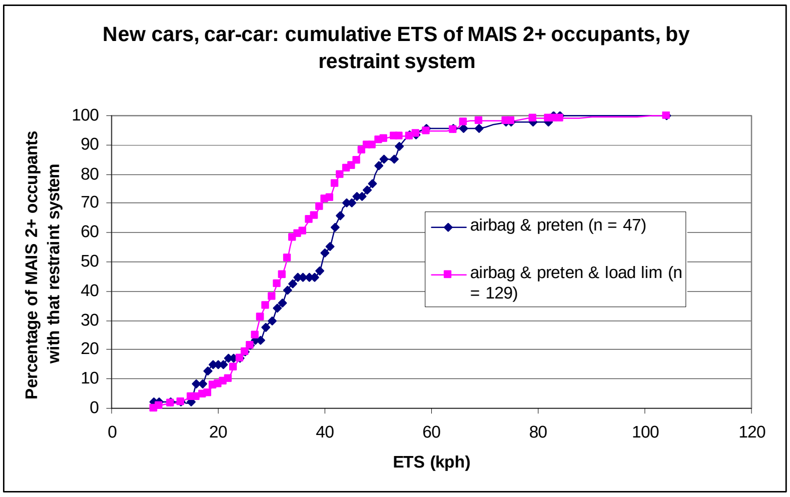

Figure 10 Cumulative ETS of occupants with MAIS 2+ injuries in new cars, by restraint type

Figure 10 shows the ETS distribution for the two groups. Occupants of vehicles equipped with load limiters appear to have sustained their injuries at slightly lower crash severities. However, numbers in the non-load limiter group are small.

In Figure 9 the presence or absence of a load limiter has little influence on the percentage of occupants that have 'no thorax injury'. If a load limiter was reducing injuries in the thorax, particularly those caused by restraint loading, which earlier analysis has shown to be a major cause of injury, it would be expected that an increase in the number of occupants with 'no thorax injury' in the load limiter sample would be observed. This is not the case and it can be seen that the influence of the load limiter varies with respect to the anatomical structure damaged. Thus, we see a reduction in the proportion of more serious ('organ' and 'skeletal and organ') injuries, together with an increase in the proportion of 'skeletal' injuries, which tend to be less serious. There is therefore some evidence that load limiters have had a positive effect, but this analysis has not been able to quantify the magnitude of any improvement, partly because of the relatively small differences observed between injury rates with and without load limiters. It is also recognised that load limiters have been grouped together, when in reality it is known that they have different performance characteristics, which are tuned in conjunction with the overall restraint system. This is likely to mean that some restraint systems perform better than others for different occupant groups.

Conclusions

- An initial comparison of the two datasets comprising 'new' and 'old' car occupant groups showed that there were significant differences between them and these are acknowledged to have some influence on the comparisons which have been made in this paper. However, these differences have been borne in mind in the interpretation of the results.
- Applying the VC-COMPAT compatibility models to the 'new' and 'old' car datasets resulted in a predicted benefit that was similar to that in the original analysis. A greater benefit was predicted for old cars, compared to new cars, showing that the rate of intrusion and contact induced thorax injury has decreased in newer cars. However the analysis showed that thorax injuries are not significantly mitigated by the compatibility models in either old or new cars. This is the same as the findings in the original VC-COMPAT project. Serious injuries to body regions such as the legs and arms were reduced by over 50 % for the contact model, whereas injuries to the thorax were only reduced by about 15 %.
- The main body regions injured at the AIS 3+ level for both the old and new datasets were the thorax and the lower extremities.

- An important observation was that AIS 3+ thorax injury was seen at a lower collision severity in the new car dataset compared to the old car dataset. However, possible underlying factors behind this observation include the different occupant demographics between the datasets and the increased stiffness of new cars, which could cause both an under estimation of the collision severity (ETS) and increased risk of deceleration induced injury.
- The most frequently cited causes of thorax injuries, in car to car impacts, are the seat belt and steering wheel. The seat belt is more frequently recorded as the cause of AIS 3+ injury for occupants of the new car dataset whereas the steering wheel was the principal cause of these injuries in the old car dataset. Differences between the dataset characteristics, namely the lower collision severity and occupant age, are likely to have contributed to this. However, it should be noted that the new car occupants still experience intrusion of the forward structures and therefore still experience some interior contact injuries due to intrusion into the compartment environment.
- For the new car dataset it was seen that when 'load limiters' were present less serious thoracic injury occurred compared to when they were not. This was due to a change in the distribution of injuries with reductions in the generally more serious 'organ and skeletal' and 'organ only' injury categories and a proportional increase in the 'skeletal only' injuries.
- In summary, the analysis has highlighted that thoracic injury remains a priority for future vehicle injury mitigation improvements.

Recommendations for the Way Forward

- Although this report has begun to classify the nature of the thoracic injury sustained by occupants of cars registered post 2000, more in-depth biomechanical studies are needed to evaluate the loading mechanisms in more detail. This is especially true for oblique chest loading by the seat belt webbing.
- A limitation of the work undertaken to date is that the load limiter technologies have been grouped together. Future work should seek to categorise the technologies with respect to their performance characteristics and link to the overall restraint system specification.
- There would be advantages for future work to correlate the cars' structural loading and the restraint system performance and assess the injury output controlling for the two.
- One of the possible factors affecting the comparison of the new and old car datasets was the possible under-estimation of the collision severity (ETS) for new cars. The CCIS technical team are currently developing the project's protocols to account for any potential bias in the calculations that are used to determine ETS for old and new cars.

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The work described in this paper was carried out in the Accident Research Group of TRL. The authors are grateful to Roy Minton who carried out the quality review and auditing.

This report used accident data from the United Kingdom Co-operative Crash Injury Study (CCIS) collected during the period 1998-2007.

Currently CCIS is managed by TRL Limited, on behalf of the DfT (Transport Technology and Standards Division) who fund the project along with Autoliv, Ford Motor Company, Nissan Motor Company and Toyota Motor Europe. Previous sponsors of CCIS have included Daimler Chrysler, LAB, Rover Group Ltd, Visteon, Volvo Car Corporation, Daewoo Motor Company Ltd and Honda R&D Europe(UK) Ltd.

Data was collected by teams from the Birmingham Automotive Safety Centre of the University of Birmingham; the Vehicle Safety Research Centre at Loughborough University; TRL Limited and the Vehicle & Operator Services Agency of the DfT.

Further information on CCIS can be found at http://www.ukccis.org

The views expressed in this report belong to the authors and are not necessarily those of the DfT.

