European Enhanced Vehicle-safety Committee

EEVC WG 19

PRIMARY SECONDARY SAFETY INTERACTION

This report represents the first output of the EEVC with respect to the interaction of primary and secondary safety systems. The report includes an initial empirical approach to the assessment of active safety systems, in this case as an example Emergency Brake Assist is used.

The Steering Committee of the EEVC recognises that there may be a need for a further evidence based approach and that performance requirements may need to be developed before EEVC can make recommendations with respect to the assessment of particular systems or technologies. – Wording agreed by the EEVC SC

11/03/2006

FOREWORD

The EEVC Steering Committee, in the meeting held on September 24 & 25th, 2002 agreed the creation of a new Working Group regarding the interaction between primary and secondary safety in vehicles. The Terms of Reference (TOR) proposed were:

1. Overview of existing and future techniques
2. Effect of these techniques on priorities for injury prevention
3. Effect of these techniques on existing regulations

With this decision, extended a period of 12 months from the 1st meeting, the EEVC Steering Committee recognize the increasing importance of systems designed to increase the protection of vehicle occupants and other road users through actions developed from the point in which the collision is considered unavoidable.

In the meeting held on October 30th, 2002 of the EEVC Steering Committee it was decided to appoint Prof. Francisco Aparicio Izquierdo as a chairman of the WG19.

As representatives of the countries participating in the EEVC Steering Committee the following members were proposed:

Spain	Chairman:-	Mr. Francisco Aparicio Izquierdo. (INSIA)
	Representative:	Mr. Felix Moreno
	Technical Advisors:	Mr. Xabier Agustín Ripoll
		Mr. Javier Luzón
	Collaborator	Mr. José Antonio Montañés
France :-	Representative:	Mr. Luc Lesage
	Technical advisors:	Mr. Bruno Piranda
		Mrs. Benedicte Sol
Germany :-	Representative:	Mr. Andre Seeck
	Technical advisor:	Mr. Raimondo Sferco
Italy :-	Representative:	Mr. Ugo Fermi
The Netherlands :-	Representative:	Mr. Kamel Labibes (Technical secretary)
Sweden :-	Representative	Mr. Sören Hedberg
United Kingdom :-	Representative:	Mr. Geoff Harvey
		Mr. Ian Yarnold
		Mr. Iain Knight

Poland :- Representative: Mr. Jerzy Kownacki

During the working period of WG19 several meetings have been held, as described below:

1st meeting	27&28 February 2003	INSIA, Madrid, Spain
2nd meeting	22&23 July 2003	SEAT, Barcelona, Spain
3rd meeting	20 November 2003	INSIA, Madrid, Spain
4th meeting	26&27 January 2004	TNO, Helmond, The Netherlands
5th meeting	22&23 July 2004	INSIA, Madrid, Spain

Abbreviations

ABS	Antilock Braking System
ACEA	Association des Constructeurs Européens d'Automobiles
CEESAR	Centre Européen d'Études de Sécurité et d'Analyses des Risques
EACS	European Accident Causation Survey
ELASIS	Sistema Ricerca FIAT nel Mezzogiorno Analisi Incidenti
ESP	Electronic Stability Program
(A)DAS	(Advanced) Driver Assistance Systems
INRETS	Institut National de Recherche sur les Transports et leur Sécurité
INSIA	Instituto Universitario de Investigación des Automóbil
LAB	Laboratoire d'Accidentologie et de Biomécanique
MAIS	Maximum Abbreviated Injury Scale
BAS	Brake Assist System
ACC	Autonomous Cruise Control

I. SUMMARY

The Steering Committee Meeting of the EEVC held in Berlin on 20th of September, 2001; proposed to set up an ad-hoc group (EEVC-WG19) to structure the field of interaction between primary and secondary safety. As a result of that three Terms Of Reference (TOR) were defined:

- Overview of existing and future techniques.
- Effect of these techniques on priorities for injury prevention.
- Effect of these techniques on existing regulations.

In a first phase, the EEVC WG19 provided a clear description of the field confines related to primary and secondary safety interaction based on the existing safety models developed within different research projects. These safety models illustrate the different safety stages in a traffic accident scenario covering the driving phases from normal driving state to post-collision state. Despite their slight dissimilarity, all models introduce an overlapped zone that involves the instants before the impact and extend throughout the collision. In this zone some new safety actions emerge designed to decrease the severity of the collision and offer improved protection to the occupants and other road users. This is the area in which WG19 has developed its activities.

The EEVC WG19 focus is on Intelligent Vehicle Safety Systems operational in the unavoidable accident phase (PHASE 3 of the ACEA model).

Consistent with that proposal, 5 main objectives were defined:

1. To define and to establish the scope of the Primary and Secondary safety interaction concept.
2. To analyse, based on suitable accident data, the effect of these techniques on priorities for injury prevention.
3. To set up the State-of-the-Art of the techniques involved and their future development.
4. To analyse the effect of these techniques on existing regulations identifying gaps and providing recommendations.
5. To suggest new studies and research activities or new pilot projects; in order to set up the future work-plan of the EEVC-WG19.

The primary and secondary safety interaction concept is the process to take a safety action during the unavoidable collision and collision phases with the aim of decreasing or eliminating the injury of car occupant or pedestrian. The safety action is based on information provided by systems, which sense outside or/and inside vehicle environment.

The WG19 has limited the scope of its activities to those shown in chapter 3. The tables represent the relevance grade, considered by the EEVC, given to the different situations, taking into account the type of vehicle equipped with PSSIS and the other opponent (table 1), type of collision (table 2) and type of safety system (table 3). An index of relevance ranging from 1 (Relevant) to 3 (Excluded) has been included.

For the accident data analysis task, it was stated that the available databases and associated methodologies for the analysis of primary safety performance are not as well developed as those used for secondary safety analysis. The EACS database was chosen for the analysis because of the available information related to the pre-crash phase. Caution should be taken, however, when drawing conclusions from the database because of the constraints concerning the representativeness of the obtained data. Nevertheless, the results of the analysis of the accident data provide some evidence of the effects of systems like ABS and they give some hints on driving situations where the driver or special groups of drivers, needs support. Some highlights from chapter 4 are reported hereafter.

A complete list of all the electronic devices which are, or will in future be, fitted to cars was provided in chapter 5. From this list, EEVC WG19 experts have selected the devices that could be used within the unavoidable accident phase. An indication on how the feature could reduce injuries was provided. Several methods were identified to achieve this goal:

- To decrease of the speed just before the impact. As the speed is the main factor of the energy [$E=f(V^2)$], decreasing the speed before the impact is most important.
- To prepare the vehicle for the impact. In the majority of the cases, the systems pre-arm the actuators. Two kinds of pre-arming were found: reversible or non-reversible one. This can be an important point for the purpose of responsibility of the builder.
- To prepare the occupants for the impact. In all cases, the preparation of the occupants is a consequence of the preparation of the car to the impact.
- To optimise the impact angle of the car before the crash.

The warning systems were mentioned although these systems have no direct link to injury reduction. In this case, the warnings must immediately direct the driver to evaluate and react to threats with sufficient time to perform some action to avoid or mitigate a potential crash. To achieve this, audible, visible, and possibly haptic cues will be employed. For all the measures described, the EEVC WG19 believes that the driver must be able to overrule the electronic systems when the time is sufficiently long before the crash to react

17 systems that are of special interest with regard to frontal and pedestrian impacts were selected to study their potential effects on reducing injuries. Out of these 17 systems, 4 systems were identified for further analysis:

- Pre-Crash Braking using Forward Collision Warning

- Brake Assist
- Deployable Bonnet with Pre-Crash Sensor
- Pre-Crash Sensing with Electronic Belt Pretensioner.

The differences between the selected systems concerning the relevant accident conditions were highlighted. A study to evaluate the potential effectiveness for one of the systems chosen by the experts has been performed. For this analysis of the safety potential, the brake assist has been selected because a lot of systems designed to improve the braking performance of vehicles are among the systems that were judged by the experts to be the most interesting ones.

The influence of Intelligent Vehicle Safety Systems on existing regulations has been tackled in some EC funded projects. Two projects were found specifically relevant to the work of EEVC WG19: The CHAMELEON project and the RESPONSE (1 and 2) project. The main results from these projects were taken into account in this report. Note that the needs for amendments to the Directives were carried out in the frame of the RESPONSE project but not in the Chameleon project. Relevant existing directives for EEVC WG19 were defined in chapter 7. A directive was declared relevant to the EEVC WG 19 group once it fits with the following criteria:

- The directive is related to injury assessment, occupant protection and/or pedestrian protection
- The directive includes physical parameters operational in phase 3 that can affect the crash severity.
- The conclusions from chapter 7 are reported hereafter:

The main issue related to legislation is the definition of crash alarm confidence level which has a direct impact on safety aspects. A summary on the aspects, which can result to the non fulfilment of existing directives or to a need of new directives are listed below:

- Need of new frequencies allocation due to the introduction of remote sensors technology
- Lack of generic guidelines for the evaluation of safety devices triggered before the impact (need of new methodologies for safety evaluation) some examples are given below:
  - The systems can not be tested in all environmental and weather conditions (from chameleon project)
  - Need of a strong basis to define acceptable confidence levels for false and missing alarms?
  - Fault tolerance

- Automatic braking is not defined for M1 vehicles (From Response project)
- Automatic steering is not defined

- ESP systems were defined relevant safety system for WG19 (table 3 of chapter 3) but is not included in legislation..

The recommendations from chapter 7 are reported hereafter
The Commission intends to promote the development, deployment and use of integrated safety systems, called Intelligent Vehicle Safety Systems. The measures to be taken fall into the following three categories:

1) Promoting Intelligent Vehicle Safety Systems
2) Adapting the Regulatory and Standardisation Provisions and
3) Removing the Societal and Business Obstacles.

To do so the EC initiated the e-safety forum. The second point on regulations is partly tackled by EEVC WG 19 (IVSS operating in phase 3 of ACEA model). The EEVC WG19 should create a link with the relevant WG of the e-safety forum to share expertise and avoid overlapping. Furthermore EEVC WG19 should create link to relevant EC Integrated projects and NoE (e.g. Aprosys, prevent etc…) which are actually tackling some of the issues. The EEVC WG 19 group would in a first step collect all relevant information for synthesis purpose and to define further needs.

On the current legislation amendments could be added regarding automatic braking (automatic braking should be probably allowed by regulations in the non avoidable accident phase)

Generic methodologies for the assessment of Intelligent Vehicle Safety Systems operating in the unavoidable accident phase should be to find out the acceptable confidence levels for false and missing alarms (assuming that a 100% confidence is not possible when using information from remote sensors like radar, laser and cameras.

Find out the possibility of using virtual testing for the systems evaluation in different weather and environmental conditions

Some of the new technologies as described in chapter 6 are unfortunately rather expensive. If we will see a penetration of these technologies into the small to medium passenger vehicle segments, incentives for the industry would most certainly be needed to speed up the development and introduction.

Therefore, and because of ongoing research and technical progress in the area of primary/secondary safety interaction, it is appropriate to introduce a certain degree of flexibility in the legislation for type approval of Vehicles.

As been explained in chapter 1, crash protection objectives can be achieved by a combination of primary and secondary safety measures, thus measures in Phase 3 is complimentary to measures in Phase 4. A combination is preferred as it brings about added value such as less crash violence to counterparts and in particular to vulnerable road users. This added value will form an essential part of future improvements of Road Safety.

Depending on technological progress, alternative measures to the requirements laid down in the Directives might be developed, including Primary Safety measures designed to prevent accidents or to reduce the collision severity. Such measures, that may have a substantial protective effect, should preferably be taken into account when the Secondary safety level of a vehicle type is being assessed.

Accordingly, further development of Directives for Secondary safety functions, should incorporate a wider scope of functions active in Phase 3, to reach a certain prescribed safety level.

Therefore, in view of the speed of technological development in this area, the industry should in future be allowed to introduce alternative measures to complement the present requirements in Directives for Frontal and Side Crash Protection, to arrive at, as a minimum, to an equivalent level of effectiveness. For passenger cars in the higher mass classes it will be possible to avoid the dangerous high stiffness of their front ends. This will benefit crash partners to Sport Utility Vehicles and Vans. Passenger cars in all mass classes will benefit from lower fuel consumption and may be equipped with less aggressive air bags.

II. INDEX

1. INTRODUCTION

Nowadays, the current state-of-the-art of the technology for increasing vehicle safety fades the boundary between primary and secondary safety. Primary safety systems like ESP (Electronic Stability Programme) or ABS (Anti-lock Braking Systems) focus on providing assistance to the driver from a normal driving state up to the moment in which the crash is unavoidable. Secondary safety measures include all actions oriented to protect the occupants when an accident occurs (e.g. airbags, headrest, crumple zones, etc…). Secondary safety aims to lessen the consequences for those involved in the accident. secondary safety is effective during the collision.

In the opinion of some experts, primary safety has great opportunities for further improvements; in contrast, it is not expected that such enhancement will be possible in the secondary safety field. Accordingly, a new viewpoint is emerging. It is envisaged that in the near future primary and secondary safety technologies will interact together being more efficient protecting all road users. The expanded use of electronics, micro-controllers, actuators, sensors, high-speed data buses, and X-by-wire technologies in the automotive industry will have a major impact on the architecture of future safety systems in the framework of the Integrated Safety concept.

Today's passenger restraint systems are mainly based on the data provided by crash sensors just at the time of impact; however, the integration of improved and emerging sensors or platform sensors with existing technology will, in the near future, make further advances in vehicle safety possible by, for example, measures such as pre-setting the airbag system an instant before the collision occurrs. Sensors such as radar, lidar (or ladar), real-time video processing systems, ultrasound or infrared could be used for controlling and monitoring the area around the vehicle to provide the information required for such technology. Other benefits may be achieved in the field of occupant monitoring. Such technology could be used to identify the location and position of the occupants (especially those that are out-of-position) within the vehicle and make it possible to develop personal protective measures adapted to all passengers.

The next goal would be to identify an "unavoidable accident phase" in the most accurate way, so that the consequences of the accident would be minimised (Pre-crash System). This could be achieved by activating in advance, solely based on pre-crash information, reversible secondary safety systems present in the vehicle, such as a reversible belt pretensioner. In a more distant future it is envisaged that far-reaching measures may be applied. This may lead to a safety system that overrides the driver's actions, taking over control of the whole vehicle. Finally, as an overview of the existing models of primary and secondary interaction safety proposed, the following models can be highlighted.

1.1. Existing safety models

1.1.1. ACEA safety model

The ACEA model (Figure 1) distinguishes five phases. During the first two phases, only primary safety systems, e.g. Ergonomics, lightning, braking, etc, are involved. In phase 3, where a crash is stated as unavoidable, there is an evolution in which systems belonging to the primary and secondary safety interact and develop in parallel until the beginning of phase 4. During phase 4, only secondary safety actions are executed. Finally, the ACEA model adds phase 5 that includes all actions taken after the collision event.

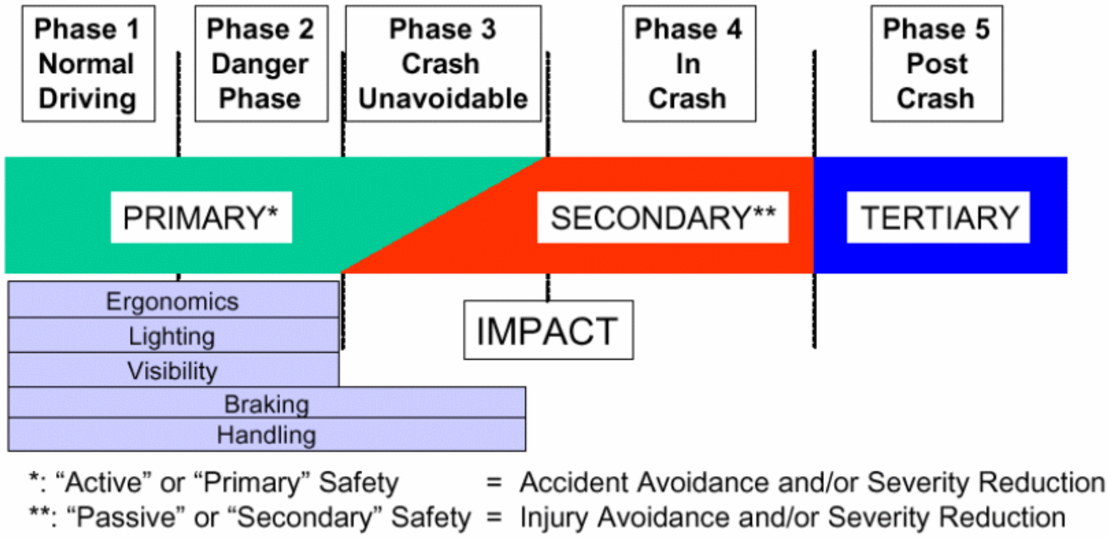


Figure 1.
ACEA safety model

1.1.2. Delphi safety model

The Delphi model [1] identifies a series of interdependent safety states included within two zones. Three safety states are part of the avoidance zone: the normal driving state, the warning state and the collision avoidable state. These states are oriented to reduce the probability of an accident and include all actions carried out before the collision occurs. The mitigation zone comprises three states: Collision avoidable state, collision unavoidable state and post event state. These last safety states focus in lessening the seriousness of the accident and all safety actions taken in these states focus on reducing the effects of a collision. The collision avoidable state belongs to both the avoidance and mitigation zone.

The reason is that many of the systems used in collision avoidance come into play for damage mitigation in cases where the accident cannot be avoided.

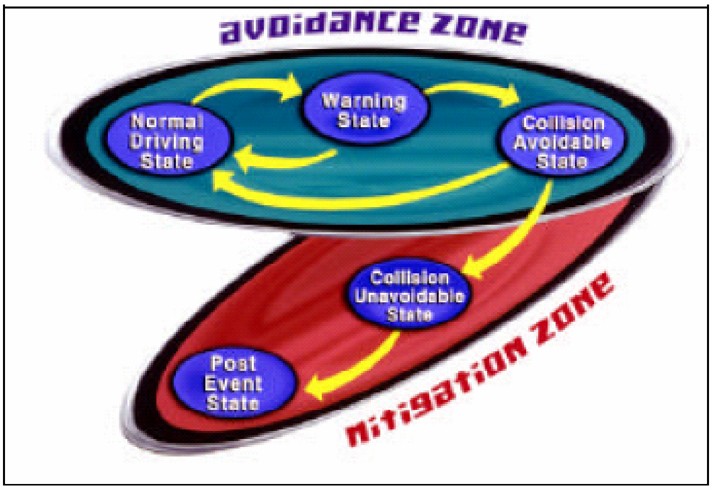


Figure 2.
Delphi safety model

1.1.3. Mercedes-Benz safety model

This safety model (Figure 3) differentiates seven phases coined by the so-called Real Life Safety Concept. These are the warning phase, assistance phase, precrash phase, minor accident phase, less serious accident phase, serious accident phase and postcrash/rescue phase.

During the warning phase, sensors detect a safety deficit or a running state which deviates from the desired state and therefore the driver or the passenger are informed by warning alerts. During the second phase if sensors detect a critical operating condition the driver is assisted by automatic safety systems, e.g. ESP, BAS, etc. If sensors detect a high probability of an accident, phase 3 is activated along with further action designed to avoid accident. In this phase protective measures can be activated. During phase 4, 5 and 6, occupant protection systems are deployed according the severity of the accident. During the postcrash rescue phase protective systems are activated to deal with possible secondary impacts and vehicle-related measures designed to facilitate passenger rescue are initiated.

Unlike other models, this suggests dividing into three different stages the severity of the accident during the postcollision phase; ranging from a minor accident to serious accident.

As depicted, the assistance and precrash phases are included within the collision mitigation and presafe fields. Both fields, in particular presafe, represent where further enhancement of overall vehicle safety may be taken.

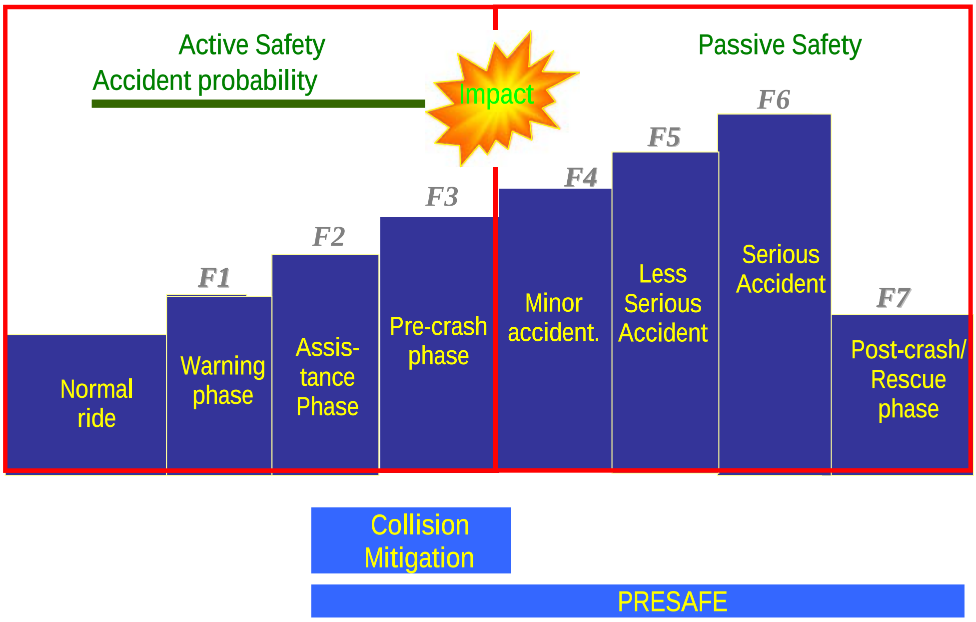


Figure 3.
Mercedes-Benz safety model

1.1.4. <u>Autoliv safety model</u>

The Autoliv safety model (figure 4) agrees with the models represented above. It distinguishes 5 stages grouped by system actuation. Thus, during a normal driving state, only assisting and warning systems work, e.g. lane change aid, ACC, night vision, etc. As a lack of safety is detected and the likelihood of a collision increases other systems are activated. During this state, warning and automatic systems carry out actions, e.g. road departure warning, collision warning, ESP, emergency braking, etc, oriented to avoid or mitigate the collision. Automatic systems focus on the precrash phase as is shown in the representation below. Immediately after the collision, protection systems are deployed, e.g. leg protection, smart belts, etc. providing optimum protection to the occupants and other road users. Finally, in the last state post-crash systems such as fuel cut-off, battery cut-off, emergency calls, etc, are executed.

