PRIORITIES FOR
EU MOTOR VEHICLE SAFETY DESIGN

Brussels 2001

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ISBN: 90-76024-12-X

Acknowledgements

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ETSC is grateful for the financial support provided by the Energy and Transport Directorate of the European Commission and for the contribution towards the printing and dissemination costs of this review provided by BP, KeyMed, Railtrack Group PLC, Scania, and Shell International. The contents of this review are the sole responsibility of ETSC and do not necessarily reflect the view of the sponsors nor the organisations to which research staff participating in the Working Party belong.

The European Transport Safety Council

The European Transport Safety Council (ETSC) is an international non-governmental organisation which was formed in 1993 in response to the persistent and unacceptably high European road casualty toll and public concern about individual transport tragedies. Cutting across national and sectoral interests, ETSC provides an impartial source of advice on transport safety matters to the European Commission, the European Parliament and, where appropriate, to national governments and organisations concerned with safety throughout Europe.

The Council brings together experts of international reputation on its Working Parties, and representatives of a wide range of national and international organisations with transport safety interests and Parliamentarians of all parties on its Main Council to exchange experience and knowledge and to identify and promote research-based contributions to transport safety.

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EXECUTIVE SUMMARY

Road crashes continue to be the main source of accidental death and injury in the European Union and throughout the world. In EU countries annually over 42,000 road users are killed and, when under-reporting is taken into consideration, around 3.5 million are injured. This accounts for an annual cost of over 160 billion Euro and untold pain and suffering. Improvements throughout the traffic system and using all the known strategies from crash prevention through to injury reduction and post impact care are needed to respond to the growing lack of public acceptance of road crash injuries. This review highlights the enormous potential which still exists to reduce the frequency and severity of road casualties by improvements to motor vehicles.

Since the ETSC reviews, Reducing traffic injuries through vehicle safety improvements: the role of car design (1993) and Consumer information on the crash performance of cars (1995), there have been significant improvements in the protection available to car occupants. The frontal and side impact Directives and consumer information from the European New Car Assessment Programme (EuroNCAP) have led to the most rapid developments in car occupant protection that Europe has experienced but a great deal more can be achieved. Much of the research and development activity necessary for improvements in other areas of vehicle safety has been completed and now requires the political will to bring about its adoption in legislation.

Vehicle engineering improvements for safety can either be achieved by modifying the vehicle to help the driver avoid accidents, or by modifying the vehicle to provide protection against injury in the event of a crash. Although much can be done to stop some accidents from happening, it is clear that for the foreseeable future the majority will continue to occur. A recent study in one EU Member State reviewed the effectiveness of casualty reduction measures nationally since 1980 and demonstrated that the greatest reduction was from vehicle crash protection (15 per cent) compared to drink/drive measures (11 per cent) and road safety engineering measures (6.5 per cent). Reducing the risk of injury in accidents is and will remain a priority and the single most effective way of achieving this is by improving the safety of cars. For pedestrians and cyclists hit by the front of the car, although significant improvements are possible, little has yet been done.

KEY ROAD CASUALTY PROBLEMS IN THE EUROPEAN UNION

Looking at fatality numbers, car occupants are the largest single casualty group. They comprise 57 per cent of total EU deaths with the majority of car occupant fatalities occurring on non-motorway rural roads. The majority of fatal car occupant casualties are sustained in side impacts and frontal impacts with frontal impacts being dominant for serious casualties.

Looking at fatality risk, the traffic system is the least safe for the more vulnerable road users, where the risk of death on EU roads is substantially higher than for car occupants: for pedestrians and cyclists the risk is 8-9 times higher and for motorcyclists it is 20 times higher. The majority of fatally injured pedestrians are hit by the fronts of cars. The majority of serious and fatal motorcyclist injuries are to the head and leg.

Accident research continues to show that many road user injury situations are not catered for by current measures. Crash tests only deal with a limited number of crash scenarios and protection is focussed on the average-sized male occupant. Other accident configurations and occupants of different sizes also need consideration. In future, for demographic reasons, the average age of the driving population will increase and become more vulnerable to injury. At the same time advances in vehicle crash protection will allow more road users than at present to survive impacts and the need to prevent injuries with long term effects will become more important. The socio-economic costs of many disabling injuries, such as ‘whiplash’, are poorly represented by their severity, which is usually measured in terms of threat to life.

SUMMARY OF IMMEDIATE PRIORITIES FOR EU ACTION

The following list of priorities for EU action comprise those measures which offer the greatest opportunities for large reductions in casualties in the short to medium term with due account being taken of the state of the art of research and development in each case.

Legislation

Top Priority

- Safer car fronts for pedestrians and cyclists (adoption of 4 EEVC tests)
- Improved offset frontal impact test, extended to cover additional vehicle types
- Seat belt reminder systems
- Universal ISOFIX child restraint anchorages with an effective third restraint
- Side impact test procedure for child restraints
- High deceleration frontal crash test for restraint system assessment
- Daytime running lights for motorcycles

Priority

- Improved side impact test for cars
- Daytime running lights for cars
- Anti-lock brakes on motorcycles
- Improved rear and side HGV underrun protection
- Seat belt fitment to minibuses, coaches and heavy goods vehicles

Consumer information

Top Priority

- Member States to join and fund EuroNCAP
- Improved dissemination of EuroNCAP results
- Combine EuroNCAP pedestrian and child restraint performance with occupant ratings
- EuroNCAP to encourage the on-going improvement of seat belt reminder systems
- Incorporation of a high deceleration frontal impact into EuroNCAP
- Assessment of Compatibility in EuroNCAP

Priority

- Further review the appropriateness of EuroNCAP requirements to accident needs

Research and development

Top Priority

- EU in-depth accident and injury causation studies
- Specification for smart audible seat belt warning devices
- Car frontal and side impact compatibility and advanced protection
- Protection in side impacts at higher severities and for non-struck side occupants
- Greater understanding of “whiplash” injuries, their causes and prevention
- Measures to improve motorcycle leg and upper torso protection
- Research into standards for Intelligent Speed Adaptation

Priority

- Criteria and instrumentation for frontal impact injury to the abdomen and knees
- Performance and concerns regarding European air bags
- Development of advanced intelligent restraints
- Energy-absorbing front underrun protection for heavy goods vehicles
- More comprehensive biomechanical data, injury performance criteria, improved crash dummies
- Pedestrian head protection measures for the windscreen surround
- EU standard for GPS based warning of accidents
- Specifications for on-board crash recorders for all motor vehicles

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

Car design for occupant protection

1. Improving EU frontal impact protection requirements

a) The test speed for the frontal impact test should be raised to 64 – 65 km/h.
b) The frontal impact Directive should be extended to cover N1 vehicles up to 2.5 tonnes, M1 vehicles above 2.5 tonnes and M2 vehicles.
c) A requirement to limit the lateral displacement of the steering column to 80 mm should be added to the existing vertical and horizontal requirements.
d) All the current injury criteria need to be maintained.
e) When available, consideration should be given to using an improved dummy with improved criteria for the lower legs.
f) Research is needed to develop criteria and instrumentation to assess the risk of injury to the abdomen and knees.
g) The recommended limit on footwell intrusion recommended by the EEVC should be adopted with a requirement for its review in the light of further accident experience.
h) For the present time the current design of deformable barrier face should be retained.
i) An additional full frontal high deceleration crash test is required to provide a better test of restraint protection

2. Improving EU side impact protection requirements

a) The derogation regarding seating position should be removed from the Directive.
b) All the current performance criteria should be retained and the Viscous Criterion should become a mandatory requirement.
c) Protection of the lower limbs needs to be considered for the future. To provide for the protection of the lower limbs, dummy instrumentation and criteria for the lower limbs need developing.
d) Research should be carried out to determine the best method of increasing the severity of the side impact test to be more able to address the accident problem. This should enable a further review of the Directive to be made to enable the higher speeds of impact in accidents to be addressed.
e) Urgent consideration needs to be given to instrumenting all the load paths into the EuroSID dummy and developing criteria for them.
f) In any future side impact dummy, all possible load paths need to be instrumented by design.
g) When the EEVC research is complete, a single design specification of barrier face should be specified in the Directive. This barrier face must be capable of being manufactured to the same standard of performance by competing suppliers around the world.
h) A pole impact test is required to evaluate head protection in side impact. Consideration should be given to the development of a test to simulate accidents involving impacts with poles. This would require research into the levels of protection possible.

3. Improving car to car compatibility

a) Compatibility is seen as the next major step forward in improving car occupant safety. Further developments of frontal impact protection need to be considered in association with compatibility and this is seen as a top priority for vehicle safety research.

4. Improving seat belt use

a) The fitment of effective seat belt reminder systems is seen as a high priority for early action.

b) EuroNCAP can provide an immediate incentive for manufacturers to develop and install simple effective seat belt reminder systems and then to continue to develop more advanced ones.
c) When effective seat belt reminder systems become available, consideration should be given to enacting legislation for their mandatory fitment.

5. Frontal protection front air bags
a) Driver airbags should be fitted universally.
b) Where passenger airbags are fitted, clear instructions are needed to avoid the fitment of rearward facing child restraints on the seat.
c) The provision of automatic detection of child restraints and out of position occupants is needed to switch off the passenger airbag.
d) If manual switches are provided, an effective warning about their setting needs to be incorporated.

6. Side protection air bags
a) With the growing number of side airbags fitted in cars, accident research is needed to identify their benefits and any associated problems.

7. Restraint of children in cars
a) Children in cars should be provided with suitable child restraints for their age and size.
b) The use of rearward facing restraints provides the best protection and should be used up to as high an age as possible.
c) Further research is needed to assess the effects of modern car designs to identify necessary changes for restraint design and regulatory tests.
d) A mandatory side impact test procedure is required to assess child restraints for all age groups of children.
e) The fitting of ISOFIX anchorages, with provision for an effective third restraint in the front and rear seats should be made mandatory.
f) ECE R44 should be developed to assess universal ISOFIX seats, with effective third restraints.

8. Reducing injuries through contact with the car interior
a) An interior headform test procedure should be developed for use in Europe.
b) A sub-systems test procedure needs to be developed to assess the risk from knee impacts against that part of the fascia that knees are able to impact.
c) Footwell intrusion requirements need to be added to the Frontal Impact directive.
d) As soon as validated improved lower legs are available for the frontal impact dummies they should be used in the mandatory test and EuroNCAP.
e) Improved injury protection criteria need to be developed for use with improved dummy lower limbs.

9. Improving rear occupant protection
a) Measures need to be taken to increase rear seat belt wearing rates.
b) 3-point seat belts, with pre-tensioners and load limiters, should be required for all rear seats.
c) Dynamic testing of rear seat back strength needs to be mandatory.

10. Improving protection in rear impacts
a) A new dynamic test standard for seat backs should be developed.
b) Further research is required to provide a better understanding of “whiplash” injuries and their cause.
c) Evaluation of neck protection devices from accident experience is required to determine their effectiveness.

d) Injury classification schemes need to take proper account of non-life threatening injuries such as “whiplash.”

11. Safer car fronts for pedestrians and cyclists

a) Introduction of EU Directive requiring the four EEVC sub-system tests for the protection of vulnerable road users
b) Consumer information e.g. through EuroNCAP
c) Research on head injuries caused by the windscreen surround

Car design for crash prevention

12. Reducing vehicle speeds

a) Work is required to develop harmonised standards for Intelligent Speed Adaptation systems with the aim of eventual universal fitment.
b) In the meantime, encouragement should be given to manufacturers providing ISA systems via the European New Car Assessment Programme to enable the consumer to start benefiting from a voluntary system.

13. Reducing driver impairment

a) Further work is required to develop practical driver impairment systems and to understand their effectiveness and acceptability.
b) Consideration should be given in developing such systems in combination with an electronic driving licence system.

14. Improving conspicuity

a) It is recommended that early consideration is given to a mandatory fitment requirement for daytime running lights in the EU.

15. Improving braking and stability

a) Research would help to ascertain whether anti-lock braking systems alone have a role to play in accident reduction.
b) Monitoring of braking assistance systems is required to determine how well they can identify and respond to the driver’s intended braking behaviour and to determine their accident reduction potential.
c) Monitoring of the dynamic stability systems being made available by car manufacturers is needed to determine their influence on accident occurrence.

Motorcycle design to improve safety

a) Daytime running lights and anti-lock braking systems should be mandatorily fitted to motorcycles.
b) Further research is urgently needed:
   - to determine seating positions with a relatively high seat elevation and upright body position to reduce the possibility of lower leg entrapment
   - to provide leg protection to protect the wearer from the impact of external forces and to serve as an element that affects the trajectory in a positive way
   - to develop suitable airbags to provide riders with protection in frontal impacts

Heavy goods vehicle design

a) Development of a test specification for energy-absorbing front underrun protection is needed towards a mandatory fitment requirement.
b) Rear and side underrun protection legislative requirements need to be amended to reflect needs identified by accident research.

c) An EU Directive is needed to require the compulsory fitment of seat belts in heavy commercial vehicle cabins
d) EU Directives should be introduced aimed at improved mirror systems and providing retro-reflective contour marking on heavy commercial vehicles.

Minibus and light van design

a) Seat belt wearing rates are lower in minibuses and light vans than in cars and should be increased. All existing exemptions should be removed nationally.
b) A mandatory requirement is needed at EU level for the fitment of seat belts.
c) The frontal impact occupant protection requirements should be extended to minibuses and light vans.

Bus and coach design

a) European requirements need to be developed to enhance the structural integrity of buses and coaches and their seats, and seat to floor mountings
b) Consideration should be given to improved side glazing to reduce the risk of ejection without impeding evacuation
c) An EU requirement is needed to fit seat belts to coaches

Alerting the emergency services

a) A uniform EU standard needs to be established to provide a GPS warning signal to emergency departments.

Crash Investigation Tools

a) Develop specifications for the fitment of on-board crash recorders on all vehicles
b) A new monitoring system to gather systematic in-depth accident and injury causation information needs to be established at EU level.
c) Collecting human response and injury data should be a key research priority in the field of passive safety as good information for many body areas is still lacking.
d) Research and development aimed at improving crash dummies in terms of human likeness in response, injury assessment capabilities and application

1. INTRODUCTION

Road crashes continue to be the main source of accidental death and injury in the European Union (EU) and throughout the world. Each year in EU countries over 42,000 road users are killed and, when under-reporting is taken into consideration, around 3.5 million are injured. This accounts for an annual cost of over 160 billion Euro and untold pain and suffering. Improvements throughout the traffic system using all the known strategies from crash prevention through to injury reduction and post impact care are needed to respond to the growing lack of public acceptance of road crash injuries. This review is intended to indicate the enormous potential which still exists to reduce the frequency and severity of road casualties by improvements to motor vehicles.

Since the ETSC reviews, “Reducing traffic injuries through vehicle safety improvements: the role of car design” (1993) and “Consumer information on the crash performance of cars” (1995), there have been significant improvements in the protection available to the occupants of cars. The frontal and side impact Directives and consumer information from the European New Car Assessment Programme (EuroNCAP) have led to the most rapid developments in car occupant protection that Europe has experienced. Much of the research and development activity necessary for improvements in other areas of vehicle safety has been completed and now requires the political will to bring about its adoption in legislation.

Vehicle engineering improvements for safety can either be achieved by modifying the vehicle to help the driver avoid accidents, or by modifying the vehicle to provide protection against injury in the event of a crash. National road safety plans generally indicate that vehicle safety measures are now deemed to be an essential part of any strategy aimed at reducing human suffering on the roads. The ultimate road safety goal must be to prevent crashes leading to serious, disabling or fatal injury from happening and new technologies can help the vehicle to play its part in preventing such crashes. However, it is clear that for the short to medium term, preventing or reducing the severity of injuries in crashes is the major role for car safety improvements.

New technologies are opening new opportunities as more intelligent systems are being developed for road vehicles. Communications, route and traffic information, systems for autonomous control of the vehicle and other “intelligent” systems are already becoming a feature in the marketplace. Many of these systems are claimed to have casualty reduction potential by increasing the levels of control the traffic system has over an individual vehicle therefore reducing the risk of an accident. These systems can appear desirable to the consumer and therefore to the manufacturer as they can be incorporated as a marketing item. In many cases, the primary intended value of these systems is to improve the comfort or convenience to the road user or to provide additional functionality to the systems within the vehicle. The development of the systems is generally technology driven and casualty reduction opportunities are usually as yet unproven. Frequently, estimates for casualty savings are based on hypothetical performance in specific situations. This is in contrast with the experience from passive safety measures which have shown large benefits and are responsible for a large part of the casualty reductions over the last decade. Broughton (Broughton et al, 2000) has recently reviewed the effectiveness of casualty reduction measures in the UK and demonstrated that the greatest contribution to casualty reduction over the years 1980 – 1996 was secondary safety improvements to vehicles. These accounted for around 15 per cent of the reduction compared to 11 per cent for drink/drive measures and 6.5 per cent for road safety engineering measures.

There are still many opportunities for further casualty reductions using passive safety measures for example in terms of pedestrian safety, side impact protection, frontal protection and improved compatibility. These are expected to remain major policy items for achieving road safety targets. Reducing the aggressiveness of roadside obstacles which may be impacted by vehicles is also important. There is a need for consideration to be given to designing both vehicles and roadside obstacles to interact better in crashes.