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Spine injuries in motor vehicle accidents - an analysis of 18353 traffic accidents between 1985 and 2004 with special consideration of injuries of the thoracolumbar spine in relation to injury mechanisms

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Abstract - This study aims to analyze spine injuries in motor vehicle accidents. Between 1985 and 2004 the Hannover accident research unit documented 18353 accidents. We identified 161 front passengers (0.53%) with cervical spine injuries, 84 (0.28%) with thoracic and 95 (0.31%) with lumbar injuries. Technical and medical data was reviewed. Patients' records were retrieved. X-rays were evaluated and fractures were classified according to the Magerl classification. 68% and 57% of thoracic and lumbar fractures occurred in accidents with multiple impacts. Delta-v was 50, 40 and 40 kph in passengers with cervical, thoracic and lumbar spine, resp. Passengers with spinal fractures frequently showed numerous concomitant injuries, e.g. additional vertebral fractures. The influence of seat belts and airbags is discussed. Patient work-up has to include a thorough investigation for additional injuries.

INTRODUCTION

Injuries of the spine are a considerable threat to life and quality of life in motor vehicle users. In comparison to injuries of other organ systems, spinal and spinal cord injuries are associated with the worst functional outcome and the lowest rate of reintegration into work life [1]. Great efforts have been spent to improve safety of car drivers and passengers. Overall mortality in traffic accidents has been markedly reduced during the last 20 years: In 1970, the "death toll" on German roads was more than 20.000, in 2007 4949 people were killed. Still, the number of injured people was more than 430.000 (Statistisches Bundeamt Wiesbaden, 2008). In this study, we aim to evaluate the current risk for spinal injuries in restrained front passengers and implications on car safety issues as well as on medical treatment at the scene and in the hospital.

METHODS

Data Collection by an Accident Research Unit

A local traffic accident research unit, that had been established in 1972 collected prospective data in regard to all reported traffic crashes within the area. 300 vehicular collisions per year up to 1987 and 1000 accidents per year since then were documented. Specially trained documentation personnel are notified by police dispatchers and arrive on scene, often simultaneously with the rescue personnel. The circumstances of the crash are investigated by taking photographs and using a 3D-laser scanner. Slide and skid marks of involved objects, vehicles and persons are measured for later reconstruction of the crash and calculation of collision speeds. Furthermore technical features of involved vehicles, e. g. weight and size are obtained as well as on-scene clinical data from injured persons. Additional data is collected at the hospital which admits the injured occupants, with documentation of x-ray films, diagnoses after the first in-hospital examination and estimation of injury severity. A report of each accident is written. The data collected and calculated is put into a data bank which comprises demographic data, type of road user (car/truck occupant, motorcyclist, cyclist, pedestrian), delta-v (km/h; change of velocity at the collision time as a basic force indicator) of motorized vehicle user; vehicle collision speed (km/h) of motorbikes, Abbreviated Injury Scale (AIS), Maximum AIS (MAIS), Injury Severity Score (ISS) and incidence of serious and/or severe multiple injuries (polytrauma, ISS ≥ 16) [2-5]. The data base used in this study comprises 18352 traffic accidents which were documented between 1985 and 2004. Traffic crash reports were analyzed for the involvement of car occupants. In a first step, all reports were screened for front passengers who received a spinal injury were extracted.

Data was analyzed for collision speed, age, sex, AIS score, MAIS score, ISS, and incidence of other injuries.

Review of x-rays and medical records

In a second step, all victims of fractures of the thoracic or lumbar spine were extracted. All x-rays and medical records that were retrievable were analyzed. Fractures were classified according to the classification proposed by Magerl [6]. Crash circumstances were evaluated from the technical crash reports and correlated to the type of injuries.

RESULTS

The data base revealed 30421 front passengers who where involved in motor vehicle accidents. There were 161 persons (0.53%) with injuries of the cervical spine (209 fractures), 84 persons (0.28%) with injuries of the thoracic (117 fractures) and 95 persons (0.31%) with injuries of the lumbar spine (122 fractures).

Demographic data

The mean age of all front passengers was 35.5 years. The mean age in front passengers with injuries of the cervical, thoracic or lumbar spine was 35, 37 and 38 years, respectively. Overall, 60% were male, 37% female and 2% unknown. 61%, 68% and 60% of front passengers with injuries of the cervical, thoracic or lumbar spine, respectively, were male. Overall, 6.3 % were aged 65 and older. 8, 6 and 14% of front passengers with injuries of the cervical, thoracic or lumbar spine, respectively, were aged 65 and older. Children with vertebral fractures were extremely rare. All demographic data is shown in table 1.

	all front passengers		**fx cervical spine**		**fx throracic spine**		**fx lumbar spine**	
	30421	100,0%	**161**	100%	**84**	100%	**95**	100%
sex								
male	**18188**	59,8%	**98**	61%	**57**	68%	**57**	60%
female	**11347**	37,3%	**63**	39%	**27**	32%	**38**	40%
pregnant	**59**	0,2%	**0**	0%	**0**	0%	**0**	0%
unknown	**598**	2,0%	**0**	0%	**0**	0%	**0**	0%
age								
child up to 6y	**670**	2,2%	**1**	1%	**0**	0%	**0**	0%
child 6 to 12 years	**675**	2,2%	**2**	1%	**1**	1%	**1**	1%
adolescent 13-17	**760**	2,5%	**10**	6%	**0**	0%	**4**	4%
18 to 64 y	**24244**	79,7%	**132**	82%	**77**	92%	**77**	81%
65 y and older	**1918**	6,3%	**13**	8%	**5**	6%	**13**	14%
unknown	**1837**	6,0%	**2**	1%	**1**	1%	**0**	0%
safety belt usage								
used	**23792**	78,2%	**115**	71%	**53**	63%	**72**	76%
not used	**1986**	6,5%	**31**	19%	**22**	26%	**15**	16%
unknown	**4643**	15,3%	**15**	9%	**9**	11%	**8**	8%
airbag deployment								
none	**29132**	95,8%	**144**	89%	**77**	92%	**89**	94%
only front	**1159**	3,8%	**13**	8%	**5**	6%	**6**	6%
only side	**72**	0,2%	**1**	1%	**1**	1%	**0**	0%
front and side	**58**	0,2%	**3**	2%	**1**	1%	**0**	0%

Table 1: Demographic data

Crash mechanism

Overall, 45% of all front passengers had a head-on collision, 20% a side-collision, 9.9% a rear-end collision, 0.7% a roll-over and 24% sustained multiple collisions. Out of all front passengers with cervical, thoracic and lumbar spine injuries 29%, 17% and 28% had head-on collisions, 22%, 7% and 12% side-collisions, 2%, 5% and 0% rear-end collisions, 2%, 4% and 2% isolated roll-overs and 43%, 68% and 57%, resp., multiple collisions, cf. table 2.