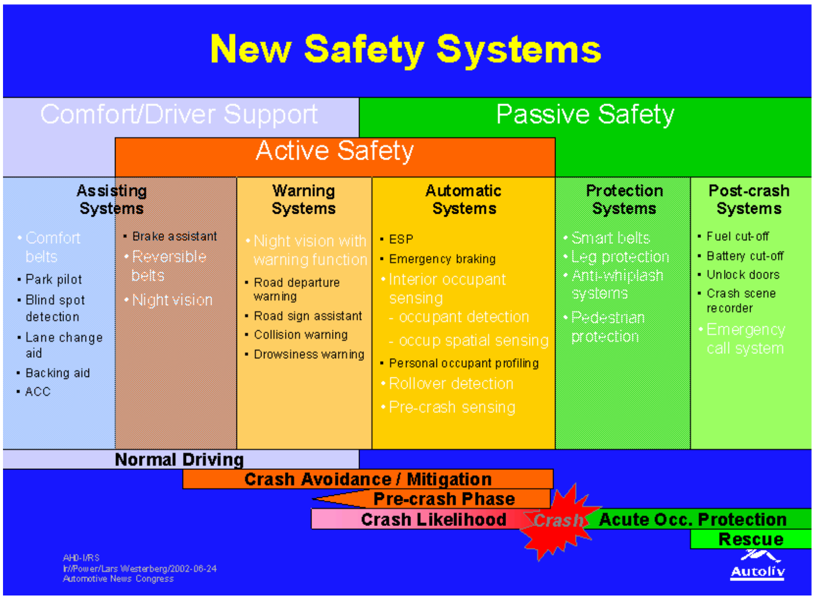


Figure 4.
Autoliv safety model

1.1.5. TNO safety model

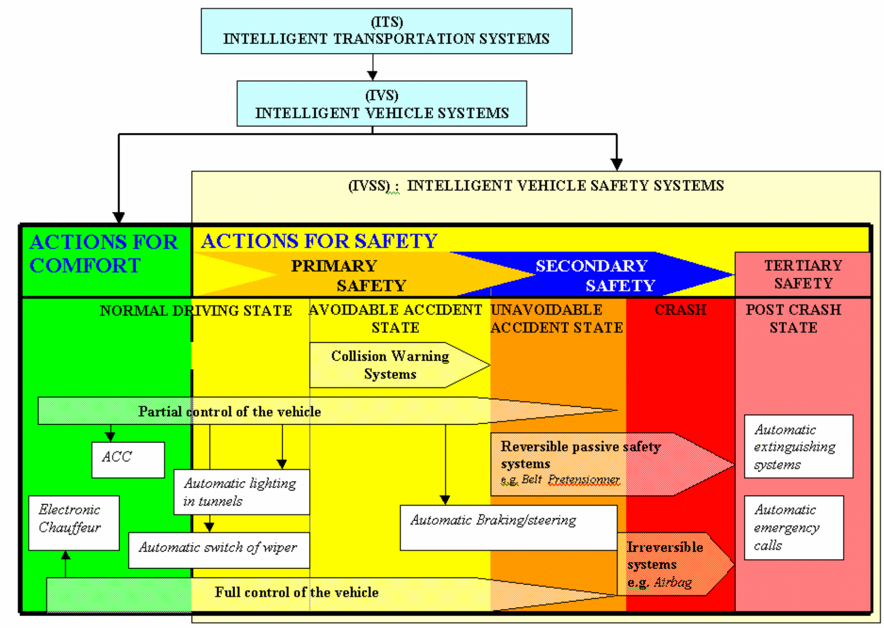


Figure 5.
TNO safety model

For TNO-automotive, pre-crash sensing systems include 5 phases (as in the ACEA model) and are part of the Intelligent Transportation Systems (ITS) structure. ITS include a sub-set called Intelligent Vehicle Systems (IVS) which acts for comfort and/or for safety. Intelligent Vehicle Safety Systems (IVSS) involve all IVS that act for safety purposes. Collision avoidance systems and pre-crash sensing systems are two examples of IVSS. A holistic view is shown in figure 5.

1.2. Active/primary and passive/secondary terms

An observation should be made concerning the terminology used in the project regarding the terms active/primary and passive/secondary. Within the systems involved on the conventional scenario of active and passive safety, it is possible to find systems that, depending on their actions, may be considered “active” or “passive”. Tyres, for instance, remarkably take part in the active safety field although their performance could be considered “passive” since they do not modify their characteristics according to different circumstances. Likewise, other systems, like the conventional suspension or others, present similar characteristics. Alternatively, systems like ABS, active suspension, ESP, etc… may be considered “active” within the framework of active safety.

Concerning passive safety, traditionally the protective systems have performed in a non-changing manner or “passively” while most recent innovations in the passive field and those covered by the activities of the WG19 behave “actively” so as to provide protective conditions more adapted to the collision and occupants or other road users.

Apart from these safety systems and features; the safety actions extend beyond a mere collision to improve the rescue and treatment to the people affected; however, these measures are not included within the scope of active or passive safety.

Consequently, it seems to be more appropriate, for the activities of the WG19, to use the “primary” and “secondary” safety terms in place of “active” and “passive” safety respectively. This would allow a more accurate classification of their contents and would make it easier to incorporate the tertiary safety as it has been done in other works.
Primary safety can be defined as systems that act to avoid or reduce the severity of an accident. Secondary safety can be defined as any thing that acts to avoid or reduce the severity of injury sustained during any accident. Tertiary safety can be defined as any system that acts to improve safety after the collision has occurred.

1.3. Conclusions

It is observed that further developments for increasing vehicle safety fall within the boundary between the primary and secondary safety, this will mean that in future both fields will no longer be clearly separated from one another. Evidence of this trend is given by the former models.

The safety models presented in 1.1 shown different safety stages covering all driving phases from the normal driving state to the postcollision state. Despite their slight dissimilarity, all 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 interval considered shows a high and promising potential for increasing road safety, thus for that reason this will be the area in which the WG19 will develop its activities.

2. OBJECTIVES AND CONTENTS

The Steering Committee Meeting of the EEVC held in Berlin on 20th of September, 2001; proposed to set up an ad-hoc group (EEVC-WG19) to structure the field of interaction between primary and secondary safety. As a result of that three Terms Of Reference (TOR) were defined:

- Overview of existing and future techniques.
- Effect of these techniques on priorities for injury prevention.
- Effect of these techniques on existing regulations.

According to that proposal, the members of the EEVC-WG19 decided to develop the necessary work-plan with the following next objectives:

1. To define and to establish the scope of the Primary and Secondary safety interaction concept.
2. To set up the State-of-the-Art of the techniques involved and their future development.
3. To analyse, based on suitable accident data, the effect of these techniques on priorities for injury prevention.
4. To analyse the effect of these techniques on existing regulations identifying gaps and providing recommendations.
5. To suggest new studies and research activities or new pilot projects; in order to set up the future work-plan of the EEVC-WG19.

The members of the EEVC-WG19 also agreed with the content of the final report to be achieved. This final report shall be submitted to the Steering Committee of the EEVC for its approval; and its content shall be as follows:

PRIMARY & SECONDARY INTERACTION WG19 Report

1. Introduction
2. Objectives and content
3. Primary & secondary safety interaction. Definition and Scope
4. Accident data analysis
5. Involved systems. Type of actual development (state-of-the-art)
    - Technological progress
    - Commercial applications
    - Studies, researches and demonstration projects accomplished
    - Design & Validation tools
    - User acceptance
    - Foresee future development
    - Legal implication
6. Effectiveness study of these systems to reduce injure severity
7. Recommendation to adapt regulations or develop new ones
8. Recommendations for studies, research and pilot project

9. Conclusions
10. Proposal for future work: WG19 matters
11. Bibliography
Annex 1. Definitions

Chairman of the EEVC-WG19: Prof. Francisco Aparicio (INSIA-UPM, SPAIN)
Members of the EEVC-WG19:

- Representatives:
  - Mr. Luc Lesage (France)
  - Mr. A. Seeck (Germany)
  - Mr. Ugo Fermi (Italy)
  - Mr. Kamel Labibes (The Netherlands), Secretary of EEVC-WG19
  - Mr. Felix Moreno (Spain)
  - Mr. Sören Hedberg (Sweden)
  - Mr. Ian Yarnold & Mr. Iain Knight (UK)
- Technical Advisor:
  - Mr. Bruno Piranda (France)
  - Mr. R. Sferco (Germany)
  - Mr. Xavier Agustin (Spain)
- Collaborator :
  - Mr. José Antonio Montañés (Spain)

Kick-off: February 28, 2003. Timeframe: 12 months.

3. 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 situations where a collision has become unavoidable.

Primary & secondary safety interaction includes:

- 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.

- 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…

- 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.

3.1. Scope

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. The tables shown below represent the relevance grade, considered by the EEVC WG19, given to the different situations, taking into account the type of vehicle equipped with PSSIS and the other opponent (table 1), type of collision (table 2) and type of safety system (table 3).

Consequently, the cases marked with 1 are included within the scope of the WG19, those cases marked with 3 are fully excluded and those marked with 2 may be considered in future research.

3.1.1. Collision between a vehicle equiped with pssis [1] and other opponents

	VEHICLE EQUIPED WITH PSSIS	OPPONENTS							
		M 1	M 2	M 3	L	VULNERABLE ROAD USERS	ANIMALS	INFRASTRUCTURE	OTHER STATIONARY OBJECTS
VEHICLE CATEGORY *	M1	1	1	1	1	1	1	1	1
	M2 & M3	1	1	1	1	2	3	1	1
	N1	1	1	1	1	1	1	1	1
	N2	3	3	3	3	2	3	3	3
	N3	3	3	3	3	2	3	3	3
	L	3	3	3	3	2	3	3	3

Table 1. Relevance of type of vehicle and their potential obstacles for EEVC WG19[2]

M1 weight vehicles is limited to 3.5 tonnes

* Vehicle category classification according to the Commission Directive 2001/116/EC,

3.1.2. COLLISION TYPE / RELEVANCE FOR PSSIS

COLLISION TYPE**	RELEVANCE FOR PSSIS CONSIDERED BY THE WG19
FRONTAL	1
FRONTAL/SIDE	1
REAR	2
ROLLOVER	2

Table 2 Relevance of type of collision.

** Collision type according to the ISO 6813:1998,

Regarding the collision classification, it is questioned whether it will be necessary to identify the type of collisions to be covered by the activities of the WG19 in more depth.

3.1.3. SAFETY SYSTEMS / RELEVANCE FOR PSSIS

SAFETY SYSTEMS	RELEVANCE FOR PSSIS CONSIDERED BY THE WG19
Adaptive seat belts	1
Airbag	1
Seat	1
Headrest system	1
Sunroof & Windows	1
Brake	1
Steering	1
Ride-Height adjustment	2
Extendable bumpers	2
External airbag	2
Deploy bonnet	1
ESP	1

Table 3. Examples of relevant safety systems

Systems, features and regulations related with the systems in the table 3, are included in the annex provided by Ford.

4. ACCIDENT DATA ANALYSIS

4.1. Introduction

In general, the available databases and associated methodologies for analysing real world primary safety performance are not as well developed as those used for secondary safety analysis.

There are, however, a number of opportunities available. These include:

- The ACEA/EC funded European Accident Causation Survey ('EACS') – the only European study dedicated to accident causation issues.

- More general studies such as GIDAS (Germany) and OTS (UK) which include significant elements on accident causation, particularly the immediate pre-crash phase.

- Specific studies carried out by other organisations (such as Dekra) or vehicle manufacturers.

- National statistics which can provide a more general overview of accident scenarios and essential exposure data.

Although these databases are not freely accessible, between them, the members of EEVC WG19 have access to all of the significant data sources.

The type of analysis which can be carried out is very dependent on the level, content and size of the database. For example, the type of analysis used on in-depth databases such as EACS or GIDAS is not appropriate for analysing national statistics.

In general, there are two approaches to analyse in-depth accident databases:

1. Predictive approaches (sometimes called 'A Priori' analyses) in which attempts are made to identify the likely benefit which would result from implementing a particular feature/system/improvement. As an example, this approach was used by Ford/LAB to estimate the likely benefit from the wide scale introduction of ESP.

2. Direct comparisons (sometimes called 'A Posteriori' analyses) between vehicles with and without a particular feature/system/improvement. This approach has been used by DaimlerChrysler to prove the actual real world effect of introducing ESP.

Experience has shown that it is frequently necessary to explore primary safety issues using 'indirect' methods and drawing conclusions by 'inference' rather than the more direct routes used for secondary safety analysis. These methods are useful for both in-depth studies and the less-detailed but larger databases such as national statistics.

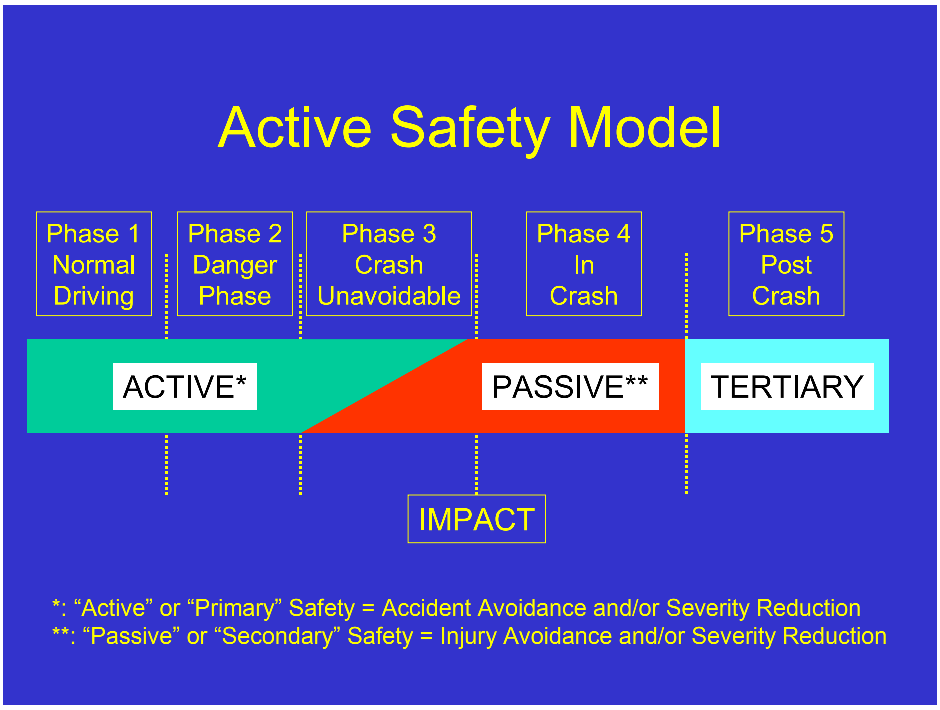


Figure 6: The ACEA Safety Model.

In the ACEA safety model (Figure 6), five phases were identified. In the first two phases ('Normal Driving' and 'Danger Phase'), only primary safety systems are involved. During the third phase ('Crash Unavoidable'), there is a transition between primary safety and secondary safety systems but some of the sensing and triggering of secondary safety systems being considered by WG19 actually take place during Phase 2. However, most of the available data for the pre-crash phases only considers Phase 3. Therefore, data analysis is restricted mainly to Phase 3.

Depending on the question being asked / issue being explored, etc., different variables will need to be considered. The following list makes some suggestions for key variables which might be included. In the following data analysis, as much of these key variables as possible are considered.

1. Vehicle type - Although the main focus is on 'passenger cars', 'light trucks' and 'vans', the analyses should also consider 'heavy trucks' and 'motorcycles'

(where the opportunities for secondary safety improvements are limited and primary safety is therefore more important).

2. Accident severity – Depending on the issue, it might be appropriate to select or group cases according to either crash severity or injury outcome.

3. Road user characteristics – For example, male and female drivers might have different driving styles. Therefore, the gender of the driver should be considered. Other factors such as age, driving experience, impairment through drugs or alcohol etc. may also be important.

4. Collision type - Frontal, driver's side, passenger side, rear end, rollover, multiple.

5. Accident type - Appropriate categories of accident types should be used. The basis could be the German Federal Statistical Office's Pictograms. Special attention should be paid to loss-of-control accidents.

6. Accident causation - Appropriate categories of accident causes should be used.

7. Collision object - Passenger car, small van, truck, bicycle, motorcycle, pedestrian, stationary object etc.

8. Environment aspects – Consideration of issues such as light condition (night, day), weather conditions (sunshine, rain, fog, snow etc.) and road surface (dry, wet) may be appropriate.

9. Accident location – Type of road, posted speed limits, etc.

10. Vehicle aspects – vehicle age, power, equipment levels, loading, condition, etc.

In the following, first the structure and the special characteristics of the EACS database will be described. Second, direct comparisons between accident data of vehicles equipped with and not equipped with several Driver Assistance Systems (DAS) will be made. Finally, the accident data of the EACS database will be analysed in order to estimate the potential benefits resulting from the implementation of special (A)DAS.

4.2. The European Accident Causation Survey (EACS)

4.2.1. Overview

EACS is a European Research Project aimed at improving knowledge about accident causation. For this, a comprehensive questionnaire was developed allowing a much more detailed description of accident causation and evolution than other accident databases. Furthermore, the software 'DAMAGE' ('A Database to analyse Accident Mechanism and Accident Genesis in Europe') was developed as a means to manage the database and to perform database queries (EACS Vol.2).

In 1996, the EACS project was initiated by ACEA and the European Commission. The project co-ordination was done by CEESAR (France). Further members of the consortium were: LAB (Renault, Peugeot-Citroën, France), DEKRA (Germany), ELASIS (FIAT, Italy), INRETS (France), INSIA (Spain), Medical University Hannover (Germany), University Turku (Finland), TNO (The Netherlands) and the University of Oulu (Finland).

From 1996 to the end of the project in 2001, a total of 1904 accidents were documented and described on the basis of the EACS questionnaire. Sixty seven percent (67%) of these accident reports were provided by the German consortium members, mainly by DEKRA (1170 cases; EACS Vol.6).

4.2.2. Structure of the EACS Database

For the description of the accidents, the EACS database contains coded data as well as short text passages, photos, sketches and reconstruction data (EACS Vol.1). It consists of a total of 822 variables. Some of these variables can be measured objectively; others represent subjective statements of persons involved in the accident or the conclusions and estimations of experts.

The structure of the EACS database as determined by the 'DAMAGE'-software corresponds to that of the questionnaire (Figure 7). Each accident is documented in an 'Accident General Form' containing the general information on the accident and providing connections to the other forms that describe the accident in more detail. For each motor vehicle involved in the accident, there is a 'Vehicle Form', for each concerned occupant an 'Occupant Form', and for each pedestrian involved in the accident, there is a 'Pedestrian Form'. Furthermore, there is a 'Reconstruction Form', and a 'Road Infrastructure Form' as well as photos and sketches (EACS Vol.1).

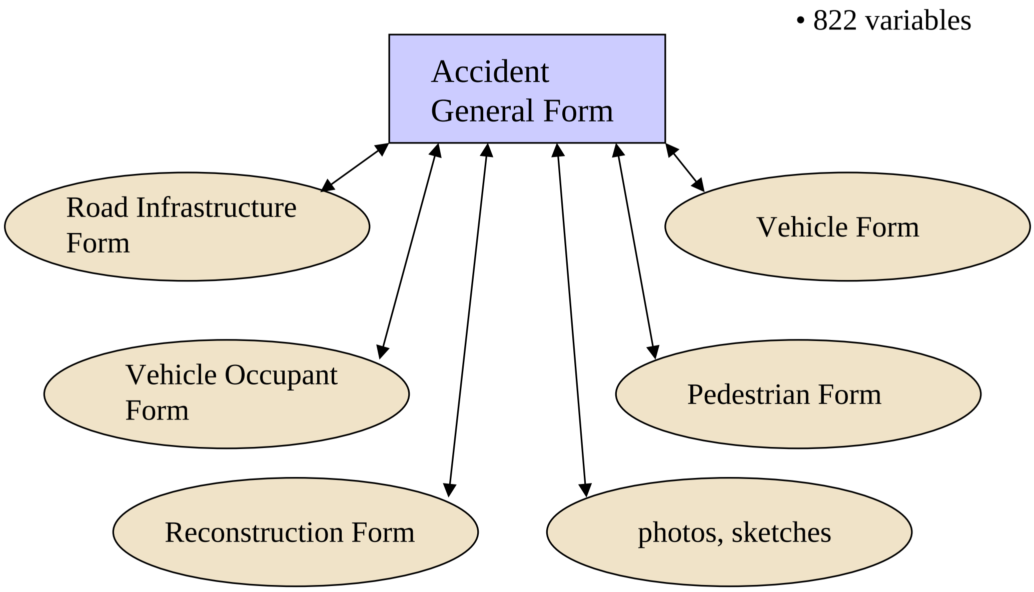


Figure 7: Structure of the EACS database.

The EACS database contains only those accidents with at least one person injured and at least one motor vehicle less than 3.5 tons involved (EACS Vol.3).

4.2.3. Characteristics of the EACS Data

As a first examination of the EACS database and an analysis of 5 of the 6 project reports revealed, there are some characteristics of the EACS data that have to be taken into account when analysing them[1]. These special features of the EACS database will be described in the following.

4.2.3.1. Representativeness of the Data

Thirty four percent of the accidents documented in the EACS database were fatal for at least one person. In contrast to that, the proportion of fatal accidents in the national statistics is 3-4% of the accidents with injured persons (EACS Vol.3) or even less (DESTATIS, 2002; Schepers et al., 2002). Consequently, fatal accidents and severe accidents are over-represented in the EACS database. This may be due to the fact that it was intended from the beginning to document only those accidents where at least one person had been injured. Furthermore, the accident documentation teams used to be notified of the accident by the police. Perhaps, the police notified them more often in cases where a severe accident had happened.

1 The fourth project report was not available.

It should also be considered that the relative frequency of accidents contributed by the 6 European countries involved in the project does not correspond to the actual frequency of accidents in these countries (EACS Vol.5). This can easily be demonstrated by the fact that 67% of the documented accidents come from Germany causing a significant overrepresentation of German accidents (see section 2.1). Therefore, concerning some questions, in addition to an analysis of the complete EACS data also an analysis of the German accidents reported by DEKRA will be performed.

4.2.3.2. Missing Data

The EACS data are far from being complete. The project was divided into three project phases and most of the data were collected in Phases 1 and 2. For this part of the documented accidents, 80% of the data are available (EACS Vol.5 and 6). The incompleteness of information is especially high for personal data ('Driver, Occupant, Pedestrian Form'). This may be partly due to the fact that some information was not available because the person to be asked for the information had been killed or severely injured in the accident (for the extremely high proportion of fatal accidents in the EACS database see section 4.2.3.1). Interpreting the results of an analysis of these data, it must be considered that they might be biased by the high number of missing values.