Accident research continues to show that many situations are not catered for by current measures. Crash tests only deal with a limited number of crash scenarios and protection is focussed on the average-sized male occupant. Other accident configurations and occupants of different sizes also need consideration. In future, for demographic reasons, the average age of the driving population will increase and become more vulnerable to injury. At the same time advances in vehicle crash protection will allow more road users than at present to survive impacts and the need to prevent injuries with long term effects will become more important. The socio-economic costs of many disabling injuries, such as 'whiplash', are poorly represented by their severity, usually measured in terms of threat to life.

As part of ETSC's current programme, which receives matched funding from the European Commission's Energy and Transport Directorate, this review of future priority needs for motor vehicle safety design aims to provide a source of impartial advice to the EU institutions and Member States in identifying safety priorities for the EU Whole Vehicle Type Approval process, European consumer information and Community research programmes.

The review has been carried out by ETSC's Road Vehicle Safety Working Party which brings together a multi-disciplinary group of safety experts from across the European Union.

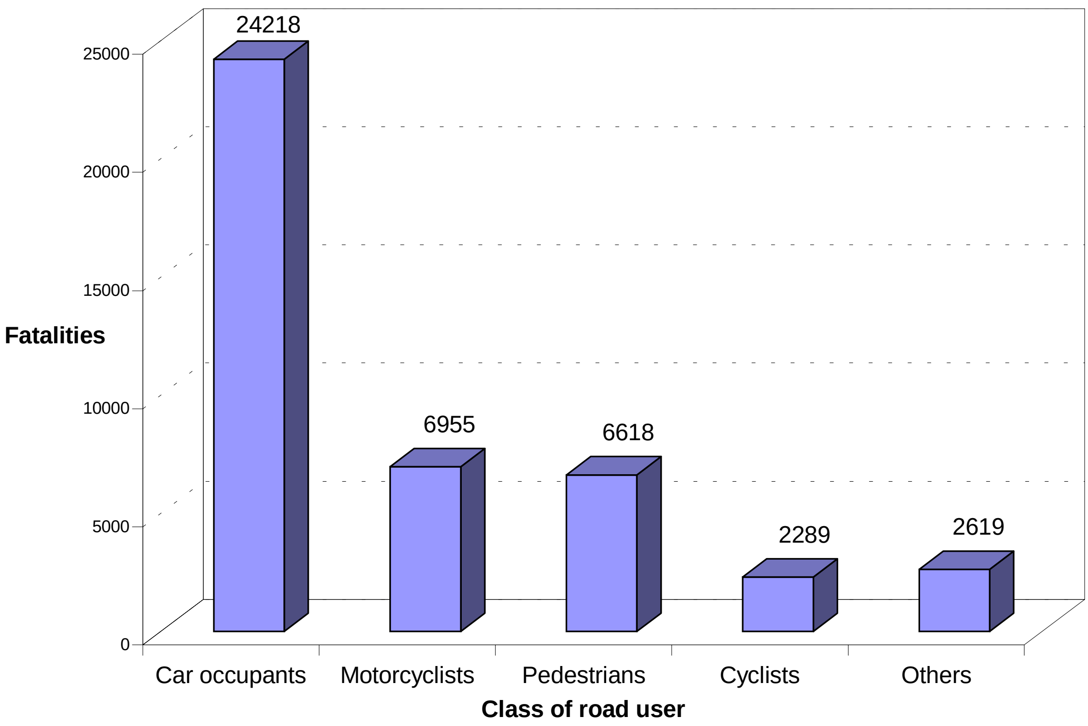
Section 2 of this report outlines the key crash injury problems involving motor vehicles on EU roads. Section 3 considers how motor vehicle design can reduce crash injuries for all types of motor vehicles from two-wheeled motor vehicles to heavy goods vehicles. Designs are considered which affect not only the occupants of motor vehicles but also the other road users that motor vehicles hit. All the vehicle-related, road safety strategies are considered – crash prevention, crash protection and post impact care. This section also reviews developments of required information and design tools: crash information recorders, in-depth crash data, biomechanics and dummy development. Section 4 summarises ETSC immediate priorities for EU legislation, consumer information and research and development.

2. KEY CRASH INJURY PROBLEM AREAS

Number of fatalities in the European Union

In 1998, the most recent year for which data are available, there was a total of 42,699 road transport related fatalities in Europe. The numbers of non-fatal casualties cannot yet be precisely counted but it is estimated there is a total of around 3.5 million casualties injured on EU roads including those not routinely reported to the authorities.

Figure 1:EU Fatalities by Class of Road User 1998



IRTAD data 1998,1995

Figure 1 shows the majority of fatalities to be car occupants. In 1998 over 24,000 of these died representing 57% of all road deaths. There were also 6,955 motorcyclist, 6,618 pedestrian and 2,289 cyclist fatalities. Other types of road users, such as users of trucks, agricultural vehicles, and other road vehicles accounted for the remainder. Of these it has been estimated that there are typically 150 bus and coach occupant fatalities each year within the EU (ECBOS).

Table 1 shows the fatality risks associated with each type of road user compared with other transport modes. The risks of fatality are calculated in two ways – by the risk for every 10^8 person km travelled and for every 10^8 person hours of exposure.

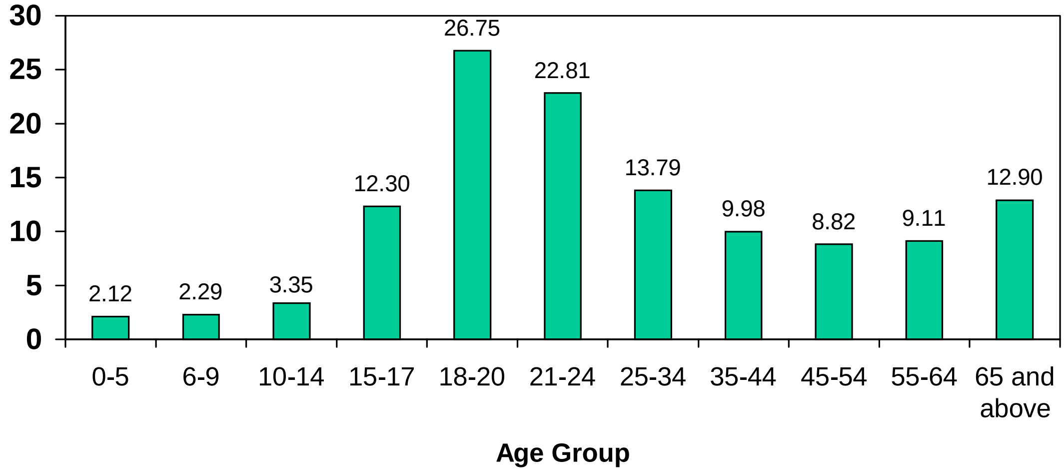
Table 1. EU fatality risks by distance travelled and exposure time for different travel modes in the EU.

Mode		Per 10^8 person km	Per 10^8 person hours
Road	Total	1.1	33
	Bus/Coach	0.08	2
	Car	0.8	30
	Foot	7.5	30
	Cycle	6.3	90
	Motorcycle/Moped	16.0	500
Trains		0.04	2
Ferries		0.33	10.5
Planes		0.08	36.5

(ETSC, 1999)

The age distributions of fatally injured road users in the EU in 1998 are shown in Figure 2. The per capita risk is greatest for road users aged between 18-24 years.

Figure 2: EU road accident fatalities by age band per 100,000 population

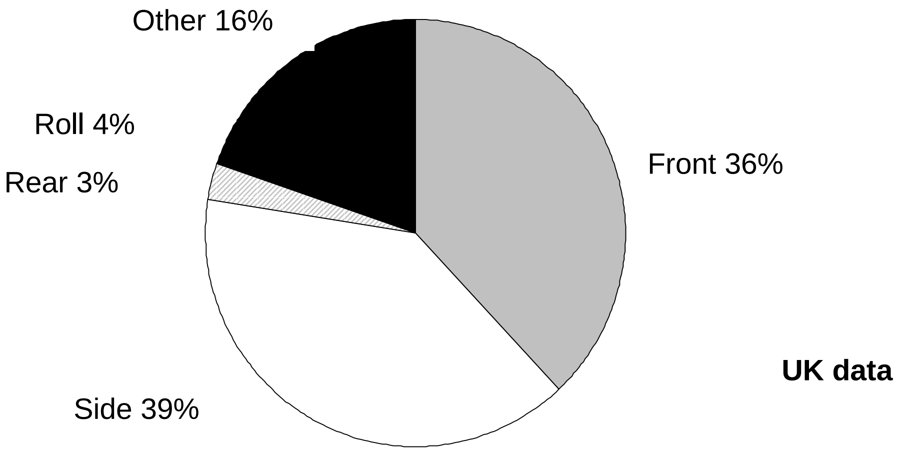


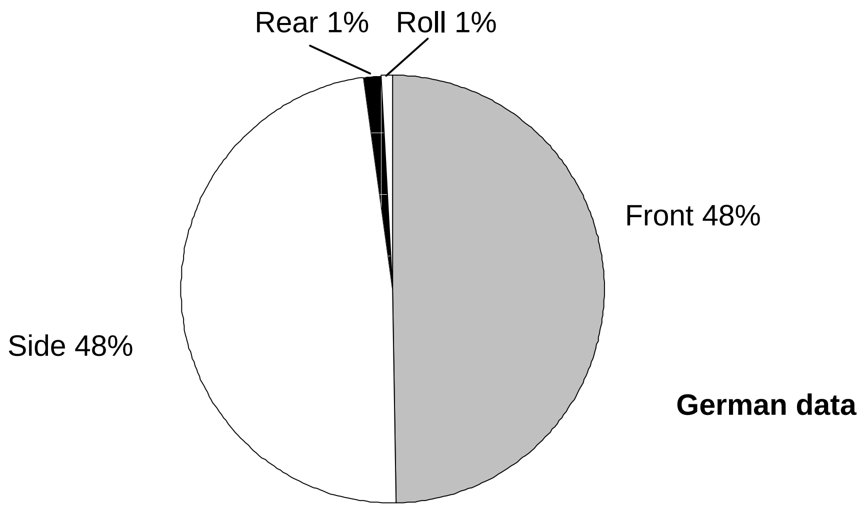
Car Occupant Casualties

Car occupant casualties are the largest single group in the EU casualty totals. The engineering countermeasures employed are dependent on the nature of the crash configuration, i.e. the direction of the impact and type of collision partner.

Figure 3 shows the distribution of impact direction for fatally injured car occupants for the UK and Germany. In both countries the proportions of front to side impacts are similar, highlighting the need for further protection in both impact directions. This is a reflection of the relative improvements that have been made in frontal crash protection and also the challenge of providing similar levels of side impact occupant protection. Differences in classification method between the two data sets result in a significant proportion in the UK data classified as ‘other’ but both confirm that the numbers dying in rear impacts and rollovers are small proportions of the total.

Figure 3: Collision Direction – fatally injured casualties –UK and German data.

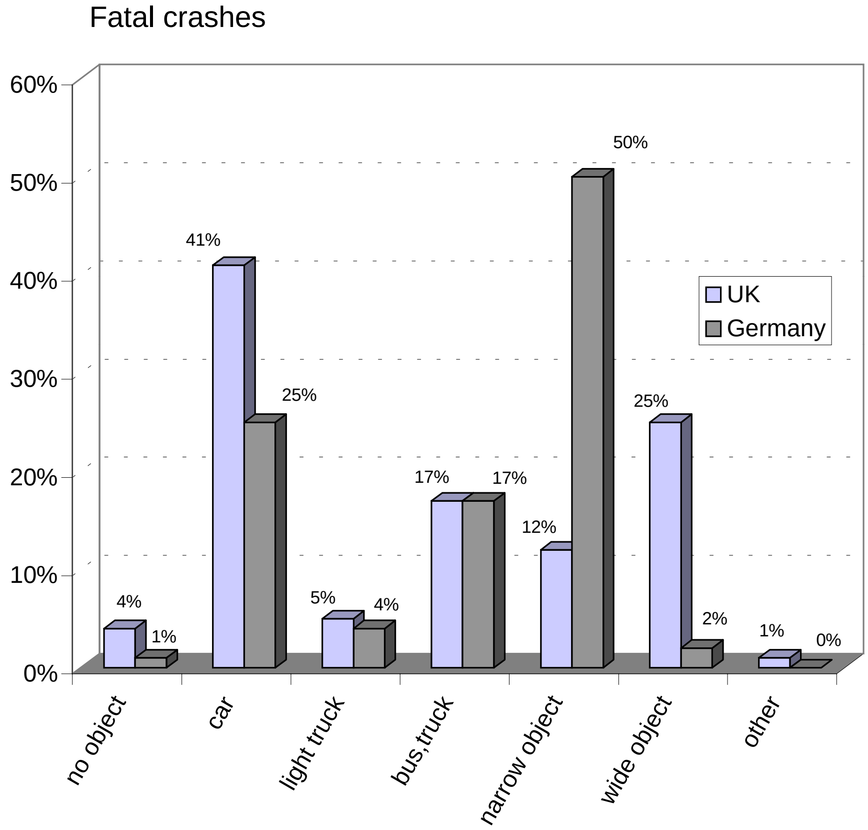


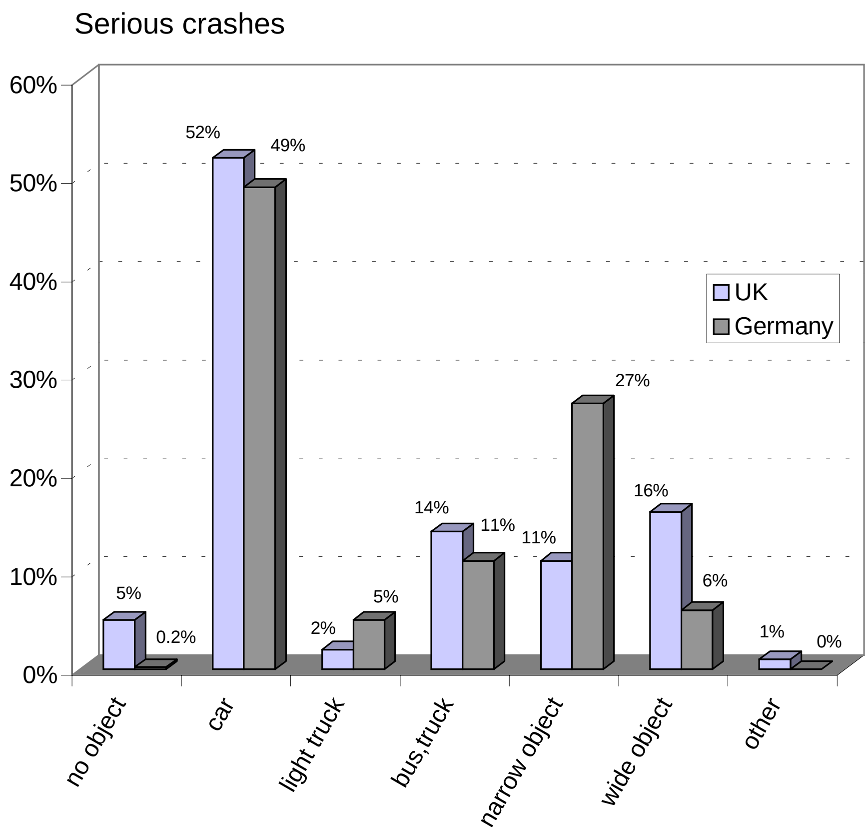


The data highlight the importance of fatal side impacts (39% UK Co-operative Crash Injury and 48% Medical University of Hannover), which marginally exceed the total fatalities in frontal collisions. The nature of the collision partner, figure 4, shows some differences between the two countries, 41% of UK fatalities die in collisions with other cars compared with only 25% in Germany. In contrast 50% of German fatalities die in collision with poles or trees compared to only 12% in the UK.

Analysis of the injuries reveals that life threatening injuries are most commonly sustained by the head and chest in pole impacts and other side collisions. The protection of these body regions is a priority in injury reduction.