	all front passengers		**fx cervical spine**		**fx throracic spine**		**fx lumbar spine**	
	30421	100,0%	**161**	100%	**84**	100%	**95**	100%
Collision partner								
car	**11293**	37,1%	**30**	19%	**9**	11%	**16**	17%
truck	**1662**	5,5%	**16**	10%	**7**	8%	**5**	5%
motorbike	**1801**	5,9%	**0**	0%	**0**	0%	**0**	0%
bicycle	**3753**	12,3%	**0**	0%	**0**	0%	**0**	0%
pedestrian	**2422**	8,0%	**0**	0%	**0**	0%	**0**	0%
object	**1959**	6,4%	**44**	27%	**10**	12%	**19**	20%
multiple	**7232**	23,8%	**70**	43%	**57**	68%	**54**	57%
unknown	**299**	1,0%	**1**	1%	**1**	1%	**1**	1%
Impact site								
front	**13560**	44,6%	**47**	29%	**14**	17%	**27**	28%
side	**6043**	19,9%	**35**	22%	**6**	7%	**11**	12%
rear	**2996**	9,8%	**4**	2%	**4**	5%	**0**	0%
isolated roll-over	**199**	0,7%	**5**	3%	**3**	4%	**2**	2%
multiple	**7232**	23,8%	**70**	43%	**57**	68%	**54**	57%
other	**385**	1,3%	**0**	0%	**0**	0%	**1**	1%
unknown	**6**	0,0%	**0**	0%	**0**	0%	**0**	0%

Table 2: Collision characteristics

As a parameter for the severity of the car crash the change of speed (delta-v) due to the collision was calculated. Delta-v was 21.4 km/h in all front passengers, 50 km/h in front passengers with cervical spine injuries and 40 km/h both in those with thoracic or lumbar spine injuries, resp., cf. figure 1.

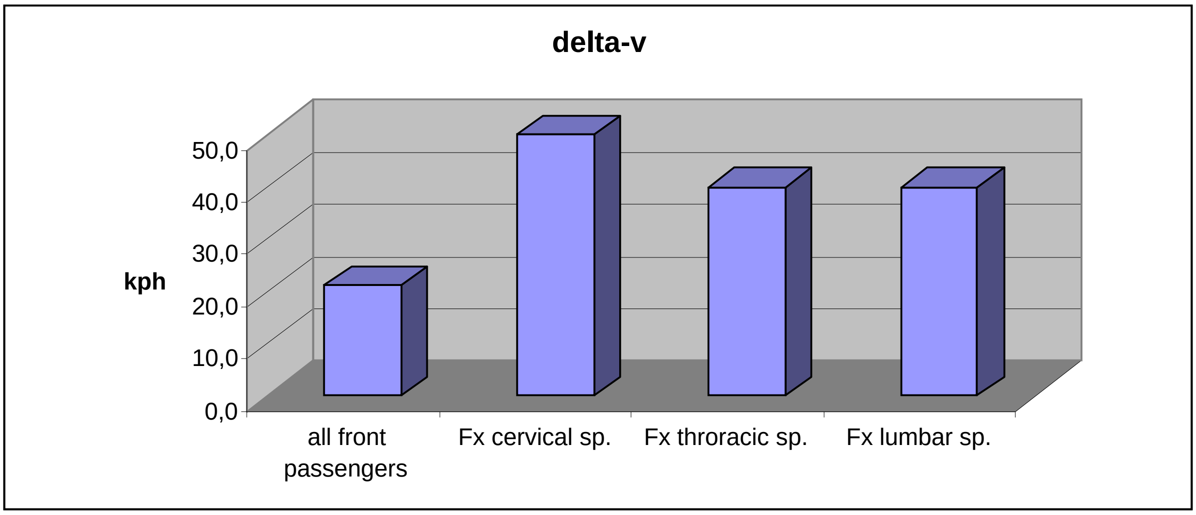

Figure 1: delta-v

Injury severity and associated injuries

In all occupants, ISS as well as AIS-head, AIS-neck, AIS-thorax, AIS-upper extremities, AIS-abdomen, AIS-pelvis and AIS-lower extremities and the resulting MAIS were determined. The ISS was 4.0 in front passengers without any spine injuries and 50, 23 and 10 in front passengers with fractures of the cervical, thoracic or lumbar spine, respectively. MAIS was 1.33 in front passengers without spine injuries and 4.3, 3.3 and 2.7 in those with cervical, thoracic or lumbar fractures. Figure 2 shows detailed data of AIS in front passengers with or without spine fractures, which reflects the high rate of associated injuries. Car occupants with spinal fractures in either part of the spine were more likely to have vertebral fractures in other regions of the spine: 7% and 3% of occupants with fractures of the cervical spine had additional fractures of the thoracic and lumbar spine. 14% and 11% of occupants with fractures of the thoracic spine had additional fractures of the cervical and lumbar spine. 5% and 9% of occupants with fractures of the lumbar spine had additional fractures of the cervical and thoracic spine.

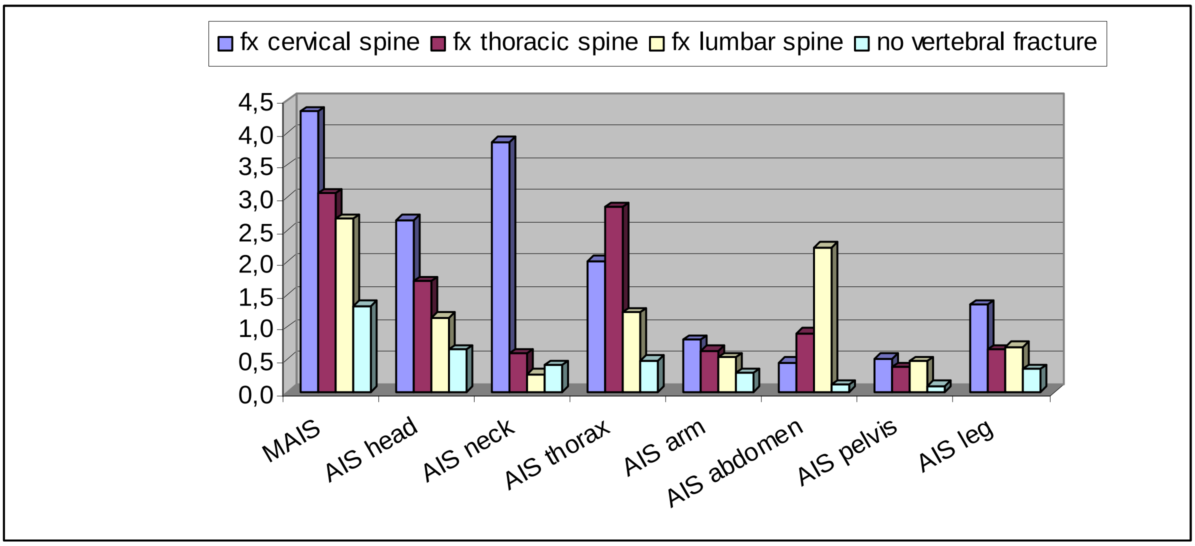

Figure 2: AIS

Fracture type classification

In 80 patients the type of fracture could be determined by x-rays, detailed patients' records or report of autopsy. 44 thoracolumbar fractures were classifiable after Magerl. There were 30 compression type fractures (A1.1 to A1.3), 2 slice fractures (A2), 5 burst fractures (A3.1 to A3.3) and 6 complex spinal injuries (B and C). 22 were fractures of the lateral processus of the vertebral body, 2 fractures pertained to the sacrum, the remaining were fractures of the upper cervical spine.

