

EEVC WG19 ACTIVITIES ON PRIMARY AND SECONDARY SAFETY INTERACTION

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ABSTRACT

The European Enhanced Vehicle Committee (EEVC) established a new Working Group (WG19) in December 2001, to carry out a study on primary and secondary safety interaction. During the first phase (until 2004), the study was performed under the following terms of reference: overview of existing and future techniques, effect of these techniques on priorities for injury prevention and effect of these techniques on existing regulations.

The achievements obtained after the first phase of work is summarized hereafter:

The conceptual framework of primary and secondary safety interaction was defined and established within the new concept of integral vehicle safety and taking into account existing safety models. It was also established priorities regarding situations and systems in which the group will center its activities in the future: adaptive occupant protective systems, intelligent break system and pedestrian protection.

WG19 performed an analysis of the European accident databases including the EACS database. The analysis revealed the lack of data related with the instants straight before the impact that fully satisfied the requirements of the WG19.

WG19 developed an inventory, of existing and future possible systems, that are of interest for precrash issues. Moreover, a methodology was set up to evaluate the potential effects of selected systems on reducing injuries.

WG19 identified a number of directives and regulations related with the subject covered by the working group; finding out the needs of suggesting modifications for some of them or establishing new ones.

Finally, WG19 established also priorities for its future activities; the focus will be on adaptive occupant protective systems, intelligent braking systems and pedestrian protection implicated in the pre-crash phase.

The objective of this paper is to show in more details the results of the first phase of work and to inform about the objectives of the WG19 for the next three years period.

INTRODUCTION

While primary safety systems focus on providing assistance to the driver in normal driving and in crash scenarios, secondary safety aims to lessen the consequences of the accident. Today's conception of vehicle safety has blurred the boundary between primary and secondary safety. The extended use of electronic systems in vehicles is foreseen to enable primary and secondary safety interaction, leading to the Integrated Safety concept.

Future safety systems will permit the evaluation, in real time, of the scenario as defined by the vehicle itself, its passengers and the environment, and eventually identify an "unavoidable accident" phase, presetting all safety systems for optimal actuation in crash.

In this context, different conceptual frameworks for integrated vehicle safety have been established, including different traffic scenario phases. The ACEA safety model proposes five phases: (1) Normal driving, (2) Danger, (3) Crash unavoidable, (4) In crash, and (5) Post crash. Other safety models are also available as the Delphi safety model, Mercedes Benz safety model, Autoliv, and TNO models.

WG19 employs the terms "primary" and "secondary" safety instead of the traditional "active" and "passive". The main reason is that many actual systems do not fit into the classical definitions, proving to provide both active and passive safety.

The main objective of WG19, at the first stage of its work, was to structure the field of interaction between primary and secondary safety. In this line, three terms of reference for the group were defined: (1) Overview of existing and future techniques, (2) Effect of these techniques on accident injuries, and (3) Analysis of these techniques within the existing regulatory context. This paper provides an overview on the main activities of the EEVC WG19.

DEFINITION

The interaction between primary and secondary safety, in vehicles, is the process whereby using information provided by systems which sense the vehicle environment (outside and/or inside) co-ordinated actions are performed by the vehicle control and protection systems. These actions are performed during the pre-collision and collision phases with the aim of decreasing or eliminating injuries to vehicle occupants, or to vulnerable road users. This concept is restricted to situations where a collision has become unavoidable.

Vehicles are involved in a large variety of collisions. Considering the state-of-the-art technology and real world accident data, Primary Secondary Safety Interaction Systems (PSSIS, detailed definition follows) have more immediate relevance to some of them. Vehicles of types M1 and N1 present the highest relevance regarding frontal and frontal/side collisions against other vehicles, vulnerable road users and other obstacles. Primary and Secondary Safety Interaction includes:

1. ADAS (Advanced Driver Assistance Systems) designed to lessen the severity of the collision by means of reducing the impact velocity, varying the location of impact (e.g. side to front) for the vehicle to which the system is fitted or the relative orientation of the path of the vehicles involved.
2. Structural or geometrical adjustments (e.g. extendable bumpers, automatic elevation of the vehicle to fulfil compatibility requirements, raising the bonnet to protect pedestrians...) and

devices, other than restraint system such as knee bolsters, moving steering column, automatically closing sunroof, activating external airbags etc...

3. Optimized actions developed by the restraint systems, such as seatbelt pre-tensioners, seat conditioning and airbag deployment depending on the type of crash and collision severity, occupant characteristics and other factors.