4.2.3.3. Comparability of Data from different Organisations

The accident data contained within the EACS database were collected by 9 teams coming from 6 European countries (see section 4.2.1). In order to ensure a comparability of the data, the quality of the documentation was assessed by the institutes themselves and supervised by the project co-ordinator CEESAR. Nevertheless, the quality reports of the 9 participating organisations reveal that the teams differ with regard to their composition and the way data were collected and documented. This is a further argument to analyse the data first at a national level or even separately for the single institutions (see also section 4.2.3.1).

4.3. Analysis of the EACS-Data with Regard to (potential) Effects of Driver Assistance Systems

In a first step, the effects of several DAS on driving safety will be analysed by a direct comparison of the vehicles equipped with and those not equipped with the respective DAS. As it will be demonstrated, such a direct approach is not applicable for the majority of ADAS, because the proportion of vehicles equipped with them is too small to allow statistical comparisons. Therefore, in a second step, following a predictive approach, the accident data of the EACS database will be analysed with respect to the potential benefits of different ADAS.

4.3.1. Analysis of the Effects of Driver Assistance Systems on Accident Severity and Accident Development

In the vast majority of the accidents reported in the EACS database, one or two motor-vehicles are involved. As shown in Table 4, in only a minority of cases, more than two vehicles are involved. The whole EACS database contains 2946 vehicle forms representing a total of 2946 vehicles involved in the 1904 reported accidents.

Accidents with 1 vehicle involved	974
Accidents with 2 vehicles involved	830
Accidents with 3 vehicles involved	84
Accidents with 4 vehicles involved	10
Accidents with 5 vehicles involved	4
Accidents with more than 5 vehicles involved	0
Total number of motor vehicles involved in the accidents	2946

Table 4. Number of motor vehicles involved in the accidents reported in the EACS database.

Table 5 shows how many vehicles involved in the accidents reported in the EACS database were equipped with the DAS 'Control of stability', 'Cruise Control', a navigation system or an 'Antilock Braking System' (ABS). Since only a very small percentage of the motor vehicles were equipped with a stability control, it is not sensible to make a comparison between vehicles equipped with this DAS and those not equipped with it (see also Sferco et al., 2001). The same is true for ADAS like 'Adaptive Cruise Control' for example. The percentage of vehicles in the database equipped with these highly developed DAS is extremely small and exact quantitative data are not available. For the further analysis, we will focus on the two systems 'Cruise Control' and 'Navigation System', and additionally ABS, because these systems were installed in more than 100 vehicles in the database allowing a comparison of the vehicles equipped with them and those not equipped with them. Especially the effects of ABS (installed in 22% of the vehicles in the EACS database) on accident development and accident severity will be analysed in detail.

DAS		yes	% yes	no	unknown	total
Control of stability	total	24	0,8	2850	69	2943
	DEKRA	9	0,5	1730	32	1771
Cruise Control	total	138	4,7	2674	130	2942
	DEKRA	117	6,6	1580	74	1771
Navigation System	total	148	5,0	2653	141	2942
	DEKRA	117	6,6	1567	86	1770
ABS	total	655	22	2153	132	2940
	DEKRA	464	26	1221	85	1770

Tale 5 Number and percentage of vehicles equipped with several DAS, separately for all cases of the EACS database and for the German accidents described by DEKRA. The differing total scores are due to missing values.

4.3.1.1. Effects of Cruise Control on Accident Severity

In Table 6, it is shown how many motor vehicles equipped and not equipped with Cruise Control were involved in fatal and non-fatal accidents. To test the hypothesis that severity of injury is influenced by the equipment of a vehicle with Cruise Control, a Chi^2-Test was performed with the α-level set at 5% which yielded a non-significant result ($Chi^2_{(df=1)}$=0.018; n.s.). Thus, there is no evidence in the data for a systematic interrelationship between the fatality of accidents and the equipment of a vehicle with Cruise Control.

number of vehicles	with Cruise Control	without Cruise Control	total
fatal accidents	44 (5%)	895 (95%)	939 (100%)
non-fatal accidents	90 (5%)	1774 (95%)	1864 (100%)
total	134 (5%)	2669 (95%)	2803 (100%)

Table 6: Number of motor vehicles equipped and not equipped with Cruise Control involved in fatal accidents and non-fatal accidents.

4.3.1.2. Effects of Navigation Systems on Accident Severity

In Table 6, it is shown how many motor vehicles equipped and not equipped with a navigation system were involved in fatal and non-fatal accidents. The hypothesis that severity of injury is influenced by the equipment of a vehicle with a navigation system, was tested by means of a Chi^2-Test which yielded a non-significant result ($Chi^2_{(df=1)}$=1,648, n.s.). Therefore, there is no evidence in the data for a systematic interrelationship between the fatality of accidents and the equipment of a vehicle with a navigation system.

number of vehicles	with navigation system	without navigation system	total
fatal accidents	58 (6%)	872 (94%)	930 (100%)
non-fatal accidents	86 (5%)	1771 (95%)	1857 (100%)
total	144 (5%)	2643 (95%)	2787 (100%)

Table 6: Number of motor vehicles equipped and not equipped with a navigation system involved in fatal accidents and non-fatal accidents.

4.3.1.3. Effects of ABS on Accident Severity

number of vehicles	with ABS	without ABS	total
fatal accidents	255 (27%)	698 (73%)	953 (100%)
non-fatal accidents	398 (22%)	1448 (78%)	1846 (100%)
total	653 (23%)	2146 (77%)	2799 (100%)

Table 7: Number of motor vehicles equipped and not equipped with ABS involved in fatal accidents and non-fatal accidents.

In Table 7 and Figure 8, it is shown how many motor vehicles equipped and not equipped with ABS were involved in fatal and non-fatal accidents. To test the hypothesis that severity of injury is influenced by the equipment of a vehicle with ABS, a Chi^2-Test was performed which yielded a highly significant result ($Chi^2_{(df=1)}$=8.96, sign.). Among all vehicles involved in the accidents documented in the EACS database, the relative probability to be involved in an fatal accident is higher for vehicles equipped with ABS than for vehicles with normal brakes. This rather unexpected result is not confirmed if only the data contributed by DEKRA are examined ($Chi^2_{(df=1)}$=0,25, n.s.) (Table 8, Figure 9; see also section 2.3.3). The analysis of the DEKRA data does not reveal any effect of ABS on severity of injury.

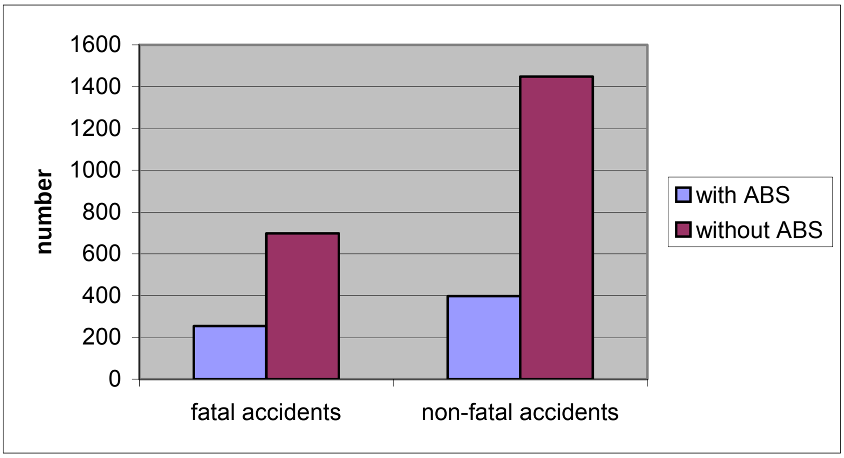


Figure 8: Number of motor vehicles equipped and not equipped with ABS involved in fatal accidents and non-fatal accidents.

number of vehicles	with ABS	without ABS	total
fatal accidents	224 (28%)	580 (72%)	804 (100%)
non-fatal accidents	236 (27%)	639 (73%)	875 (100%)
total	460 (27%)	1219 (73%)	1679 (100%)

Table 8: Number of motor vehicles equipped and not equipped with ABS involved in fatal accidents and non-fatal accidents. Only the German accidents documented by DEKRA were analysed.

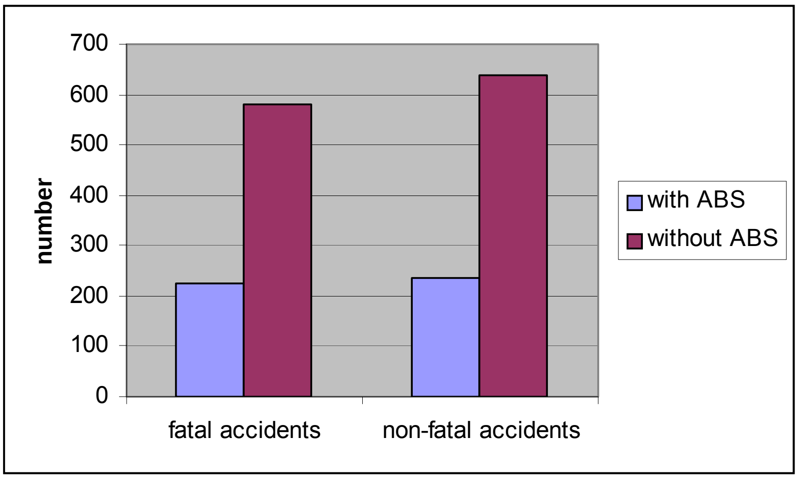


Figure 9: Number of motor vehicles equipped and not equipped with ABS involved in fatal accidents and non-fatal accidents. Only the German accidents documented by DEKRA were analysed.

For a more detailed analysis of the effects of ABS on accident severity, the MAIS values (Maximum Abbreviated Injury Scale) for the occupants of vehicles equipped and not equipped with ABS are shown in Table 9 and Figure 10. The proportion of severely injured occupants (MAIS 3+) is slightly higher for vehicles equipped with ABS (17%) than for vehicles without ABS (12%).

MAIS	with ABS		without ABS	
	number	%	number	%
0	333	28	1090	30
1	226	19	660	18
2	109	9	380	11
3	91	8	249	7
4	11	1	48	1
5	29	3	58	2
6	60	5	81	2
unknown	60	5	81	2
total	1174	100	3630	100

Table 9: Severity of the injuries of the occupants of vehicles equipped and not equipped with ABS. MAIS: Maximum Abbreviated Injury Scale (0: uninjured, 1: minor, 2: moderate, 3: serious, 4: severe, 5: critical, 6: maximum).

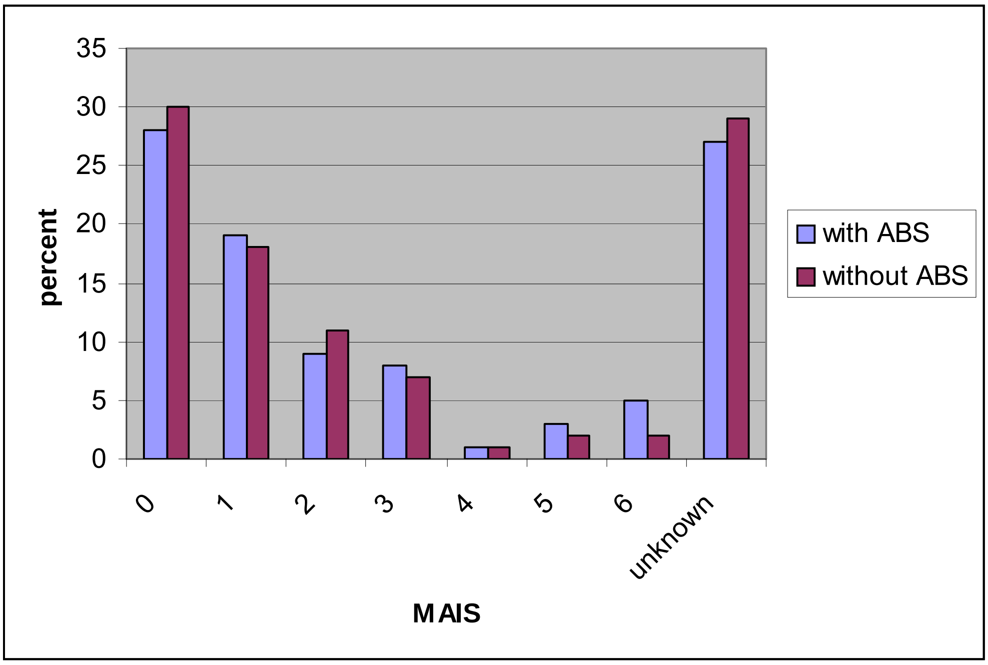


Figure 10: Severity of the injuries of the occupants of vehicles equipped and not equipped with ABS. MAIS: Maximum Abbreviated Injury Scale (0: uninjured, 1: minor, 2: moderate, 3: serious, 4: severe, 5: critical, 6: maximum).

The MAIS values for pedestrians involved in accidents with vehicles equipped and not equipped with ABS are shown in Table 10 and Figure 11. The proportion of severely injured pedestrians (MAIS 3+) is slightly higher for accidents with vehicles equipped with ABS (57%) than for those with vehicles without ABS (51%).

MAIS	with ABS		without ABS	
	number	%	number	%
0	0	0	0	0
1	3	4	9	4
2	4	5	17	7
3	14	19	34	14
4	5	7	21	9
5	8	11	36	14
6	15	20	36	14
unknown	26	34	95	38
total	75	100	248	100

Table 10: Severity of the injuries of pedestrians involved in accidents with vehicles equipped and not equipped with ABS. MAIS: Maximum Abbreviated Injury Scale (0: uninjured, 1: minor, 2: moderate, 3: serious, 4: severe, 5: critical, 6: maximum).

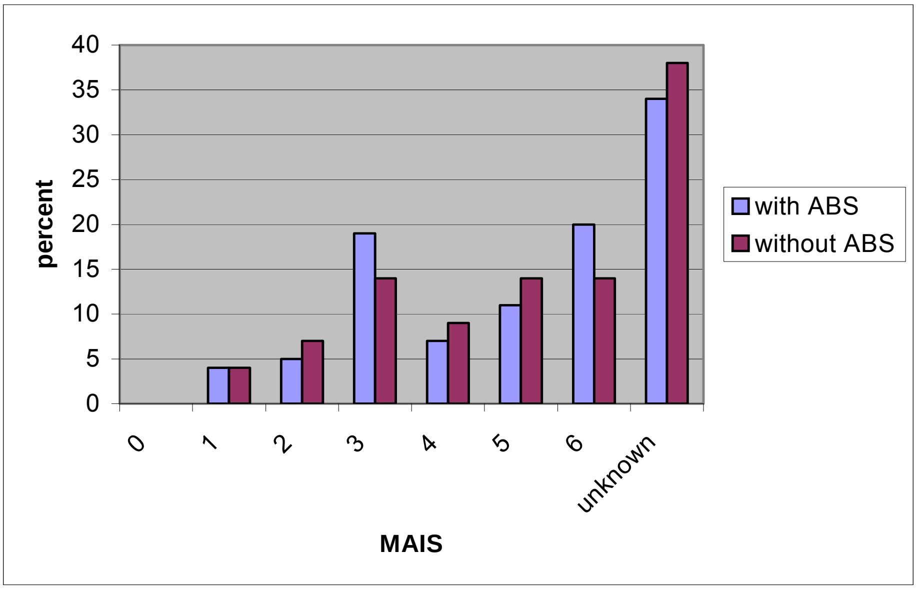


Figure 11: Severity of the injuries of pedestrians involved in accidents with vehicles equipped and not equipped with ABS. MAIS: Maximum Abbreviated Injury Scale (0: uninjured, 1: minor, 2: moderate, 3: serious, 4: severe, 5: critical, 6: maximum).

As a technical criterion for accident severity, Delta V (velocity difference for the first impact) was chosen. This measure is available for 740 of the 2141 vehicles without ABS (35%) and for 232 of the 644 vehicles equipped with ABS (36%). On average, Delta V is about 1 km/h higher for the vehicles with normal brakes (mean Delta V = 27,9 km/h, sd = 23,5 km/h) than for those equipped with ABS (mean Delta V = 26,7 km/h, sd = 22,6 km/h). Taking into account the high variability of this measure, there is no evidence for any difference of accident severity between vehicles equipped and not equipped with ABS. The same is true if only the data provided by DEKRA were analysed (mean Delta V for vehicles with normal brakes = 29,2 km/h, sd = 26,2 km/h; mean Delta V for vehicles with ABS = 29,2 km/h, sd = 24 km/h).

In order to investigate whether the results concerning accident severity were influenced by the type of the vehicles equipped and not equipped with ABS, the mean motor capacity of both vehicle categories was computed for the complete EACS data as well as only for the DEKRA data. The results for the complete EACS data showed that the mean motor capacity of the vehicles equipped with ABS was higher (110,56 kW; sd = 67,3 kW) than that of vehicles with normal brakes (60,73 kW, sd = 40 kW). The same was true if only the data provided by DEKRA were analysed (mean motor capacity of the vehicles with ABS = 112,7 kW, sd = 65 kW; mean motor capacity of the vehicles with normal brakes = 64,4 kW, sd = 44,6 kW). Taking into account the high variability of this measure, there is no evidence for a difference between the DEKRA data and the complete EACS data.

4.3.1.4. Effects of ABS on Type of Impact

Type of Impact	with ABS		without ABS	
	number	%	number	%
frontal	408	64	1317	61,7
side	160	25	587	27,5
rear	43	6,8	139	6,5
roll-over	10	1,6	44	2
tip-over	0	0	6	0,3
multiple	4	0,6	21	1
unknown	13	2	23	1
total	638	100	2137	100

Table 11: Type of impact for vehicles equipped and not equipped with ABS.

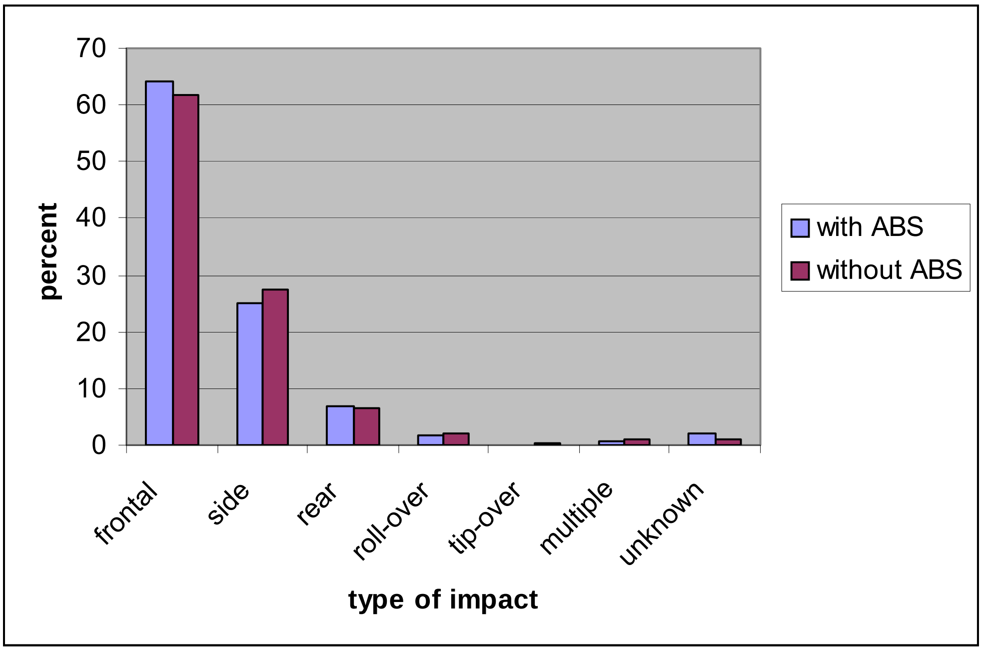


Figure 12: Type of impact for vehicles equipped and not equipped with ABS.

For vehicles equipped with ABS as well as for vehicles with normal brakes, the vast majority of first impacts are frontal collisions. In about a quarter of the cases, the first impact is a side collision. Furthermore, there are some cases of rear collisions in the EACS data. Roll-over, tip-over, and multiple collisions are very rare (Table 11, Figure 12).

4.3.1.5. Effects of ABS on Pre-collision Behaviour

Pre-collision marks	with ABS		without ABS	
	number	%	number	%
no marks	431	67	1283	60
braking	78	12	509	24
scraping	3	1	9	0,5
rolling	5	1	32	1,5
sliding	60	9	173	8
braking and sliding	8	1	26	1
unknown	59	9	109	5
total	644	100	2141	100

Table 12: Presence of pre-collision marks for vehicles with and without ABS.

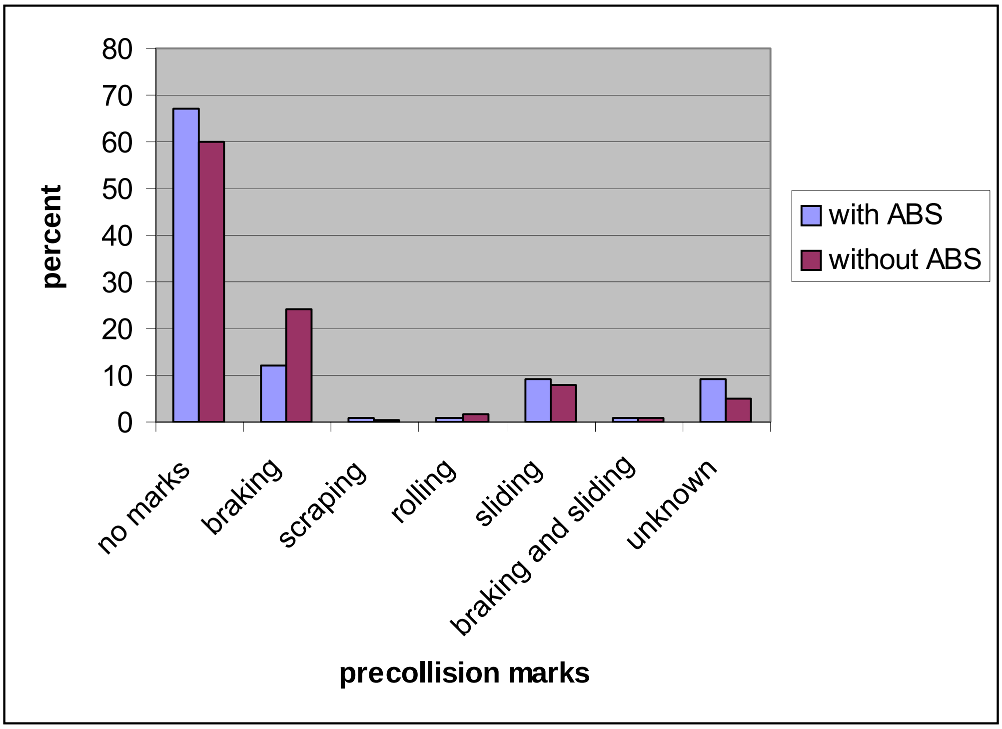


Figure 13: Presence of pre-collision marks for vehicles with and without ABS.