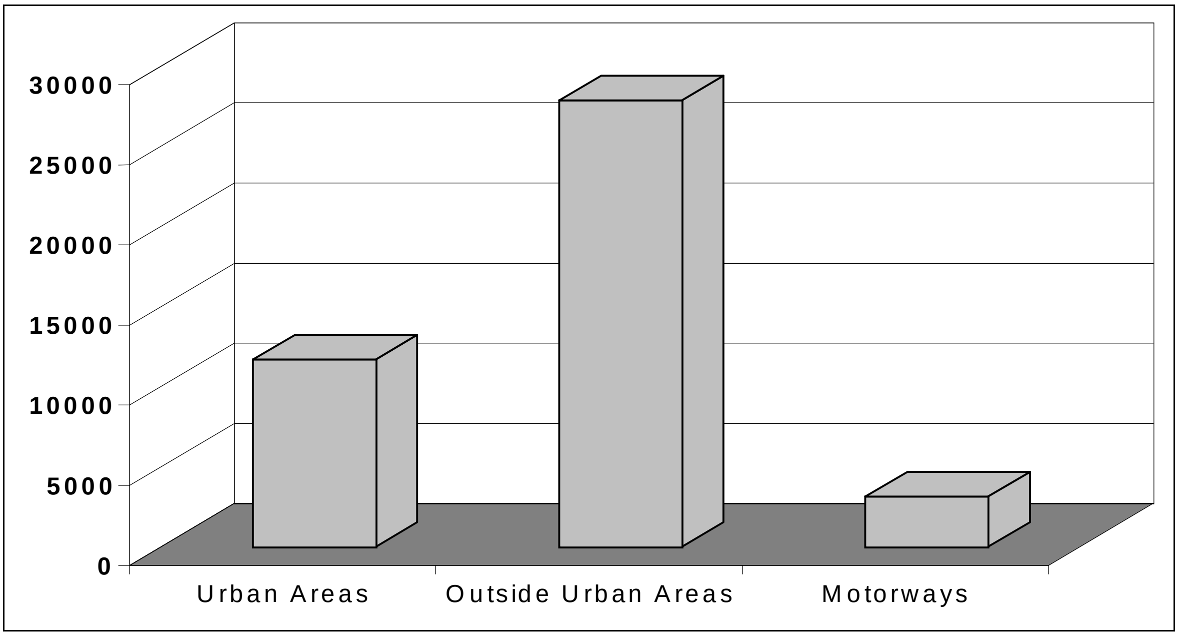
Figure 4. Fatal and serious injury car crashes - collision partner - UK and German data





(UK data from Thomas and Frampton, 1999; German data from Hannover University)

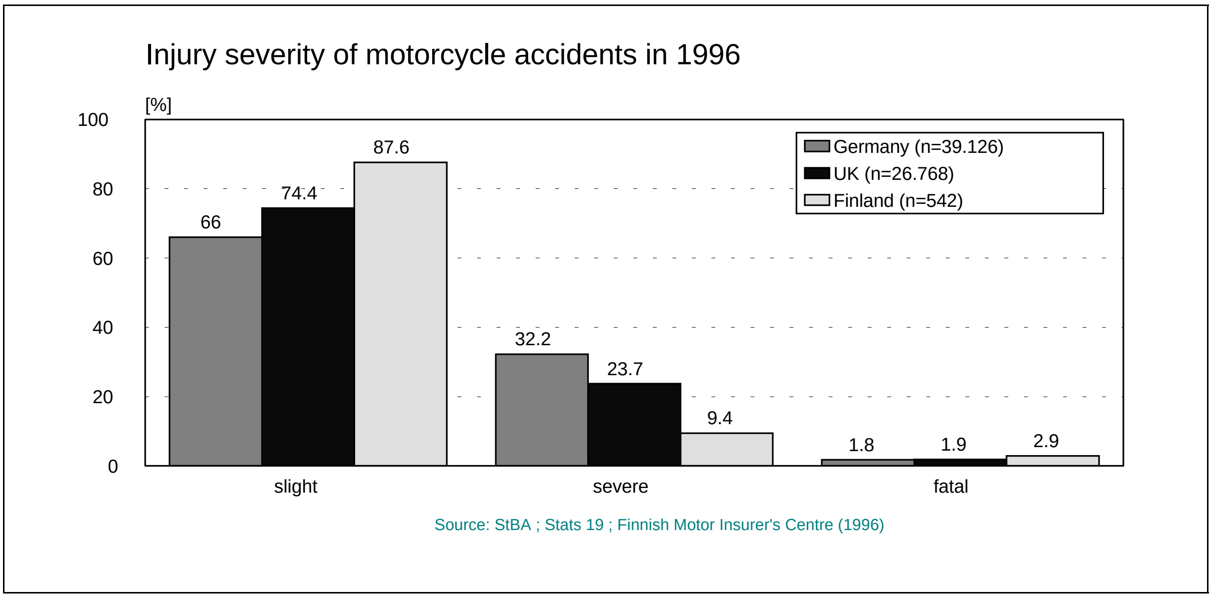
Figure 5. Accident location – Urban, non-urban or motorway



The IRTAD data for 1998 also show the location of the crash and demonstrate that 65% of all fatalities die outside urban areas with an additional 7% on motorways. The rural location of many crashes has implications for the performance requirements of vehicle based accident avoidance technologies. Those systems designed for well-controlled motorway traffic conditions may be less able to address the crash conditions of the majority of the fatalities. Speeds outside urban areas are significantly greater than those in urban areas with a consequent increased risk of a fatal or impairing crash.

Motorcyclist casualties

Figure 6. Comparison of motorcyclist injury severity in different countries – Cost 327 report, 2000



The COST 327 report presents the situation of injured motorcyclists and fatalities for three European countries. The injury risk distributions are given in Figure 6. The major injury risks are to the head and legs. Sixteen per cent of those admitted to hospital sustained a head injury of AIS 2-4 with just under 20% sustaining a head injury.

Pedestrian casualties

UK data for 1997 show that the majority of pedestrian fatalities are struck by car fronts. Two-thirds of all fatally injured pedestrians were impacted by the front of a car compared with only 11% other parts of the car. Impacts with all other vehicle types accounted for only 23% of all pedestrian fatalities. Clearly the primary focus for vehicle based injury countermeasures is the front of passenger cars (Fig.7).

Low speed impacts with car fronts only involve a small risk of serious and fatal injury but as the travel speed increases so does injury risk. The EEVC (European Enhanced Vehicle-safety Committee) WG 17 pedestrian sub-systems test procedures are based around an impact speed of 40 km/h, Figure 8 shows that this speed covers 90% of minor injury collisions, where the pedestrian only sustains cuts and bruises. Serious injuries include fractures to the legs; pelvis and some impairing head injuries and 75% are covered by the nominal test speed. For fatalities 33% of fatal injuries are covered by a nominal test speed of 40km/h. The priority for the longer term, once a Directive is in place, is to increase the levels of protection at higher speeds. At these higher speeds it is not uncommon for an impacted pedestrian to travel over the roof of the car, sustaining injuries both from the initial impact with the car and from the second impact with the ground. These ground-based injuries may represent up to a third of all injuries at higher speeds and innovative approaches to vehicle design will be needed to address them while managing post-impact pedestrian kinematics.

Figure 7. Vehicles and areas of vehicles striking fatally injured pedestrians

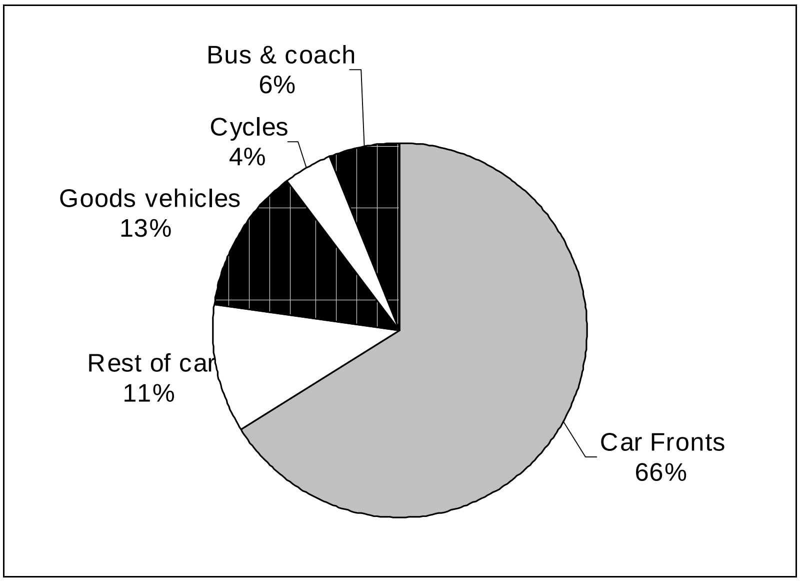
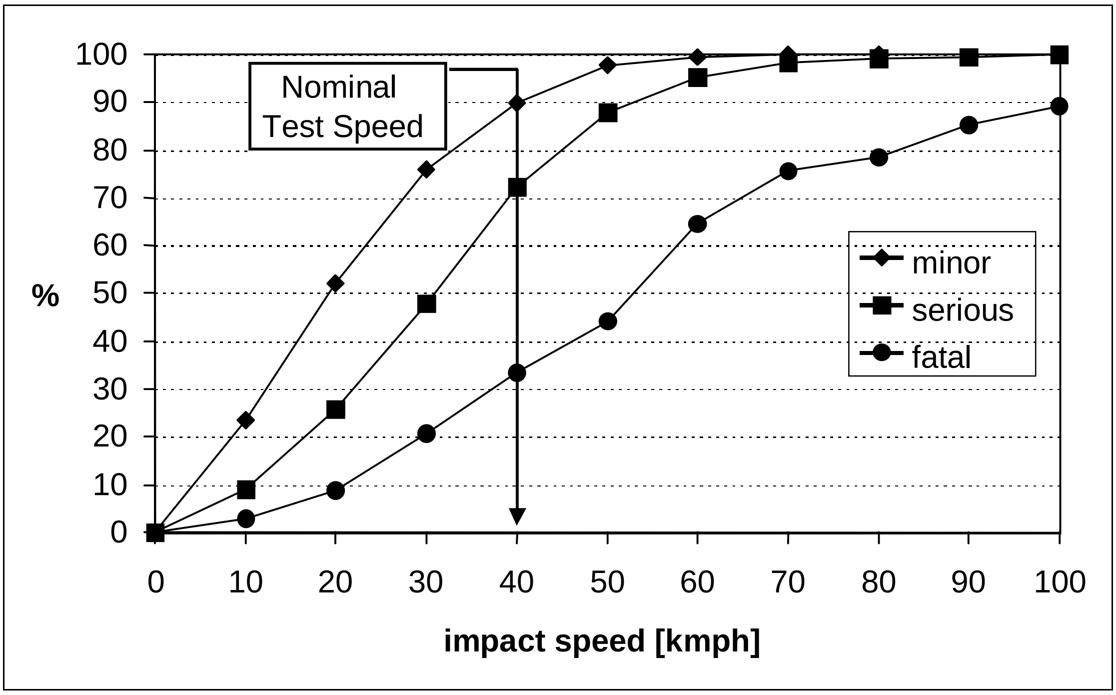


Figure 8. Injury v Speed



(University of Hannover, 2001)

3. PRIORITIES FOR VEHICLE SAFETY DESIGN

3.1 CARS AND CAR DERIVATIVES

3.1.1 Crash prevention

(a) Intelligent speed adaptation – driver support

New information and communication technologies offer the possibility of Intelligent Speed Adaptation (ISA). Almost all drivers exceed the speed limit at some times, and many drivers exceed the speed limit at virtually every opportunity. Speed is intimately related to the risk and severity of a crash. A review of international research on the relationship between speed, speed limits and accidents came to the conclusion that a 1 km/h change in the mean speed of traffic produces a 3% change in injury accidents (Finch et al, 1994).

Other studies show the contribution of speed variance: vehicles moving much slower or much faster than the median speed are over-involved in accidents (Munden, 1967; Hauer, 1971; Maycock et al, 1998; Quimby et al, 1999).

Experience has shown that the most effective way to bring down speeds is to make it difficult or impossible to drive faster than the speed limit set by the highway authority. This has been shown by traffic calming measures, where accident savings of the order of 60% have been achieved in 30 km/h zones.

ISA is the global name for systems that “know” the permitted maximum speed and use that knowledge to inform the driver and/or intervene in the vehicle’s control to prevent it from being driven faster than the permitted limit. Intervention control can be by:

- haptic throttle (i.e. a throttle providing force feedback to the driver), in some versions, this can be overriden by the driver with a “kickdown,” or
- through the engine management system to ignore demand from the driver for speeds exceeding the limit, perhaps supplemented by
- mild braking.

There are three types of ISA in terms of the degree of intervention of the system. The lowest level is informative or *Advisory* ISA. Next is voluntary or *Driver Select* ISA. Here the information on speed limit is linked to the vehicle controls but the driver can choose whether or not to have the control enabled. Finally there is *Mandatory* ISA where speed limiting is enforced.

Knowledge of the speed limit could come from roadside beacons or from a modified navigation system in the form of an enhanced on-board digital road map coded with speed limits for each road combined with a GPS-based location system. The latter is the so-called autonomous version of ISA which does not require extensive investment in roadside infrastructure.

The most recent estimates of the accident savings from ISA have been made by a UK national research project and are shown in Table 2 (Carsten and Tate, 2000). These estimates are based on a prediction of 40% compliance with an Advisory system and 50% compliance with a Driver Select system. Full compliance with speed limits would occur with a Mandatory system.

From British information on traffic speeds for different road types, a mean traffic speed has been calculated. From this, the reduction in mean speed can be computed for a Mandatory

ISA system, where the speed limit cannot be exceeded. Combining this information with that relating the reduction in injury accidents to reduction in speed, estimates of the reduction in injury accidents have been made. From additional information which indicates that: injury accidents are proportional to the square of speed, serious accidents are proportional to the cube of speed and fatal accidents are proportional to the fourth power of speed, savings estimates have been computed.

Table 2 provides a range for the estimated accident savings for Great Britain. Clearly, the Mandatory systems predict the largest accident savings, with the Dynamic Mandatory system being the most effective. These predictions are broadly in line with estimates previously made for Sweden (Várhelyi, 1996).

Table 2. Predicted accident savings for Great Britain by ISA type

System Type	Speed Limit Type	Injury Accident Reduction	Fatal and Serious Accident Reduction	Fatal Accident Reduction
Advisory	Fixed	2–21%	4–30%	5–37%
	Variable	2–22%	4–31%	5–39%
	Dynamic	3–27%	5–38%	6–47%
Driver Select	Fixed	5–21%	8–30%	10–37%
	Variable	6–22%	9–31%	11–39%
	Dynamic	10–27%	14–38%	18–47%
Mandatory	Fixed	11–31%	15–43%	20–53%
	Variable	12–33%	17–45%	22–55%
	Dynamic	19–50%	28–65%	35–75%

A number of steps have to be taken before ISA can be implemented:
1. Agreement needs to be reached on standards for such aspects as: road maps, driver interface, vehicle control and, for Dynamic ISA, communications. This needs to be harmonised at a European level to enable a pan-European capability.
2. ISA-capable cars need to be put into manufacture.
3. Before mandatory use can be considered, a majority of the vehicle fleet should be equipped.
4. There has to be public and political acceptance.

Recommendations

- Work is required to develop harmonised standards for ISA systems towards eventual universal fitment. This could start at the simpler voluntary systems but which would be capable of being developed into an eventual mandatory specification.
- Encouragement should be given to manufacturers providing ISA systems via the European New Car Assessment Programme to enable the consumer to start benefiting from a voluntary system

(b) Electronic driving licences

One means of reducing crash risk is to prevent unauthorised or unqualified persons from driving. Electronic driving licences (EDL) could be used to operate an electronic ignition switch. This could ensure that vehicles are only driven by a properly qualified person. In Sweden, an Electronic Driving Licence has been developed and tested (Goldberg, 1995). There are, however, many practical issues to be solved by further research and development before a large-scale introduction could take place. The availability of electronic driving licences provides further opportunities to link personal data to fitness to drive information and adaptive safety systems, such as advanced restraints.

Recommendation

- Consideration should be given to the possible wider use of personalised electronic means of controlling the use of vehicles.

(c) Conspicuity of motor vehicles - daytime running lights

The use of daytime running lights (DRL) involves the illumination of lights (whether multi-purpose or specially designed) on the front of a vehicle during daylight hours to increase its conspicuity. Several countries now require varying degrees of DRL use by law either by requiring drivers to switch on headlamps or by a requirement to fit special lamps to vehicles.

Studies to date reveal mostly positive findings about the effectiveness of car daytime running lights. While the studies may not always be individually statistically significant or they may be subject to experimental shortcomings, they collectively present an encouraging picture. Although the effectiveness of DRL is greater in countries which lie closer to the poles, results from studies indicate that there are still mostly positive effects to be gained in other countries. By interpolating from the relationship between latitude and DRL effectiveness for EU countries (which range from 35 degrees to 58 degrees latitude) the estimated DRL effect would range from about an 8% to a 29% reduction in multiple road user daytime accidents. The introduction of DRL, therefore, offers significant potential for accident reduction.

Recommendation

- It is recommended that early consideration is given to a mandatory fitment requirement for daytime running lights in the EU.

(d) Driver impairment monitoring

A number of systems exist for detecting driver impairment caused by drowsiness, illness, or drug abuse, and then warning the driver or performing an emergency control function that will stop the vehicle (Coda et al, 1997; Hancock and Verwey, 1997; Lind, 1997; Renner and Mehring, 1997).

The effect of drowsiness on accidents is still inadequately understood. Fatal motorway accidents, due to sleepiness, have been reported to be of the order of 24% in Germany and 26% in France. Research in the UK has indicated that tiredness was contributory factor in 20% of motorway accidents, 14% of rural road accidents and 7% of urban road accidents (Maycock, 1995).

While many systems are at different stages of development with, in some cases, their feasibility being unknown, one particularly promising application is the alcohol interlock system. This is a device which works through a breath test analyser to prevent the vehicle being started if the driver is impaired. Such systems are being used as part of drink-driving rehabilitation programmes in North America. In Europe, Swedish trials found that user response was generally favourable, and users were particularly positive about the potential for the prevention of theft and unauthorised driving. Some reliability issues were raised by the study, but the conclusion was that these could be solved with a different type of smart card. Further trials with the alcohol interlock are planned. It has yet to be established whether such systems would be accepted by non-offenders.