STATE OF THE ART OF THE SYSTEMS POTENTIALLY INVOLVED IN PRIMARY AND SECONDARY SAFETY INTERACTION (PSSI)

Following, a summary overview of the electronic systems with which cars are currently equipped or will be equipped in the future is introduced. EEVC WG19 experts have focused on devices that could be used in phase 2 and/or 3 of the ACEA safety model described before. In general, all these systems are available for passenger cars or could be in the near future, but not necessarily for commercial vehicles at this time. For the selected systems, some information will be presented.

The table below provides a non exhaustive selection of safety systems, representative of the safety principles described below. For each selected system, the following information is given:

- **Column 1:** "Year of implementation" for light vehicles. Usually the date of introduction for heavy vehicles will be later.
- **Following columns:** Actions of the systems directed to incrementing safety.

Feature	Year of introduction	Decrease the speed	Prepare vehicle to the impact	prepare occupants to the impact	optimise the impact angle	Alert the driver
ABS - 4 channel & EBD	2000	X				
Active Camber Variation	2005	X			X	
Active Knee Restraints			X			
Deployable Knee Bolster	2002					
Active Roll Control	2000		X		X	
Active Roll Mitigation	2001		X		X	
Active Roll Stabilization	2001		X		X	
Active Safety - Pedestrian Avoidance	n/a	X	X			
Active Safety - Pedestrian Warning	n/a					X
Active Steering Wheel	2005		X		X	
Adaptive Airbag Inflator	2003			X		
Adaptive Cruise Control (ACC) with Forward Collision Warning (FCW)	2000	X				X
Adaptive Cruise Control (ACC) with Reduced Stopping Distance (RSD)	2005	X				X
Brake Assist (BA)	2000	X				
Brake Assist with Forward Collision Warning	2003	X				
Collision Avoidance Systems	2006	X			X	
Collision Mitigation by Braking (CMbB)	n/a	X			X	X
Compatibility - Bumper Airbag	2005		X			
Compatibility - Nose Dipping	2004		X			
Cornering Brake Control (CBC)	2000	X			X	
Deployable Bonnet			X			
Pedestrian Contact Sensor	2004					
Deployable Bonnet			X			
Pre-Crash Sensing	2006					
Deployable Head Restraints	2001		X	X		
Dynamic Traction Control	2002				X	
Electric Active Steering (EAS)					X	
Active Front Steering (AFS)					X	
Electrical Belt Pretensioner	2001		X	X		
Electronic Stability Program (ESP)	2000	X			X	
Electronic Stability Program	2001	X			X	
ESP - Under steer Control Logic (UCL)	2002				X	
Forward Collision Warning (FCW)	2000					X
Forward Collision Warning with Threat Assist HM	2006					X
Intersection Collision Warning	n/a					X
Lane Change Aid (LCA)	2002					X
Pre-Brake Light Signalling	2004	(X)				X
Pre-Crash Body Structure Adaptation	2005		X			
Pre-Crash Braking	2001	X				
Pre-Crash Interior Re-configuration	2002		X	X		
Pre-Crash Restraints Deployment	2003		X	X		
Pre-Crash Sensing (PCS)				X		
Closing Velocity (CV) Sensing				X		
Pre-Crash Vehicle Compatibility	2004		X			
Rollover Prevention - Non-active	2000		X			
Rollover Protection - Convertible	2002		X			
Rollover Protection - Convertible	2004		X			

Table 1. Selection of safety systems.

The presented devices are based on one or more principles to increment vehicle safety; the main guidelines are as follows:

1. Decrease of the speed immediately before impact: This decreases the energy involved in the accident: $E=f(V^2)$.
2. Preparation of vehicle for impact. In the majority of the cases, the systems pre-arm the actuators. There exist two kinds of pre-arming: reversible or non-reversible.
3. Preparation of occupants for the impact. This is a consequence of the preparation of the car for the impact.
4. Optimization of the impact angle of the vehicle.
5. Some cases were identified in which a direct link to injury reduction was not found. In these cases, the warnings must immediately direct the driver to evaluate and react to threats with sufficient time to react in order to avoid or mitigate a potential crash. Audible, visible, and possibly haptic cues will be employed.

ACCIDENT DATA ANALYSIS

The database of the European Accident Causation Survey (EACS) was analyzed with regard to potential effects of (Advanced) Driver Assistance Systems ((A)DAS) on traffic safety. In contrast to most other available accident databases, the EACS database was created to allow in-depth analyses of accident causation.

From 1996 to the end of the project in 2001, a total of 1904 accidents with at least one person injured and at least one vehicle less than 3.5 tons involved were documented. 67% of these accident reports were provided by the German consortium members, mainly by DEKRA.