Crash mechanisms in severe thoracolumbar fractures

Five from six complex spinal injuries (B and C type) and four from five burst fractures (A3) were roll-overs or, mostly, multiple hits. There was no significant difference in delta-v. ISS and MAIS were higher in the more severe fractures. Seat belts had been used in all of these cases.

Case presentation

Figures 3 to 5 show the record of a belted driver of an Opel Astra. He was driving on a highway, suddenly decided to change lanes quickly without noticing a safety fence separating two lanes. He collided with a traffic sign and sustained multiple roll-overs before he collided with another safety fence. He sustained a compression fracture of the third thoracic vertebra which was treated conservatively. His additional injuries were epidural bleeding and multiple lacerations and decollement injuries of the left arm, which required multiple surgical revisions. He recovered fully. Figures show technical reconstruction, accident site and x-rays at admission.

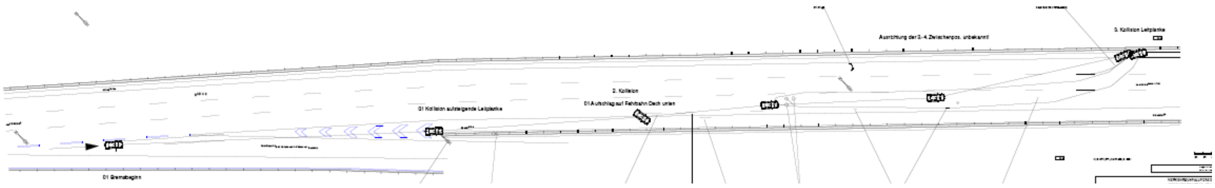

Figure 3: Technical reconstruction of accident site

Figure 4: Accident site

Figure 5: X-rays at admission

DISCUSSION

Crash mechanism

Significant injuries of the thoracolumbar spine typically occur in complex injury mechanisms like multiple hits or roll-over rather than in "simple" front collisions. These findings confirm data from Richards et al who found a low rate of 0.6% vertebral fractures in front collision below 60 kph by screening the data base of the National Automotive Sampling System (NASS)[7]. Still there were a number of compression fractures in front collisions below 20 kph. They compared these findings with data from crash-tests and found that axial forces in these crashes were well below forces which are found in lifting activities. In our data the mean delta-v was 40 kph which is approx. the double of what is found in car crashes without spinal injuries. Taking into account that most fractures occurred in multiple-hit-mechanisms, we conclude that the injury mechanism might be much more important than actual delta-v. This is supported by the finding that there is no clear correlation between fracture severity and delta-v on the one hand but there is an even higher proportion of multiple hits in the more severe fracture types.

Injury severity and associated injuries

In general, most fractures of the thoracolumbar spine are due to falls [8]. These patients usually present with single injuries. In contrast, almost all car passengers with vertebral fractures present with a number of additional injuries. Winslow et al found that passengers with significant injuries and fracture of the cervical spine were twice as likely to have fractures of the thoracolumbar spine as well [9]. This confirms our finding of an increased risk of additional vertebral fractures in those patients with fractures of the spine. This is even more apparent in passengers with fractures of the thoracic spine. Ball et al found up to 57% concomitant intraabdominal injuries with vertebral fractures in front collisions [10]. When comparing thoracic and lumbar fractures we find that only passengers with fractures of the lumbar spine but not those with injuries of the thoracic spine are older than passengers without vertebral fractures. This probably reflects a proportion of osteoporotic fractures which might easily occur in low-impact accidents and "simple" front collisions. Accordingly, we find a lower ISS in passengers with lumbar fractures and a higher proportion of front collisions.

The effect of safety belts

Earlier investigations at our department showed different fracture types according to the usage of safety belts. Unrestrained car occupants were more likely to sustain compression and chance fractures by an injury mechanism described as "forward and backward". Passengers with safety belts were more likely to show strain fractures of transversal processes due to the so-called "psoas effect" [11]. Safety belts used in this former study used to be mostly lap-belts only. Nowadays, three-point safety belts are mandatory in the EU. There has been a report about a series of four restrained car occupants with anterolateral wedge compression of a thoracolumbar vertebra with lateral compression occurring on the side opposite the restrained shoulder. The posterior elements were disrupted contralateral to the anterolateral body compression. The authors postulate a mechanism of injury, referred to as the „roll-out phenomenon" with flexion and rotation about the axis of the shoulder strap [12]. We were not able to show this phenomenon in our study but the question remains if 4-point fixation as used in motor sports might help to reduce the incidence of spine injuries in road traffic accidents. Airbag deployment was to rare to have a statistical influence in our study. Likewise, no difference could be shown in the study by Richards [7].

CONCLUSION

The overall risk for fractures of the spine in restrained front passengers is quite low, esp. for fractures of the thoracic and lumbar spine. Our data show clearly, that mainly complex injury mechanisms with multiple hits or roll-overs lead to fractures of the spine. Therefore the determination of the actual impact that leads to a spinal fracture or disruption remains difficult. Safety belts obviously play a major role in the prevention of injuries of the thoracolumbar spine. Car occupants frequently show severe additional injuries. The clinical management of polytraumatized victims of car crashes therefore has to include a thorough work-up of possible spine injuries, even if other injuries are more striking. Current protocols include CT scans of the complete spine in these patients.

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Conference Program

Hannover Medical School

University of Technology Dresden

3rd International Conference ESAR

"Expert Symposium on Accident Research"

Hannover Medical School

Hannover, Germany

September 5 - 6, 2008

Conference Program

Foreword

In September 2004 the first international symposium called ESAR was carried out at the University of Hannover, followed by the second symposium two years later. This two year rhythm will now continue in 2008 and beyond. ESAR is a scientific colloquium and can be seen as a platform for exchange of information on accident research issues. Representatives from authorities as well as from medical and technical institutions come together to discuss new research issues and exchange experiences on accident prevention and the complex methodologies of accident reconstruction. Special focus is given to the target the European Union set for itself in 2000 which stipulates that within 10 years the number of person killed in road traffic accidents must be cut in half. To reach this goal, optimized measures, comprehensive research and analysis are necessary. A key hurdle comes from the European Union extension to 27 member states, each featuring different levels of traffic safety standards and different accident scenarios. Existing results from long term research projects in Europe, the USA, Australia and Japan including analyses of infrastructure, population, vehicle fleet and driver behaviour offer an excellent basis for understanding and improving countermeasures and research support needs in underdeveloped countries.
ESAR's goal is to bring together researchers from all parts of the world, who will report on their methods and recommendations to improve traffic safety based on "In-Depth-Investigations" of real world accidents. These In-depth-investigations of accidents require thorough documentation and an accident data analysis on multi-disciplinary levels which must be carried out immediately after it occurs. ESAR presents scientists the opportunity to present their studies.
I cordially invite you to be our guest in Hannover again in 2008!
In recent years considerable progress in active and passive safety of road vehicles has been made. In most European countries the number of fatalities is decreasing despite growing traffic and road usage. Nevertheless, the number of casualties in road traffic accidents is high enough, thus more progress is needed if the number of fatalities is to be reduced by 50%, as postulated by the European Commission for the year 2010.