As shown in Table 12 and Figure 13, in the majority of cases, no pre-collision marks were present. The pre-collision marks most frequently observed were braking marks. For vehicles equipped with ABS, the frequency of braking marks is half that for vehicles with normal brakes (12% vs. 24%).

To examine whether the equipment of a vehicle with ABS influenced the steering and braking behaviour of the drivers in the pre-collision phase, the frequencies of different combinations of braking and steering behaviour aimed at avoiding the crash have been listed in Table 13. Unfortunately, there is no category 'combined braking and steering' in the EACS data, only categories containing sequential braking and steering. As shown in Table 13, the most frequent evasive action is simply braking, slightly more frequent for vehicles without ABS than for vehicles with ABS (25% vs. 21%). If the drivers had combined braking and steering sequentially to avoid the crash, most of them first braked and then steered to the left or right (10% for vehicles with ABS and 6,7% for vehicles with normal brakes).[2]

[2] For more information on the frequency of different evasive actions see section 3.2.5.

Most important evasive action	with ABS		without ABS	
	number	%	number	%
braked	134	21	530	25
braked and then turned to the left or right	65	10	144	6,7
turned to the left or right and then braked	4	0,6	45	2
confused combination of turning left or right with or without braking	10	1,6	43	2
others or unknown	425	66,8	1365	64,3
total	638	100	2127	100

Table 13: Pre-collision braking and steering behaviour of drivers of vehicles with and without ABS.

4.3.1.6. Discussion and Conclusion

Out of the direct approach of data analysis arises no evidence that accident severity is influenced by a 'Cruise Control' or by 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 only if the criteria were measures of injury severity. No such effect was found if only the data from DEKRA were analysed or if a technical measure of accident severity was chosen (Delta V). Motor capacity was found to be higher for the vehicles equipped with ABS than for those with normal brakes, but no difference was found between the complete EACS data and the DEKRA data with regard to this measure. Therefore, it is concluded that the differences between them with regard to the effect of ABS on injury severity are dependent on national differences or on differences in the accident documentation by the different organisations. Furthermore, it has to be noted that this analysis is done only with data from vehicles involved in accidents. Consequently, without knowing how many percent of the vehicles in the whole vehicle fleet in the respective years were equipped with ABS, it is not possible to examine whether ABS influences the risk to be involved in an accident at all (moderate or severe). The same argument applies to the other DAS.

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 vehicles equipped with ABS tended to combine braking and steering prior to the collision more often than drivers of vehicles with normal brakes. But it has to be remarked that in the EACS database only sequential combinations of braking and steering behaviour are documented. With respect to an analysis of the effects of ABS, it would have been useful to document also simultaneous braking and steering.

4.3.2. Analysis of Accident Causation

In the following, the EACS data will be analysed with the aim of obtaining information about accident causation. The analysis will examine which accident types are the most frequent ones, under which environmental conditions these accidents happened, why these accidents happened and whether special driver characteristics that are connected to special accident types can be identified. From the results of this analysis, it will be concluded whether there are specific situations or specific aspects of the driving task where the driver needs support. Furthermore, it will be asked whether groups of drivers needing special support can be identified. In a last step, the potential benefit from a wide-scale implementation of several ADAS will be estimated.

4.3.2.1. Classification of the Accidents

A classification of the accidents in the EACS database with regard to the accident object shows that the majority of the accidents are car-to-car accidents (37%) followed by single-car accidents (21%), car-to-two-wheelers (16%) and car-to-pedestrian accidents (15%; Figure 14).

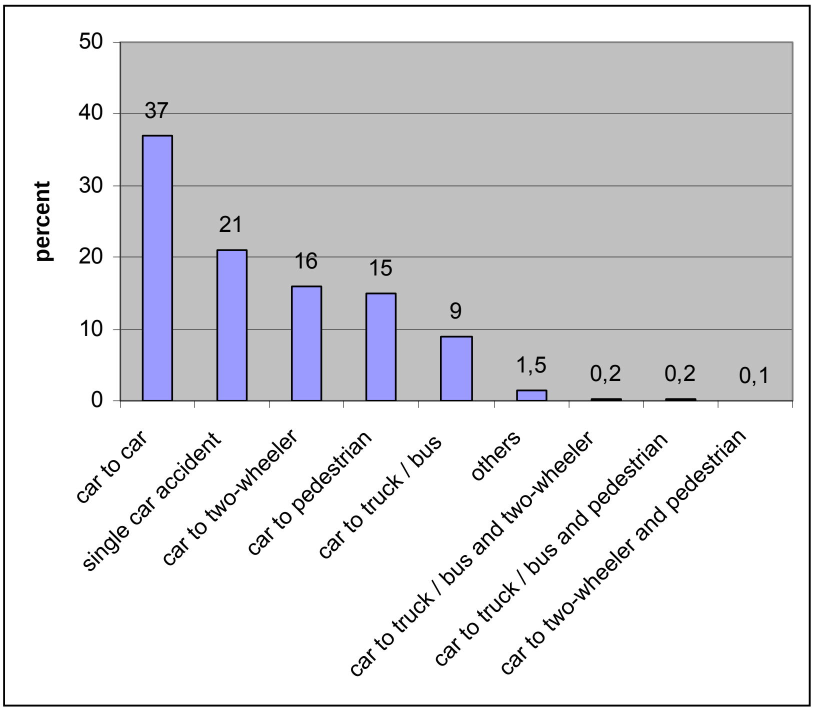


Figure 14: Classification of the accidents in the EACS database with respect to the collision object. Data are taken from the EACS Statistical Report (EACS Vol.6).

When the accidents are classified according to accident type (Figure 15), most accidents fall into the category 'Crossing', i.e. accidents in connection with direction changes and / or at crossings (29%). Also frequently occurring accident types are accidents with longitudinal traffic, i.e. with traffic in the same or the opposite direction (23%), and driving accidents, i.e. accidents due to driving errors and not caused by conflicts with other vehicles or persons (23%). 11% of the accidents are classified as accidents due to a conflict between a vehicle and a pedestrian crossing the road. Minor categories are accidents with stationary traffic, such as parking cars for example, (5%) and other accidents not belonging to any of the categories mentioned before (9%).

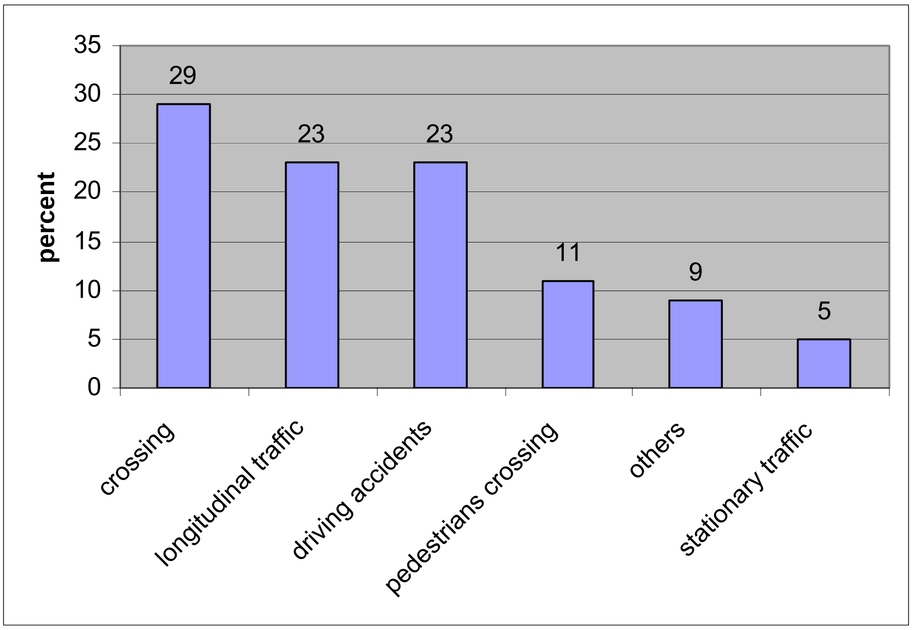


Figure 15: Classification of the accidents in the EACS database according to accident type. Crossing: Direction change accidents and accidents at crossings; Longitudinal traffic: Accidents with traffic in the same or the opposite direction; Pedestrians crossing: Accidents with pedestrians crossing the road; Others: Other types of accidents (e.g. with objects on the road); Stationary traffic: Accidents with stationary traffic (vehicles parking on the road). Classification slightly modified according to Forschungsgesellschaft für Straßen- und Verkehrswesen (1998)[3].

4.3.2.2. Severity of Injuries

A further analysis of the different accident types with respect to severity of accident consequences reveals that severity of injury is dependent on the accident type. Most fatal accidents are driving accidents although the most

[3] This classification distinguishes 7 types of accidents. For this analysis, types 2 and 3 were combined to build the category 'crossing'.

frequent accidents are those at crossings or with crossing vehicles (Figure 16 and Table 14)[4]. Another category with a high percentage of fatal accidents is that containing accidents due to conflicts with crossing pedestrians (40% fatal accidents). Accidents caused by conflicts with stationary traffic are also very often fatal (42%), but the relative frequency of this accident type is rather low (5% of the accidents in the EACS database (Figure 15).

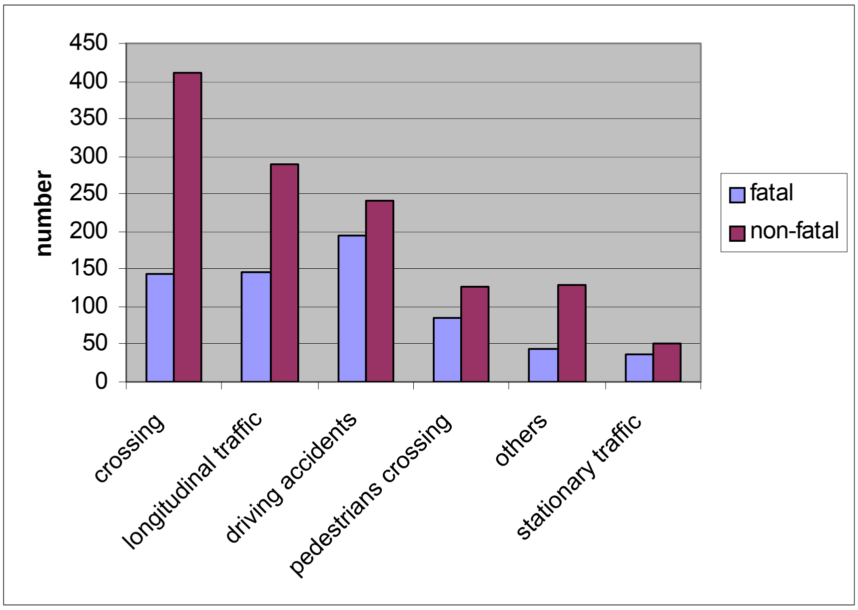


Figure 16: Classification of the accidents in the EACS database according to accident type, differentiated with respect to accident severity. For an explanation of the accident types see Figure 15.

Accident type	fatal accidents	% fatal accidents	non-fatal accidents	% non-fatal accidents
crossing	144	26 %	412	74 %
longitudinal traffic	147	34 %	290	66 %
driving accidents	194	45 %	241	55 %
pedestrians crossing	85	40 %	127	60 %
others	43	25 %	128	75 %
stationary traffic	37	42 %	51	58 %

Table 14: Number and proportion of fatal accidents for the different accident types. For an explanation of the accidents types see Figure 15.

4 Driving accidents were investigated in more detail by Sferco et al. (2001) who analysed the EACS data with regard to the potential benefit resulting from a widespread implementation of ESP ('Electronic Stability Program').

4.3.2.3. *Environmental Conditions*

An analysis of the four major accident types with respect to lighting conditions shows that the relative frequency of the different accident types is dependent on the daytime or the lighting conditions respectively. While most of the 'crossing' and 'longitudinal traffic' accidents happen at daylight, driving accidents happen about equally often at daylight and at darkness, and accidents due to crossing pedestrians happen more often in darkness than at daylight (Figure 17 and 18). Therefore, it can be suggested that poor visibility plays an important role in the causation of this last type of accidents.

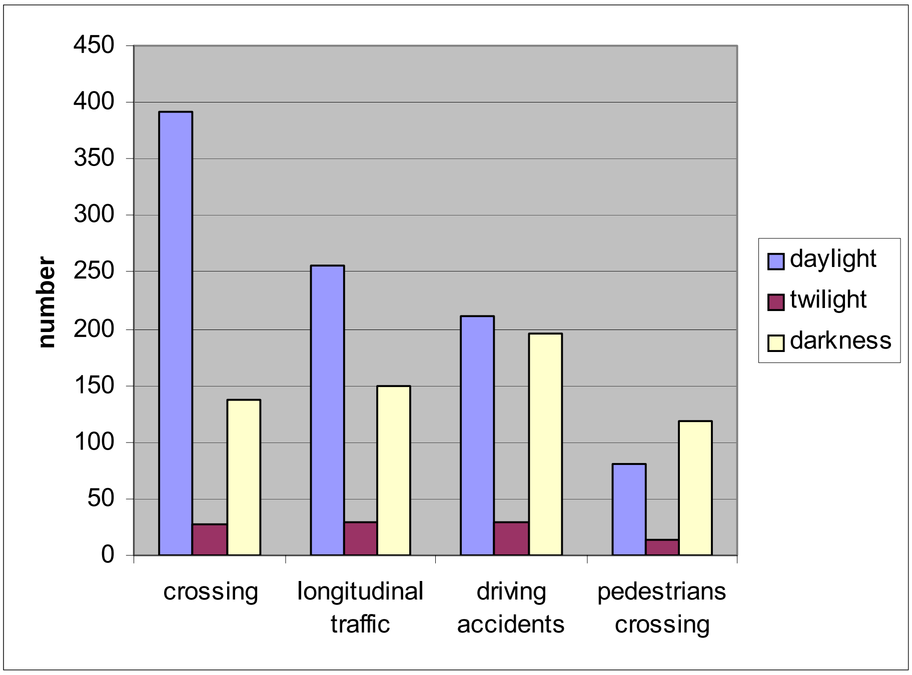


Figure 17: Number of accidents of four accident types, separately for different lighting conditions. For an explanation of the accident types see Figure 15.

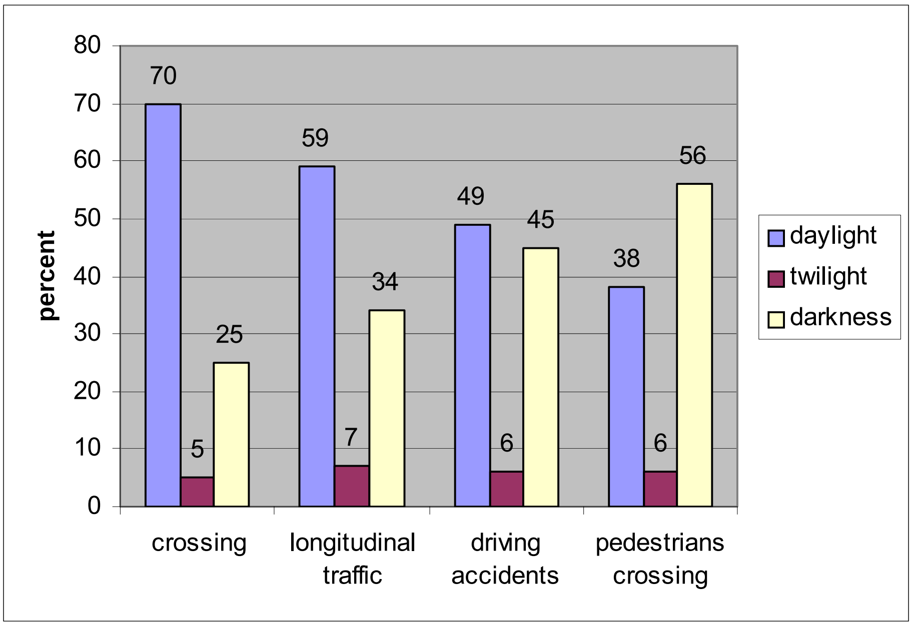


Figure 18: Proportion of accidents at different lighting conditions, separately for four accident types. For an explanation of the accident types see Figure 15.

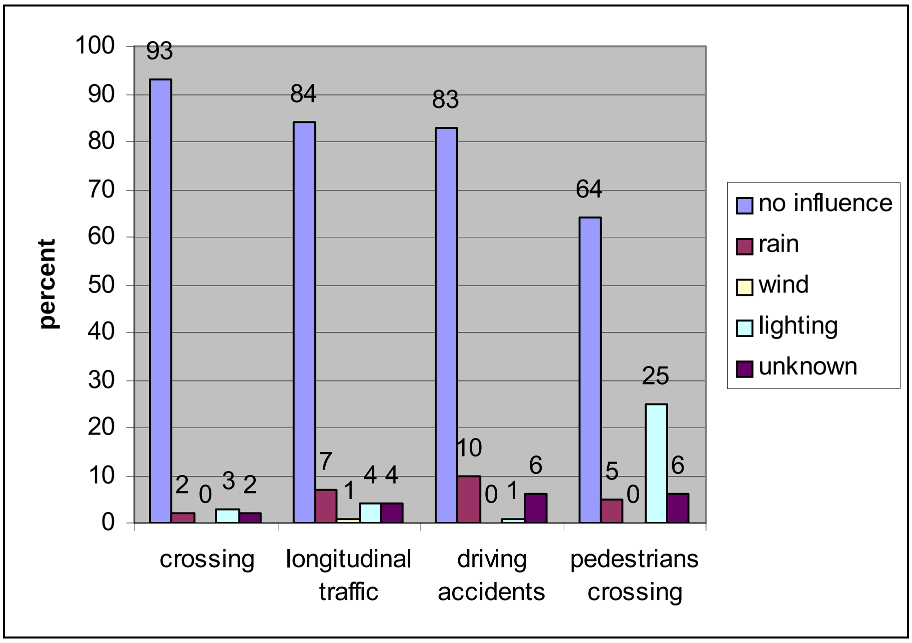


Figure 19: Proportion of accidents probably influenced by rain, wind or lighting conditions (according to expert ratings), separately for four accident types. For an explanation of the accident types see Figure 15.

This suggestion is supported by the expert judgements shown in Figure 19. According to the opinion of the experts, the majority of the accidents were not influenced by environmental conditions. But in contrast to the other accident types, 25% of the accidents due to pedestrians crossing the road were probably influenced by the lighting conditions.

According to the judgement of the experts, wind plays only a minor role in the causation of the accidents in the EACS database. In contrast to that, rain might have influenced some of the accidents, especially driving accidents (10%). Perhaps, some drivers had lost control over their vehicles because of slippery roads. In the following, the accident causes will be analysed for the four major accident types.

4.3.2.4. Accident Causes

The experts who documented the accidents for the EACS database had to choose the main accident causes from a list of 89 possible causes. As shown in Table 15, in most cases, no specific accident cause could be identified. The accident cause that was most frequently stated was non-adapted speed either with or without exceeding the speed limit (12% and 7%). Other frequently stated accident causes were failures to observe traffic signs regulating priority, mistakes made when turning, influence of alcohol, physical and mental driver status, and other driver errors that did not fit in any of the 89 categories offered by the questionnaire.

Accident Causation	DEKRA		total	
	number	%	number	%
no cause identified	377	19	685	21
non-adapted speed with exceeding the speed limit	319	16	403	12
non-adapted speed without exceeding the speed limit	133	7	235	7
failure to observe the traffic signs regulating priority	118	6	204	6
other mistakes made by the driver	157	8	180	6
influence of alcohol	97	5	136	4
physical and mental driver status	41	2	117	4
mistakes made when turning	78	4	112	3

Table 15: The main accident causes most frequently stated by the experts. Data are taken from the EACS Statistical Report (EACS Vol.6). The complete list consists of 90 different accident causes.

Accident cause	crossing	longitudinal	driving acc.	pedestrian
non-adapted speed with exceeding the speed limit	170 (15%)	68 (8%)	92 (16%)	39 (16%)
non-adapted speed without exceeding the speed limit	39 (3,4%)	77 (9%)	84 (14,5%)	13 (5%)
failure to observe the traffic signs regulating priority	202 (18%)	0 (0%)	1 (0%)	0 (0%)
other mistakes made by the driver	44 (4%)	37 (4,4%)	63 (11%)	4 (2%)
influence of alcohol	17 (1,5%)	23 (2,7%)	70 (12%)	5 (2%)
physical and mental status of the driver	10 (1%)	31 (3,7%)	38 (6,6%)	2 (1%)
mistakes made when turning	88 (8%)	7 (1%)	2 (0%)	0 (0%)
improper behaviour of a pedestrian	4 (0,4%)	0 (0%)	0 (0%)	49 (22%)
total (complete list)	1133 (100%)	893 (100%)	579 (100%)	222 (100%)

Table 16: Number and percentage of nominations of several accident causes as main accident causes, separately for four accident types. The complete list consists of 90 different accident causes. For an explanation of the accident types see Figure 15.