The EACS database is based on an accident form, constituted by specific, vehicle, passenger, driver and auxiliary forms which may include photographic and other documentation. Resulting from this structure, a complete characterization of each accident is available.

Unfortunately, EACS database also presents some particular aspects which require special treatment in statistical analysis, and at the time of evaluating results. Due to the fact that it only considers accidents with injured people and a certain category of vehicle involved, the database is not representative of all accidents. It should be also noticed that most cases have been documented by DEKRA (Germany), thus biasing the representativeness at a European scale. Further, some forms are partially incomplete due to severe injury or death of the drivers or passengers involved. Finally, the different data sources (nine teams coming from six countries) also imply a certain degree of comparability problems.

Effects of DAS on Safety

In a first approximation, the effects of several DAS on driving safety were analysed by direct comparison between the vehicles equipped with

(A)DAS and those not. Such a direct approach was not applicable for the majority of (A)DAS, because the proportion of vehicles in the database equipped with them is too small for reliable statistical comparisons.

Out of the direct approach of data analysis arises no evidence that accident severity is correlated with a 'Cruise Control' or with a navigation system. On the other hand, a tendency of vehicles equipped with ABS to be involved in more severe accidents was found, but only if the data were analysed at a European level and if the criteria were measures of injury severity. No such effect was found if only the data from DEKRA were analysed or if the criterion was a technical measure (Delta V). Therefore, it is concluded that this effect is dependent on national differences or on differences in the accident documentation by the different organisations.

For the complete EACS data as well as for the DEKRA data, it was found that vehicles equipped with ABS had a higher engine capacity than non-equipped vehicles, reflecting the fact that in the majority of cases, DAS are installed in high class vehicles at first. The analysis of the accident data showed that the frequency of different types of impact does not differ between the vehicles equipped and those not equipped with ABS. Furthermore, no clear difference between them was found with regard to the driver behaviour aimed at avoiding the crash, although the drivers of ABS vehicles tended to combine braking and steering sequentially prior to the collision more often than drivers of vehicles without ABS.

Accident Causation

In a second step, the EACS data were analysed with respect to accident causation, in order to make predictions about potential benefits from the implementation of special (A)DAS. Firstly, accidents were classified by categories representing accident type.

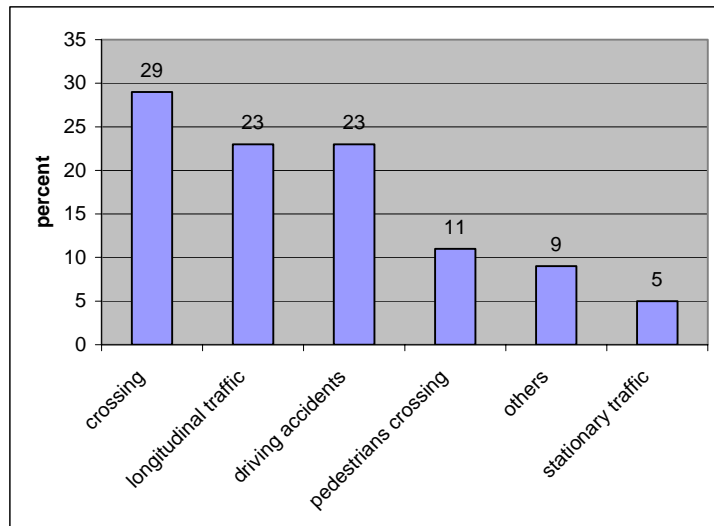


Figure 1. Accidents classified by accident type.

Categories are as follows:

- **Crossing:** Accidents in connection with direction changes and/or at crossings.
- **Longitudinal traffic:** With traffic in the same or the opposite direction.
- **Driving accidents:** Accidents due to driving errors, not caused by conflicts with other vehicles or persons.
- **Pedestrian Crossing.**
- **Stationary traffic:** For example, parked cars.