Recommendations

- Further work is required to develop practical systems and to understand their effectiveness and acceptability
- Consideration should be given to developing such systems in combination with an electronic driving licence system.

(e) Collision avoidance systems

Research on collision warning and collision avoidance systems is taking place in Japan, the United States and Europe. Very large estimates of the safety potential of such systems have been claimed but there are a lot of difficulties in many of the concepts for collision warning and avoidance, both in technical and in behavioural terms. Most of the proposed systems require a well controlled traffic situation, such as that found on motorways, to be practical. To be effective in addressing significant accident problems, consideration needs to be given to extending the systems to work on urban and rural, non-motorway roads. In considering collision avoidance systems, it is important to be aware of possible driver behaviour adaptation. Such adaptation may negate some of the effectiveness.

Forward collision avoidance: Systems that apply the brakes automatically may avoid some of the problems caused by long driver reaction times.

Lane-change warning: Times to collision in safety-critical lane changes are normally much less than one second. Since mean driver reaction time is about one second, there is not sufficient time for a driver to respond to a warning before crashing. Because there is insufficient time for reaction to a warning, lane change and merging crashes can probably only be avoided by intervening systems. But these have their own problems: how to detect driver intentions and how to intervene. This may be by taking over the steering from the driver or by providing feedback through the steering wheel.

The technical and operational feasibility of such systems has still to be demonstrated and there is a long way to go before collision avoidance systems could offer an effective route to safety improvement.

(f) Anti-lock braking systems

The most widely used driver assistance system is the anti-lock braking system (ABS) which is now fitted to many new cars.

Prospective accident studies suggest that ABS should reduce relevant severe and fatal accidents by around 5-7%, since the driver is still capable of braking and steering. However, studies have also indicated that such benefits might be reduced or negated by behavioural adaptation.

Recommendation

As recommended by ETSC's last vehicle safety review in 1993, further European research would help to ascertain whether ABS alone has a role to play in accident reduction.

(g) Braking assistance systems

Many motorists brake too gently in emergency situations, increasing stopping distances. Trials have shown that brake assistance systems could help by providing full braking effect, where the driver does not press hard enough on the pedal. Brake assistance systems can use the ABS capability to allow heavy braking without the risk of wheel locking. Such systems have to be able to recognise emergence braking from normal braking and to be able to correctly respond to the driver's reduction in brake pressure.

Recommendation

- Monitoring of braking assistance systems is required to determine how well they can identify and respond to the driver's intended braking behaviour and to identify their accident reduction potential.

(h) Dynamic stability control

Loss of control due to skidding is a significant accident problem with some studies reporting that 25% - 30% of all car accidents with severe injury involve skidding (Langwieder, 1999).

Dynamic stability control systems are designed to improve the stability of vehicles in a potential loss of control situation and to help the driver to maintain control of the vehicle in critical situations.

Recommendation

- Monitoring of the systems being made available by car manufacturers is needed to determine their influence on accident occurrence.

3.1.2 Crash injury reduction

Although much can be done to stop some accidents from happening, it is clear that for the foreseeable future the majority will continue to occur. Reducing the risk of injury in accidents is and will remain a priority. The single most effective way of achieving this is by improving the safety of cars. New legislation and the introduction of EuroNCAP have led to unprecedented improvements in occupant safety but a great deal more can be achieved. For the protection of pedestrians hit by the front of the car, legislation is urgently needed as little improvement has yet been demonstrated in EuroNCAP tests.

For car occupants, contact with the car's interior, exacerbated by the presence of intrusion, is the greatest source of serious and fatal injury. Consequently, the recent priority in improving frontal impact protection has been to improve the car structure to endure severe offset impacts with little or no intrusion. In the absence of intrusion, the seat belts and airbags are provided with the space to decelerate the occupant with minimum injury risk.

Although many new cars are capable of absorbing their own kinetic energy in their frontal structures, so avoiding significant passenger compartment intrusion, there is currently no control of the relative stiffness of the fronts of different models of car. Consequently, when cars of different stiffness impact, the stiffer car overloads and crushes the weaker car. Historically, larger cars have tended to be stiffer than small cars, resulting in over-crushing problems for the small car. However, before the stiffness of car fronts can be matched, to provide greater compatibility, it is necessary to overcome the problems of poor structural interaction between cars when they impact.

Even where intrusion is prevented and the restraint systems work well, there is still a high likelihood that the occupants' knees will impact the facia. Until the introduction of EuroNCAP, little or no attention had been paid to the safety of the knee impact area, other than at the specific locations where the dummies' knees impact. Significant hazards continue to exist for the knees themselves and for the upper legs and hip joints.

Loading of the feet and ankles by the footwell and pedals is inevitable in frontal impacts. Although injuries below the knee are rarely life-threatening, disabling injuries often result. Improvements to dummies, biomechanical requirements and the cars themselves are all required.

In side impacts, the struck side occupant is intimately involved in the impact itself. Contact with the car's interior is difficult to prevent so improvements rely on improving the nature of the intrusion, the provision of padding and of side airbags. Although head protection is a priority, the current European side impact test does little to address the risk of injury to the head. The introduction of a pole test would help and it could also help to guide car design, so that protection, for the whole body, in impacts with trees and posts could be improved.

The continuing need to improve protection in cars puts increasing demands on the capabilities of test dummies and the biomechanical knowledge necessary to set performance limits. There is an ongoing need for research in these areas to provide information for the future.

When the European offset deformable frontal impact test was being developed, airbags were rare in European cars. The overwhelming need was for a test to address the problem of intrusion, with the car having a deceleration pulse similar to that experienced in a car-to-car impact. With the almost universal fitting of frontal protection airbags and the increased fitting of seat belt pre-tensioners and load limiters, it is becoming increasingly important to avoid restraint characteristics being optimised for a single impact type. The offset deformable barrier impact is a relatively low deceleration event and a higher deceleration impact is required to complement it. With road accidents generating a wide range of deceleration pulses, testing cars with both a low deceleration and a high deceleration pulse encourage a better compromise of restraint characteristics. For this purpose, the introduction of a full width barrier impact for Europe is a priority. Such a test could be based on the US NCAP test and it might be developed into a test for compatibility (Edwards et al, 2000).

(a) Front and side impact - review of EU Directives

When the European frontal and side impact Directives were introduced there was a specific requirement for them to be reviewed. This review was to cover certain specifications for the tests and their criteria. Subsequently, the European Commission requested that certain additional aspects be included in the review.

Frontal impact

Impact Speed
The accident data used to inform the research behind the Directive showed that an impact speed equivalent to a car-to-car impact at around 55 km/h, was required to address around 50% of the fatal and serious accident casualties. This equates to a test speed of around 65 km/h. However, because of concern about the ability of manufacturers to build cars which

could survive test speeds of 60 km/h or above, it was initially recommended by the EEVC that the test speed should be 56 km/h.

More recent co-operative accident analyses carried out in a number of European countries has confirmed that 65 km/h would be the most appropriate test speed. Experience in EuroNCAP has shown that protection at this speed is readily achievable, even with small cars. There is therefore no justification for not increasing the test speed to 64 or 65 km/h. At the time that it reported, some members of EEVC Working Group 16 had continuing concerns about the effect on compatibility of raising the test speed above 60 km/h. Subsequent to this, EuroNCAP tests have shown that testing at 64 km/h is having the beneficial effect of increasing the stiffness of small cars much more than that of large cars.

Recommendation

- The test speed for the frontal impact test should be raised to 64 – 65 km/h.

Extension to N1 Vehicles and M1 Vehicles over 2.5 tonnes

Currently, N1 light goods vehicles are not subjected to the offset deformable test requirement. Similarly, the test has not been applied to M1 cars over 2.5 tonnes, nor is it applied to M2 minibuses.

There can be no acceptable justification for not applying the test to car derived N1 vehicles. These vehicles can share the same structure as their car equivalents and have a lower unladen mass. Similarly, the requirement to protect their occupants demands that the test be applied to minibuses. It is unacceptable to collect groups of people together to transport in vehicles with inadequate occupant protection.

The application to larger M1 cars and N1 goods vehicles can be justified on the grounds of protecting their occupants but could be opposed on the grounds that they would become more aggressive to other car occupants. In practice, larger N1 vehicles are very aggressive and the introduction of the test is likely to bring about some improvement as the frontal structures become better connected. As far as stiffness is concerned they are already much stiffer than cars and any increase is unlikely to have a significant effect. With larger M1 cars, protecting their occupants in single vehicle impacts also requires that they are tested but without limiting their ability to give adequate chest protection in the US full width test.

Recommendation

- The frontal impact Directive should be extended to cover N1 vehicles up to 2.5 tonnes, M1 vehicles above 2.5 tonnes and M2 vehicles.

Steering wheel intrusion

Control of the vertical and rearward movement of the steering wheel has been confirmed as important by the EEVC. The widespread introduction of steering wheel airbags has increased the need to ensure that their “launch platform” position is maintained throughout the impact. Concern over this and problems of the stability of the head contact on the airbag has resulted in the EEVC recommending the addition of a lateral displacement requirement of 80mm maximum.

Recommendation

- A requirement to limit the lateral displacement of the steering column to 80 mm should be added to the existing vertical and horizontal requirements.

Injury criteria
The EEVC has reviewed the need for all the injury criteria, initially recommended. It concluded that all the criteria were required. In particular, all the recommended neck criteria were required as they detected different phenomenon and any one could be the criterion that led to test failure. The need for a better dummy precludes the introduction of further performance requirements. When a suitable dummy is available there is a need to develop criteria for better assessment of lower leg injury risk. Furthermore, there is a need to develop criteria and instrumentation to assess the risk of injury to the abdomen and knees.

Recommendations
- All the current injury criteria need to be maintained.
- When available, consideration should be given to using an improved dummy with improved criteria for the lower legs.
- Research is needed to develop criteria and instrumentation to assess the risk of injury to the abdomen and knees.

Footwell intrusion
Injuries to the lower legs are highly correlated with footwell intrusion, although it is recognised that the elimination of intrusion does not remove the risk of injury. EEVC WG16 has recommended a limit for the extent of footwell intrusion. ETSC considers this limit to be conservative, such that it may need review in the future.

Recommendation
- The recommended limit on footwell intrusion recommended by the EEVC is adopted with a requirement for its review in the light of further accident experience.

Deformable barrier face
The EEVC developed the frontal barrier face and produced a design specification. This was because of the earlier experience of having a performance specification for the side impact barrier face. Alternative designs for barrier face have been proposed and tested. However, so far all the alternatives have proved to create greater problems than they have solved. The current face is considered to be to best compromise of those faces so far developed. Because of this it is considered that the design of barrier face should remain as at present.

Recommendation
- For the present time the current design of deformable barrier face should be retained.

Side impact

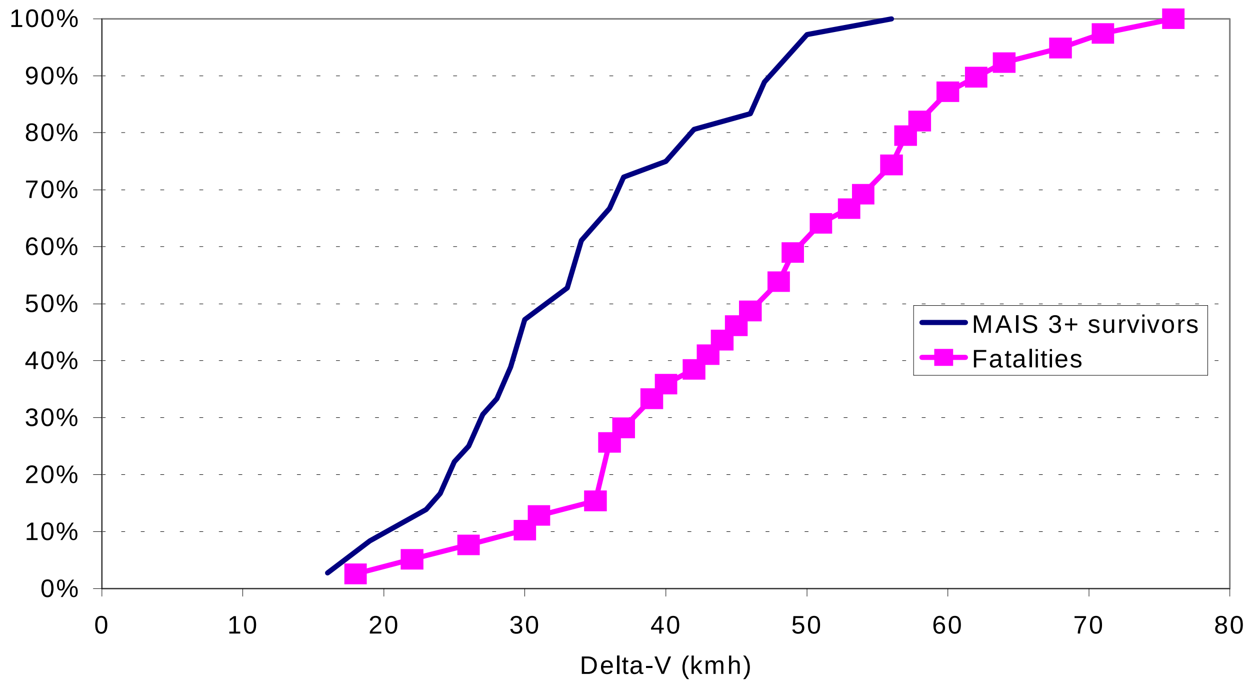
The European side impact test uses a mobile deformable barrier to impact the side of a car, with a collision speed of 50 km/h, to simulate a car-to-car side collision. There is one EuroSID dummy seated in the front seat which is used to measure the risk of head, thorax, abdomen and pelvic injury.

Recent analysis of UK and German crash injury data suggests that serious and fatal injuries to car occupants tend to occur at high crash speeds. Furthermore, occupants seated on the non-struck side of the vehicle are also at serious risk of injury.

Impact severity
The change in velocity of the car (delta-v) is one indicator of accident severity and it can be determined in field accident analysis. Real car-to-car impacts show that 80% of the struck-

side survivors suffered impacts with a delta-v of up to 50 km/h. For fatalities this 80% value is reached at 70 km/h with 60% of fatalities having a delta-v of more than 40 km/h.

Figure 9. Delta-V Distributions, MAIS 3+ Struck-side Survivors and fatalities



Although accident research indicates that the impact severity in the test is much less severe than that seen in serious and fatal injury accidents, the EEVC have concluded that it would be inappropriate, at this stage, to increase the severity by increasing the test speed. It was thought that it would be appropriate to increase the ground clearance of the barrier face, which would more realistically reproduce the limited extent of interaction with the sill. However, the resulting increase in height of the top of the barrier face would then be inappropriate. To increase the ground clearance but maintain the top height would require a re-specification and validation of the barrier face. It was thought that this work could not be completed in time for the Directive review.

<u>Recommendation</u>

- Research should be carried out to determine the best method of increasing the severity of the side impact test to better address the accident problem. This should enable a further review of the Directive to be made to enable the higher speeds of impact in accidents to be addressed.

Seat position derogation

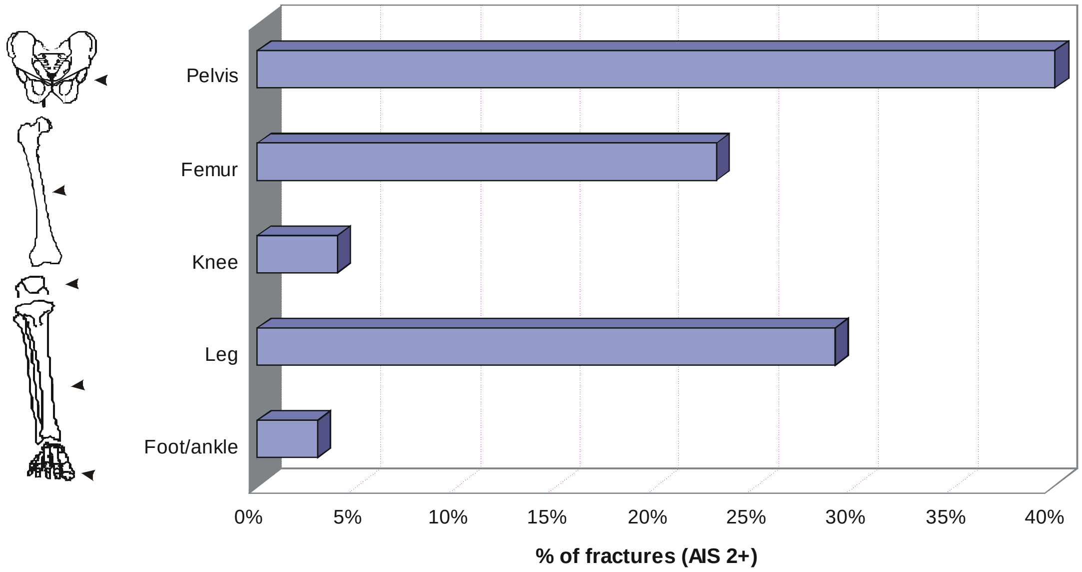
The side impact Directive defines a mid fore/aft seating position, for use in the test. However, this can be changed to cover a worst case position. Because of concerns about the ability of car designers to provide protection when the dummy was positioned alongside the B pillar, a limit was placed on the how far back the seat could be positioned. With the advent of side impact airbags, it has been shown that protecting an occupant seated adjacent to the B pillar is feasible. Consequently, the need for the derogation no longer exists.