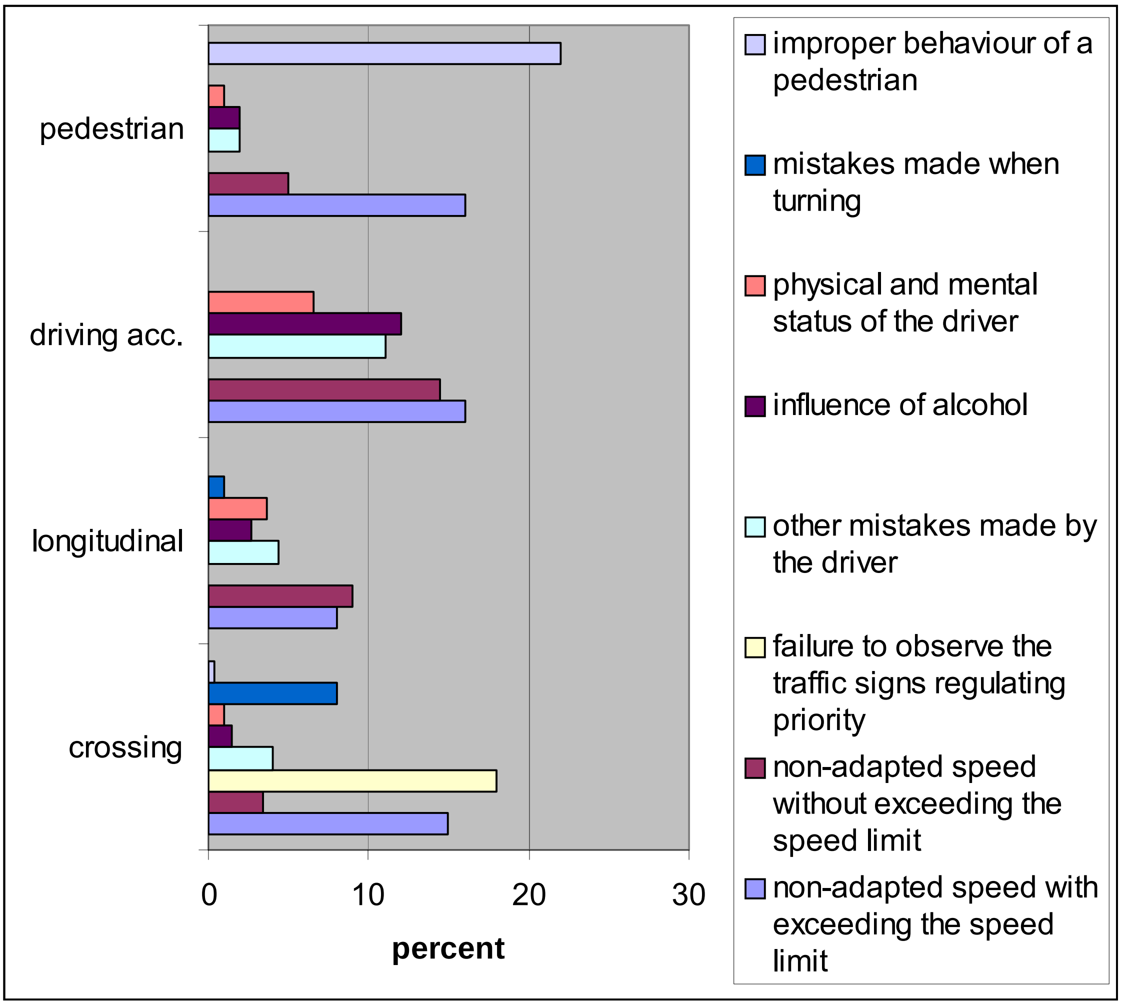


Figure 20: Proportion of nominations of several accident causes as main accident causes, separately for four accident types. For an explanation of the accident types see Figure 15.

An analysis of the main accident causes (as judged by the experts) separately for the four most frequent accident types reveals that each accident type has a special pattern of causation. While two of the most prominent causes for 'crossing accidents' are failures to observe the traffic signs regulating priority and mistakes made when turning, these failures are of no relevance for the other accident types (Table 16, Figure 20). Driving accidents are characterised by a causation pattern consisting of non-adapted speed either with or without exceeding the speed limit and unspecified driver errors, partly influenced by the physical and mental status of the driver. Alcohol is judged to be a causing factor especially for driving accidents. A non-adapted speed with exceeding the speed limit at the same time is a prominent accident cause independent of the accident type, but an inappropriate speed *without* exceeding the speed limit is a factor that is of relevance especially for driving accidents and accidents with the longitudinal traffic. As expected, an improper behaviour of pedestrians is a causing factor that is characteristic for accidents involving pedestrians crossing the road.

4.3.2.5. Evasive Actions of the Driver prior to the Accident

Evasive action	DEKRA		total	
	number	%	number	%
not applicable or unknown	616	30	786	25
braking	446	22	759	23
unable to describe the reactions	299	15	348	11
sequential combination of braking and steering	159	7	278	9
no reaction: astonished	173	9	285	9
no reaction: no perception of danger	87	4	254	8
turning to the right or to the left	115	6	236	8

Table 17: Most frequently stated evasive actions by the driver. Data are taken from the EACS Statistical Report (EACS Vol.6).The complete list consists of 23 actions.

11 % of the drivers were not able to describe their actions aimed at avoiding the accident (Table 17). For an even bigger proportion of drivers (25%), this question was not applicable, for example because they had been killed or severely injured in the accident. Those drivers who remembered their evasive actions most frequently stated that they had been braking (23%), turning either to the left or to the right (8%), or braking and steering sequentially (9%). It must be remarked that in the EACS data, there is no category for 'braking and steering at the same time'. Such a category would be useful, because DAS like ABS and ESP enable the driver to perform braking and steering manoeuvres at the same time (see also section 3.1.5). 17 % of the drivers said that they had not done anything to avoid the accident either because they had been too astonished to react (9%) or because they had not perceived any danger (8%).

Table 18 and Figure 21 show that the pattern of evasive reactions described above does not differ remarkably between the four major accident types with the exception that braking seems to be a less prominent evasive reaction for driving accidents than for the other accident types, especially for accidents involving pedestrians crossing the road.

Evasive action	crossing	longitudinal	driving acc.	pedestrian
braking	312 (28%)	173 (20%)	87 (15%)	100 (45%)
unable to describe the reactions	104 (9%)	86 (10%)	84 (15%)	27 (12%)
no reaction: astonished	125 (11%)	82 (9%)	32 (5,5%)	18 (8%)
no reaction: no perception of danger	115 (10%)	58 (7%)	26 (4,5%)	14 (6%)
sequential combination of braking and steering	92 (8%)	98 (11%)	22 (4%)	27 (12%)
turning to the right or to the left	54 (5%)	77 (9%)	60 (10,4%)	7 (3%)
total (complete list)	1131 (100%)	889 (100%)	578 (100%)	221 (100%)

Table 18: Number of nominations of several evasive actions by the driver, separately for four accident types. For an explanation of the accident types see Fig.10. The complete list consists of 23 actions.

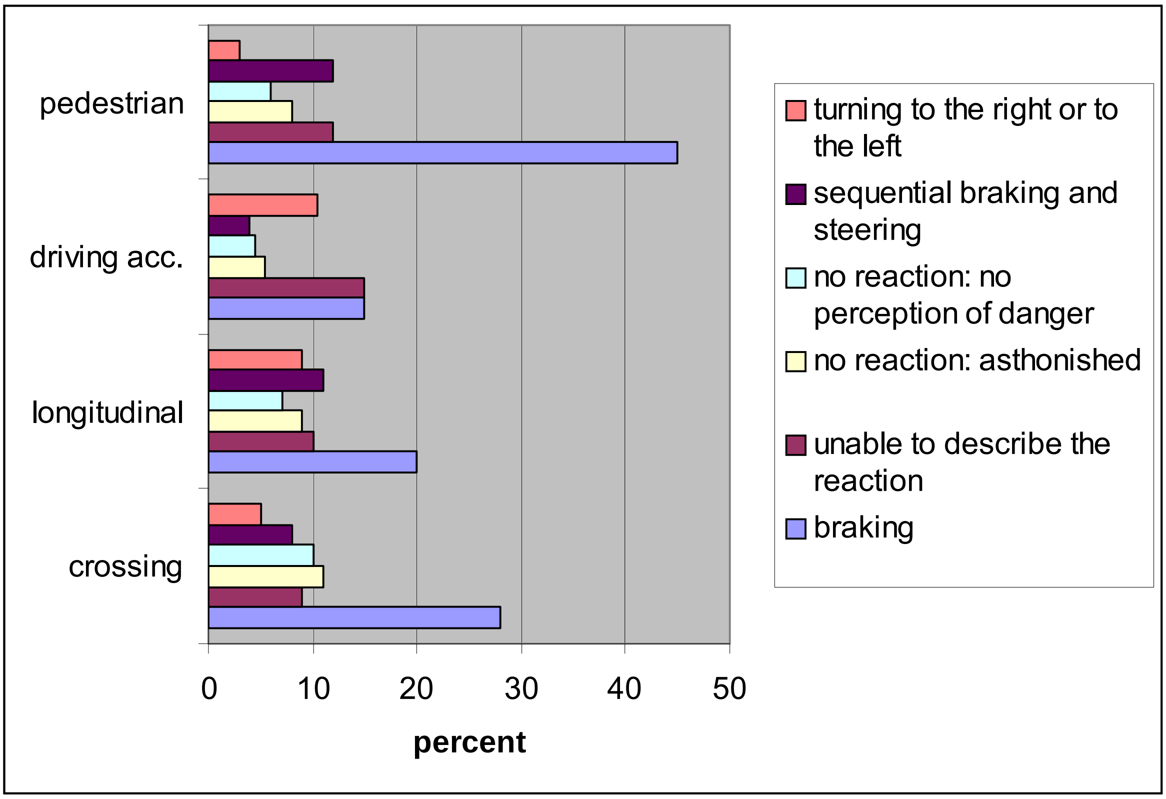


Figure 21: Most frequent evasive actions as stated by the driver, separately for four accident types. For an explanation of the accident types see Figure 15.

4.3.2.6. Driver Characteristics

Accidents	male	female	unknown	total
total	2452 (76%)	702 (22%)	64 (2%)	3218 (100%)
crossing	826 (73%)	291 (26%)	11 (1%)	1128 (100%)
longitudinal	684 (78%)	157 (18%)	34 (4%)	875 (100%)
driving accidents	459 (79%)	117 (20%)	7 (1%)	583 (100%)
pedestrian	156 (71%)	64 (29%)	0 (0%)	220 (100%)

Table 19: Sex of the drivers listed for the whole database and separately for four accident types. For an explanation of the accident types see Figure 15.

As shown in Table 19, 76% of the drivers involved in the accidents of the EACS database are male and 22% of them are female. For all four major accident types, the proportion of male drivers is much higher than that of female drivers with the highest percentage of male drivers observed for driving accidents (79%) and the highest percentage of female drivers for accidents due to pedestrians crossing the road (29%) (Table 19).

An analysis of the accident data with regard to the age of the drivers revealed that younger drivers (<25 years) are involved in driving accidents above average while elder drivers (>65 years) are especially prone to be involved in accidents at crossings (Table 20).

Accidents	< 25 years	25-65 years	> 65 years	unknown	total
total	845 (26%)	1987 (62%)	206 (6%)	180 (6%)	3218 (100%)
crossing	280 (25%)	684 (60%)	117 (10%)	47 (5%)	1128 (100%)
longitudinal	189 (22%)	586 (65%)	33 (5%)	67 (8%)	875 (100%)
driving acc.	203 (35%)	331 (57%)	19 (3%)	30 (5%)	583 (100%)
pedestrian	58 (26%)	144 (66%)	12 (5%)	6 (3%)	220 (100%)

Table 20: Age of the drivers listed for the whole database and separately for four accident types. For an explanation of the accident types see Figure 15.

4.3.3. Experts' Rating of the possible Effects of Driver Assistance Systems

For each accident, the experts had to estimate whether the accident could have been influenced or even avoided if one of the nine DAS listed in Table 21 had been installed in at least one of the vehicles involved in the accident. The answers could be chosen between 1: 'Would definitely not have influenced the accident' to 5: 'Would definitely have avoided the accident'. For the analysis, all answers >2 were summed up, i.e. all cases where the experts estimated that the DAS would have influenced the accident at least probably.

As the results show, the Collision Avoidance System is the DAS that is believed by the experts to have the greatest impact on accidents (Table 21). In 38% of the accidents, the European experts estimated that a Collision Avoidance System would have influenced the accident at least probably. If only the German accidents reported by DEKRA were analysed, this holds true for even 46% of the cases. The Automatic Emergency Call was judged to have possible effects in only 11% of the accidents or 16% if only the German accidents described by DEKRA are analysed. For the other DAS, the estimations lie in between (Table 21). In general, the German experts from DEKRA seem to be more optimistic about the possible effects of the DAS than the European experts. On the other hand, the accidents reported by DEKRA may differ in some aspects from the accidents reported by other organisations and this fact might have caused the different estimations.

	total: 1904		DEKRA: 1170	
Driver Assistance System	number	%	number	%
Collision Avoidance	715	38	537	46
Co-operative Driving	592	31	461	39
Driver Monitoring	510	26	395	34
Lane Keeping	519	27	358	31
Surveillance of power, safety reserves, driving stability	441	23	329	28
Visibility Monitoring	417	21	324	28
Autonomous regulation of speed and space	406	21	312	27
Improving visibility	386	20	316	27
Automatic Emergency Call	216	11	191	16

Table 21: Number and percent of accidents where the experts estimated that the respective DAS could have influenced the accident definitely or at least probably, separately for all cases of the EACS database and for the German accidents described by DEKRA.

4.4. Discussion and Conclusions

In the following, on the basis of the analysis of the EACS data, some ideas will be developed about how (A)DAS could contribute to an enhancement of traffic safety. Because the EACS data are characterised by some constraints concerning their representativeness, completeness, and internal consistence (→4.2.3), it is not possible to conclusively identify the percentage of accidents that could be mitigated or avoided by special (A)DAS. This must also be taken into account when interpreting the estimations of the experts on the possible effects of some (A)DAS (→4.3.3). Nevertheless, the results of the analysis of the accident data provide some evidence on the effects of DAS like ABS and they give some hints on driving situations where the driver, or special groups of drivers, need support.

4.4.1. Safety Effects of ABS

The analysis of the effects of ABS on accident severity and development yielded ambiguous results (→4.3.1.3). A tendency of vehicles equipped with ABS to be involved in more severe accidents than vehicles with normal brakes was found, but only if the data were analysed at a European level and 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). The different results of the analysis of the complete EACS data and of the DEKRA data could not be explained by different motor capacities of the respective vehicles. For the complete EACS data as well as for the DEKRA data, it was found that vehicles equipped with ABS had a higher motor capacity than vehicles with normal brakes. This finding reflects the fact that mostly, DAS are at first installed in higher class vehicles.

Furthermore, 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. No clear difference between them was found with regard to the driver behaviour aimed at avoiding the crash although the drivers of vehicles equipped with ABS tended to combine braking and steering sequentially prior to the collision more often than drivers of vehicles with normal brakes.

An interpretation of these results is difficult because on the basis of accident data alone, it is not possible to make a statement on the accident risk of vehicles equipped with ABS in comparison to vehicles with normal brakes. Nevertheless, it is remarkable that no evidence for a safety-enhancing effect of ABS was found in the EACS data. This finding could be explained by assuming that the drivers were not informed or misinformed about the function and the special advantages of ABS and therefore did not adapt their braking and steering behaviour appropriately. This hypothesis is supported by the finding that the majority of drivers of vehicles with normal brakes as well as of vehicles with ABS tried to avoid the accident by simply braking (→4.3.1.5). On the other hand, it must be taken into account that the EACS questionnaire does not provide any category to document combined braking and steering behaviour and that it is not known whether such a behaviour would have been successful in avoiding some of the accidents. Nevertheless, it is recommended that drivers should be better informed and trained with respect to the use of ABS and other (A)DAS. With respect to ABS, it can be assumed that combined braking and steering as an action to avoid a pending crash is a behaviour that must be exercised.

4.4.2. Driver Needs for Support

The analysis of the EACS data revealed that the most frequent accident type is accidents at crossings or accidents involving direction changes (→4.3.2.1). The most prominent cause for this accident type is a 'failure to observe traffic signs regulating priority' (→4.3.2.4). Therefore, it can be concluded that at least some drivers would stand to benefit from support, e.g. in detecting traffic signs, in these complex traffic situations. Especially older drivers would benefit from such support because this driver group is especially prone to be involved in accidents at crossings (→4.3.2.6). On the other hand, further research has to clarify which aspect of complex traffic situations is responsible for the difficulties of the drivers, especially of the older ones. Is the problem actually the perception of traffic signs as suggested by the EACS data or is it merely the necessity of quick decisions and reactions in the crossing situation itself (Matzke & Gelau, 1994; Gelau, Metker & Tränkle, 1994)?

In contrast to older drivers, the younger drivers are involved in driving accidents an above average rate (→4.3.2.6). This accident type is most frequently caused by a non-adapted speed either with or without exceeding the speed limit (→4.3.2.4). It is always difficult to interpret the statement of non-adapted speed as a main accident cause because in principle, every accident happens because the vehicle speed is not appropriate in the respective situation. But nevertheless, the risk of driving accidents could possibly be reduced by supporting the driver (especially younger drivers) in choosing the appropriate speed. The effectiveness of ESP to avoid or mitigate accidents of this type is discussed by Sferco et al. (2001). On the other hand, it has to be noted that 45% of the driving accidents happen at night (→4.3.2.3) and 12% of them are mainly caused by a driver under the influence of alcohol (→4.3.2.4). Therefore, an important measure to reduce the number of driving accidents is to prevent people from driving while intoxicated, especially to prevent them from driving home from a party or from the discotheque at night when they had been drinking alcohol. This means that (A)DAS alone cannot solve the problem because driving too fast and drunk driving is mostly dependent on motivational factors.

23% of the accidents of the EACS database were classified as accidents with longitudinal traffic (→4.3.2.1). For this accident type, no prominent accident cause could be identified (→4.3.2.4). 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 astonished or because they did not perceive any danger (→4.3.2.5). Another 10% of the drivers were not able to describe their evasive actions. ADAS warning the driver of approaching dangers, e.g. of accidents that had happened or of a traffic jam, might provide more time to the driver to react appropriately and to adjust their speed.

Accidents involving pedestrians crossing the road happen more often during darkness than other accident types (→4.3.2.3). According to the judgement of the experts, lighting conditions influenced especially the development of this accident type (→4.3.2.3). Therefore, improving the detection and/or the visibility of pedestrians could help to prevent accidents of this type. 22% of these accidents are caused by an improper behaviour of the pedestrians (→4.3.2.4). This means that the development of ADAS for a better protection of pedestrians should be accompanied by measures to improve the behaviour of pedestrians in traffic. Although this accident type is not the most frequent one, it is an important aim to enhance the safety of pedestrians because the injuries of pedestrians resulting from accidents are much more severe on average than those of vehicle occupants (→4.3.1.3).

4.5. Summary

In this chapter, the database of the European Accident Causation Survey (EACS) was analysed 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 ('European Accident Causation Survey') 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.

In a first step, the effects of several DAS on driving safety were analysed by a direct comparison of the vehicles equipped with and those not equipped with the respective DAS. Such a direct approach was not applicable for the majority of ADAS, because the proportion of vehicles in the database equipped with them is too small to allow 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 motor capacity than vehicles with normal brakes 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 vehicles equipped with ABS tended to combine braking and steering sequentially prior to the collision more often than drivers of vehicles without ABS.

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. It is shown that the most frequent accident type is accidents at crossings or involving direction changes (29% of all accidents). The most prominent cause for this accident type is a 'failure to observe traffic signs regulating priority'. Therefore, it can be concluded that at least some drivers would stand to benefit from support, e.g. in detecting traffic signs, in these complex traffic situations. Especially older drivers could be expected to benefit 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, especially to the older ones.

In contrast to older drivers, the younger drivers are involved in driving accidents (23% of all accidents) above average. This accident type is most frequently caused by a maladjusted speed either with or without exceeding the legal speed limit. Therefore, the risk of driving accidents might be reduced by supporting the driver (especially younger drivers) in choosing the appropriate speed. On the other hand, it is shown that in 12% of the driving accidents, alcohol is identified as the main accident cause. Because driving while intoxicated and speeding can be assumed to be mainly based on motivational factors, it was concluded that (A)DAS alone cannot solve these problems.

23% of the accidents of the EACS database were classified as accidents with longitudinal traffic. For this accident type, no prominent accident 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 the driver of approaching hazards, e.g. of accidents that had happened or of a traffic jam, might provide more time to the driver to react appropriately and to adjust their speed.

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 type. Although this accident type is not the most frequent one (11% of all accidents), it is an important aim to enhance the safety of pedestrians because the injuries of pedestrians resulting from accidents are much more severe on average than those of vehicle occupants. Because 22% of these accidents are caused by an improper behaviour of the pedestrians, the development of ADAS for a better protection of pedestrians should be accompanied by measures to improve the behaviour of pedestrians in traffic.

5. STATE-OF-THE-ART

5.1. Introduction / Working methodology

In this chapter, a list of the systems considered will be presented, highlighting the State–of-the-Art of current systems and the likely future development of this technology.

Below is a complete list of all the electronic devices with which cars are currently equipped or will be equipped in future. From this list, EEVC WG19 experts have selected the devices that could be used in phase 2 and / or 3 of the ACEA model, which is described in chapter 1. In general, all these systems are available for passenger cars but not necessary for commercial vehicle. Then, for the selected devices, we point out information:

- In the first column, we indicated in which phase of the ACEA model the devices operate

- In the second one, we tried to mention, for each system, the “Year of implementation”, the year indicated in this column is for light vehicles. Normally, the year of implementation for heavy vehicles will be later.

  An indication on how the feature could reduce injuries is provided. Several methods are identified to achieve this goal:

  - The first one is to decrease the speed just before the impact. As the speed is the main factor of the energy [E=f (V^2)], decreasing the speed before the impact is most important.
  - The second one is to prepare the vehicle for the impact. In the majority of the cases, the systems pre-arm the actuators. Then we found two kinds of pre-arming: reversible or non-reversible. This can be an important point for the purpose of responsibility of the builder.

  - We have also identified the preparation of the occupants for the impact. In all cases, the preparation of the occupants is a consequence of the preparation of the car to the impact, that’s why we symbolized this by a “→”.

  - The last one is the optimization of the impact angle of the car before the crash.

  - One more case was identified that does not have a direct link to injury reduction. In this case, the warnings must immediately direct the driver to evaluate and react to threats with sufficient time to perform some action to avoid or mitigate a potential crash. To achieve this, audible, visible, and possibly haptic cues will be employed

- The two last columns indicate the names of the features and a short description of each system.