Following this classification, and based on extensive review of the database, the experts who documented EACS judged which, among 89 possibilities, were the main accident causes. The conclusions can be observed in this graphic:

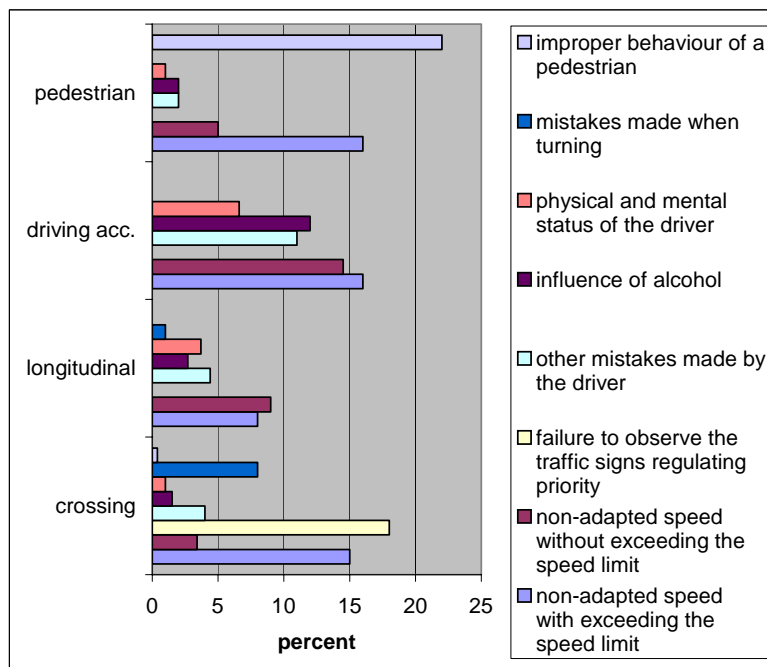


Figure 2. Experts' judgement of main accident causes.

It is shown that the most frequent accident types are accidents at crossings or involving direction changes (29% of all accidents), caused by 'failure to observe traffic signs regulating

priority'. A further analysis was carried out, in order to evaluate the influence of environmental conditions on the accidents.

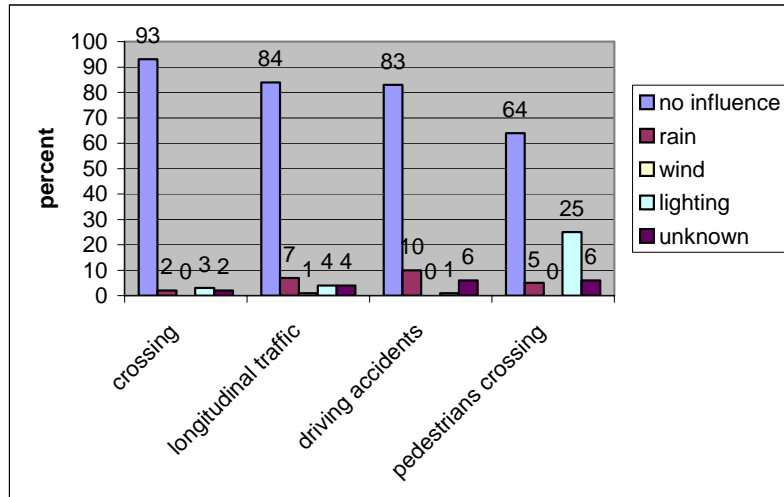


Figure 3. Experts' judgement of the influence of environmental conditions for four accident types.

From these results it can be concluded that at least some drivers would benefit from support, e.g. in detecting traffic signs, in these complex traffic situations. Older drivers could be expected to benefit especially from such a support because this driver group is especially prone to be involved in accidents at crossings. It was recommended that further research should clarify which specific aspects of the complex traffic situation at crossings are actually causing problems to the drivers.

In contrast to older drivers, the younger drivers are involved in an above number of driving accidents (23% of all accidents). This accident group is most frequently related with accidents involving inappropriate speed, either exceeding the legal speed limit or not. Therefore, the risk of driving accidents might be reduced by supporting the driver (especially younger drivers) in choosing the appropriate speed. However, alcohol is identified as the main accident cause in 12% of driving accidents. This phenomenon can be considered to be mainly due to motivational factors, out of the direct scope of action of (A)DAS.

23% of the accidents of the EACS database were classified as accidents with longitudinal traffic. For this type of accident, no prominent cause could be identified, but it is remarkable that in 16% of these accidents the drivers stated that they had not tried to avoid the crash because they were either too surprised or because they did not perceive any danger. Another 10% of the drivers were not able to describe their evasive actions. ADAS warning of approaching hazards, e.g. of accidents on the road, or of a traffic jam, could eventually

provide more time to the driver to react appropriately.

Accidents involving pedestrians crossing the road happen more often during darkness than other accident types. Therefore, improving the detection and/or the visibility of pedestrians could help to prevent accidents of this nature. Although this kind of accident is not the most frequent one (11% of all accidents), it is particularly important, because the injuries of pedestrians are much more severe on average than those of vehicle occupants.