<u>Recommendation</u>

- The derogation regarding seating position should be removed from the Directive.

Injury criteria
The EEVC has reviewed the need for all the injury criteria, initially recommended. They concluded that all the criteria were required. In particular, it was agreed that the Viscous Criterion was required to protect against internal organ injury.

Figure 10. Percentage of fractures AIS 2+



(source Thomas and Frampton, 1999)

The current side impact test has no requirements for the protection of the lower limbs despite being a common injury site, as shown in Figure 10.

Recommendations
- All the current performance criteria should be retained and the Viscous Criterion should become a mandatory requirement.
- Protection of the lower limbs needs to be considered for the future

Pole impact
Despite the predominance of head injuries, the current side impact test is ineffective in assessing head protection. The introduction of head protecting side airbags has made head protection feasible, even in impacts where the head is threatened by an external object. A pole impact test can assess the level of head protection offered by such systems.

Accidents involving side impacts into poles are also important and frequently fatal. A pole impact test would be capable of assessing the level of protection offered in such circumstances. For this purpose, the test speed would need to be elevated above that currently used in EuroNCAP for evaluating head protection devices. At these higher speeds it is not yet clear what level of protection is currently feasible.

Recommendations
- A pole impact test is required to evaluate head protection in side impact.
- Consideration should be given to the development of a test to simulate accidents involving impacts with poles. This would require research into the levels of protection possible.

Side impact dummy
The EuroNCAP test programme has shown that some manufacturers are taking advantage of un-instrumented load paths into the EuroSID dummy. This may often be by accident but it is clearly intentional in a number of cases. There is a need to overcome these problems either by removing the un-instrumented load paths or by adding instrumentation and its associated criteria. This would require some pragmatic decision to be taken about the criteria, as similar load paths do not necessarily exist in humans. The load paths requiring consideration are: through the dummy's backplate to unload the chest, abdomen and pelvis, up the spine from the pelvis and abdomen to unload the chest, through the shoulder to unload the chest, through the femur to load the pelvis and spine and through the pelvis and abdomen missing the instrumentation.

Recommendations
- Urgent consideration needs to be given to instrumenting all the load paths into the EuroSID dummy and developing criteria for them.
- In any future side impact dummy, all possible load paths need to be instrumented by design.
- To provide for the protection of the lower limbs dummy instrumentation and criteria for the lower limbs need developing.

Mobile deformable barrier
The mobile deformable barrier face is currently specified by a performance specification. This specification is inadequate and has led to the development of different barrier faces with different performances in car tests. The EEVC has compared the available barrier faces with a view to recommending a single design and associated design specification. An important requirement is that the barrier face can be manufactured by competing suppliers around the world.

Recommendation
- When the EEVC research is complete, a single design specification of barrier face should be specified in the Directive. This barrier face must be capable of being manufactured to the same standard of performance by competing suppliers around the world.

(b) Frontal impact test which guides restraint sensing

The introduction of airbags for frontal impact protection and the widespread adoption of seat belt pre-tensioners have added a new dimension to frontal impact test needs. For optimum protection in crashes, restraint systems need to perform well over a wide range of impact decelerations. Legislation or consumer tests which encourage manufacturers to optimise on a single low or high deceleration impact may offer inadequate protection in other accident situations. In Europe, the Offset Deformable Barrier test provides a low deceleration impact, with high vehicle deformation but there is currently no high deceleration test. Conversely in the US, there is a high deceleration test, with low vehicle deformation. To provide improved guidance for future restraint system designs, both types of test are required. This has now been recognised by the International Harmonisation of Research Activities Working Groups and in the US, NHTSA (National Highway Traffic Safety Administration) propose to introduce an offset deformable barrier test. In Europe, there is a similar need to introduce a high deceleration test, such as that used in the USA.

Recommendation

- A high deceleration impact test, such as that used in the US, needs to be adopted, to provide improved guidance for restraint systems.

(c) Frontal and side compatibility issues

Frontal Impact

Many accident analyses have shown that, in collisions between cars of different masses, the risk of injury in the heavy car is less than that in the light car. This has usually been accounted for on the basis of simple momentum, with the lighter car undergoing a greater velocity change. Recent research has shown that there are more important aspects to compatibility. The requirement for all cars to pass crash tests has resulted in each car being able to absorb its own kinetic energy with little or no passenger compartment intrusion. To achieve this, heavy cars have to absorb greater amounts of kinetic energy than light cars. As their impact crush extents do not generally increase in line with mass, heavier cars have tended to be much stiffer than lighter ones. Consequently in a collision, a stiff heavy car will overload the structure of a weaker light car. The resulting passenger compartment intrusion gives rise to greatly increased risk of injury in the lighter car. In order to overcome this incompatibility problem, control of the frontal stiffness of cars is necessary.

However, for the control of frontal stiffness to be effective, a more immediate problem has to be addressed. Currently, when two cars collide, it is rare for their frontal structures to interact properly. This results in inefficient use of the cars' energy absorbing structures which in turn results in a greatly increased risk of passenger compartment intrusion. In many cases, this poor interaction results in the structure of one car over-riding that of the other. This is common even when two identical cars collide.

Compatibility research indicates that increasing the homogeneity of stiffness, laterally and vertically, across the front of the car should improve the structural interaction between impacting cars. It is anticipated that an adequate measure of force homogeneity can be obtained from data from a load cell wall in a full width frontal impact test.

Once the problem of structural interaction is addressed, it will then be worthwhile to address the stiffness of the car. By controlling the maximum force generated by the front of the car in the impact and ensuring that it is below that which the passenger compartment of all cars can withstand, the integrity of the passenger compartment can be maintained, with little or no intrusion. The force imposed by the front of the car can be assessed from a load cell fitted behind the deformable barrier face in the current test configuration, at 64-65 km/h. Then a simple structural overload test, in which the car is subjected to a high speed offset deformable barrier impact, may be used to measure the passenger compartment's strength.

Further into the future, it will become necessary to impose some control over the force / deflection characteristics of cars' frontal structures. This will help to control the deceleration of the car and, in combination with the restraint system, will help to protect the growing number of elderly and frail occupants against deceleration induced injuries.

Side Impact

Side impact protection has proved much more difficult for people to understand than other types of impact. Frequently the findings are initially counter-intuitive. Although, there is still much to learn about side impact compatibility, there is general agreement about certain aspects.

With the struck side occupant being intimately involved in the impact, the initial intruding velocity of the car side has much more relevance than the final velocity change of the whole car. The most serious and relevant injuries are determined well before the car has reached its final velocity. The consequence of this is that the impact velocity of the bullet vehicle is the most appropriate indicator of impact severity, rather than the target car's velocity change. During the period when the injuries occur, the overall change in velocity of either vehicle is small and this explains why vehicle mass has little influence.

Similarly, the stiffness of the bullet car's front also has little influence. In general, frontal stiffnesses are very much greater than those of the car's side and there is usually little deformation of the bullet vehicle's main structure.

As for frontal impact, the quality of the structural interaction between the cars has a major effect. High fronted bullet vehicles impact above the sill of the target car loading the door and the occupant directly. Bullet vehicles, which interact with the sill and door pillars, put reduced loads through the door. In a perpendicular impact, homogeneously stiff fronts can spread their load across the side of the car picking up on the pillars and sill. Weaker structures can be deformed by the pillar and sill allowing the car's front to pass between them, deform the door and load the occupant. Because of this, weaker fronts can be more aggressive.

The intrusion profile of the car side has been long recognised as influencing injury risk. Clearly, by their shape and stiffness, the front of the bullet car has the potential help to promote more uniform intrusion profiles.

(d) Van compatibility (<2.5 tonnes)

An obvious compatibility problem exists between very large vehicles and cars. The problems relate to both mass differences and to differences in their structures. Heavy goods vehicle underrun is an obvious example. With over-riding being seen in car to car impacts, it is no surprise that this is also a problem in impacts between cars and light goods vehicles.

When tests and criteria for compatibility are developed they need to be applied to N1 light goods vehicles. This should provide control over their structural interaction with cars and over their frontal stiffness. Furthermore, any perceived obstacle to extending the frontal impact requirements to such vehicles would also be removed.

<u>Recommendation</u>

- Compatibility is seen as the next major step forward in improving car occupant safety. Further developments of frontal impact protection need to be considered in association with compatibility and this is seen as a top priority for vehicle safety research.

(e) Seat belt wearing reminder systems

Reported front seat belt wearing rates vary between 53% and 92% in the various EU Member States (ETSC, 1996). Belt use in accidents is, however, significantly lower. In a Swedish study of fatally injured occupants in Stockholm, only 40% used their seat belt

(Kamrén, 1994). In Germany, belt use rates of 50 to 70% have been seen in fatal car occupant accidents (Langwieder et al, 1994; GDV, 1998). In another Swedish study a 50% belt use was found for severely injured occupants in rural crashes and 33% in urban crashes (Bylund and Björnstig, 1995). These numbers should be compared with the 90% Swedish wearing rate for front seat occupants. An estimated number of approximately 15,200 unbelted occupants are killed every year within the EU. If the belt use could be increased to 100% approximately 7,600 lives could be saved annually, assuming a seat belt effectiveness of 50%. If belt use could be increased to 95%, the highest level reached internationally, approximately 6,800 lives would be saved.

Several prototype seat belt reminder systems have been presented and tested in Sweden by Folksam, the Swedish National Road Administration and the Swedish national insurance co-operation - Försäkringsförbundet. Studies from Sweden and Australia have shown that by installing audible and visual seat belt reminder systems, belt use could be increased to at least 95% (Turbell and Larsson, 1997; Harrison, 2000). Actions taken to rapidly implement such systems are therefore important.

An EEVC Working Group is currently working on a test specification for seat belt reminder systems and EuroNCAP is considering including such systems in its assessment of cars.

Recommendations

- The incorporation of effective seat belt reminder systems is seen as a high priority for early action.
- EuroNCAP can provide an immediate incentive for manufacturers to develop and install simple systems and then to continue to develop more advanced ones.
- When experience of effective systems is available, consideration should be given to enacting legislation for their mandatory fitment.

(f) Airbags

Driver Frontal Protection Airbags

A study from 350 cases of the Munich Institute for Vehicle Safety of the German Insurance Association (GDV) shows that front airbags can reduce the risk of serious head injury by around 40% for belted drivers (Langwieder et al, 1997). The UK CCIS database found reductions of 50% for drivers wearing belts. For both data sets, no significant reductions in chest injury were observed. A Swedish study, where identical car models with and without airbags were compared, showed that airbags reduce injuries by 28% (AIS 1 and above) for belted drivers (Kullgren et al, 2000). Moderate and more severe injuries (AIS 2 and above) were reduced by approximately 50%. Whether minor or the more severe injuries, the largest reductions were found for injuries to the head and neck with 31% and 42% reductions respectively. The large reduction of neck injuries mainly relates to whiplash injuries. Significant reductions were found for all injuries, except for chest and arm injuries. Accident research at the Medical University of Hannover indicates that airbags give good protection against severe injuries on the driver side with 10% of serious injuries reduced overall. An increased number of minor injuries was not found in the GDV study, nor in the Swedish study.

In summary, driver airbags show large reductions of moderate or more severe injuries for belted drivers, especially regarding head injuries with effects of approximately 50%.

In those countries where seat belt use is not high, Southern European countries in particular, it is better to encourage seat belt use rather than rely solely upon the air bag to protect unrestrained occupants. This is because airbags protect in fewer impact types than seat belts, although no seat belt offers full protection in every impact. Also, experience elsewhere points to several potential disbenefits associated with airbags. These need to be borne in mind.

Some of the protective measures provided by airbags that have been designed for adults in a normal seating position will pose a serious threat to out-of-position (OOP) adults. A few dozens of OOP occupants are being killed every year in the USA by the airbag. Usually, these people are not wearing a seat belt. With European airbags, there is currently too little information to indicate whether or not the same problems exist.

Small drivers sitting close to the steering wheel are also at risk of being injured by the deploying airbag. The injury risk increases the closer the driver sits to the steering wheel.

More accident research is required before an effective European performance requirement could be developed for airbags, which could address these problems.

Passenger Frontal Protection Airbags

Passenger airbags have been fitted in the USA for many years with an estimated reduction in fatality risk of 5%. This compares with a reduction of 15-20% for driver airbags in the US. In the EU countries passenger airbags have not been fitted to the same extent. Therefore the benefits in Europe have to date not been evaluated.

As for drivers, passenger airbags, designed for adults in normal seating positions can pose a serious threat for out-of-position (OOP) adults and children. The use of child restraints on the front seat, in conjunction with an airbag, has also been shown to pose a high risk of life-threatening injury.

While such negative effects have not shown up in EU accident research, steps are needed to prevent it becoming a problem in the future. More advanced airbag systems, which respond to information about seating position seatbelt use, are required. Automatic systems to switch off the airbag, where a child restraint is present, need to be developed. The alternative of providing manual switches to turn off the airbag create a new problem if the setting of the switch is not clearly indicated to the car users each time the car is used.

Recommendations

- Driver airbags should be fitted universally.
- Where passenger airbags are fitted, clear instructions are needed to avoid the fitment of rearward facing child restraints on the seat.
- The provision of automatic detection of child restraints and out of position occupants is needed to switch off the passenger airbag.
- If manual switches are provided, an effective warning about their setting needs to be incorporated.

Side airbags

Side airbags are becoming more common in passenger cars, a few providing protection for rear seat passengers. Currently, there is limited accident data to show the benefits from side airbags and further evaluation is needed. However, the early indications are encouraging.

Some concerns have been raised about the potential risk to passengers, particularly children, who may be leaning against or close to the car's side. Currently an ISO working group is preparing a document on interactions with side airbags (ISO/TC22/SC10/WG3 N204, ISO Technical draft report 14933, Road vehicles – Test procedures for evaluating occupant interactions with deploying side impact airbags).

There is potential concern regarding side airbag deployment for OOP occupants. This is primarily for those resting or positioning their head against the car side. OOP sensing may be able to protect against such problems which would, in any case, appear to be less than those associated with passenger frontal protection airbags.

Head protecting airbags are now becoming more common. They help to provide protection for the head against impacts with car's interior and particularly with structures outside the car. Their introduction, in combination with torso protecting airbags offers the possibility of providing protection against the stiff B pillar.

<u>Recommendation</u>

- With the growing number of side airbags fitted in cars, accident research is needed to identify their benefits and any associated problems.

(g) Car design for the safe carriage of children

<u>Types of restraints and their effectiveness</u>

Several types of child restraint systems are in use within the EU. These include: infant carriers, child seats, booster seats and booster cushions. Infant carriers are used rearward-facing up to the age of 9 months. Both forward and rearward-facing child seats are used for children between 6 months and 3 years old. Booster seats and cushions are used forward facing up to approximately 10 years of age. The mix of restraint systems in use varies across the EU.

The effectiveness of the different restraints varies. Rearward-facing systems have been shown to reduce injuries between 90% and 95%, while forward-facing systems have been shown to have an injury reducing effect of approximately 60% (Tingvall, 1987; Volvo, 1997). The difference relates primarily to differences in protection to the head and neck in frontal impacts (GDV study).

Recent research has shown that new car models generate higher acceleration levels in impacts than older models, due to the improved structural performance of the passenger compartment (Folksam, 1998). This can result in increased restraint forces on car occupants and this has led to improved restraint systems, such as airbags, seatbelt load limiters and pre-tensioners. Occupants seated in the rear of cars are less exposed to intrusion problems so that improving the intrusion resistance of passenger compartments is likely to provide less benefit to rear seat occupants, particularly children. However, any associated increase in vehicle acceleration may give rise to an increased risk of deceleration induced injury, particularly to the neck, in forward-facing restraints.

<u>Recommendations</u>

- Children in cars should be provided with suitable child restraints for their age and size.
- The use of rearward facing restraints provides the best protection and should be used up to as high an age as possible.
- Further research is needed to assess the effects of modern car designs to identify necessary changes for restraint design and regulatory tests.

Side impacts

One problematic area for all child restraint systems is side impacts. A Swedish study has shown that approximately 50% of the fatally injured children up to 3 years age occurred in side impacts (Malm et al, 1997). EuroNCAP has shown the limited ability of current restraints to constrain the movement of the child's head and prevent contact with the car's interior. Improved side impact protection in child restraints is important. A side impact test procedure for child restraints is under the development within ISO TC22/SC12/WG1.

Recommendation

- A mandatory side impact test procedure is required to assess child restraints for all age groups of children.

Usage rates

Usage rates vary among the EU countries. In the mid 1990's the highest usage rate of between 80 and 90% was found in Sweden, UK and France, while Greece showed the lowest usage rate of approximately 15%. In Germany the introduction of compulsory child protection in cars in April 1993 led to a clear increase in the usage rate of child restraints. This in turn caused a substantial reduction in the number of fatally injured children in cars (BASt, 1997). Increasing the use of child restraint systems is the most important action in countries where the usage rate is low. The new seatbelt and child restraint legislation proposed by the European Commission should help (CEC, 2000).