5.2. The systems involved

See tables below

Phase	Year of implementation	Decrease the speed,	Prepare vehicle to the impact	prepare occupants to the impact	optimise the impact angle	Alert the driver	Feature	Description
2 – 3	2000	X					ABS - 4 channel & EBD	ABS with channel for each wheel & electronic brake distribution
2 – 3	2005	X			X		Active Camber Variation	When cornering the camber angle on the outer wheels are adjusted by up to 20 degrees. This system can be used in conjunction with ABC (Active Body Control). Improved grip, stability, cornering speed. Can sustain lateral acceleration as high as 1.28g.
3 – 4	2002		X				Active Knee Restraints - Deployable Knee Bolster	Inflatable knee bolster in area of steering column. These airbags emanate from the bottom half of the IP, and restrain the occupant during an impact in a way that contributes towards lower head impact risk.
2 – 3	2000		X		X		Active Roll Control	An Electronically controlled hydraulic element placed between the anti-roll bar and front & rear lower control arms, tensions the anti-roll bar to compensate for roll motions, reducing roll angles.
2 – 3	2001		X		X		Active Roll Mitigation (Advanced IVD / Yaw Control)	Advanced IVD: A roll rate sensor and new control logic are added to the current generation of IVD/ESP systems to implement Roll Stability Control and to achieve significant improvements over base IVD functionality. Roll Stability Control actively suppresses excessive roll of a vehicle for on-road (non-tripped) and soft-tripped events, which might otherwise result in rollover. Brakes are applied to select wheel(s) in response to excessive roll. Applied brake forces reduce tire lateral forces and the roll overturning moment to increase roll stability margin. Vehicle roll information is used to improve detection of vehicle sideslip tendency, increasing the yaw stability levels achieved by ESP/IVD systems.
2 – 3	2001		X		X		Active Roll Stabilization	Active roll control system.
3	-	X	X				Active Safety - Pedestrian Avoidance	A Pedestrian Avoidance system is designed to make an autonomous brake application when it determines a collision with a pedestrian is imminent in a low speed environment. This function has not been fully defined at this time, but will likely be bundled with the Pedestrian Warning function as well.
2 – 3	-					X	Active Safety - Pedestrian Warning	A Pedestrian Warning system is designed to warn the driver when there is a risk of a collision with a pedestrian, at sufficient distance to allow the driver to avoid, or reduce the effect of, the potential collision. Detection ability may also include large animals and bicyclists. Other factors are very similar to the Forward Collision Warning system description.
2 – 3	2005		X		X		Active Steering Wheel	Links LDW (Lane Departure Warning) with EAS (Electric Active Steering). If the car is wandering out of its lane, as detected by LDW, a degree of resistance in the steering wheel is provided by EAS to help the driver keep in the lane. Early stages of Collision Avoidance and Autonomous driving.
3 – 4	2003			X			Adaptive Airbag Inflator	Airbag inflator with: variable output variable onset controlled mass flow Occupant, position and crash severity adaptation, optimal use of occupant restraining distance.

Phase	Year of implementation	Decrease the speed,	Prepare vehicle to the impact	prepare occupants to the impact	optimise the impact angle	Alert the driver	Feature	Description
2 – 3	2000	X				X	Adaptive Cruise Control (ACC) - Forward Collision Warning (FCW)	A Forward Collision Warning system is designed to warn the driver when there is a risk of a collision with another vehicle, at sufficient distance to allow the driver to avoid, or reduce the effect of, the potential collision. The warning will come in the form of an audible and / or visible indication via a unique human machine interface (e.g. head up display, stereo system, etc.). No tactile indication is planned at this time. These indications are intended to supplement the driver's normal diligence in operating the vehicle, which may be of particular effectiveness in situations with heightened workload (e.g. conversation with a second individual, distraction by roadside events, etc.) without being intrusive to the point of annoyance. These warnings may also reflect varying degrees (probability) of threat and some directionality as well. Forward (frontal) collision warning for use on highways. Driver warned by means of a coloured flash onto the windscreen. Sensor can detect stationary objects at a longer range allowing a higher performance, and offers a route to collision avoidance. Use of dynamic maps data to filter out spurious sensor information such as road signs and, through greater map accuracy predict the vehicles path from road curvature.
2 – 3	2005	X				X	Adaptive Cruise Control (ACC) - Reduced Stopping Distance (RSD)	Utilize data from Adaptive Cruise Control system to reduce stopping distance in emergency brake situations. System combines functionality of brake assist with pre-emptive brake pressure build up and collision mitigation by braking. See also Pre-Crash Braking
2 – 3	2000	X					Brake Assist (BA)	The rate of brake pedal application by the driver is monitored and used to detect an emergency braking situation. If the driver applied pedal force/travel is insufficient to provide full braking, the system will automatically increase the brake pressure.

Phase	Year of implementation	Decrease the speed,	Prepare vehicle to the impact	prepare occupants to the impact	optimise the impact angle	Alert the driver	Feature	Description
3	2003	X					Brake Assist with Forward Collision Warning (Collision Mitigation by Braking - CMbB)	A Collision Mitigation system will make an autonomous brake application when it determines a collision with another vehicle is unavoidable in both high speed and low speed environments. The CM function assumes the driver has ultimate authority over vehicle control and will not interfere with any potential evasive manoeuvres intended by the driver. Since the distance required braking for avoidance usually exceeds the distance required to steer for avoidance, the system is limited to mitigation by braking only. This function can also include a panic brake assist function if a driver has applied an inadequate level of braking to avoid a collision or hesitates in full application. Using date from a Forward Collision Warning sensor (distance, closing speed, deceleration, likelihood of impact), the brake assist system can calculate the exact level of braking required and apply it. Early form of collision avoidance that requires driver confirmation (through hard and sudden brake application). A Forward Collision Warning system is designed to warn the driver when there is a risk of a collision with another vehicle, at sufficient distance to allow the driver to avoid, or reduce the effect of, the potential collision. The warning will come in the form of an audible and / or visible indication via a unique human machine interface (e.g. head up display, stereo system, etc.). No tactile indication is planned at this time. These indications are intended to supplement the driver's normal diligence in operating the vehicle, which may be of particular effectiveness in situations with heightened workload (e.g. conversation with a second individual, distraction by roadside events, etc.) without being intrusive to the point of annoyance. These warnings may also reflect varying degrees (probability) of threat and some directionality as well.
3	2006	X			X		Collision Avoidance Systems	Automatic braking and steering to reduce crash impact. Independent from the driver, the car takes evasive actions to reliably avoid collisions. Requires Collision Sensing, Steer by Wire, Brake by Wire and Vehicle Path Prediction.
3	-	X			X	X	Collision Mitigation by Braking (CMbB) - Autonomous Braking w/ Warning & Adaptive Chassis Precursor	-
3	2005		X				Compatibility - Bumper Airbag	Vehicle-to-Vehicle compatibility. Deploy bumper airbag on SUV's when impact is predicted. Of particular benefit for side impacts.
3	2004		X				Compatibility - Nose Dipping	Means to ensure Vehicle-to-Vehicle compatibility. Lower the front suspension on SUV's when impact is predicted. Requires air suspension.
2 – 3	2000	X			X		Cornering Brake Control (CBC)	Electronic brake force distribution whilst cornering which compensates over- or under steer.

Phase	Year of implementation	Decrease the speed,	Prepare vehicle to the impact	prepare occupants to the impact	optimise the impact angle	Alert the driver	Feature	Description
3 – 4	2004		X				Deployable Bonnet - Pedestrian Contact Sensor	When the pedestrian contact sensor, mounted in the front bumper, detects an impact an algorithm determines that pedestrian impact conditions have been met and triggers pyrotechnic devices to lift the hood, at the rear edge, to deployed height to give required bonnet / engine clearance. A deployable hood system triggered by a bumper contact sensor to reduce the level of styling changes needed for pedestrian head impact protection (HIC < 650). Specific technologies include: Bumper Contact Sensor & Signal Processor, Pyrotechnic Hood Hinge (rear), Pyrotechnic Hood Latch (rear).
3	2006		X				Deployable Bonnet - Pre-Crash Sensing	Through the use of pre-crash microwave sensor, pedestrians can be detected before impact, and counter measures such as deployable bonnet initiated sooner, reducing pedestrian injuries.
3 – 4	2001		X →	X			Deployable Head Restraints	Pyrotechnically deployed head restraints to reduce whiplash. Pyrotechnic device used to deploy the headrest through 60mm of movement. This achieves a faster response than existing passive systems.
2 – 3	2002				X		Dynamic Traction Control	Allows the driven wheels to break traction up to a speed of 70 kph or a lateral acceleration of 0.4g to give the driving characteristics of a car fitted with a limited slip differential.
1 - 3	2003				X		Electric Active Steering (EAS) - Active Front Steering (AFS)	Semi Steer-by-wire: Still with steering column but electronically controlled variable steering gear/transmission (steering angle reduction). Speed sensitive torque and damping (better comfort, higher stability, better agility), active return, series differentiation, fuel economy, package. Active influencing of steering angle in critical drive conditions. Modifies road wheel angle based on driver input while maintaining mechanical steering link. Closed loop system. Augmented steer angle does not require hand wheel input. Acceptable torque feedback to driver. Planetary gear set between steering and road wheels allows adjustment of steering angle independent of driver. This facilitates a range of functions like, lock to lock steering at parking speeds in just 1 turn of the wheel, as well as automatic angle corrections for stability control
2 – 3	2001		X →	X			Electrical Belt Pretensioner	Activate belt pretension when safety critical situation is anticipated. Electrical belt pretension are resetable restraints; after activation no need to be exchanged. Requires pre-crash sensing (anticipatory sensing).
1 – 3	2000	X			X		Electronic Stability Program (ESP) Interactive Vehicle Dynamics (IVD)	Enhancement to ABS & TCS with additional modulator control valves and sensors for steering angle, yaw rate, lateral acceleration and brake pressure and usually a pre-charge brake pressure device (e.g. active brake booster). Corrective brake modulation and reduced engine torque to avoid under or over steer.
1 – 3	2001	X			X		Electronic Stability Program Interactive Vehicle Dynamics - AWD	ESP for All-Wheel-Drive Variants

Phase	Year of implementation	Decrease the speed,	Prepare vehicle to the impact	prepare occupants to the impact	optimise the impact angle	Alert the driver	Feature	Description
2 – 3	2002				X		ESP - Under steer Control Logic (UCL)	ESP with undesteer control logic features a new control program. Apart from countering over steer, the system works effectively in the event of severe under steer or loss of grip of the front wheels. Correction us achieved by reducing engine torque and applying brakes to reduce speed. Control of under steer works on two wheels on one side, or on all four wheels at once according to severity of under steer. As it may involve strong decelerations, the stoplights are illuminated at more than 0.8 m/s^2.
2 – 3	2000					X	Forward Collision Warning (FCW)	A Forward Collision Warning system is designed to warn the driver when there is a risk of a collision with another vehicle, at sufficient distance to allow the driver to avoid, or reduce the effect of, the potential collision. The warning will come in the form of an audible and / or visible indication via a unique human machine interface (e.g. head up display, stereo system, etc.). No tactile indication is planned at this time. These indications are intended to supplement the driver's normal diligence in operating the vehicle, which may be of particular effectiveness in situations with heightened workload (e.g. conversation with a second individual, distraction by roadside events, etc.) without being intrusive to the point of annoyance. These warnings may also reflect varying degrees (probability) of threat and some directionality as well.
2 – 3	2006					X	Forward Collision Warning with Threat Assist HMI	A Forward Collision Warning system is designed to warn the driver when there is a risk of a collision with another vehicle, at sufficient distance to allow the driver to avoid, or reduce the effect of, the potential collision. The warning will come in the form of an audible and / or visible indication via a unique human machine interface (e.g. head up display, stereo system, etc.). No tactile indication is planned at this time. These indications are intended to supplement the driver's normal diligence in operating the vehicle, which may be of particular effectiveness in situations with heightened workload (e.g. conversation with a second individual, distraction by roadside events, etc.) without being intrusive to the point of annoyance. These warnings may also reflect varying degrees (probability) of threat and some directionality as well.
2 - 3	-					X	Intersection Collision Warning	Extension of forward collision warning. Warning if collision in intersection is imminent
2 - 3	2002					X	Lane Change Aid (LCA)	Network of sensors and image cameras around the vehicle provide the driver with a warning if the indicator signal is used whilst the system detects another vehicle in a potentially hazardous situation. Improve driver awareness during intentional or unintentional lane change or merging maneuvers to reduce vehicle-to-vehicle accidents.
2 - 3	2004	(X)				X	Pre-Brake Light Signalling	Using data from a Forward Collision Warning (FCW) / Pre-Crash Sensor (distance, closing speed, deceleration and likelihood of impact), the brake lights can be illuminated before the driver has applied the brakes. Gives warning to other road users that the vehicle is likely to perform an emergency brake.
2 - 3	2005		X				Pre-Crash Body Structure Adaptation	Before an expected accident the bodywork is re-configured to enhance crash performance. Must be reversible in case the driver makes a recovery. Extendable front bumper could be used to increase crush space. (See also 'Compatibility - Bumper Airbag')

Phase	Year of implementation	Decrease the speed,	Prepare vehicle to the impact	prepare occupants to the impact	optimise the impact angle	Alert the driver	Feature	Description
2 - 3	2001	X					Pre-Crash Braking	Using data from an Forward Collision Warning (FCW) / Pre-Crash Sensor (distance, closing speed, deceleration and likelihood of impact), the brakes are locked on if an obstruction is detected 10 meters in front of the vehicle and speed is such that an impact is inevitable. Collision Mitigation: A Collision Mitigation system will make an autonomous brake application when it determines a collision with another vehicle is unavoidable in both high speed and low speed environments. The CM function assumes the driver has ultimate authority over vehicle control and will not interfere with any potential evasive maneuvers intended by the driver. Since the distance required to brake for avoidance usually exceeds the distance required to steer for avoidance, the system is limited to mitigation by braking only. This function can also include a panic brake assist function if a driver has applied an inadequate level of braking to avoid a collision or hesitates in full application.
2 - 3	2002		X →	X			Pre-Crash Interior Re-configuration	Before an expected accident the interior is re-configured to enhance occupant safety. Must be reversible in case the driver makes a recovery. The ability to move the power seats into an optimal crash position, close the sunroof, and even deploy the interior door panels to protect occupants during a side impact.
2 - 3	2003		X →	X			Pre-Crash Restraints Deployment	Use of pre-crash sensing technology to improve the response of restraints through raising their state of readiness prior to deployment. Use of Electric Seat Belt retractors would give resetable Pre-tensioning. May make meeting legislation easier. (See also Pre-Crash Sensing). Before an expected accident restraint devices are deployed to enhance occupant safety. Must be reversible in case the driver makes a recovery. An electric seat belt pretensioner that tensions the belt before impact, or a deployable knee protector are possibilities.
2 - 3	2001	X	X X →	X			Pre-Crash Sensing (PCS)	Anticipatory sensing in pre-crash phase. Enabler for refined active and passive safety systems. Use of pre-crash sensing technology to improve the response of restraints through raising their state of readiness prior to deployment. May make meeting legislation easier. Using data from an Forward Collision Warning (FCW) / Pre-Crash Sensor (distance, closing speed, deceleration and likelihood of impact), the brakes are locked on if an obstruction is detected 10 meters in front of the vehicle and speed is such that an impact is inevitable. Through the use of pre-crash microwave sensor, pedestrians can be detected before impact, and counter measures such as deployable bonnet initiated sooner, reducing pedestrian injuries.
2 - 3	2003			X			Pre-Crash Sensing (PCS) - Closing Velocity (CV) Sensing	Closing velocity sensing by means of short range radar or lidar to improve robustness of impact sensing and improve deployment times of restraining devices to improve overall performance of the restraints system.
2 - 3	2004		X				Pre-Crash Vehicle Compatibility	Before an expected accident the ride height is adjusted, either upward or downward, using the Active Body Control (air suspension) system, to ensure crash compatibility. Will require Phase 3 of Crash Detection (Image processing) to determine the size of the target vehicle. (See also 'Compatibility - Nose Dipping')
2 - 3	2000		X				Rollover Prevention - Non-active	Active use of the ESP to prevent rollovers. An additional roll sensor is needed to identify risks for rollovers. When needed, the ESP system will apply the brakes to stabilize the vehicle. Upgrade to ESP software, use tires/brakes to slide.

Phase	Year of implementation	Decrease the speed,	Prepare vehicle to the impact	prepare occupants to the impact	optimise the impact angle	Alert the driver	Feature	Description
2 - 3	2002		X				Rollover Protection - Convertible	The addition of a reliable sensor to detect a vehicle rollover situation can be used to deploy restraint systems appropriately. Typically, the deployable roll bars are activated.
2 - 3	2004		X				Rollover Protection - Convertible	Convertible rollover protection with lamella bag & ropes development, including reinforced A-ring structure.
1 to 4	2006		X		X		Steer by Wire	Mechanically decouple steering wheel and tires. No physical connection between the steering wheel and the rack. The steering wheel provides inputs to an electric motor on the rack. Requires 42 volts with 14 volts back-up system for redundancy. Safety and packaging benefit from elimination of steering column. Safety and dynamic benefit from ability to adjust wheel angle independently from driver for ESP/IVD, Lane Keeping, Collision Avoidance.

5.3. Conclusions

As discussed, all the systems will be nearly available on cars. The acceptance of these systems by the users is also an important point in our study. There are a lot of studies on this subject. Nevertheless, in the field of action of our group, this electronic complex system works a few seconds (or even a few milliseconds) before a crash. In that case, the driver would not have the time to react or understand what is happening. But in any case we think that the driver must keep the hand on techniques and must be able to overrule the electronics systems.

6. APPROACH TO IDENTIFY POTENTIAL EFFECTS OF SELECTED SYSTEMS ON REDUCING INJURIES

6.1. Introduction

In the following, out of the plethora of systems described in the previous chapter, those systems that are of special interest with regard to frontal and pedestrian impacts will be selected. 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 system will be defined.

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

6.2. Systems of special interest

Out of the multitude of systems described in chapter 5 of this report, 17 systems were chosen that are of special interest with regard to frontal and pedestrian impacts. Out of these 17 systems, the representatives for each country in EEVC WG19 chose 5 systems each for further analysis. The systems that were most frequently nominated are the following:

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

From this list, two systems were excluded because their main activity is not located within phase 3 of the ACEA safety model. A Brake Assist based on Forward Collision Warning is effective mainly in the Danger Phase (Phase 2 of the ACEA model) and a Deployable Bonnet with Contact Sensor is a secondary safety system working in the Crash Phase (Phase 4 of the ACEA model). The remaining 4 systems will be described in the following section.

6.3. 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, there is no need to define generic systems.

6.3.1. Pre-Crash Braking using Forward Collision Warning

Using data from a Forward Collision Warning, the brakes are locked on if an obstacle is detected 10 meter in front of the vehicle 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 function that interferes if the driver has applied an insufficient level of braking force (→6.3.2).

6.3.2. Brake Assist

The brake assist function helps the driver to fully exploit the braking potential of his vehicle. The rate of the brake pedal operation is monitored and used to detect an emergency braking situation. If the pressure applied by the driver on the brake pedal is not sufficient to achieve maximum braking pressure, the system automatically increases braking pressure until the driver releases the brake pedal.

6.3.3. Deployable Bonnet with Pre-Crash Sensor

By the use of microwave pre-crash sensors, pedestrians can be detected before the impact and countermeasures like the deployable bonnet can be initiated earlier, thus reducing pedestrian injuries. To improve pedestrian head impact protection, pyrotechnic devices lift the hood at the rear edge to give the required bonnet clearance.

6.3.4. 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 reset such that they do not need to be exchanged after activation.

6.4. Relevant accident conditions

The four selected systems all are active mainly 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 between the selected systems concerning the relevant accident conditions.

6.4.1. Pre-Crash Braking using Forward Collision Warning

For the Pre-Crash Braking System, the following accident conditions are relevant:

- Frontal collisions.

6.4.2. Brake Assist

For the Brake Assist, the following accident conditions are relevant:

- Mainly effective for frontal collisions
- All accidents where the driver did not brake must be excluded.
- Friction coefficient $\mu > 0{,}5$.

6.4.3. Deployable Bonnet with Pre-Crash Sensor

For the Deployable Bonnet, the following accident conditions are relevant:

- 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.)
- Total impact
- Frontal collisions.

6.4.4. Pre-Crash Sensing with Electronic Belt Pretensioner

For the Electronic Belt Pretensioner, the following accident conditions are relevant:

- Mainly frontal collisions and roll-over
- Seatbelt use is presumed.

6.5. Relevant parameters for a database analysis

If the potential safety effect of the systems described above shall be estimated, it is necessary to analyse in-depth databases. The more detailed the database is, the more precise the estimation can be. Furthermore, the database should be representative to allow for an extrapolation on national statistics. At least the following parameters should be included:

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

Estimating the potential effects of safety systems, extremely severe accidents should be excluded, because it can be assumed that neither system would be of a remarkable benefit in such accidents.

6.6. Effectiveness study for one selected system

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

As a suitable database for this study, the GIDAS ('German In-Depth Accident Study') database was identified. Although the primary focus of this database is on secondary safety, it contains detailed information about accident causation and especially, it provides the information that had been identified as necessary in section 6.5.

6.6.1. Determination of the Dataset

In a first step, the relevant dataset for the further analysis has to be determined. For the years 1991 to 2003, the GIDAS database contains 1091 accidents with injured pedestrians. These cases are divided according to the severity of the injuries: 535 cases with minor injuries (MAIS 1), 498 cases with serious injuries (MAIS 2-4) and 58 cases with fatalities (MAIS 5-6). From these accidents, only those are selected where the pedestrians were hit by a car with frontal impact (Table 22). In a total, the dataset for calculation of the safety benefit of the brake assist system contains 702 cases.

Table 22: Number of relevant accidents in the GIDAS database; years 1991-2003; with the following 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

6.6.2. Computation of injury risk functions

On the basis of the selected dataset of pedestrian accidents, the relationship between collision speed and injury severity is analysed and injury risk functions are computed (Figure 22). Such an analysis shows that the probability for a pedestrian to be fatally injured by a car (MAIS 5+) is significantly increasing at collision speeds higher than 40-50 km/h (Bamberg & Zellmer, 1994).