POTENTIAL EFFECTS OF SELECTED DAS ON ACCIDENTS

In the following, systems that are of special interest with regard to frontal and pedestrian impacts will be examined. These systems will then be described with respect to their functionality and the operation of different derivatives, and a generic system will be defined. For each of the selected systems, those accident conditions where the system is supposed to have no benefit will be excluded and afterwards, the relevant parameters for a database analysis to estimate the potential safety benefit of the DAS will be defined.

For one selected system, a suitable database and methodology to determine its effectiveness will be chosen. Finally, a study of potential effectiveness will be carried out.

Systems of special interest

For further analysis the following systems were selected:

- Pre-Crash Braking using Forward Collision Warning
- Brake Assist
- Deployable Bonnet with Pre-Crash Sensor
- Pre-Crash Sensing with Electronic Belt Pretensioner

Description of selected systems

Because the systems chosen by the experts for further analysis are still in the development phase, there are currently no derivatives to be described and accordingly, no need to define generic systems.

Pre-Crash Braking using Forward Collision Warning

Using data from a Forward Collision Warning, full brake force is applied if an obstacle is detected in front of the vehicle within a 10 meter range and speed is such that a crash is inevitable. A Collision Mitigation System will make an autonomous brake application in case that a collision with another vehicle is unavoidable. The function can also include a panic brake assist program that intervenes if the driver has applied an insufficient level of braking force.

Brake Assist

The brake assist function helps the driver to fully exploit the braking potential of his vehicle. The brake pedal operation is monitored and analyzed in real time in order to detect an emergency braking situation. If the pressure applied by the driver on the pedal is not sufficient for maximum braking force, the system automatically amplifies braking pressure until the pedal is released.

Deployable Bonnet with Pre-Crash Sensor

Microwave pre-crash sensors or other systems can detect pedestrians before the impact and safety devices like the deployable bonnet can be started in advance, thus reducing pedestrian injuries. To improve pedestrian head impact protection, pyrotechnic devices lift the bonnet at the rear edge.

Pre-Crash Sensing with Electronic Belt Pretensioner

If a safety critical situation is anticipated, the belt pretensioners are activated to increase the protection of the vehicle occupants. Electronic belt pretensioners can be reversible, i.e. they can be reset such that they do not need to be replaced after activation.

Relevant accident conditions

The four selected systems are mainly active in the Pre-Crash Phase of the ACEA safety model. Furthermore, all these systems are relevant especially for frontal and/or pedestrian impacts. Nevertheless, there are also some differences among them concerning the context of actuation:

- **Pre-Crash Braking using Forward Collision Warning:** Frontal collisions.
- **Brake Assist:** Mainly effective for frontal collisions. All accidents where the driver did not brake must be excluded. Friction coefficient $\mu > 0,5$.
- **Deployable Bonnet with Pre-Crash Sensor:** Collisions with vulnerable road users (pedestrians and two-wheelers). Impact velocity < 60 km/h (Otherwise, the body will not hit the bonnet but the windscreen.) Frontal collisions.
- **Pre-Crash Sensing with Electronic Belt Pretensioner:** Mainly frontal collisions and roll-over. Seatbelt use is presumed.

Relevant parameters for a database analysis

In order to estimate the potential safety effect of the systems described before, it is necessary to analyse in-depth databases. The more detailed the database, the more precise the estimation. It should be representative to allow for an extrapolation on national statistics. The following parameters should be included:

- Impact type
- Impact velocity
- Type of injury
- Severity of injury
- Collision object
- Driver reaction.

Extremely severe accidents should be excluded from the study as it can be assumed that no system would be of a remarkable benefit in such accidents, and they would therefore introduce biasing in statistical results.

Effectiveness study for one selected system

Taking into account the considerations made above, the method for a study of the potential effectiveness for the brake assist system will be described.

The GIDAS database ('German In-Depth Accident Study') was employed. Although the primary focus of this database is on secondary safety, it contains detailed information about accident causation.

Determination of the Dataset

The first step consisted in determining the relevant dataset for the analysis. For 1991-2003, the GIDAS database contains 1091 accidents with injured pedestrians. These cases are divided according to the AIS classification of injuries (Abbreviated Injury Scale – 1998 Revision): 535 cases with minor injuries (MAIS 1), 498 cases with serious injuries (MAIS 2-4) and 58 cases with very serious injuries (MAIS 5-6). From these accidents, only those where pedestrians were hit by a car with frontal impact were selected (Table 22). In total, the dataset for calculation contained 702 cases.

variables known: MAIS, collision speed > 3 km/h, kind of vehicle, weight of vehicle, impact direction

MAIS	1	2-4	5-6	Total
Accidents with injured pedestrians	535	498	58	1077
+ collision with a car	475	448	35	958
+ frontal impact	336	335	31	702

Computation of injury risk functions

On the basis of the selected dataset, the relationship between collision speed and AIS injury severity were analysed and injury risk functions were computed. Such an analysis shows that the probability for a pedestrian to fall into category MAIS 5+ significantly increases at collision speeds higher than 40-50 km/h (Bamberg & Zellmer, 1994).