Recommendation

- All Member States should endeavour to maximise child restraint usage.

Misuse

Misuse of child restraints has in many EU Member States been identified as a major problem. An important aspect is that most child restraints are not manufactured by car manufacturers and have not been integrated into the original design of the car. German research shows that the safety of children is very dependent on restraint quality. Surveys show that in about two-thirds of all cases, children had been improperly secured in their seats or that the child restraint system had been improperly installed (Langwieder et al, 1997). Approximately half of the mistakes were so serious that the safety benefit of the child restraint systems was clearly diminished and in a few cases was non-existent. Misuse would probably be reduced if car manufacturers took more responsibility for the development of child restraints.

A potentially more effective solution is to simplify and standardise the method of installing child restraints. ISOFIX is such a standardised installation, which has been developed by ISO. ETSC believes that ISOFIX ISO standard 13216-1 should be adopted, including an effective third restraint - research and experience suggests top tethers would be the appropriate solution - for forward-facing seats within the Regulation ECE-R44 and adopted in EU Whole Vehicle Type Approval. A universal approval for ISOFIX-seats would also be beneficial.

It is important that ISOFIX is also promoted in the front as well as rear seating positions in view of the high injury reducing effects of rearwards facing systems which are better used in the front passenger seat. To date just a few child seats are available on the market and these are mainly forward facing seats.

Recommendations

- The fitting of ISOFIX anchorages, with provision for a third restraint, in the front and rear seats should be made mandatory.
- ECE R44 should be developed to assess universal ISOFIX seats, with effective third restraints.

(h) Car Occupant interior head, knee and lower leg protection

Head

The head continues to be the highest priority for protection against life-threatening injury. Although airbags can do much to help, currently they cannot prevent contact with the car's interior in all circumstances. Angled frontal impacts present considerable head injury risk as restraint and airbag systems are optimised for forward impact and may not prevent contact with parts of the car such as the windscreen pillar. There is a need to ensure that those interior surfaces that can be impacted by the head are correctly padded. An interior headform test would be an appropriate tool for such testing and there is considerable experience with such tools.

Recommendation

- An interior headform test procedure should be developed for use in Europe.

Knee

Currently there is no dummy instrumentation or biomechanical data to cover knee damage from direct impact against the knee. Furthermore, there is no test procedure for testing the whole of the potential knee impact area of the facia. Assessment in a full scale frontal impact is impractical as only a single impact location can be tested. In most cases, this location is already benign. Because of the disabling nature of joint injuries, improvements in this area are important. Some action is being carried out as a consequence of the EuroNCAP inspection procedures but this is subjective and does not cover all cars.

Recommendation

- A sub-systems test procedure needs to be developed to assess the risk from knee impacts against that part of the facia that knees are able to impact.

Lower Legs, Feet and Ankles

Offset frontal collisions present a high risk for lower extremity injuries with long impairment and high societal costs. Crashworthiness optimisation to alleviate serious injury risk to some body regions leads to changes in injury distribution patterns and shifts the focus to other areas of the body. Injuries to the lower legs have been neglected until recently and the introduction of an improved dummy leg is awaited. Lower leg injuries can result from direct impact against the fascia, parcel shelf or foot pedals or from loads applied to the foot or leg. Requirements for protection against such loadings need to be developed along with appropriate test procedures.

For the feet and ankles, better injury criteria and dummy components are awaited. The best correlation with injury risk is related to footwell and pedal intrusion. There is an early need to introduce a footwell intrusion requirement, although it is recognised that injuries can occur in the absence of intrusion.

The in-depth real-world crash injury data have demonstrated that there is a clear association between intrusion and lower extremity injury. As intrusion increases so does the rate of injury to both the upper and lower parts of the extremity. As intrusion increases, measured at the footwell, so do the numbers of serious injuries and this occurs independently from the speed of the collision. However other factors, such as the rate of loading and the design of the pedals, are also significant and the crash injury data indicate that 29% of all AIS 2+ lower leg injuries are sustained without intrusion.

In general, the car has to be constructed so that the passenger cell gives enough survival space in relevant crash configurations. To improve the injury outcome increased stability of the passenger compartment, padding and new airbag technology should be developed and used.

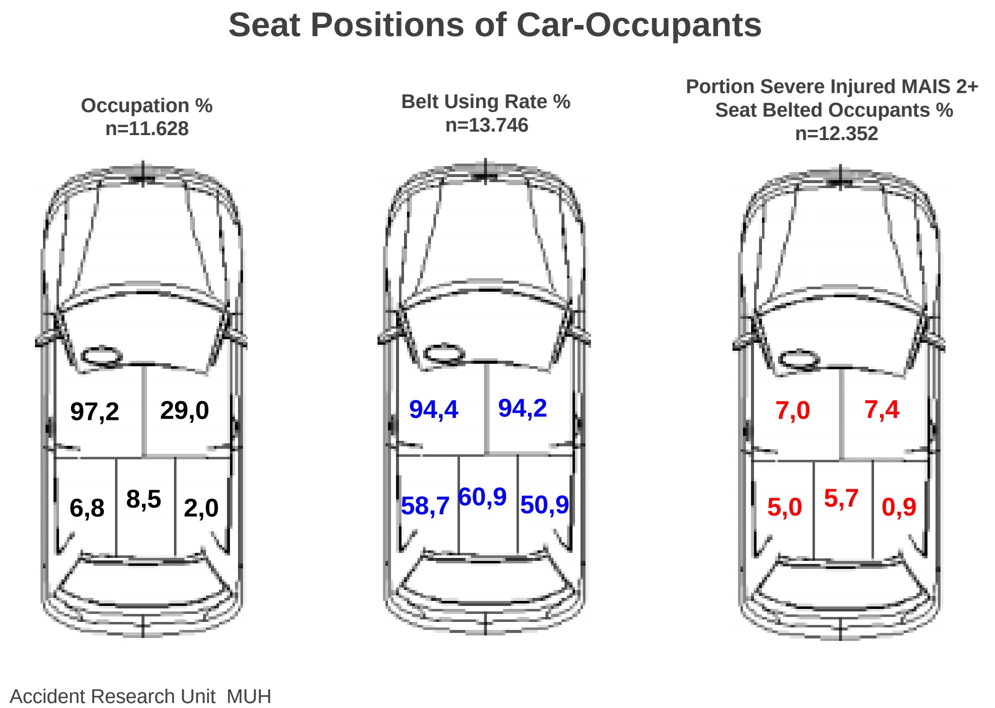
Recommendations

- Footwell intrusion requirements need to be added to the Frontal Impact directive.
- As soon as validated improved lower legs are available for the frontal impact dummies they should be used in the mandatory test and EuroNCAP.
- Improved injury protection criteria need to be developed for use with improved dummy lower limbs.

(i) Rear seat passenger protection

The rear seats of cars are occupied much less frequently that the front seats and the severity of injury is generally lower, where seat belts are worn.

Figure 11. Frequency and injury severity of front and rear seat occupants (Accident Research Unit, Medical University of Hannover)



However, seat belt wearing rates in the rear are generally low across the EU. As a priority, seat belt wearing levels need to be increased to the same as rates in the front seat. Each seat needs to be fitted with 3-point belts, pre-tensioners and load limiters.

In order to prevent rear seat passengers from suffering additional loading from luggage in the car's rear the rear seat backrests need to be strong.

<u>Recommendations</u>

- Measures need to be taken to increase rear seat belt wearing rates.
- 3-point seat belts, with pre-tensioners and load limiters, should be required for all rear seats.
- Dynamic testing of rear seat back strength needs to be mandatory.

(j) Measures to reduce neck injuries

In Sweden approximately 60% of all injuries leading to long-term disability from car crashes are AIS 1 neck injuries, often called whiplash injuries (Krafft, 1998). Around 50% of these injuries occur in rear impacts, 30% in frontal impacts and the remaining 20% occur in side impacts and rollover accident. German data indicates similar proportions. Of all reported whiplash injuries, between 5% and 10% leads to long-term disability (Nygren, 1984). In many EU Member States whiplash injury has been found to be one of the important injuries. From an epidemiological standpoint reducing whiplash injuries is a key action of major importance.

To date, several hypotheses of injury mechanisms of whiplash injuries have been proposed. It seems possible that the injury mechanisms could be similar in rear-end and frontal impacts (Krafft, 1998; Kullgren et al, 2000). It could be influenced within extension and flexion movement of the cervical spine (Hell and Langwieder, 1999).

Correlation between dummy measurements for predicting whiplash injuries and the risk of both short and long-term consequences has been studied with promising results (Boström et al, 2000a). Much research is still necessary in order to find better parameters correlating dummy readings with real-life outcome. The indications already found show that optimising seat and restraint systems against these parameters would probably be positive, although parameters better predicting whiplash injuries should be investigated with high priority: the deep cervical spine musculature might be injured in the late part of the crash phase. (Hell and Langwieder, 1999).

It has been shown that the dynamic behaviour of seat backs is one of the parameters most influencing neck injury risk (Krafft, 1998; Hellstedt and Jansson, 2000; Muser et al. 2000). Seats with low stiffness and with yielding seat backs that deform with remaining deformation after the crash seem, in a lower delta v range, positive. However, a collapsing seatback at higher velocities could be dangerous and produce severe injuries, therefore this parameter should be not neglected. Furthermore, car seats will have different dynamic behaviour for different crash pulse (Hellstedt and Jansson, 2000; Muser et al, 2000). The dynamic response of the system of occupant and seat back is influenced by the combination of seat back properties and impact severity. To cover the important dynamic response of the seatback, as well as of the whole seat system, all car front seats could be tested and improved with a dynamic seat test standard. Test proposals have been discussed within ISO, GRSP and research groups. Currently discussed are one or two sled or full-scale tests at changes of velocity between 10, 15 and 30 km/h and at accelerations between 4 and 10 g. Until greater knowledge is found, it is advisable to test each seat in more than one crash pulse, since each seat responds differently to a particular crash pulse and since a wide range of crash pulses could be experienced in the real-world.

Systems aimed at preventing neck injuries in rear impacts have been presented in recent years and used in several car models (Lundell et al, 1998; Wiklund and Larsson, 1998). The injury reducing effects of these systems have, however, to date not been evaluated. An extensive research programme where 10,000 devices aimed at preventing whiplash injuries are retrofitted in used cars has been started in Sweden by Folksam and Autoliv. The solution used is to yield the seat back in a controlled way. The injury reducing effect of the system will be evaluated using crash pulse recorders mounted in the vehicles. The evaluation will be finalised in year 2001 or 2002. Since all these whiplash systems have been constructed with different injury mechanisms in mind, it is important to rapidly evaluate the injury reducing effect of such systems. If a positive effect is found, actions aimed at rapidly implementing such devices on a larger scale are important.

Regarding prevention of neck injuries in frontal impacts, recent research has shown that airbags, pre-tensioners and load limiters are effective in reducing the number of neck injuries leading to both short and long-term disability (Boström et al, 2000b; Kullgren et al, 2000; Bohman et al, 2000). It is important to optimise triggering levels for the combination of the three sub-systems also for whiplash injuries in frontal impacts.

A new dynamic seat test standard for rear impacts needs to be developed as quickly as possible. Consumer test programmes, such as EuroNCAP, should also include rear impact tests in their car safety ratings. However, it is important to further analyse parameters and dummies influencing whiplash injuries in the development of a standard. Moreover, since there may exist several neck injury mechanisms, this must be taken into account in the development of both test methods and whiplash preventive systems. There could, otherwise, be a risk of sub-optimisation.

It is important also to take the long-term effects, especially regarding the whiplash injury, into account when creating future injury classification systems.

Recommendations

- A new dynamic test standard for seat backs should be developed.
- Further research is required to provide a better understanding of “whiplash” injuries and their cause.
- Evaluation of neck protection devices from accident experience is required to determine their effectiveness.
- Injury classification schemes need to take proper account of non-life threatening injuries such as “whiplash.”

3.2. SAFER CAR FRONTS FOR PEDESTRIANS AND CYCLISTS

In most (non-single) accident cases pedestrians and pedal cyclists are impacted by the front of a passenger car. Research and development studies related to the influence of shape, stiffness and speed of passenger cars on the resulting kinematics and injuries of pedestrians and pedal cyclists have been conducted since the late seventies. Between 1988 and 1994 EEVC Working Group 10 ‘Pedestrian Protection’ developed a complete series of test methods to evaluate the front of passenger cars in this respect (EEVC, 1994). In these tests the vulnerable road user is represented by crash dummy parts, representing an adult leg, upper leg and head, and a child head. These test tools are used to evaluate respectively the bumper, the bonnet leading edge and the bonnet top of the passenger car. Further improvements of these EEVC test methods were presented in 1998.

ETSC estimates that if all cars on the road today would be provided with the protection expected from adoption of the EEVC test methods, up to 2,100 deaths and around 18,000 serious pedestrian and pedal cyclist casualties could be prevented annually (ETSC, 2001). ETSC believes that the introduction of EU legislation requiring new cars to pass EEVC test methods to provide safer car fronts for pedestrians and pedal cyclists is one of the most important actions that the EU could take to improve road safety. Both the Council of Ministers and the European Parliament have called for the introduction of legislation as soon as possible. The Commission has cited the measure as one of six priority legislative measures for the short term.

EEVC WG10 also performed test series on off-road vehicles equipped with so-called *bull-bars* or crash-bars, meant to protect the headlights and other front parts in a crash. It was shown that these bent and welded steel tubes are very pedestrian and pedal cyclist unfriendly (EEVC, 1996).

Since the end of 1996 the EEVC test methods are being used in the European New Car Assessment Programme (EuroNCAP) to evaluate the protection afforded by new passenger cars. The results are used to rate the performance of the car and the final rating is published. From this programme it can be concluded that current car designs do not fulfil the EEVC pedestrian protection requirements.

Recommendations

- Introduction of EU Directive for protection of vulnerable road users
- Consumer information e.g. through EuroNCAP
- Research on head injuries caused by the windscreen surround

3.3 TWO-WHEELED MOTOR VEHICLES

3.3.1 Crash prevention

(a) Conspicuity

Nearly all studies (the exceptions being those with methodological shortcomings) show that the use of motorcycle daytime running lamps is even more effective than daytime running lights for cars, because the conspicuity of motorcycles is less than that of cars. Recent studies (Malaysia, where 60% of the motor vehicles are motorcycles and Austria where the post law effect has been long term since the introduction of legislation in 1982) have shown that the effect, expressed as the effect of a change from 0 to 100% usage is a reduction of 35% of day-time motorcycle casualties and deaths where two or more vehicles are involved.

The use of daytime running lights is compulsory in several Member States. Some of these require action on the part of users to switch on headlamps and usage levels are around 90%. In other countries their use is encouraged, but as in the case of the UK, usage is often less than 70%.

A European requirement for the fitment of automatic daytime running lamps on all new vehicles would result in time in usage to 100% from about 65% in one fifth and from about 90% in four fifths of EU countries. For the EU as a whole this would reduce daytime accidents where two or more vehicles are involved (damage only as well as casualties and deaths) by about 7%. This translates into a minimum saving of around 250 deaths and 1500 casualties annually.

Since motorcyclists have the highest risk, by far, of all road users, a European mandatory fitment standard should be introduced as soon as possible.

(b) Brakes

The last few years have seen developments in braking that have clearly overshot the mark. The aggressive front wheel brake systems in use today are, on the one hand, important to keep the enhanced driving performance in check, but on the other, in the case of emergency braking, they cause the front wheel to block and the driver to fall off the motorcycle. Studies have shown that drivers can brake with the rear brake only under at least 0,2g (Hackenberg, 1983).

Modern braking systems featuring ABS and combined braking systems are able to receive an optimised deceleration of more than 0.7g and avoid such falls. According to a recent prospective estimate ABS could reduce the number of accident victims by at least 10% (Sporner and Kramlich, 2000).

Recommendations

- Daytime running lights and anti-lock braking systems should be mandatorily fitted to motorcycles.

3.3.2 Crash injury reduction

(a) Two-wheeled motor vehicle crash test configurations

Of all road users, motorcyclists have by far the highest injury risks. If an accident occurs, 98% of motorcyclists sustain injuries. Reducing the consequences of injury sustained in a motorcycle accident will always lag behind the possibilities offered by a car. All safety elements that claim to reduce injury must pass through a comprehensive test programme in compliance with ISO Standard 13232.

While improvements to helmets and increasing use has more than halved the incidence of head injuries in the last thirty years, helmet use rates still need to be increased further. ETSC welcomes the EU Council of Ministers resolution inviting the Commission to introduce a compulsory helmet use Directive. Accident studies show that the major body regions for injury risk beside the head are the leg, shoulder, elbows, and pelvis.

b) Motorcycle leg protection

Injuries to the legs of the motorcyclist occur in approximately 80% of all accidents. However, the kinematics differ depending on the type of collision.