Professor Dietmar Otte

Hannover Medical School

Conference Program

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Conference Program

Day One - Friday 5th September 2008

8:00 - 9:00

Conference Registration

9:00 - 9:40

Welcome Session

Conference Chairman: Dietmar Otte, *Hannover Medical School*

Representatives Government and Industry

9:00

Dietmar Otte
Conference chairman
Hannover

9:10

BASt
President of German Federal Highway Research Institute BASt
Bergisch Gladbach

9:15

Rodolfo Schöneburg
Head of Passive Safety Durability Vehicle Functions, Daimler AG
Sindelfingen

9:20

Christian Krettek
Director Department of Trauma Surgery at Medical School Hannover
Hannover

9:25 - 9:45

Keynote Lecture

Importance of In-Depth Accident Analysis for Future Research Activities for European Enhanced Vehicle Safety EEVC

1. Dominique Cesari
Director of INRETS and Chairman of European Enhanced Vehicle Safety EEVC
Lyon, France

9:45 - 10:15

break

Conference Program

Day One - Friday 5th September 2008

10:15 - 11:40

Session: Accident Investigation and Methodology

Chair: Brühning

10:15

2. **In-Depth Crash Investigation at the Centre for Automotive Safety Research**
M. R. J. Baldock, J. E. Woolley, G. Ponte, L. N. Wundersitz, V. L. Lindsay, S. Doecke
University of Adelaide
Australia

10:30

3. **Recommendations for establishing Pan European Transparent and Independent Road Accident Investigations**
R. K. Elliman, L. K. Rackliff, A. P. Morris, H. Jähi, M. Jänsch, D. Otte, G. Giustiniani, D. Usami, H. Fagerlind, K. Parkkari, G. Vallet
Loughborough University
United Kingdom

10:45

4. **Crash Involvement Studies Using Routine Accident and Exposure Data: A Case for Case-Control Designs**
H. Hautzinger
Institute of Applied Transport and Tourism Research
Germany

11:00

5. **Integrated traffic accident database for accident analysis considering driver's accident and violation records**
Y. Nishida
ITARDA
Japan

11:15

6. **Study on Characteristics of Event Data Recorders Using J-NCAP data**
H. Ishikawa, N. Takubo, K. Kato, T. Okuno, R. Oga, T. Ikari
NRIPS, National Agency for Automotive Safety and Victim's Aid
Japan

11:30 - 12:00

break

Conference Program

Day One - Friday 5th September 2008

12:00 - 13:00

Session: Accident Analysis and Passive Safety

Chair: Sferco

12:00

Characteristics of Side Impacts of Passenger Cars to Pole in European Traffic Accidents - Analysis of German and UK In-depth data using different approaches

7. V. Eis, D. Otte, R. Schaefer
Ford, Hannover Medical School
Germany

12:15

Lateral Impacts in Australia and Germany

8. B. Fildes, D. Logan, D. Otte
Monash University, Hannover Medical School
Australia, Germany

12:30

Single Vehicle Accidents, Incidence and Avoidance

9. H. Hoschopf, E. Tomasch
Technical University Graz
Austria

12:45

Comparative Assessment of the Passive Safety of Passenger Cars

10. F. Kramer, J. Bakker
SAFE, Daimler AG
Germany

13:00 - 14:00
break / lunch

Conference Program

Day One - Friday 5th September 2008

14:00 - 14:20
Keynote Lecture

Speech of State Secretary
11. Matthias von Randow
State Secretary, Federal Ministry of Transport, Building and Urban Affairs
Berlin

14:20 - 15:35
Session: Active Safety and Methodology - Part I
Chair: Gail

14:20
Implementation of ACASS (Accident Causation Analysis with Seven Steps) in GIDAS
12. M. Jänsch, B. Pund, D. Otte, U. Chiellino, M. Hoppe
Hannover Medical School, TÜV Hessen, Uniklinik Regensburg, Volkswagen AG
Germany

14:35
Hypotheses based psychological accident causation analysis within ACASS (Accident Causation Analysis with Seven Steps)
13. B. Pund, D. Otte, M. Jänsch
TÜV Hessen, Hannover Medical School
Germany

14:50
Development of an In-depth European Causation Database
14. H. Fagerlind
Chalmers University of Technology
Sweden

15:05
Determination of Accident Causation and Risk Factors in Traffic Accidents from the Point of View of Motorcyclist Users
15. A. Molinero, J. M. Perandones, A. Mansilla, D. Pedrero, O. Martín
CIDAUT, Department of Accident Analysis and Human Factor
Spain

Day One - Friday 5th September 2008

15:20

Methods for Analyzing the Efficiency of Primary Safety measures based on real life accident data

16. H. Schittenhelm, J. Bakker, P. Frank, H. Bürkle, J. Scheerer
Daimler AG
Germany

15:35 - 16:00
break

16:00 - 16:20
Keynote Lecture

The EU Action for Road Safety and the Role of In-Depth-Investigation of Road Accidents

17. Jean-Paul Repussard
Directorate General Energy and Transport, European Commission
Brussels

16:20 - 17:35
Session: Active Safety and Methodoloy - Part II
Chair: Bakker

16:20

Multivariate Benefit Estimation of Future Vehicle Safety Systems

18. L. Hannawald
VUFO
Germany

16:35

In-vehicle Multi-channel Signal Processing and Analysis in UTDrive Project: Driver Behavior Modeling and Active Safety Systems Development

19. P. Boyraz, J. H. L. Hansen
University of Texas
USA

Conference Program

Day One - Friday 5th September 2008

16:50

The scope and potential effectiveness of advanced lane change driver assistance technologies

20. M. Gregoriades, J. Lenard, J. Hill
Loughborough University
United Kingdom

17:05

Just a matter of bad luck – or - is it possible to predict fatal accidents?

21. C. Pastor
Federal Highway Research Institute (BASt)
Germany

17:20

Risk factors quantification based on mutual information ratio for in depth investigation of GIDAS data base

22. M. Mougeot, R. Azencott
Université ParisX, University of Houston
France, USA

17:35
end of first day

19:30

Conference dinner

Cavallo königliche Reithalle
Dragonerstraße 14, 30163 Hannover

Conference Program

Day Two - Saturday 6th September 2008

8:00 - 9:00

Poster Session

Chair: D. Otte, *Hannover Medical School*

8:00

The accuracy of vehicle damage based protocols to quantify impact severity

23. R. Cookson, R. Cuerden, J. Neades
TRL, Ai Training Services
United Kingdom

8:05

The Escalating Burden of Road Traffic Injuries in the Emro Region

24. H. F. El-Sayed
Suez Canal University
Egypt

8:10

Simulation of real pre crash accident scenarios using German In-Depth Accident Study (GIDAS)

25. C. Erbsmehl, L. Hannawald, H. Liers
VUFO
Germany

8:15

Benefit Analysis of Driver Information and Driver Assistance Systems

26. L. Hannawald, H. Brehme
VUFO
Germany

8:20

A European Fatal Crash Database

27. A. Morris
Loughborough University
United Kingdom

8:25

Who doesn't wear seat belts?