Table 2.
Number of relevant accidents in the GIDAS database; years 1991-2003; with the following

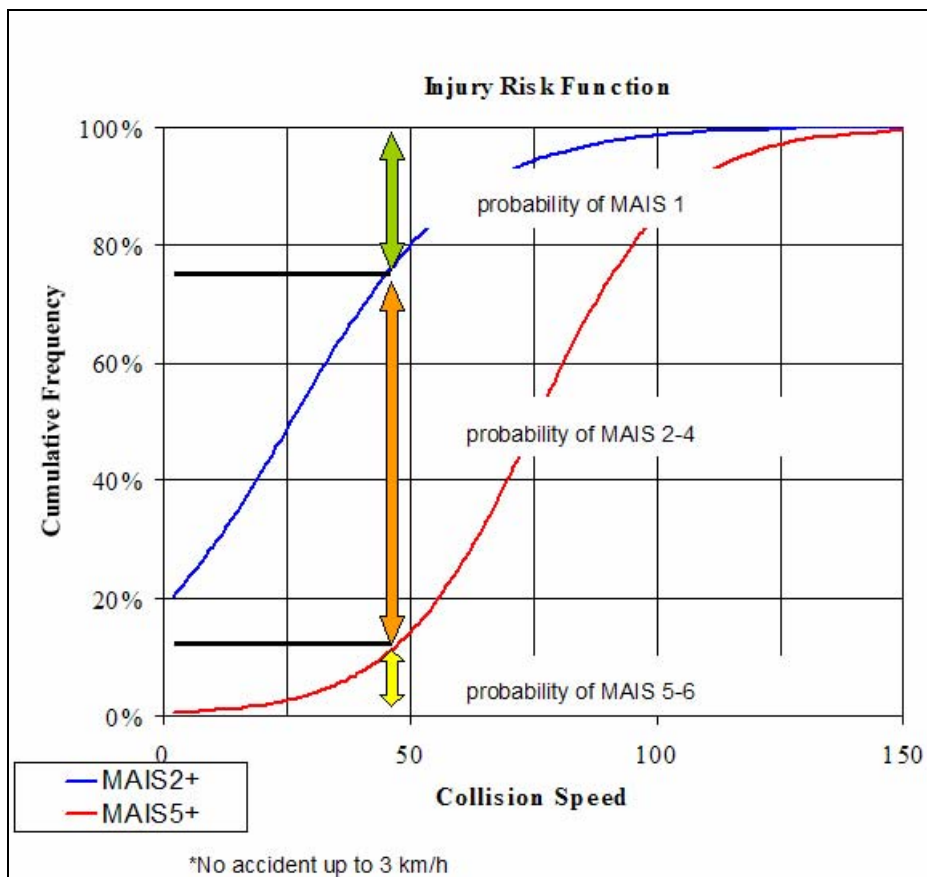


Figure 4. Schematic representation of injury risk functions.

Case-by-case analysis of the safety effects

The computation of the potential safety effect of brake assist is subject to the following assumptions:

1. That a brake assist would have reduced the collision speed in those of the selected accidents where the driver had braked with a deceleration of at least 6 m/s^2 .
2. That in these cases, the available adhesion would have provided for a minimum braking deceleration rate of 8.6 m/s^2 , i.e. the accidents took place on clean, smooth, dry high friction surfaces.
3. The hypothetical collision speed is deduced taking into account the measured braking distance (distance from the beginning of the braking to the point of collision, taken from the GIDAS data that was based upon wheel slip evidence at the scene).

Whilst brake assist helps to optimise the efficiency of braking in case of an emergency braking, it should be noted that there are no measures in the GIDAS database that allow for a direct judgement whether a brake assist would have been activated in the respective case.

The resulting hypothetical shift in collision speed leads to a reduction of the probability to be severely or fatally injured as shown in the injury risk functions. This computation was made for each single accident and the resulting values of reduction averaged. This procedure yields an estimation of the safety benefit of the brake assist expressed as the average reduction of the probability for a pedestrian to be severely or fatally injured in case of a frontal collision with a car.