In all collisions in which the motorcyclist is hit in the side by a car or other party, the forces involved impact the legs directly. Leg protectors could help to reduce such injuries. Studies show different possibilities for optimising leg protection (Otte, 1994). In collisions in which the motorcyclist crashes into another party, there is only a secondary impact of force on the legs. In this case, the head and upper torso are the first to make contact with the other party. In this situation, crash test results have indicated that motorcycle leg protectors, while effectively protecting the lower extremities, could have a negative effect on the risk of head injury as it influences the path of movement. The problem arises where there is expectation that the safety measure can protect in all cases.

Studies with airbags have been carried out in the past (Sporner et al, 1990; Sporner, 2000) and the development of airbag systems for the motorcycle should be continued.

Safety can only be increased by several measures that do not have a mutually negative effect. If the motorcyclist is prevented from falling prior to the collision by an active safety element such as ABS, for instance, the severity of injury is reduced, since the motorcyclist collides with the other party in an upright position and the effect of seat height and body position make it possible for the motorcyclist to be thrown over the obstacle.

<u>Recommendations</u>:
Further research is urgently needed:

- to determine seating positions with a relatively high seat elevation and upright body position to reduce the possibility of entrapment of the lower extremities
- to provide leg protection to protect the wearer from the impact of external forces and to serve as an element that affects the trajectory in a positive way
- to develop suitable airbags to provide riders with protection in frontal impacts

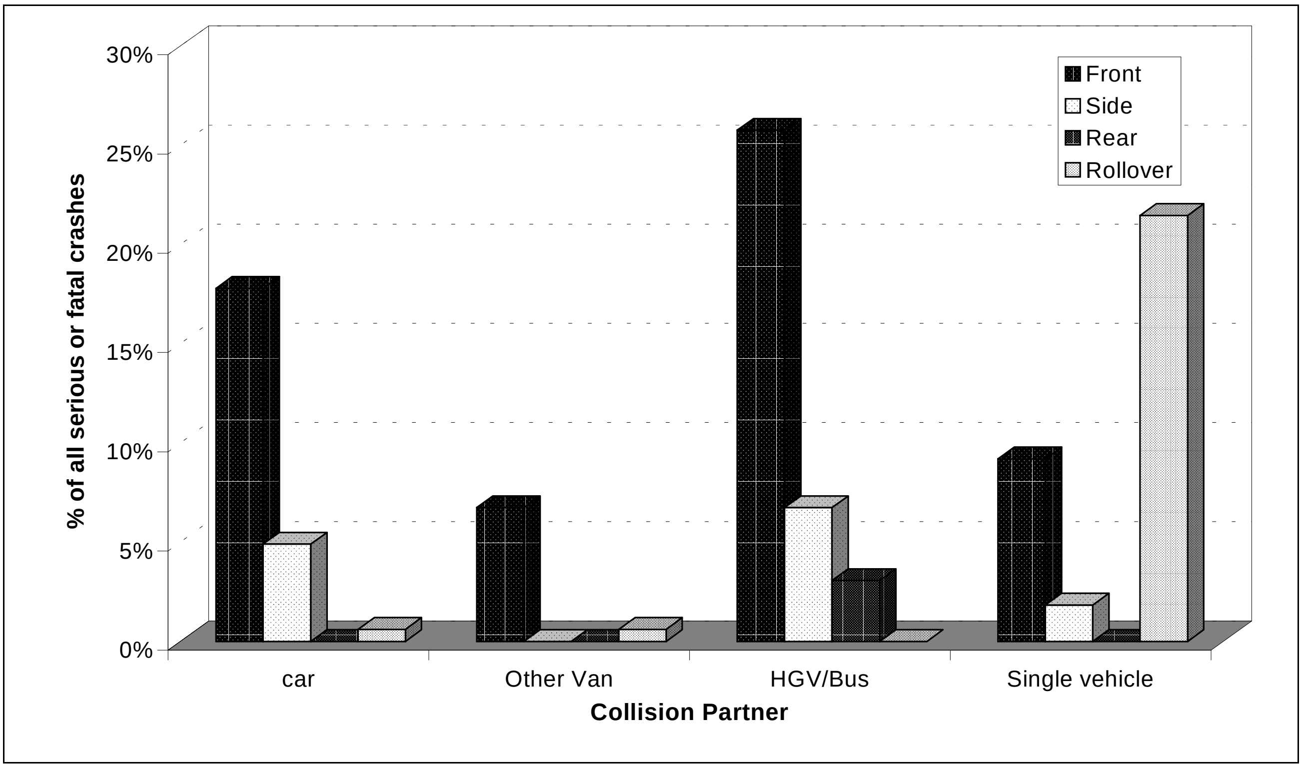
3.4. LIGHT VANS AND MINIBUSES

Vans, meaning the larger N1 vehicles that are not car-derived, and minibuses share several features in common. When supplied by the manufacturer rather than being a conversion they may be based on the same body-shell and drive-train. This means they also share a number of features that concern the crash and its outcomes.

Both classes of vehicles will typically have a mass, stiffness and height advantage when in collision with cars and as a result impacts with cars impose a lower level of risk to the van and minibus occupants. Figure 12 shows the collision partner and impact direction for the group of van occupants sustaining serious (MAIS2+) or fatal injuries.

The most common crash configurations where serious or fatal injuries are sustained are frontal collisions with a truck or bus (26%), rollovers (21%), and frontal collisions with a car (18%). Minibuses appear to have the same main collision types, although the available data is very sparse. As indicated previously, ETSC believes that frontal impact test requirements should now be extended to cover N1 vehicles up to 2.5 tonnes, M1 vehicles above 2.5 tonnes and M2 vehicles, however, the extension of the side impact barrier requirement to either of these classes of vehicles is not likely to result in large reductions in casualties.

Figure 12. Collision Partner and Impact Direction – Fatal and Seriously Injured casualties



(UK data from Ford Motor Co.)

Vans and some minibuses are frequently used for local deliveries and for some years several EU Member States introduced exemptions for the seat belt use requirements on convenience grounds. While recent changes to EU Directives may have imposed belt use requirements, the usage rates amongst the drivers and front passengers of these vehicles are still low. Roadside checks of seatbelt use may not include this category of vehicle and there is very little crash injury data available for this class of vehicle.

The observed belt use rates for front occupants of larger N1 vans that are involved in crashes in the UK was 59%. In comparison comparable data taken from the UK co-operative crash injury study indicates over 95% of car front seat occupants are wearing their belts. The levels of protection offered by cars and vans is generally focused on restrained occupants so these van occupants will not normally be receiving optimised safety. ETSC recommends that any remaining exemptions for seat belt use should be removed and levels of enforcement be increased to improve protection levels significantly.

Occupants of minibuses that are involved in rollover crashes are frequently at risk of either partial or complete ejection, particularly when unrestrained. A Directive requiring the fitment of three point belts in all seats in minibuses comes into force in October 2001. This will improve the levels of protection available provided they are used. However, rear seatbelt use in cars is routinely lower than in the front seats. Local enforcement actives should be geared to ensure that the rear occupants of minibuses are restrained as well as the occupants of other vehicles.

Recommendations:

- Seat belt wearing rates are lower in minibuses and light vans than in cars and should be increased. All existing exemptions should be removed.
- The frontal impact occupant protection requirements should be extended to minibuses and light vans.

3.5 BUSES AND COACHES

Control of Driving Time

Many investigations have shown that a huge number of truck and bus drivers flout driving time regulations. A forthcoming EU rule on the installation and use of digital tachographs on trucks and buses should lead to improvements (See ETSC, 2001a for further discussion).

Enhanced structure

The structural integrity of a bus or coach should provide sufficient occupant survival space. ECE-Regulation 66 prescribes several alternative dynamic tests, such as a rollover test, referring to the strength/stiffness of the body superstructure. This is insufficient. The industry applies additional test set-ups to evaluate the integrity in more detail. Frontal collisions are carried out into rigid flat barriers, trailer back barriers, offset barriers, angled barriers. Over the past years several investigations have revealed that bus/bus or bus/truck collisions create enormous forces. As a result of the high energy, the body of bus structure might suffer deformation that endangers occupant safety seriously. The survival space is directly related to intruding parts. As far as the driver is concerned, the intruding parts might be the steering wheel and steering column. Both are forced to move during a frontal collision and may injure the driver.

Enhanced seat and seat belt anchorage safety

Bus seat and belt anchorages are points of concern (ECE-R14, ECE-R16, ECE-R80). Several studies including large coach accidents showed that seats and their anchorages are often unable to resist the forces to which they are exposed. The risk of being injured by failing seat and anchorages should be reduced.

Integrated systems, with the seat belt anchorages on the seat, place a great demand on the seat-to-floor connection. Standards to control the strength of seats and their connections would be beneficial.

Effective coach occupants evacuation / penetration resistance glazing

In many serious accidents passengers are hindered from using the emergency doors either because they are severely injured or the doors are locked due to the impact. ECE-Regulation 107 prescribes the technical rules with respect to the emergency doors. In rollover cases where the side windows get broken, the risk of ejection of passengers rises. Ejected passengers can be crushed by the bus itself.

An effective measure would be a side window which, even broken, would remain in position and would act as a safety net keeping passengers in the bus interior. However, care is needed to maintain good provision for passenger evacuation. The corridors in the coaches should enable the rapid evacuation of the occupants. This requires the possibility of ejecting the windows easily after the coach comes to rest. Pyrotechnic charges can be used for this.

Recommendations

e) European requirements need to be developed to enhance the structural integrity of buses and coaches and seats and seat to floor mountings
f) Consideration should be given to improved side glazing to reduce the risk of ejection but not impede evacuation

3.6 HEAVY GOODS VEHICLES

Electronic Stability Device

Investigation of several accidents with trucks indicate that they occurred due to failure in speed and steering behaviour, especially by driving through narrow curves or during evasive movements. The truck or the trailer begins to slide, to jacknife or to overturn. Today only ECE-Regulation 79 is available with respect to the steering and a qualitative definition of the dynamics of driving. An Electronic Stability Device for all trucks is proposed. First investigations have shown that such devices could improve the safety during the driving through curves by about 40 % (VDI, 2000).

Enhanced mirror systems

The mirror systems for trucks are regulated in the Council Directive 71/127/EEC. Trucks with a gross weight over 7.5 tonnes have to be equipped with two mirrors outside (left and right), one mirror outside with a wide angle and one special mirror for the right side to recognise bicycle riders or pedestrians. Based on real accident investigations it is known that the view out of trucks, especially to see pedestrians and bicycle riders is restricted. Furthermore, there is a high potential danger whilst manoeuvring or reversing a truck.

There is a need to get a better view out of the truck. Fitting an improved mirror system on the passenger side of the truck would be helpful. In addition, cameras on the rear-end of a truck or a trailer in combination with a monitor in the driver's cab could bring higher safety, especially during reversing.

Retro-reflective contour markings

Current real crash investigations show that nearly 5% of severe truck accidents can be traced back to poor conspicuity of the truck or its trailer at night. These accidents can be characterised by the fact that car drivers failed to recognise trucks or truck combinations that are turning off the road, turning around or driving ahead of them. Different studies showed that trucks can be rendered much more conspicuous by marking the sides and rear of commercial vehicles using retroreflective markings (Langwieder et al, 2000). Therefore the optional regulation ECE-R 104, referring to the conspicuity of long and heavy vehicles and their trailers should be adopted into a compulsory European rule.

Enhanced driver cabin structure
Currently in Europe two (optional) regulations exist relating to the stiffness of the driver cabins (ECE-Regulation 29, VVFS or “Sweden-Test”). Ongoing investigations show that the stiffness of the driver cabin, especially for truck/truck collisions or single-truck collisions is not sufficient. The existing optional regulation ECE-R 29 should be modified and implemented as a compulsory EC Directive.

In Germany between 1992 -1997 the number of fatally injured truck occupants increased from 220 to 250. Furthermore, the number of severely injured truck occupants increased by 7.7%. The numbers of fatalities and injured persons could be reduced if the structure of the driver cabin was enhanced, but only if restraint use by truck drivers increases.

Restraint systems
Since January 1992 it has been compulsory to equip trucks with a seatbelt. Further regulations to restraint systems like airbag or seatbelt tensioners do not exist in Europe. The restraint rate of truck drivers and also of passengers of trucks is very low in Europe. In Germany it ranges between 5% and 10%.

To improve restraint use, 3-point belts should be integrated directly into the seat of the driver and passenger. The comfort of the seatbelt would be increased and, as a consequence, the acceptance of wearing a seatbelt would increase.

ETSC welcomes the forthcoming Directive which requires that all restraints fitted should be worn in heavy goods vehicles. A mandatory fitment Directive is needed too.

Front underrun protection systems
Due to the size and mass of heavy vehicles, the problem of compatibility with other road users is a serious matter. Trucks are stiff, heavy and high and may pose a serious threat to the occupants of other vehicles. Frontal car-to-truck collisions are the greatest problem in accidents where trucks are involved.

An EU requirement has recently been introduced requiring mandatory rigid front underrun protection defining a rigid front underrun protection system for trucks with a gross weight over 3.5 tonnes (CEC, 2000a).

Rigid underrun protection is a step in the right direction, but, as these collisions normally take place at higher relative speeds where energy absorption is necessary on the truck, ECE-Regulation 93 should be extended with *energy absorbing* front underrun protection systems and should be compulsory within the European Union. Studies performed by EEVC WG 14 have shown that passenger cars can ‘survive’ a frontal truck collision with a relative speed of 75 km/h if the truck is equipped with an energy absorbing underrun protection system. Furthermore, these systems could reduce about 1,176 fatalities and 23,660 seriously injured car occupants in Europe per year. The monetary benefit is about 1,482 million Euro.

Rear underrun protection systems
The Council Directive 70/221/EEC defines a rear underrun protection system for trucks and trailers with a gross weight of more than 3.5 tonnes. The regulation describes for example a ground clearance of 550 mm and test forces of maximum 25 kph, respectively 100 kN, depending on the test point.

An in-depth study of 58 car/truck collisions has shown that today’s rear underrun protection systems are not sufficient, especially because of the large ground clearance and their insufficient strength. The ground clearance needs to be reduced to 400mm. Furthermore, the test forces need to be doubled. First conservative estimates of EEVC WG14 showed that improved rear underrun protection systems with a lower ground clearance as well as higher test forces would reduce fatally and severely injured car occupants by a third in rear underrun impacts in Europe. In addition, Working Group 14 has found that the costs for fatalities and severe injuries could be reduced by 69 -78 Million Euro.

Side underrun protection systems

Trucks and trailers have to be equipped with a protection system at the side as defined in the Council Directive 89/297/EEC. The essential aim of these side underrun protection systems is to prevent pedestrians, bicycle riders and motorcyclists from falling under the wheels of the truck when it turns. The protection system fills the open space between the wheels, however current legislation accepts an ‘open’ frame (e.g. two planks on the side with a maximum distance of 30cm). Therefore, under some circumstances pedestrians and bicycle riders could be caught by such a side underrun protection system. Furthermore, for side collisions with cars and motorbikes the strength of current side underrun protection systems is insufficient.

It would be desirable for the requirements to be modified, to specify full area side underrun protection system. Investigations have shown that improved side underrun protection system could reduce fatalities to pedestrians and cyclists in such situations by about 45%. In addition the strength requirement should be increased to accommodate side collisions with cars and motorbikes.

Recommendations

- Development of a test specification for front underrun protection is needed towards a mandatory fitment requirement.
- Rear and side underrun protection legislative requirements need to be amended to reflect needs identified by accident research.
- An EU Directive is needed to require the compulsory fitment of seat belts in heavy commercial vehicle cabins
- EU Directives should be introduced aimed at improved mirror systems and providing retro-reflective contour marking on heavy commercial vehicles.

3.7 POST IMPACT CARE

Mayday systems

Some accident victims are found hours after the accident, where survival chances are dramatically reduced. Therefore automatic Emergency Systems should be implemented in vehicles based on modern GSM/GPS technology. Here solutions from different providers and manufacturers exist in some countries but are very different in concept.

Recommendation

A uniform EU standard needs to be established to provide an acute GPS warning signal to emergency departments.

3.8 TOOLS

(a) Restraint systems that record impact information

Knowledge from real-world accidents will always be important to validate new safety technology. As injury preventing systems become more complex it will be more important to have high quality data from real-world accidents. Often methods to collect such data give data of too low quality (Kullgren and Lie, 1998, Kullgren, 1998). Therefore, actions aimed at increasing measurement accuracy and quality are important. Such increase could be achieved with recorded information from restraint systems and crash recorders.

In the US, the car manufacturer GM has been using event data recorders since the 1970s to evaluate the performance of airbags in crashes and in Germany a special accident recorder so-called UDS by Mannesmann/VDO has been on the market for more than 10 years. Approximately 20,000 devices are built in present cars (Lehmann, 1995). The recorders have been further developed and more parameters can be recorded in recent models, such as vehicle change of velocity, brake lamps, belt use etc. Other parameters useful for the improvement of future restraint systems could be belt loads, triggering points of pre-tensioners and airbags, seatback deformations etc.

Triggering systems for airbags and seat belt pre-tensioners may also be used to record pre crash, crash and post crash acceleration signals in crashes. The technique used by Volvo provides one example (Norin, 1995). Also self-contained crash recorders to measure vehicle kinematics and acceleration have been presented and used (Kullgren, 1998, Koch and Salomonsson, 1991). Such information is important in order to establish human injury tolerance limits, which are not only essential in the development of crashworthy vehicles but also for the development of a crashworthy road transportation system. Experience in Germany gained with the Accident Data Recorder shows that it can influence driving behaviour considerably and thus contributes to accident reduction, especially in vehicle fleets, of between 20 – 30% (police study Berlin, EU-project SAMOVAR).