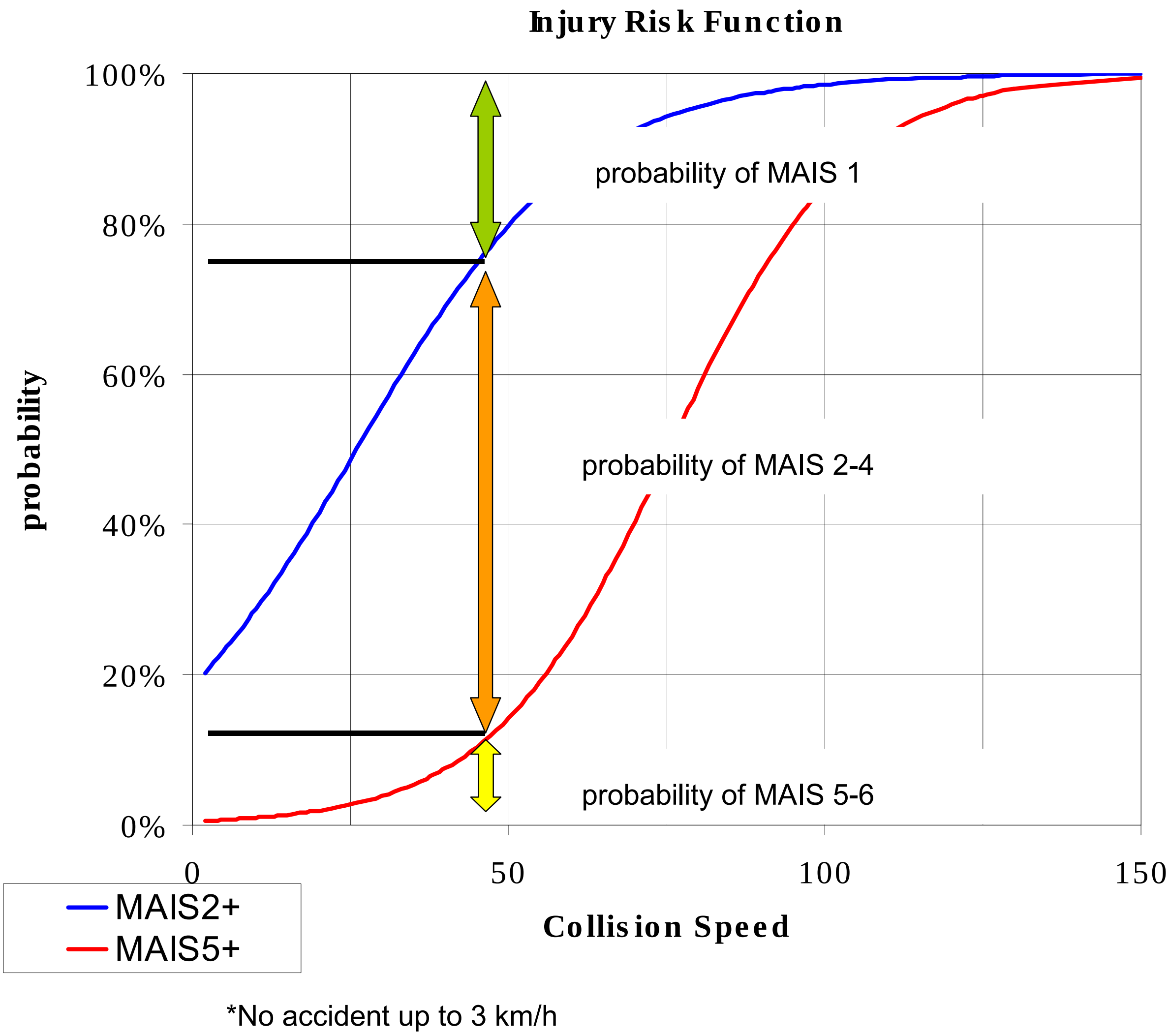


Figure 22: Schematic representation of injury risk functions.

6.6.3. <u>Case-by-case analysis of the safety effects</u>

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

- 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.
- That in these cases, the available adhesion would have provided for a barking deceleration rate of 8.6 m/s^2.
- The accidents took place on clean, smooth, dry high friction surfaces.

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 (Figure 23). This computation of the shift in collision speed and of the resulting reduction of injury probability is done for each single accident and then the values of reduction are 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.

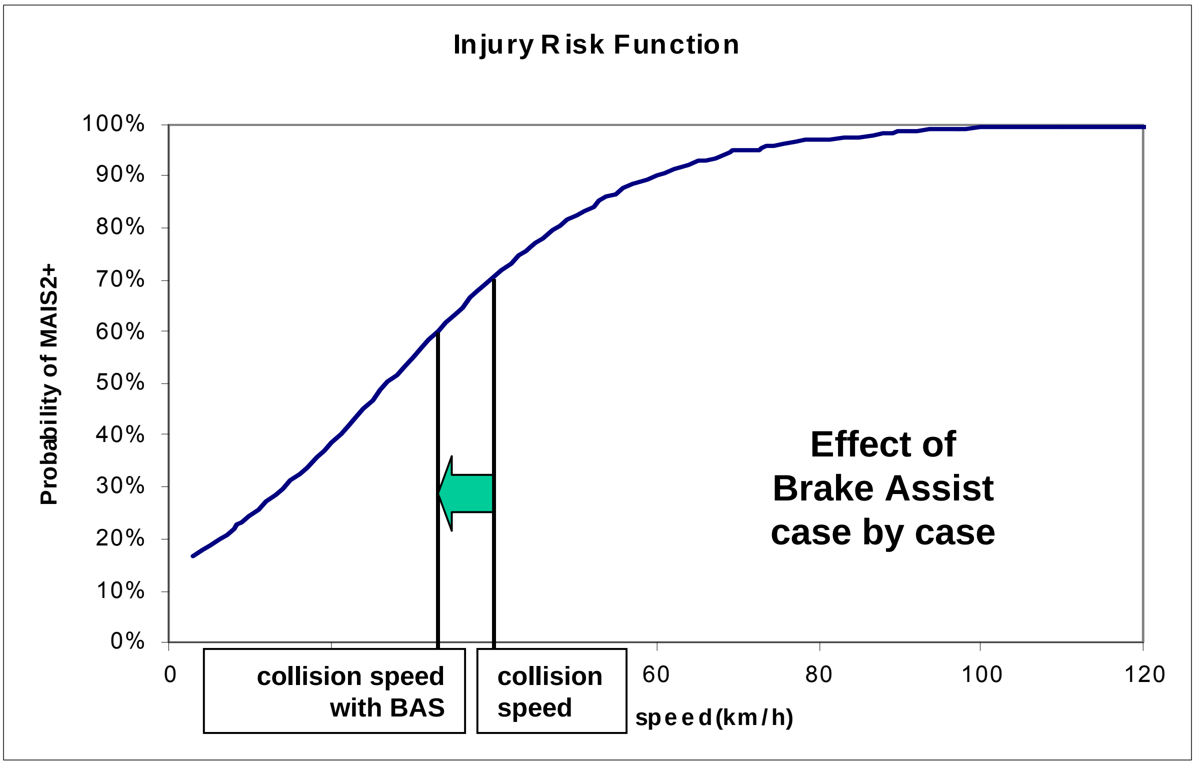
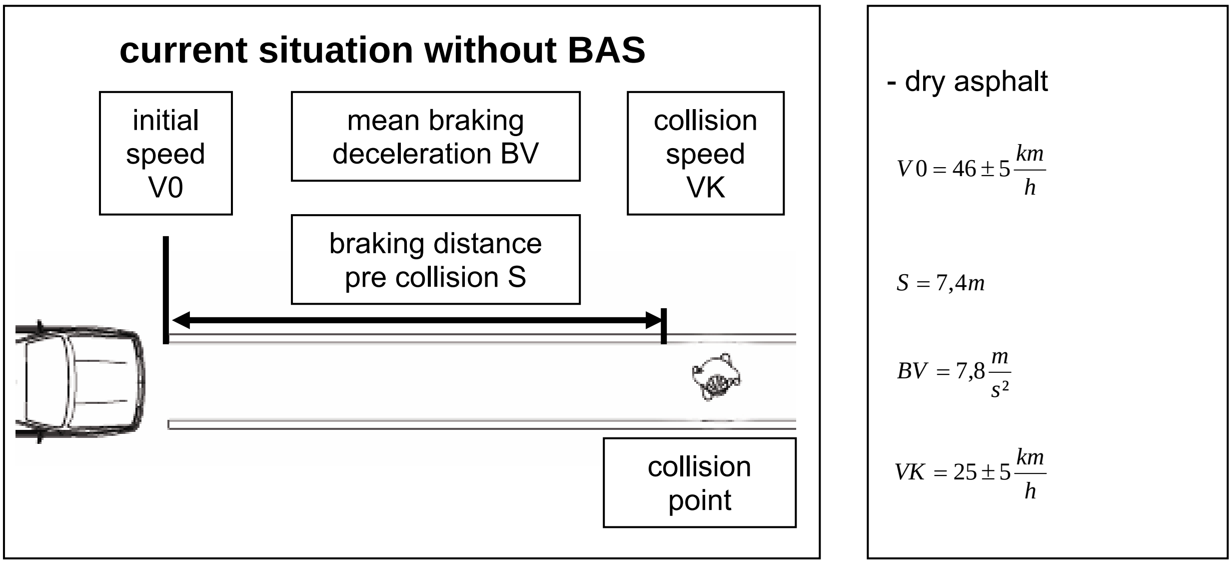


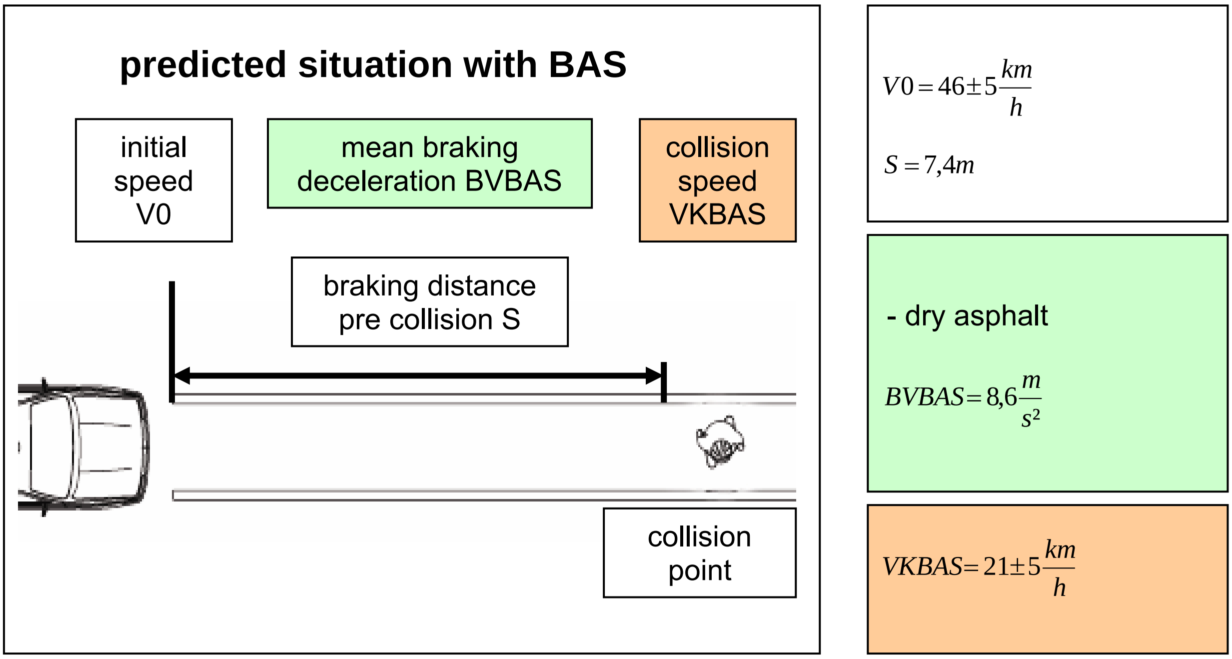
Figure 23: Schematic representation of the effect of the Brake Assist.

6.6.4. 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 brake assist is very complex and time consuming. Furthermore, specific data are necessary. With regard to the example of the brake assist, for each accident, the collision speed, the braking distance, the maximum deceleration and the injury severity of the pedestrian must be known. This means 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 a more unspecific estimation of the safety benefits. Because the safety effect of the brake assist is computed for each relevant accident on the basis of data from the accident reconstruction, this allows for a very precise estimation of the safety benefit provided that the in-depth accident database is representative.





6.7. FINDINGS AND DISCUSSION

The calculated benefit in this study addresses fatal and seriously injured pedestrian (MAIS 2+). The potential savings are the differences between the predicted numbers of casualties affected by implementation of safety measures and the casualties in the current real world situation. It is notable that the potential effectiveness of safety measures is referring to all pedestrian accidents.

The result shows that BAS as a single countermeasure is able to decrease pedestrian casualties. In the GIDAS dataset 56 cases (7.9%) out of 702 could completely avoid the collision by the implementation of a BAS (BAS collision speed = 0). The injury reducing effect on MAIS 2+ injured pedestrian includes 81 cases (11.5%).

In the past, achievements in increasing secondary safety of passenger cars to better protect occupants and vulnerable road users are remarkable. However, several publications indicated that further improvement of secondary safety would not deliver similar results than in the past. Especially with respect to vulnerable road users physical laws might limit the effect of secondary safety countermeasures. The latest developments in electronic and sensor technology are promising a successful contribution of primary safety systems. Several primary safety systems 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 potential benefit from such systems. The example of BAS shows a positive effect to reduce the consequences of pedestrian accidents by completely leaving out the additional benefit of BAS in other accident situations. The importance of primary safety will further increase with technical progress in future.

7. RECOMMENDATION TO ADAPT REGULATIONS OR DEVELOP NEW ONES

7.1. Applicable directives and regulations

7.1.1. Background

- The UN-ECE (United Nations Economic Commission for Europe) regulations: In 1958, in Geneva, a mutual recognition framework was set-up aimed at developing international rules for the approval of certain components intended for the motor vehicle sector. Since that period 115 UN/ECE Regulations have been adopted.

- The framework Directive 70/156/EEC: The so-called Framework Directive was set-up in February 1970. Since then more than 50 directives were adopted. Council Directive 92/53/EEC of 18 June 1992 amended Directive 70/156/EEC by introducing mandatory Community type-approval for passenger cars from 1 January 1996 in respect of new types placed on the market, and from 1 January 1998 for passenger cars covered by earlier national type-approval. Nowadays, both UN-ECE regulations and EC directives are in force within Europe. Over 45 UN-ECE regulations are equivalent to EC directives. The so-called European Whole Vehicle Type Approval (EWVTA) is based on 54 systems and components directives.

7.1.2. Existing legislation

In table 23, the list of the directives for motor vehicles and their equivalent UN-ECE regulations is provided in a chronological order. The regulations/directives related to primary and secondary safety systems are highlighted in yellow and green respectively.

	Item/ title	**Base EC directives**	**Adaptations & Amendments**	**UN-ECE regulations**
0	Framework directive	70/156/EEC *		
1	**Noise/** Permissible sound level & the exhaust system	70/157/EEC *	73/350/EEC 77/212/EEC 92/97/EEC 1999/101/EC	ECE R51.02
2	**Exhaust emission/** Measures to be	70/220/EEC *	77/102/EEC 78/665/EEC	ECE R 83.03

	taken against air pollution by emissions		2001/1/EC	
3	**Tank protection/** Liquid fuel tank & rear protective device	70/221/EEC *	2000/8/EC	ECE R 34.01 ECE R 67.00 (LPG) ECE R110.00 (CNG)
4	**Rear license plate/** Space for mounting and the fixing of rear registration plates	70/222/EEC *		
5	**Steering Equipment**	70/311/EEC *	92/62/EEC 1999/7/EC	ECE R79.01
6	**Doors**	70/387/EEC *	98/90/EC 2001/31/EC	
7	**Horns installation** Audible warning devices	70/388/EEC *		
8	**Rear view mirrors**	71/127/EEC *	79/795/EEC 85/205/EEC 86/562/EEC 88/321/EEC	ECE R46.01
9	**Braking devices**	71/320/EEC *	74/132/EEC 75/524/EEC 79/489/EEC 85/647/EEC 88/194/EEC 91/422/EEC 98/12/EC 2002/78/EC	ECE R13.09 ECE R13 H.00
10	**Radio interference** (electromagnetic compatibility)	72/245/EEC *	89/491/EEC 95/54/EC	ECE R10.02
11	**Diesel smoke emission** Measures to be taken against the emission of pollutants from diesel engines	72/306/EEC *	89/491/EEC 97/20/EC	ECE R24.03
12	**Interior fittings** Interior parts other than the interior rear-view mirrors, layout of controls, the roof or sliding roof, the backrest	74/60/EEC*	78/632/EEC 2000/4/EC	ECE R21.01

	and rear part of seats			
13	**Anti-theft device** Devices to prevent the unauthorised use of motor vehicles	74/61/EEC*	95/56/EC	ECE R18.02 ECE R97.00
14	**Safety Steering** The behaviour of the steering mechanism in the event of an impact	74/297/EEC *	91/662/EEC	ECE R12.03
15	**Seats, anchorage and head restraints**	74/408/EEC *	81/577/EEC 96/37/EC	ECE R17.06 ECE R80.01
16	**External projection**	74/483/EEC *	79/488/EEC	ECE R26.02
17	**Reverse gear & Speedometer**	75/443/EEC *	97/39/EC	ECE R39.00
18	**Statutory plates and inscriptions**	76/114/EEC *	78/507/EEC	
19	**Safety belts anchorage**	76/115/EEC *	81/575/EEC 82/318/EEC 90/629/EEC 96/38/EC	ECE R14.04
20	**Installation of lighting and light-signalling devices**	76/756/EEC *	82/244/EEC 83/276/EEC 84/8/EEC 89/278/EEC 91/663/EEC 97/28/EC	ECE R48.01
21	**Rear reflex reflector**	76/757/EEC *	97/29/EC	ECE R03.02
22	**Position, stop, end outline marker lamps** End-outline marker lamps, front position (side) lamps, rear position (side) lamps, stop lamps, daytime running lamps and side marker lamps for motor vehicles and their trailers	76/758/EEC *	89/516/EEC 97/30/EC	ECE R07.02 ECE R87.00
23	**Direction indicators lamps**	76/759/EEC *	89/277/EEC 1999/15/EC	ECE R06.01
24	**Rear registration**	76/760/EEC	97/31/EC	ECE R04.00

	plate lamps	*		
25	**Headlamps , bulbs** headlamps which function as main-beam and/or dipped-beam headlamps and incandescent electric filament lamps for such headlamps	76/761/EEC *	89/517/EEC 1999/17/EC	ECE R01.01 ECE R05.02 ECE R08.04 ECE R20.02 ECE R31.02 ECE R37.03 ECE R98.00 ECE R99.00
26	**Fog lights** Front fog lamps for motor vehicles and filament lamps for such lamps	76/762/EEC *	1999/18/EC	ECE R19.02
27	**Towing device**	77/389/EEC *	96/64/EC	
28	**Rear fog lights**	77/538/EEC *	89/518/EEC 1999/14/EC	ECE R38.00
29	**Reversing lights**	77/539/EEC *	97/32/EC	ECE R23.00
30	**Parking lamps**	77/540/EEC *	1999/16/EC	ECE R77.00
31	**Seat belt installation**	77/541/EEC *	81/576/EEC 82/319/EEC 90/628/EEC 96/36/EC 2000/3/EC	ECE R16.04 ECE R44.03
32	**Field of vision**	77/649/EEC *	81/643/EEC 88/366/EEC 90/630/EEC	
33	**Identification of controls, tell-tales and indicators**	78/316/EEC *	93/91/EEC 94/53/EC	
34	**Defroster & demister**	78/317/EEC *		
35	**Wiper & washer**	78/318/EEC*	94/68/EC	
36	**Heating system**	78/548/EEC [5]	2001/56/EC*	
37	**Wheel guards**	78/549/EEC *	94/78/EC	
38	**Head restraints**	78/932/EEC *		ECE R17.06 ECE R25.04
39	**Fuel consumption**	80/1268/EEC*	89/491/EEC 93/116/EC	ECE R84 ECE R101.00

[5] Repealed by directive 2001/56/EC

			1999/100/EC	
40	**Engine power**	80/1269/EEC*	88/195/EEC 89/491/EEC 97/21/EC 1999/99/EC	ECE-85.00
41	**Emissions** Measures to be taken against the emission of gaseous and particulate pollutants from compression-ignition engines, and the emission of gaseous pollutants from positive-ignition engines fuelled with natural gas or liquefied petroleum	88/77/EEC*	91/542/EEC 96/1/EC 1999/96/EC 2001/27/EC	ECE-49.02
42	**Lateral protection of Categories: N2, N3 O3, O4**	89/297/EEC		ECE R73
43	**Spray-suppression systems categories N and O**	91/226/EEC		
44	**Mass & dimensions category M1 (cars)**	92/21/EEC*	95/48/EC	
45	**Safety glazing**	92/22/EEC*	2001/92/EC	
46	**Tyres**	92/23/EEC*	2001/43/CE	ECE R30.02 ECE R54.00
47	**Speed limitation devices** **N2, M3 >10 Tons N3**	92/24/EEC		
48	**External projections** forward of the cab's rear panel of motor vehicles of **category N**	92/114/EEC		
49	**Mechanical coupling devices**	94/20/EC*		
50	**Burning behaviour of**	95/28/EC		

	materials used in interior construction CATEGORY M3 carrying more than 22 passengers not being designed for standing passengers and urban use (city buses).			
51	**Side-impact protection**	96/27/EC*		
52	**Frontal-impact protection**	96/79/EC*	1999/98/EC	
53	**Masses & dimensions Categories N, M2 M3**	97/27/EC	2001/85/EC 2003/19/EC	
54	**Dangerous goods Categories N and O**	98/91/EC		
55	Speed limiters	92/24		
56	Front underrun protective devices (FUP	2000/40/EC		
57	Buses and coaches[6]	2001/85/EC		
58	Pedestrian safety	2003/102/EC		

Table 23. Directives for motor vehicles and their equivalent UN-ECE regulations

It should be mentioned that Article 8 of the Council Directive No 92/53/EEC (amendment of Directive 70/156/EEC) includes exemptions for new technologies or concepts incompatible with separate directives. In this case, the Member State should provide a report containing:

- The reason why the technologies prevent the vehicle or component from complying with the requirements of the relevant(s) Directive(s)
- A description of the areas of safety and environmental protection concerned and the measures taken

[6] Contains requirements related to both primary and secondary safety

- A description of the tests and their results that demonstrate at least an equivalent level of safety and environmental protection as is provided by the requirements of one or more of the relevant separate Directives
- Proposals for amendments to the relevant separate Directives or new separate Directive(s) as applicable.

7.1.3. Future legislation

- Further improvement of pedestrian safety measures is foreseen by a proposal for a Directive relating to the use of frontal protection systems.

- The commission adopted a proposal for a directive, which will recast the legislative provisions of the framework directive 70/156/EEC. Furthermore the new directives include a set of specific measures for commercial vehicles. Chapter VIII is dedicated to new technologies or concepts incompatible with separate directives.

- Other EEVC working groups are continuously working on issues related to regulations. A new EEVC Working group will be created on the use of virtual testing results in regulations.

7.2. Effects of Primary/Secondary safety interaction on regulations

7.2.1. Existing work

The influence of Intelligent Vehicle Safety Systems has been tackled in some EC funded projects. Two projects were found that were specifically relevant to the work of EEVC WG19: The CHAMELEON project and the RESPONSE (1 and 2) project. The main results from these projects are taken into account in this chapter.