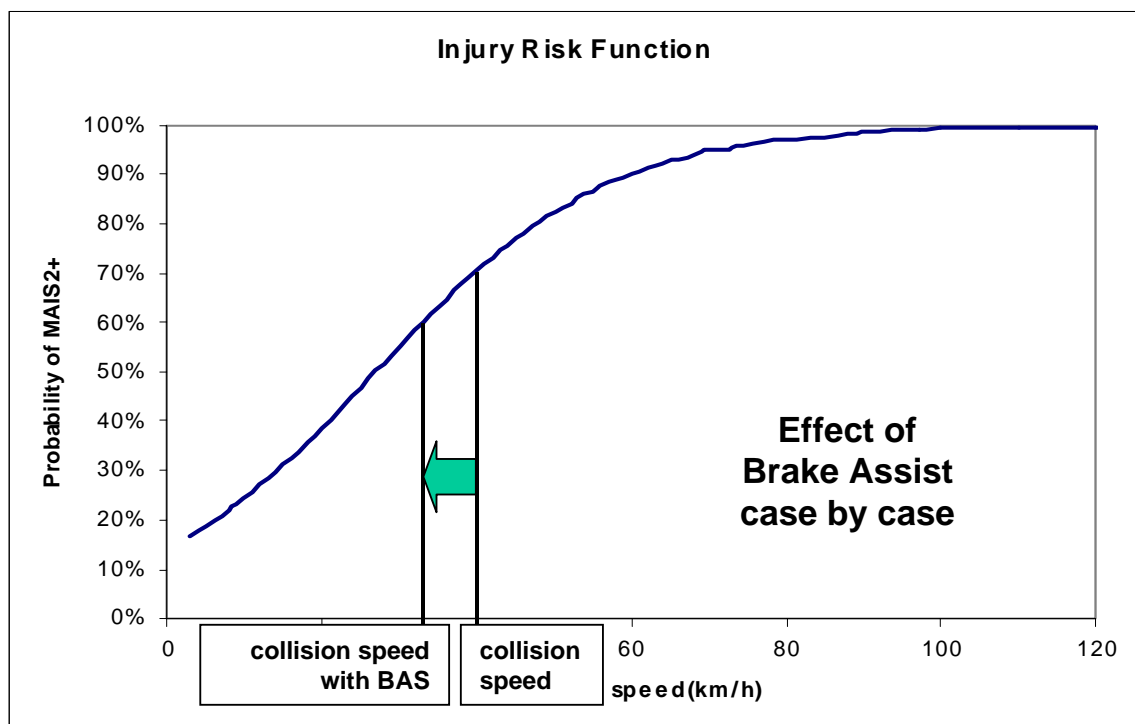


Figure 5. Schematic representation of the effect of the Brake Assist.

Assets and drawbacks of the speed-shift method

The method of a case-by-case analysis of the shift in collision speed to estimate the safety effects of a DAS is very complex and time consuming. Furthermore, specific data are necessary. With regard to the example of the brake assist, collision speed, braking distance, maximum deceleration and injury severity of the pedestrian must be known for each accident. This implies that data from an in-depth accident database are required.

On the other hand, such an analysis as described above has several advantages compared to more generic estimations. Because the safety effect of the brake assist is computed for each relevant accident on the basis of data from accident reconstruction, this allows for a more precise estimation, provided that the accident database is sufficiently representative.

The calculated benefit in this study addresses MAIS 2+ class injuries. The savings are the differences between the predicted numbers of casualties affected by implementation of safety measures and the casualties in the current, real context. The effectiveness of safety measures is referred to all pedestrian accidents.

The results show that BAS has the potential to influence the MAIS class. In the GIDAS dataset, 56 cases (7.9%) out of 702 could completely avoid collision by the implementation of a BAS (BAS collision speed = 0). The injury reducing effect on MAIS 2+ injured pedestrian results in 81 cases (11.5%).

Potential Effects of DAS on Reducing Injuries

In the past, achievements in increasing secondary safety of passenger cars to better protect occupants and vulnerable road users have been remarkable. Whilst further passive safety measures are still possible, it is widely regarded that advanced systems have much to contribute.

Especially with respect to vulnerable road users, physical laws might limit the effect of secondary safety measures. At the same time, the latest developments in electronic and sensor technology promise a successful contribution of primary safety systems. Several of these have already been introduced, and the positive effect in reducing road traffic fatalities have recently been proven – ESP is such an example. The result of this study indicates that also vulnerable road users will have a benefit from such systems.

The previous analysis for a brake assist system (BAS) suggests that primary safety systems could reduce the consequences of pedestrian accidents, as well as offering additional benefit in other accident situations. In this line, it is expected that the importance of primary safety will further increase with technical progress in future.