In future, as more advanced safety technology is used, it will be even more important to extend the use of on-board crash recorders and restraint systems that record impact information.

Recommendation

- Develop specifications for the fitment of on-board crash recorders on all motor vehicles. This would reveal important information about impact severity and aid the development of restraints and other safety features.

(b) Availability of in-depth data and its integration into safety process

The increasing responsibilities of the EU for road safety resulting from the Maastricht Treaty together with its competency for vehicle design through EU Whole Vehicle Type Approval mean that a more systematic approach is needed.

There is now a clear range of areas where the EU has the responsibility for improvements in casualty reduction and a corresponding range of data sources is needed to support safety decision making. Information on existing aspects of real-world safety problems is needed to direct new safety policy as well as to evaluate the effectiveness of recent safety countermeasures. New safety possibilities offered by technology improvements can be substantial under laboratory conditions but it is essential to ensure that they result in true safety improvements in real-world crashes.

Safety technologies may be heavily marketed to vehicle purchasers but there is a real expectation of improved protection when crashes occur. The responsibility of the EU to ensure improved crash protection is accompanied by the responsibility to assess the long-term effects of safety regulation. This means that there is now a much greater need for systematic data about vehicle performance in crashes and the resulting injuries. Crash performance regulations are typically detailed and state precise requirements for the vehicle so the data needed to monitor vehicle performance need to be similarly detailed. To provide the most effective support to safety policy these data need to be co-ordinated to ensure that all of the information needs are met.

A co-ordinated independent European road accident investigation strategy

To fully support and evaluate the safety decision-making a co-ordinated accident investigation strategy requires several key components.

- *Geographical coverage* - the data must cover the range of European crash conditions, analysis must give results that are as representative as possible;
- *Road user types* - The main casualty groups must be covered, in particular car occupants, motorcyclists and pedestrians;
- *Level of detail* - The detail in the data must be sufficient to assess the effects of detailed regulation;
- *Accident and injury causation* - the main focus must be on vehicle design and injury causation but data on accident causation are also required, particularly for high risk or vulnerable road user protection;
- *Independence* - the data collection and analysis must be conducted by groups that do not have a stake in the financial consequences of the investigations.

These requirements will not be met by a single database so a co-ordinated strategy is needed. A group of databases which are linked qualitatively and statistically will together provide the necessary building blocks. With the exception of CARE, existing studies have developed on an ad-hoc basis rather than fitting into a pre-determined framework and there is little scope to link the various data, either statistically or conceptually. While such studies may contribute to the development of new accident/injury countermeasures they do so in isolation and are not as effective as they could be.

The main gaps in current accident investigation studies concern injury causation for car occupants, pedestrians and motorcyclists. The main competency of the Commission concerns vehicle type approval, yet there is no European injury causation study for car occupants, pedestrians or motorcyclists, the most commonly injured road users. Some in-depth accident causation data have been collected under the European Accident Causation Survey (EACS) and Motorcycle Accident In-Depth Study (MAIDS), but these studies are not independent, being partially funded by the car and motorcycle industry. The EACS is not representative of the EU accident population.

The EuroNCAP consumer information programme has led to a period of dramatic technical improvements to car design yet there is no suitable accident research programme that is capable of fully evaluating the changes in injury patterns or injury risk. Previous research has indicated that injury reduction countermeasures are a more effective casualty reduction tool than attempts to reduce accidents by changing driver behaviour. An in-depth study is needed that examines injuries and identifies the causes through analysis of the associated vehicle damage. When enhanced by detailed injury information, linked to the vehicle registration or driver licensing information they will be a powerful tool to support further crashworthiness improvements. The completed STAIRS project provides the basis for this in-depth programme with links to CARE to ensure the data are statistically representative of the EU situation.

While it would be possible to combine accident and injury causation studies, it is likely to be more effective to keep them separate as they have conceptual and often methodological differences.

Accident investigation studies will not give any benefit to road users unless the data are appropriately analysed and the results formally integrated with policymaking. New mandatory safety regulations will have the greatest benefit if the development includes a reliable estimate of the likely casualty reductions. Once in force a Directive should include the requirement to evaluate the longer term effectiveness as both the frontal and side impact Directives did. In this way real-world accident and injury data can form an integral part of European road casualty reduction strategies.

Recommendation

- A new monitoring system to gather systematic in-depth accident and injury causation information needs to be established at EU level.

(c) Biomechanical tolerance data

Biomechanical research focuses on human response and injuries sustained in crash conditions taking into account the variety of occupant-vehicle interactions seen in real world accidents. Up-to-date biomechanical knowledge is important to understand the efficacy of passive safety measures in vehicles and to help improve these measures. Despite more than three decades of biomechanical research, collecting human response and injury data still is a key priority in the field of passive safety as good information for many body areas is still lacking. Moreover, the knowledge required is constantly challenged by the increasing versatility of vehicles and occupant restraint systems being introduced in the market.

The foundation of biomechanics research remains the collection of human response and injury data required to develop tools such as crash test dummies and computer models. Important areas of research are biomechanics of children, head, chest, abdomen, knee and lower leg and whiplash injuries. In parallel, further attention needs to be paid to methodology development such as advanced scaling techniques and human tissue characterisation. Improved biomechanical information needs to find its way into the design of new crash test dummies more quickly.

The limitations in dummy design and application have increased interest in the development and application of mathematical human body models. Human body models can potentially be used to study the whole road user population, from the new born and toddler in a child restraint system to various sizes or ages of adults in different postures and loading conditions. However, even more than for crash test dummies, the development of accurate human body models requires advanced biomechanical knowledge such as constitutive properties of biological materials, injury mechanisms and anthropomorphic data. In the future, new biomechanical knowledge will further raise the confidence in the prediction capabilities of these models. Future generations of human body models should allow virtual testing of a new car model before the design has left the drawing table.

Together with accident analysis, biomechanics research provides a foundation for crash safety strategies and measures. Knowledge in this area should be developed in a structured and continuous way.

Recommendation

- Collecting human response and injury data should be a key research priority in the field of passive safety as good information for many body areas is still lacking.

d) Crash dummy development

Traditionally, anthropomorphic test devices (crash test dummies) used in test procedures have played an important role in improving car occupant safety. Improvement of crash dummies in terms of human likeness in response, injury assessment capabilities and application is required to keep up with the changing crash environment of a car occupant. New crash test dummy designs are being proposed that address injuries such as whiplash which are important in terms of societal costs rather than in terms of threat to life. Standardisation of crash test dummies in global legislative test procedures is pursued not only to reduce the costs associated with safety testing for the automotive industry, but also to introduce equal levels of protection in vehicles worldwide.

Crash test dummy development firstly will be driven by the demand for enhanced biofidelity and range of application, and, secondly, by the need to harmonise test tools and safety regulations worldwide. Ongoing examples are the WorldSID side impact dummy and the Whiplash dummy developments. A third area is the improvement of current crash dummies. For instance the EuroNCAP programme has shown that some vehicle manufacturers are taking (intentional or not) advantage of uninstrumented load paths in the EUROSID-1 dummy. There is a need to overcome these problems either by removing these load paths or by adding instrumentation.

Recommendation
Research and development aimed at improving crash dummies in terms of human likeness in response, injury assessment capabilities and application is required.

3.9 SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

Car design for occupant protection

1. Improving EU frontal impact protection requirements

a) The test speed for the frontal impact test should be raised to 64 – 65 km/h.
b) The frontal impact Directive should be extended to cover N1 vehicles up to 2.5 tonnes, M1 vehicles above 2.5 tonnes and M2 vehicles.
c) A requirement to limit the lateral displacement of the steering column to 80 mm should be added to the existing vertical and horizontal requirements.
d) All the current injury criteria need to be maintained.
e) When available, consideration should be given to using an improved dummy with improved criteria for the lower legs.
f) Research is needed to develop criteria and instrumentation to assess the risk of injury to the abdomen and knees.
g) The recommended limit on footwell intrusion recommended by the EEVC should be adopted with a requirement for its review in the light of further accident experience.
h) For the present time the current design of deformable barrier face should be retained.
i) An additional full frontal high deceleration crash test is required to provide a better test of restraint protection

2. Improving EU side impact protection requirements

a) The derogation regarding seating position should be removed from the Directive.
b) All the current performance criteria should be retained and the Viscous Criterion should become a mandatory requirement.
c) Protection of the lower limbs needs to be considered for the future. To provide for the protection of the lower limbs, dummy instrumentation and criteria for the lower limbs need developing.
d) Research should be carried out to determine the best method of increasing the severity of the side impact test to be more able to address the accident problem. This should

enable a further review of the Directive to be made to enable the higher speeds of impact in accidents to be addressed.

e) Urgent consideration needs to be given to instrumenting all the load paths into the EuroSID dummy and developing criteria for them.
f) In any future side impact dummy, all possible load paths need to be instrumented by design.
g) When the EEVC research is complete, a single design specification of barrier face should be specified in the Directive. This barrier face must be capable of being manufactured to the same standard of performance by competing suppliers around the world.
h) A pole impact test is required to evaluate head protection in side impact. Consideration should be given to the development of a test to simulate accidents involving impacts with poles. This would require research into the levels of protection possible.

3. Improving car to car compatibility

a) Compatibility is seen as the next major step forward in improving car occupant safety. Further developments of frontal impact protection need to be considered in association with compatibility and this is seen as a top priority for vehicle safety research.

4. Improving seat belt use

a) The fitment of effective seat belt reminder systems is seen as a high priority for early action.
b) EuroNCAP can provide an immediate incentive for manufacturers to develop and install simple effective seat belt reminder systems and then to continue to develop more advanced ones.
c) When effective seat belt reminder systems become available, consideration should be given to enacting legislation for their mandatory fitment.

5. Frontal protection front air bags

a) Driver airbags should be fitted universally.
b) Where passenger airbags are fitted, clear instructions are needed to avoid the fitment of rearward facing child restraints on the seat.
c) The provision of automatic detection of child restraints and out of position occupants is needed to switch off the passenger airbag.
d) If manual switches are provided, an effective warning about their setting needs to be incorporated.

6. Side protection air bags

a) With the growing number of side airbags fitted in cars, accident research is needed to identify their benefits and any associated problems.

7. Restraint of children in cars

a) Children in cars should be provided with suitable child restraints for their age and size.
b) The use of rearward facing restraints provides the best protection and should be used up to as high an age as possible.
c) Further research is needed to assess the effects of modern car designs to identify necessary changes for restraint design and regulatory tests.
d) A mandatory side impact test procedure is required to assess child restraints for all age groups of children.
e) The fitting of ISOFIX anchorages, with provision for an effective third restraint in the front and rear seats should be made mandatory.
f) ECE R44 should be developed to assess universal ISOFIX seats, with effective third restraints.

8. Reducing injuries through contact with the car interior

a) An interior headform test procedure should be developed for use in Europe.
b) A sub-systems test procedure needs to be developed to assess the risk from knee impacts against that part of the fascia that knees are able to impact.
c) Footwell intrusion requirements need to be added to the Frontal Impact directive.
d) As soon as validated improved lower legs are available for the frontal impact dummies they should be used in the mandatory test and EuroNCAP.
e) Improved injury protection criteria need to be developed for use with improved dummy lower limbs.

9. Improving rear occupant protection

a) Measures need to be taken to increase rear seat belt wearing rates.
b) 3-point seat belts, with pre-tensioners and load limiters, should be required for all rear seats.
c) Dynamic testing of rear seat back strength needs to be mandatory.

10. Improving protection in rear impacts

a) A new dynamic test standard for seat backs should be developed.
b) Further research is required to provide a better understanding of "whiplash" injuries and their cause.
c) Evaluation of neck protection devices from accident experience is required to determine their effectiveness.
d) Injury classification schemes need to take proper account of non-life threatening injuries such as "whiplash."

11. Safer car fronts for pedestrians and cyclists

a) Introduction of EU Directive requiring the four EEVC sub-system tests for the protection of vulnerable road users
b) Consumer information e.g. through EuroNCAP
c) Research on head injuries caused by the windscreen surround

Car design for crash prevention

12. Reducing vehicle speeds

a) Work is required to develop harmonised standards for Intelligent Speed Adaptation systems with the aim of eventual universal fitment.
b) In the meantime, encouragement should be given to manufacturers providing ISA systems via the European New Car Assessment programme to enable the consumer to start benefiting from a voluntary system.

13. Reducing driver impairment

a) Further work is required to develop practical driver impairment systems and to understand their effectiveness and acceptability.
b) Consideration should be given in developing such systems in combination with an electronic driving licence system.

14. Improving conspicuity

a) It is recommended that early consideration is given to a mandatory fitment requirement for daytime running lights in the EU.

15. Improving braking and stability

a) Research would help to ascertain whether anti-lock braking systems alone have a role to play in accident reduction.
b) Monitoring of braking assistance systems is required to determine how well they can identify and respond to the driver's intended braking behaviour and to determine their accident reduction potential.
c) Monitoring of the dynamic stability systems being made available by car manufacturers is needed to determine their influence on accident occurrence.

Motorcycle design to improve safety

a) Daytime running lights and anti-lock braking systems should be mandatorily fitted to motorcycles.
b) Further research is urgently needed:
   - to determine seating positions with a relatively high seat elevation and upright body position to reduce the possibility of lower leg entrapment
   - to provide leg protection to protect the wearer from the impact of external forces and to serve as an element that affects the trajectory in a positive way
   - to develop suitable airbags to provide riders with protection in frontal impacts

Heavy goods vehicle design

a) Development of a test specification for energy-absorbing front underrun protection is needed towards a mandatory fitment requirement.
b) Rear and side underrun protection legislative requirements need to be amended to reflect needs identified by accident research.
c) An EU Directive is needed to require the compulsory fitment of seat belts in heavy commercial vehicle cabins
d) EU Directives should be introduced aimed at improved mirror systems and providing retro-reflective contour marking on heavy commercial vehicles.

Minibus and light van design

a) Seat belt wearing rates are lower in minibuses and light vans than in cars and should be increased. All existing exemptions should be removed nationally.
b) A mandatory requirement is needed at EU level for the fitment of seat belts.
c) The frontal impact occupant protection requirements should be extended to minibuses and light vans.

Bus and coach design

a) European requirements need to be developed to enhance the structural integrity of buses and coaches and their seats, and seat to floor mountings
b) Consideration should be given to improved side glazing to reduce the risk of ejection without impeding evacuation
c) An EU requirement is needed to fit seat belts to coaches

Alerting the emergency services

a) A uniform EU standard needs to be established to provide a GPS warning signal to emergency departments.

Crash Investigation Tools

a) Develop specifications for the fitment of on-board crash recorders on all vehicles
b) A new monitoring system to gather systematic in-depth accident and injury causation information needs to be established at EU level.
c) Collecting human response and injury data should be a key research priority in the field of passive safety as good information for many body areas is still lacking.
d) Research and development aimed at improving crash dummies in terms of human likeness in response, injury assessment capabilities and application

4. PRIORITIES FOR EU ACTION

The following list of priorities for EU action comprise those measure which offer the greatest opportunities for large reductions in casualties in the short to medium term with due account being taken of the state of the art of research and development in each case.

Legislation

Top Priority

- Safer car fronts for pedestrians and cyclists
- Improved offset frontal impact test, extended to cover additional vehicle types
- Seat belt reminder systems
- Universal ISOFIX child restraint anchorages with an effective third restraint
- Side impact test procedure for child restraints
- High deceleration frontal crash test for restraint system assessment
- Daytime running lights for motorcycles

Priority

- Improved side impact test for cars
- Daytime running lights for cars
- Anti-lock brakes on motorcycles
- Improved rear and side HGV underrun protection
- Seat belt fitment to minibuses, coaches and heavy goods vehicles

Consumer information

Top Priority

- Member States to join and fund EuroNCAP
- Improved dissemination of EuroNCAP results
- Combine EuroNCAP pedestrian and child restraint performance in with occupant ratings
- EuroNCAP to encourage the on-going improvement of seat belt reminder systems
- Incorporation of a high deceleration frontal impact into EuroNCAP
- Assessment of Compatibility in EuroNCAP

Priority

- Further review the appropriateness of EuroNCAP requirements to accident needs

Research and development

Top Priority

- EU in-depth accident and injury causation studies
- Specification for smart audible seat belt warning devices
- Car frontal and side impact compatibility and advanced protection
- Protection in side impacts at higher severities and for non-struck side occupants
- Greater understanding of “whiplash” injuries, their causes and prevention
- Measures to improve motorcycle leg and upper torso protection
- Research into standards for Intelligent Speed Adaptation

Priority

- Criteria and instrumentation for frontal impact injury to the abdomen and knees
- Performance and concerns regarding European air bags
- Development of advanced intelligent restraints
- Energy-absorbing front underrun protection for heavy goods vehicles
- More comprehensive biomechanical data, injury performance criteria and improved crash dummies
- Pedestrian head protection measures for the windscreen surround
- EU standard for GPS based warning of accidents
- Specifications for on-board crash recorders for all motor vehicles

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