28. D. C. Richards, R. Hutchins, R. E. Cookson, P. Massie, R. W. Cuerden
TRL
United Kingdom

Conference Program

Day Two - Saturday 6th September 2008

8:30

Global Accident Prevention – A road safety initiative of European FIA automobile clubs

29. V. Sander, T. Unger
ADAC
Germany

8:35

Relevant Accident Related Factors – Risk and Frequencies of Contributing to Road Traffic Accidents

30. S. Schick, P. van Elslande, C. Dinges, C. Naing, K. Fouquet, J. Plaza, Y. Page, W. Hell
LMU Munich, Inrets, VSRC, Cidaut, LAB
Germany, France, United Kingdom, Spain

8:40

Powered two wheelers accident investigation and reconstruction

31. J. Dias, T. Paulino, R. Silva
IDMEC, CARCRASH
Portugal

8:45

Praxis- related application of the new diagnosis register (AIS 2005) in accident research

32. H. Brehme
VUFO
H. Zwipp, A. Ernstberger, C. Haasper, L. Hannawald, M. Junge, C. Langer, J. Nehmzow, U. Sander, D. Otte

8:50 – 9:00

Discussion

9:00 - 9:20

break

Day Two - Saturday 6th September 2008

9:20 - 10:20
Session: Vulnerable Road Users - Part I
Chair: Brunner

9:20
A European Perspective of In-Depth Data Sampling on Cognitive Aspects of Motorcycle Helmets within COST 357
33. M. Gilchrist, D. Otte, M. Jänsch, J. Chliaoutakis, T. Lajunen, A. Morandi, T. Ozkan, J. Pereira, A. Stendardo, G. Tzamalouka
Ireland, Germany, Greece, Italy, Turkey, Portugal

9:35
Statistical Analysis of Bicyclist Accidents in Changsa of China and Hannover of Germany
34. J. Yang, D. Otte
Hunan University, Hannover Medical School
China, Germany

9:50
Accident Scenarios of Real-World Vulnerable Road User Crashes in China Urban Traffic
35. B. Deng, J. K. Yang
GM, Changsha University
USA, China

10:05
Safety in Road Traffic for Vulnerable Users in China
36. J. Chen, H. Wang
Tongji University
Shanghai, China

10:20 - 10:40
break

Day Two - Saturday 6th September 2008

10:40 - 11:20

Session: Vulnerable Road Users - Part II

Chair: Jungmichel

10:40

Injury prevention in motorcycle accidents: Italian evidence from Motorcycle Accidents in-Depth Study (MAIDS)

37. A. Morandi, A. Verri, A. Marinoni
Università di Pavia
Italy

10:55

Pedestrian Reconstruction Tools Applied to Pedestrian Accidents in Portugal

38. R. Portal, J. Dias, A. Freitas
IDMEC, CARCRASH
Portugal

11:10

Accident Involvement of Motorcycles – Description of the Current Situation in Germany Using Data from Federal Statistics and GIDAS

39. A. Berg, J. König
DEKRA
Germany

11:25

In-Depth Human Functional Failure Analysis Of Fatal Pedestrian Accidents

40. S. Schick, C. Baumgartner, S. Horion, K. Thorsteinsdottir, W. Hell
LMU Munich
Germany

11:40 - 12:00

break

Day Two - Saturday 6th September 2008

12:00 – 13:15

Session: Injury Prevention and Mechanisms - Part I

Chair: Krettek

12:00

Comparison of injury severity between AIS 2005 and AIS 90 in a large injury database

41. J. Barnes, A. Hassan, R. Cuerden
Loughborough University, University of Birmingham, TRL
United Kingdom

12:15

Severe Injuries in Passenger Cars - Development of a Software Tool for Emergency Diagnostics

42. H. Brehme, H. Zwipp
Technical University of Dresden
Germany

12:30

School-Based Program for Injury Prevention and Safety Promotion in Ismailia city, Egypt

43. H. F. El-Sayed, S. Gad, H. Saied, D. Gamal
Suez Canal University
Egypt

12:45

Injury situation of novice drivers in road traffic

44. C. Haasper, D. Otte, C. Probst, C. Müller, M. Panzica, T. Hüfner, C. Krettek
Hannover Medical School
Germany

13:00

Emergency Medical Care in case of traffic accidents in Bavaria: Actual process analysis in reference to clinical and rescue service structures

45. C. K. Lackner, S. Bielmeier, K. Burghofer
Munich University, University of Regensburg
Germany

13:15 - 13:30
break

Day Two - Saturday 6th September 2008

13:30– 14:30

Session: Injury Prevention and Mechanisms - Part II

Chair: Zwipp

13:30

A Prospective and Interdisciplinary Study on Polytraumata in Traffic Accidents

46. A. Malczyk, M. Ecker, M. Helm, U. Liener
German Insurance Association, Klinikum Augsburg, Bundeswehrkrankenhaus Ulm, Universitätsklinikum Ulm
Germany

13:45

Adult front car occupant thorax injury experience following frontal impacts

47. P. Massie, D. C. Richards, M. J. Edwards, R. W. Cuerden, A. Thompson, O. Goodacre
TRL
United Kingdom

14:00

Spine injuries in motor vehicle accidents - an analysis of 18253 accidents with special consideration of injuries of the thoracolumbar spine in relation to injury mechanisms

48. C. W. Müller, D. Otte, C. Haasper, C. Probst, M. Panzica, T. Hüfner, C. Krettek
Hannover Medical School
Germany

14:15

Trauma and accident documentation in Germany - current assessment in comparison to European systems

49. C. Probst, D. Otte, C.W. Müller, C. Haasper, M. Panzica, T. Hüfner, C. Krettek
Hannover Medical School
Germany

14:30

Closing Speech
General Chairman: Dietmar Otte, *Hannover Medical School*

End of conference

Conference Program

Congress Office

Scientific Organisation Secretariat

Prof. Dietmar Otte
Mrs. Ingrid Herburg
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Congress opening hours/registration desk

Friday 5th Sept.	8:00 – 18:00
Saturday 6th Sept.	8:00 – 14:00

Poster presentation

All posters are displayed in the main lobby near the conference hall.

Speakers Ready Room

There is a speakers' Ready Room near the conference hall (room M), please follow the signs.