REGULATION

A number of directives relevant to the work of EEVC WG19 were identified on the basis of the following criteria: *The directive should include injury assessment (protection) and/or parameters operational in the unavoidable crash phase with a potential influence on crash severity.* The parameters were defined as the factors related to vehicle dynamics, to environment and/or to human factors.

A summary on the aspects which can result in non compliance with existing directives or in need of new regulation are listed below:

- Ease the introduction of near field sensors technology (frequency allocation issues were identified by the SARA group).
- Lack of generic guidelines for the evaluation of safety devices triggered before the impact (need of new methodologies for safety evaluation)
- Automatic steering is not defined
- ESP systems were defined as relevant safety systems for WG19 to consider, but are not included in current legislation
- The definition of crash alarm confidence level is not clear while it has a direct impact on safety aspects. This issue has to be tackled by the legislation.

CONCLUSIONS

The boundaries between primary and secondary safety no longer exist. It is observed that further developments for increasing vehicle safety create an overlapping zone. This contributes to a new concept called integrated safety in vehicles.

Despite slight dissimilarities, all actual safety models agree on the existence of an overlapping zone that involves the instants before the impact and extend throughout the collision, in which new safety actions emerge designed to decrease the severity of the collision and offer improved protection to the occupants and other road users.

The interaction between primary and secondary safety in vehicles is the process whereby, using information provided by systems which sense vehicle environment (outside or/and inside), coordinated actions are performed by the vehicle control and protection systems. These actions are performed during the pre-collision and collision phases with the aim of decreasing or eliminating injuries to vehicle occupants, or to vulnerable road users. This concept is restricted to the situation of unavoidable collision.

Vehicles are involved in a large variety of collisions. Considering the state-of-the-art technology and real world accident data, Primary Secondary Safety Interaction Systems (PSSIS) have more immediate relevance to some of them.

Several EU countries delivered accident data cases to establish the EACS database aiming to improve the knowledge of accident causation and potential effects of DAS/ADAS on road traffic safety. The analysis showed that there is insufficient (in quantity and/or quality) data to fully satisfy the requirements of the EEVC WG19. The specific problems are:

- Lack of data related to the above-mentioned overlapped zone.
- Not all existing databases are representative for Europe. Some of them are not even representative for a single country.

Several safety systems and mechanisms included within the scope covered by WG19 have been found. Some systems are already available in current production vehicles and others will be introduced in the near future. Nevertheless, in the field of action of our group, these electronic systems work in a very short period of time (less than a second) before a crash. When restricted to the unavoidable accident phase, the driver would not have time to react or understand what is happening. However, where these systems may also operate in the avoidable accident phase (BAS for example) human machine interface issues (HMI) need to also be considered.

EEVC WG19 explored one approach to evaluating the effectiveness of primary safety systems that operate in the unavoidable accident zone. The effect of Brake Assist Systems (BAS) with regard to fatal and serious pedestrian accidents was calculated as an example case study. This methodology could be applied to provisionally assess safety benefits of some other systems. Others might require a different method and/or database.

Generic methodologies for the assessment of Integrated Vehicle Safety Systems operating in the unavoidable accident phase should be developed in order to find out the acceptable confidence levels for false or missing alarms. The possibility of using virtual testing for the evaluation of systems in different weather and other environmental conditions should be investigated.

FUTURE WORK

The results described here have led to WG19 making recommendations to the EEVC for future research guidelines, treating the following topics:

- Adaptive, occupant protection systems
- Intelligent braking systems
- Pedestrian protection
- Frontal collisions
- Vehicle sensorisation:
 - Sensors to detect features outside of the vehicle.
 - Sensors to acquire dynamic variables of the vehicle.
 - Sensors to determine occupant characteristics.

In this context, there exist several methodological aspects to be developed. Firstly, more experience of the application of the assessment techniques for complex electronic systems, as prescribed in UN ECE Regulations, needs to be gained. In particular it is necessary to establish whether these techniques adequately enable analysis of PSSIS according to dependability criteria. Equally, the construction of techniques and methodologies to evaluate the performance and effectiveness of PSSIS are considered necessary for future regulatory development, as well as for industrial (commercial) deployment of PSSIS.

Different knowledge gaps have been identified which need to be investigated in order to establish a sound knowledge corpus which would eventually permit the development of practical criteria and future methodologies.

The future development of PSSIS as well as their real effectiveness on safety depend largely on their acceptance by the user. On the other hand, if these systems are to be required by regulation it will be necessary to carry out an in-depth cost/benefit analysis.

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