Language

The official language of the Congress is English. Simultaneous translation is not provided.

Proceedings

All papers and posters are printed in a special conference book as report of the Federal Highway Research Institute BASt Journal M with ISBN-number.

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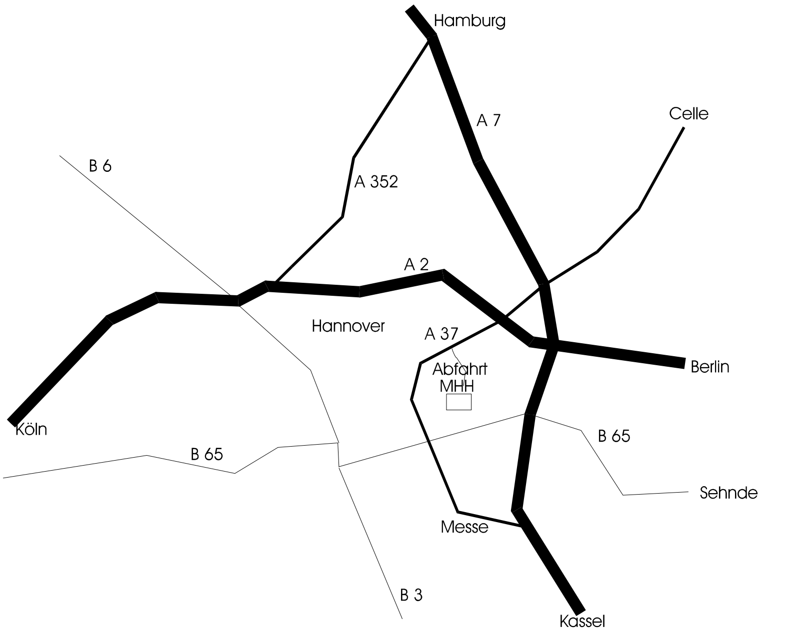
Hotel Mercure Atrium Hannover Karl-Wiechert-Allee 68 D-30625 Hannover	89,-	+49 511 54070 +49 511 5407826	H-1701@accor-hotels.com www.accorhotels.com	1 Aug. 08	*"ESA"*

including breakfast

Old Town Hall Hannover

Hannover Medical School

Travelling by car



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Building J1
2nd Floor
Lecture Hall F

Traveling by train
Arrival at Central Station "Hannover Hauptbahnhof".
Use Underground line 8 direction "Messegelände" and leave the tram at station "Aegidientorplatz" (second station after entering). Use then line 4 direction "Roderbruch" from the same platform opposite side. Leave the tram at station "Medizinische Hochschule". To find the conference hall and registration desk please look at the plan at the top of this sheet.
Traveling by aeroplane
Arrival at Airport Hannover-Langenhagen. Use S-Bahn to Central Station Hannover and follow description "travelling by train" or take a taxi (approx. € 30, 20 min)

Description of way to conference hall:

5 minutes walking distance from the hotels NOVOTEL, IBIS and Mercure

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The Organisation Committee and the Organiser, speakers, presenters and other participants gratefully acknowledge the following institutions for their various contributions in this ESAR conference:

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Schriftenreihe

Berichte der Bundesanstalt für Straßenwesen

Unterreihe „Fahrzeugtechnik“

1995

F 10: **Einsatz der Gasentladungslampe in Kfz-Scheinwerfern**
Damasky € 12,50

F 11: **Informationsdarstellung im Fahrzeug mit Hilfe eines Head-Up-Displays**
Mutschler € 16,50

F 12: **Gefährdung durch Frontschutzbügel an Geländefahrzeugen**
Teil 1: Gefährdung von Fußgängern und Radfahrern
Zellmer, Schmid
Teil 2: Quantifizierung der Gefährdung von Fußgängern
Zellmer € 12,00

F 13: **Untersuchung rollwiderstandsarmer Pkw-Reifen**
Sander € 11,50

1996

F 14: **Der Aufprall des Kopfes auf die Fronthaube von Pkw beim Fußgängerunfall – Entwicklung eines Prüfverfahrens**
Glaeser € 15,50

F 15: **Verkehrssicherheit von Fahrrädern**
Teil 1: Möglichkeiten zur Verbesserung der Verkehrssicherheit von Fahrrädern
Heinrich, von der Osten-Sacken
Teil 2: Ergebnisse aus einem Expertengespräch „Verkehrssicherheit von Fahrrädern“
Nicklisch € 22,50

F 16: **Messung der tatsächlichen Achslasten von Nutzfahrzeugen**
Sagerer, Wartenberg, Schmidt € 12,50

F 17: **Sicherheitsbewertung von Personenkraftwagen – Problemanalyse und Verfahrenskonzept**
Grunow, Heuser, Krüger, Zangemeister € 17,50

F 18: **Bremsverhalten von Fahrern von Motorrädern mit und ohne ABS**
Präckel € 14,50

F 19: **Schwingungsdämpferprüfung an Pkw im Rahmen der Hauptuntersuchung**
Pullwitt € 11,50

F 20: **Vergleichsmessungen des Rollwiderstands auf der Straße und im Prüfstand**
Sander € 13,00

F 21: **Einflußgrößen auf den Kraftschluß bei Nässe – Untersuchungen zum Einfluss der Profiltiefe unterschiedlich breiter Reifen auf den Kraftschluss bei Nässe**
Fach € 14,00

1997

F 22: **Schadstoffemissionen und Kraftstoffverbrauch bei kurzzeitiger Motorabschaltung**
Bugsel, Albus, Sievert € 10,50

F 23: **Unfalldatenschreiber als Informationsquelle für die Unfallforschung in der Pre-Crash-Phase**
Berg, Mayer € 19,50

1998

F 24: **Beurteilung der Sicherheitsaspekte eines neuartigen Zweiradkonzeptes**
Kalliske, Albus, Faerber € 12,00

F 25: **Sicherheit des Transportes von Kindern auf Fahrrädern und in Fahrradanhängern**
Kalliske, Wobben, Nee € 11,50

1999

F 26: **Entwicklung eines Testverfahrens für Antriebsschlupf-Regelsysteme**
Schweers € 11,50

F 27: **Betriebslasten an Fahrrädern**
Vötter, Groß, Esser, Born, Flamm, Rieck € 10,50

F 28: **Überprüfung elektronischer Systeme in Kraftfahrzeugen**
Kohlstruck, Wallentowitz € 13,00

2000

F 29: **Verkehrssicherheit runderneuerter Reifen**
Teil 1: Verkehrssicherheit runderneuerter Reifen
Glaeser
Teil 2: Verkehrssicherheit runderneuerter Pkw-Reifen
Aubel € 13,00

F 30: **Rechnerische Simulation des Fahrverhaltens von Lkw mit Breitreifen**
Faber € 12,50

F 31: **Passive Sicherheit von Pkw bei Verkehrsunfällen – Fahrzeugsicherheit ‘95 - Analyse aus Erhebungen am Unfallort**
Otte € 12,50

F 32: **Die Fahrzeugtechnische Versuchsanlage der BASt – Einweihung mit Verleihung des Verkehrssicherheitspreises 2000 am 4. und 5. Mai 2000 in Bergisch Gladbach** € 14,00

2001

F 33: **Sicherheitsbelange aktiver Fahrdynamikregelungen**
Gaupp, Wobben, Horn, Seemann € 17,00

F 34: **Ermittlung von Emissionen im Stationärbetrieb mit dem Emissions-Mess-Fahrzeug**
Sander, Bugsel, Sievert, Albus € 11,00

F 35: **Sicherheitsanalyse der Systeme zum Automatischen Fahren**
Wallentowitz, Ehmanns, Neunzig, Weilkes, Steinauer, Bölling, Richter, Gaupp € 19,00

F 36: **Anforderungen an Rückspiegel von Krafträdern**
van de Sand, Wallentowitz, Schrüllkamp € 14,00

F 37: **Abgasuntersuchung - Erfolgskontrolle: Ottomotor – G-Kat**
Afflerbach, Hassel, Schmidt, Sonnborn, Weber € 11,50

F 38: **Optimierte Fahrzeugfront hinsichtlich des Fußgängerschutzes**
Friesen, Wallentowitz, Philipps € 12,50

2002

F 39: **Optimierung des rückwärtigen Signalbildes zur Reduzierung von Auffahrunfällen bei Gefahrenbremsung**
Gail, Lorig, Gelau, Heuzeroth, Sievert € 19,50

F 40: **Entwicklung eines Prüfverfahren für Spritzschutzsysteme an Kraftfahrzeugen**
Domsch, Sandkühler, Wallentowitz € 16,50

2003

F 41: **Abgasuntersuchung: Dieselfahrzeuge**
Afflerbach, Hassel, Mäurer, Schmidt, Weber € 14,00

F 42: **Schwachstellenanalyse zur Optimierung des Notausstieg-systems bei Reisebussen**
Krieg, Rüter, Weißgerber € 15,00

F 43: **Testverfahren zur Bewertung und Verbesserung von Kinderschutzsystemen beim Pkw-Seitenaufprall**
Nett € 16,50

F 44: **Aktive und passive Sicherheit gebrauchter Leichtkraft-fahr-zeuge**
Gail, Pastor, Spiering, Sander, Lorig € 12,00

2004

F 45: **Untersuchungen zur Abgasemission von Motorrädern im Rahmen der WMTC-Aktivitäten**
Steven € 12,50

F 46: **Anforderungen an zukünftige Kraftrad-Bremssysteme zur Steigerung der Fahrsicherheit**
Funke, Winner € 12,00

F 47: **Kompetenzerwerb im Umgang mit Fahrerinformations-systemen**
Jahn, Oehme, Rösler, Krems € 13,50

F 48: **Standgeräuschmessung an Motorrädern im Verkehr und bei der Hauptuntersuchung nach § 29 StVZO**
Pullwitt, Redmann € 13,50

F 49: **Prüfverfahren für die passive Sicherheit motorisierter Zweiräder**
Berg, Rücker, Bürkle, Mattern, Kallieris € 18,00

F 50: **Seitenairbag und Kinderrückhaltesysteme**
Gehre, Kramer, Schindler € 14,50

F 51: **Brandverhalten der Innenausstattung von Reisebussen**
Egelhaaf, Berg, Staubach, Lange € 16,50

F 52: **Intelligente Rückhaltesysteme**
Schindler, Kühn, Siegler € 16,00

F 53: **Unfallverletzungen in Fahrzeugen mit Airbag**
Klanner, Ambos, Paulus, Hummel, Langwieder, Köster € 15,00

F 54: **Gefährdung von Fußgängern und Radfahrern an Kreuzungen durch rechts abbiegende Lkw**
Niewöhner, Berg € 16,50

2005

F 55: **1st International Conference on ESAR „Expert Symposium on Accident Research" – Reports on the ESAR-Conference on 3rd/4th September 2004 at Hannover Medical School** € 29,00

2006

F 56: **Untersuchung von Verkehrssicherheitsaspekten durch die Verwendung asphärischer Außenspiegel**
Bach, Rüter, Carstengerdes, Wender, Otte € 17,00

F 57: **Untersuchung von Reifen mit Notlaufeigenschaften**
Gail, Pullwitt, Sander, Lorig, Bartels € 15,00

F 58: **Bestimmung von Nutzfahrzeugemissionsfaktoren**
Steven, Kleinebrahm € 15,50

F 59: **Hochrechnung von Daten aus Erhebungen am Unfallort**
Hautzinger, Pfeiffer, Schmidt € 15,50

F 60: **Ableitung von Anforderungen an Fahrerassistenzsysteme aus Sicht der Verkehrssicherheit**
Vollrath, Briest, Schießl, Drewes, Becker € 16,50

2007

F 61: **2nd International Conference on ESAR „Expert Symposium on Accident Research" – Reports on the ESAR-Conference on 1st/2nd September 2006 at Hannover Medical School** € 30,00

F 62: **Einfluss des Versicherungs-Einstufungstests auf die Belange der passiven Sicherheit**
Rüter, Zoppke, Bach, Carstengerdes € 16,50

F 63: **Nutzerseitiger Fehlgebrauch von Fahrerassistenzsystemen**
Marberger € 14,50

F 64: **Anforderungen an Helme für Motorradfahrer zur Motorradsicherheit**
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Schüler, Adoplh, Steinmann, Ionescu € 22,00

F 65: **Entwicklung von Kriterien zur Bewertung der Fahrzeugbeleuchtung im Hinblick auf ein NCAP für aktive Fahrzeugsicherheit**
Manz, Kooß, Klinger, Schellinger € 17,50

2008

F 66: **Optimierung der Beleuchtung von Personenwagen und Nutzfahrzeugen**
Jebas, Schellinger, Klinger, Manz, Kooß € 15,50

F 67: **Optimierung von Kinderschutzsystemen im Pkw**
Weber € 20,00

F 68: **Cost-benefit analysis for ABS of motorcycles**
Baum, Westerkamp, Geißler € 20,00

F 69: **Fahrzeuggestützte Notrufsysteme (eCall) für die Verkehrssicherheit in Deutschland**
Auerbach, Issing, Karrer, Steffens € 18,00

F 70: **Einfluss verbesserter Fahrzeugsicherheit bei Pkw auf die Entwicklung von Landstraßenunfällen**
Gail, Pöppel-Decker, Lorig, Eggers, Lerner, Ellmers € 13,50

2009

F 71: **Erkennbarkeit von Motorrädern am Tag – Untersuchungen zum Signalbild**
Bartels, Sander € 13,50

F 72: **3rd International Conference on ESAR „Expert Symposium on Accident Research" – Reports on the ESAR-Conference on 5th/6th September 2008 at Hannover Medical School**
€ 29,50

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