The EC funded project RESPONSE (1 and 2) faced the problem of the influence of Advanced Driver Assistance Systems (ADAS) on existing regulations. The main results are related to primary safety systems. The term ADAS in RESPONSE is equivalent to IVS.

In the EC funded project Chameleon a report describing some legal issues was also delivered. The main reasons which can prevent technologies related to the interaction of primary and secondary safety systems is the use of information from remote sensor technology (e.g. radar, laser, artificial vision) to predict an upcoming crash. The system dependability issue is tackled. The system dependability is defined as the ability of the system to work correctly, giving alarms at the right moment at a stated level of confidence, in spite of the occurrence of potential faults. It is stated in the Chameleon project that 100% level of confidence is impossible to achieve. In this project some strategies which can be used to fulfil the amendment related to exemptions (Article 8 of the Council Directive No 92/53/EEC) are provided. For instance some elements on the description of the areas of safety and environmental protection concerned and the measures to be taken. In this project reference is also made to methodologies such as Fault Tree Analysis (FTA) and Failure Mode and Effect Analysis (FMEA). The potential fault causes are provided together with crash alarm confidence levels.

7.2.2. EEVC WG 19 methodology to define relevant directives

The results obtained in the Chameleon project are particularly important for EEVC WG19 work because they cover the same accident traffic phase (Unavoidable accident phase). The main issue described in the work and related to legislation is that of crash alarm confidence level. One solution to tackle crash alarm fault cause would be to remove the crash alarm fault cause (use very accurate sensors). The second solution would be to build a highly dependable system. In the Chameleon project some indications on these solutions were provided. However not all the aspects were covered. The missing points are mentioned below:

- ·The crash alarm confidence levels were intended to be used for the systems developed in the frame of the project. A generic theoretical basis on how these levels can be obtained should be provided.
- Establishing the need for amendments to the Directives was not carried out in the frame of the Chameleon project.

In this chapter, the first task will be to define the relevant existing directives for EEVC working group 19. When a directive is defined relevant, the following steps are taken: the possible issues stated in existing work will be mentioned; Furthermore EEVC WG19 experts' opinion will be added. The methodology to define these directives is described below:

A directive is declared relevant to the EEVC WG 19 group once it fits with the following criteria:

1. The directive is related to injury assessment, occupant protection and/or pedestrian protection.

2. The directive includes physical parameters operational in phase 3 that can affect the crash severity.

To facilitate this study a search of the following keywords within the different directives is used *impact, speed, braking, steering, injury, protection and pedestrian.* The parameters mentioned in the second criterion are described in more detail below. Possible effects of the upcoming technology on these regulations will be mentioned together with a list of all the relevant directives for EEVC WG19.

7.2.3. Directives related to injury assessment

The directives for frontal impact, side impact and for pedestrian protection cover the vehicle crash severity assessment. The list of directives is given below

	Item/ title	Base EC directives	Adaptations & Amendments	UN-ECE regulations
1	**Tank protection/** Liquid fuel tank & rear protective device	70/221/EEC *	2000/8/EC	ECE R 34.01 ECE R 67.00 (LPG) ECE R110.00 (CNG)
2	**Steering Equipment**	70/311/EEC *	92/62/EEC 1999/7/EC	ECE R79.01
3	**Doors**	70/387/EEC *	98/90/EC 2001/31/EC	
4	**Interior fittings** Interior parts other than the interior rear-view mirrors, layout of controls, the roof or sliding roof, the backrest and rear part of seats	74/60/EEC*	78/632/EEC 2000/4/EC	ECE R21.01
5	**Safety Steering** The behaviour of the steering mechanism in the event of an impact	74/297/EEC *	91/662/EEC	ECE R12.03
6	**Seats, anchorage and head restraints**	74/408/EEC *	81/577/EEC 96/37/EC	ECE R17.06 ECE R80.01
7	**External projection**	74/483/EEC *	79/488/EEC	ECE R26.02
8	**Reverse gear & Speedometer**	75/443/EEC *	97/39/EC	ECE R39.00
9	**Statutory plates and inscriptions**	76/114/EEC *	78/507/EEC	
10	**Safety belts anchorage**	76/115/EEC *	81/575/EEC 82/318/EEC 90/629/EEC 96/38/EC	ECE R14.04
11	**Towing device**	77/389/EEC *	96/64/EC	
12	**Seat belt installation**	77/541/EEC *	81/576/EEC 82/319/EEC	ECE R16.04 ECE R44.03

			90/628/EEC 96/36/EC 2000/3/EC	
13	**Head restraints**	78/932/EEC *		ECE R17.06 ECE R25.04
14	**Lateral protection of Categories: N2, N3 O3, O4**	89/297/EEC		ECE R73
15	**Safety glazing**	92/22/EEC*	2001/92/EC	
16	**External projections** forward of the cab's rear panel of motor vehicles of **category N**	92/114/EEC		
17	**Side-impact protection**	96/27/EC*		
18	**Frontal-impact protection**	96/79/EC*	1999/98/EC	
19	Speed limiters	92/24		
20	Front underrun protective devices (FUP)	2000/40/EC		
21	Pedestrian safety	2003/102/E C		

Table 24
Issues not tackled yet

In the Chameleon project no recommendations are provided for the amendment of existing regulations. The focus is on how a car manufacturer can reach existing certification and Type Approval for pre-crash sensing systems. Different methodologies for failure analysis applied to a pre-crash sensing system are proposed (e.g. Failure mode and Effects Analysis FMEA).

The primary safety systems triggered on the basis of a remote sensor (radar, laser, artificial vision systems, etc.) data can, however, cause some ambiguity regarding these directives:

- How should the test defined in the directive 96/79/EC (or in future legislation on pedestrian safety) take into account any safety action deployed before the crash?

- How to define on a strong basis the acceptable confidence levels of false and missing alarms?

An illustration of the upcoming technology is the concept of extendable bumpers triggered before the crash.

7.2.4. Directives related to physical parameters

The physical parameters that could influence the crash severity can be classified in three types

1. Dynamic parameters: examples are relative distance, speed, acceleration and angle between the host vehicle and the obstacle
2. Environmental parameters: e.g. weather conditions, electromagnetism…
3. Human factors parameters: e.g. sight, hearing and touch

7.2.4.1. The relevant directives related to Dynamic parameters

The dynamic parameters that can have a direct influence on the crash severity are:

- Acceleration
- Braking
- Steering

All these actions can be taken in the unavoidable accident phase. The directives including the above mentioned parameters are listed below

1. **Steering Equipment 70/311/EEC**
2. **Braking devices 71/320/EEC**

Main issues

In the EC funded project RESPONSE some important points on the existing regulations are highlighted:

- *If the active brake and steering systems cannot be overruled there will be a conflict to the requirements of directive **71/320/EEC** for brakes and **70/311/EEC** for steering systems.*
- Directive **71/320/EEC** states that "the driver can, at any time, increase or reduce the braking force through action on the control". Furthermore, the definition of automatic braking is given only for the trailer.

ABS and ESP can also improve injury reduction. Both technologies are active in phase 2 but also in phase 3 and are then relevant to the work of EEVC WG 19. Legislation is available for ABS, however no plans are foreseen for ESP. Note that automatic steering is not mentioned in the directives. Steer by wire could enable engineers to find solutions to allow the steering wheel to be retracted in case of a crash and it could be relevant for EEVC WG 19 work.

7.2.4.2. The relevant directives related to environmental parameters

The environmental parameters are :

- ·Weather conditions (rain, fog, frost, snow, …)
- Electromagnetism

The directive 72/245/EEC "Radio interference (electromagnetic compatibility) of vehicles" is concerned by this item on sensor technology.

Main issues

In the chameleon project it is highlighted that the system can not be tested in all weather and environmental conditions.

The sensor technology is a key factor for the integration of primary and secondary safety. The different types of sensors used are based on ultra-sound, radar, infrared and vision. The 24 GHz radar developed for short range applications (relevant in pre-crash sensing) is not currently permitted in the EU (an allocation was released in the US in April 2002). The main concern is the interference with other applications for which this frequency is allocated (radio astronomy)

The e-Safety working group already mentioned two recommendations:

- *Take the necessary actions for removing regulatory barriers to the use of the 24 GHz spectrum for short-range radar in Europe. This will include issuing an EU liaison statement to ECC and to national administrations requesting international regulations through the ITU-R concerning UWB Radar Sensors.*
- *Undertake the standardisation in ETSI for the 24GHz UWB Radar by implementing the EU Mandate for ETSI and completing and publishing the relevant standard.*

7.2.4.3. The relevant directives related to Human factors parameters

Three of the five human senses can receive signals triggering actions to avoid/mitigate the crash: Sight, Hearing, and Touch

- Sight
  - Lights and mirrors are primary safety systems affecting human vision
  - Cameras implemented in the car will improve vision but can also distract the driver
- Hearing
  - Horns are primary safety systems influencing the driver behaviour by warning him of danger.

-Audible signals sent electronically is a possible upcoming technology

- Touch

  - The existing mechanical link between the tyres and the wheel allow the driver to get a certain feed back on the manoeuvrability due to the road state (ice, asphalt etc…) and speed.
  - Lane keeping systems generate vibrations artificially when the driver passes over a lane marking.

All actual developed systems related to human factors parameters are relevant in the phase 2 and are, therefore, beyond the scope of WG19.

7.3. Conclusions

1. Two European Funded projects tackled some aspects of the current EEVC WG19 work (RESPONSE and Chameleon project). Their position was taken into account and reported in this chapter. In this report, a number of relevant directives 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.

The main issue related to legislation is the definition of crash alarm confidence level which has a direct impact on safety aspects. A summary on the aspects, which can result to the non fulfilment of existing directives or to a need of new directives are listed below:

1. Need of new frequency allocation due to the introduction of remote sensor technology
2. Lack of generic guidelines for the evaluation of safety devices triggered before the impact (need of new methodologies for safety evaluation)

   - The systems can not be tested in all environmental and weather conditions (from chameleon project)
   - Need of a strong basis to define acceptable confidence levels for false and missing alarms?
   - Fault tolerance
   - …

3. Automatic braking is not defined for M1 vehicles (From Response project)
4. Automatic steering is not defined
5. ESP systems were defined as relevant safety systems for WG19 (table 3 of chapter 3) but are not included in legislation.

It was proposed, at least initially, that systems related to the so-called human factors parameters are excluded from EEVCWG19 work because their influence on the crash severity is more evident in the avoidable accident phase.

A list of all relevant directives for EEVC WG 19 is provided in table 25. The list includes the directives mentioned in the previous chapter. When the systems mentioned in chapter 6 can be affected by the directive, the corresponding number is added in the last column

1. Pre-Crash Braking using Forward Collision Warning
2. Brake Assist
3. Deployable Bonnet with Pre-Crash Sensor
4. Pre-Crash Sensing with Electronic Belt Pretensioner

	Item/ title	**Base EC directives**	**Adaptations & Amendments**	**UN-ECE regulations**
1	**Tank protection/** Liquid fuel tank & rear protective device	70/221/EEC *	2000/8/EC	ECE R 34.01 ECE R 67.00 (LPG) ECE R110.00 (CNG)
2	**Steering Equipment**	70/311/EEC *	92/62/EEC 1999/7/EC	ECE R79.01
3	**Doors**	70/387/EEC *	98/90/EC 2001/31/EC	
4	**Interior fittings** Interior parts other than the interior rear-view mirrors, layout of controls, the roof or sliding roof, the backrest and rear part of seats	74/60/EEC*	78/632/EEC 2000/4/EC	ECE R21.01
5	**Safety Steering** The behaviour of the steering mechanism in the event of an impact	74/297/EEC *	91/662/EEC	ECE R12.03
6	**Seats, anchorage and head restraints**	74/408/EEC *	81/577/EEC 96/37/EC	ECE R17.06 ECE R80.01
7	**External projection**	74/483/EEC *	79/488/EEC	ECE R26.02
8	**Reverse gear & Speedometer**	75/443/EEC *	97/39/EC	ECE R39.00
9	**Statutory plates and inscriptions**	76/114/EEC *	78/507/EEC	

10	**Safety belts anchorage**	76/115/EEC *	81/575/EEC 82/318/EEC 90/629/EEC 96/38/EC	ECE R14.04
11	**Towing device**	77/389/EEC *	96/64/EC	
12	**Seat belt installation**	77/541/EEC *	81/576/EEC 82/319/EEC 90/628/EEC 96/36/EC 2000/3/EC	ECE R16.04 ECE R44.03
13	**Head restrains**	78/932/EEC *		ECE R17.06 ECE R25.04
14	**Lateral protection of Categories: N2, N3 O3, O4**	89/297/EEC		ECE R73
15	**Safety glazing**	92/22/EEC*	2001/92/EC	
16	**External projections** forward of the cab's rear panel of motor vehicles of **category N**	92/114/EEC		
17	**Side-impact protection**	96/27/EC*		
18	**Frontal-impact protection**	96/79/EC*	1999/98/EC	
19	Speed limiters	92/24		
20	Front underrun protective devices (FUP	2000/40/EC		
21	Pedestrian safety	2003/102/EC		
22	**Braking devices**	71/320/EEC *	74/132/EEC 75/524/EEC 79/489/EEC 85/647/EEC 88/194/EEC 91/422/EEC 98/12/EC 2002/78/EC	ECE R13.09 ECE R13 H.00
23	**Steering Equipment**	70/311/EEC *	92/62/EEC 1999/7/EC	ECE R79.01

Table 25.

7.4. Recommendations

The Commission intends to promote the development, deployment and use of integrated safety systems, called Intelligent Vehicle Safety Systems. The measures to be taken fall into the following three categories:

1. Promoting Intelligent Vehicle Safety Systems
2. Adapting the Regulatory and Standardisation Provisions and
3. Removing the Societal and Business Obstacles.

To do so the EC initiated the e-safety forum. The second point on regulations is partly tackled by EEVC WG 19 (IVSS operating in phase 3 of ACEA model). The EEVC WG19 should create a link with the relevant WG of the e-safety forum to share expertise and avoid overlapping. Furthermore EEVC WG19 should create links to relevant EC Integrated projects and NoE (e.g. Aprosys, prevent etc…) which are actually tackling some of the issues. The EEVC WG 19 group would in a first step collect all relevant information for synthesis purpose and to define further needs.

With respect to current legislation, amendments could be added regarding automatic braking (automatic braking should be probably allowed by regulations in the non avoidable accident phase).

Generic methodologies for the assessment of Intelligent Vehicle Safety Systems operating in the unavoidable accident phase should be to find out the acceptable confidence levels for false and missing alarms (assuming that a 100% confidence is not possible when using information from remote sensors like radar, laser and cameras.

Find out the possibility of using virtual testing for the systems evaluation in different weather and environmental conditions.

8. RECOMMENDATIONS FOR STUDIES, RESEARCH AND PILOT PROJECT

Among the whole set of systems considered relevant to the PSSIS, see table 3 in chapter “Definition and scope”, the systems shown below may prioritized to define future tasks within WG19:

- Adaptive occupant protection systems:
- Intelligent braking systems
- Pedestrian protection

Only frontal collisions will be considered in the next working phase of EEVC WG 19

Sensor involved

- Sensors to detect features outside of the vehicle.
- Sensors to acquire dynamic variables of the vehicle
- Sensors to determine occupant characteristics

Bearing those issues in mind WG19 will perform the next future actions:

With regard to the sensor systems WG19 will:

- Determine criteria to decide if a collision is unavoidable considering:
  - Type of obstacle: Characteristics (Outer)
  - Closing (relative) speed (Outer)
  - Trajectory (Outer)
- Determine criteria for protection strategy:
  - Occupant characteristics
  - Occupant position
- Determine criteria to demonstrate reliability
  - Effective in what lighting conditions
  - Effective in what weather conditions

Relating to the safety systems WG19 will:

- Determine criteria to evaluate the level of adaptability and effectiveness of the system considering the collision, occupant or opponent characteristics.

Relating to both: sensing and protection systems

- Assessment methodology
- Characteristics and type of test:
  - Physical
  - Virtual/Simulation
- Modifications to be introduced on the existing regulations or new ones

In order to achieve those objectives, the following TOR are proposed for the next 12 months:

- Carry out a thorough study of other results from other projects and/or research activities related to:

    i. Adaptive occupant protective systems
    ii. Intelligent braking systems
    iii. Pedestrian protection

- Definition of the functional and reliability requirements for the sensors and the systems under study.

- Identify methodologies to assess the performance and effectiveness of the systems

- Define research or pilot projects to fulfil the current lack of knowledge and validate the criteria and methodology adopted.

- Carry out a cost/benefit analysis.

All the above mentioned activities will be oriented to the adaptation of existing regulations or the proposal of new ones.

9. CONCLUSIONS

1. 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.

2. The safety models presented in 1.1 show different safety stages covering all driving phases from the normal driving state to the postcollision state. Despite their slight dissimilarity, all 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.

3. 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) 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 the situation of unavoidable collisions.

4. 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. The tables presented in subchapter 3.1 represent the relevance grade, considered by the EEVC WG19, given to the different situations, taking into account different parameters such as the type of vehicle equipped with PSSIS and the opponents, type of collision and type of safety system.

5. 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:
   - a lack of data related to the above-mentioned overlapped zone.
   - all existing databases are not representative for Europe. Some of them are even not representative for a single country.

   It is acknowledged that creating a database that is representative for Europe is beyond the scope of EEVC WG21 (accident studies) but it is hoped that this Working Group can contribute to solving some of these problems.

6. 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. The acceptance of these systems by the users is also an

important point in our study. There are a lot of studies on this subject. Nevertheless, in the field of action of our group, this complex electronic system works in a very short period of time (less than a second) before a crash. In that case, the driver would not have time to react or understand what is happening. In this respect, EEVC WG19 will initially focus its activities on reversible secondary safety systems and all primary safety systems that allow the driver to overrule the action executed by the respective safety system. Nevertheless those other systems that do not allow the driver to overrule the safety actions should be borne in mind during the work. The issues (e.g. liability, system safety etc.) that arise when the system can not be overruled are complex and are also tackled in the frame of other projects (e.g. EC funded RESPONSE project).

7. EEVC WG19 showed the possibility of evaluating the potential effectiveness of primary safety systems that operate in the unavoidable accident zone. The possible effect of Brake Assist Systems (BAS) with regard to fatal and serious pedestrian accidents was calculated as an example case study. The results showed that the system provide substantial benefits in accident avoidance as well as for injury severity reduction. This methodology can be applied to assess safety benefits of some other systems. Others might require a different method and/or database.

8. In this report, a number of relevant directives 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.

9. A summary on the aspects, which can result in non compliance with existing directives or to a need of new directives 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 braking is not defined for M1 vehicles
   - Automatic steering is not defined
   - ESP systems were defined as relevant safety systems for WG19 to consider but are not included in current legislation
   - One issue related to legislation is the definition of crash alarm confidence level. This has a direct impact on safety aspects.
   - Need of standards for system safety (functional safety).

10. Generic methodologies for the assessment of Intelligent Vehicle Safety Systems operating in the unavoidable accident phase should be developed 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.

11. Considering the report and these conclusions the members of WG19 conclude that, in order to achieve their objectives, their activities for the next 24 months should be focussed according to the following TOR:

    1. Carry out a thorough study of other results from other projects and/or research activities related to:
        - Adaptive occupant protective systems
        - Intelligent brake systems
        - Pedestrian protection

    2. Definition of the functional and reliability requirements for the sensors and the systems under study

    3. Identify methodologies to assess the performance and effectiveness of the systems

    4. Define research or pilot projects to fill the current gaps in knowledge and to validate the criteria and methodology adopted

    5. Carry out a cost/benefit analysis

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ANNEX

Feature	Description
ABS - 4 channel & EBD	ABS with channel for each wheel & electronic brake distribution
Accident Data Recorder	Record all relevant vehicle data prior and during impact.
Active Body Control	System to stabilize roll and pitch of the vehicle. Roll and pitch control.
Active Camber Variation	When cornering the camber angle on the outer wheels is adjusted by up to 20 degrees. This system can be used in conjunction with ABC (Active Body Control). Improved grip, stability, cornering speed. Can sustain lateral acceleration as high as 1.28g.
Active Cornering Enhancement (ACE) - Rotary Actuators	-
Active Knee Restraints - Deployable Knee Bolster	Inflatable knee bolster in area of steering column. These airbags emanate from the bottom half of the IP, and restrain the occupant during an impact in a way that contributes towards lower head impact risk.
Active Roll Control	An Electronically controlled hydraulic element placed between the anti-roll bar and front & rear lower control arms, tensions the anti-roll bar to compensate for roll motions, reducing roll angles.
Active Roll Mitigation (Advanced IVD / Yaw Control)	Advanced IVD: A roll rate sensor and new control logic are added to the current generation of IVD/ESP systems to implement Roll Stability Control and to achieve significant improvements over base IVD functionality. Roll Stability Control actively surpresses excessive roll of a vehicle for on-road (non-tripped) and soft-tripped events, which might otherwise result in rollover. Brakes are applied to selected wheel(s) in response to excessive roll. Applied brake forces reduce tire lateral forces and the roll overturning moment to increase roll stability margin. Vehicle roll information is used to improve detection of vehicle side slip tendency, increasing the yaw stability levels achieved by ESP/IVD systems.
Active Roll Stabilization	Active roll control system.
Active Safety - Pedestrian Avoidance	A Pedestrian Avoidance system is designed to make an autonomous brake application when it determines a collision with a pedestrian is imminent in a low speed environment. This function has not been fully defined at this time, but will likely be bundled with the Pedestrian Warning function as well.
Active Safety - Pedestrian Warning	A Pedestrian Warning system is designed to warn the driver when there is a risk of a collision with a pedestrian, at sufficient distance to allow the driver to avoid, or reduce the effect of, the potential collision. Detection ability may also include large animals and bicyclists. Other factors are very similar to the Forward Collision Warning system description.
Active Seat Ramp	Sheet metal inflatable structure based in seat cushion that deploys to contact the pelvis and restrain pelvis and legs including energy dissipation. (See also 'Seat Pan Airbag'). During an impact deploy a bar within the front seats that pushes up inside the front of the seat cushion to counter submarine action.
Active Steering Wheel	Links LDW (Lane Departure Warning) with EAS (Electric Active Steering). If the car is wandering out of its lane, as detected by LDW, a degree of resistance in the steering wheel is provided by EAS to help the driver keep in the lane. Early stages of Collision Avoidance and Autonomous driving.
Active Suspension	Electronically controlled units replace springs & dampers. Counters roll and pitch; improves ride through control of damping.
Active Throttle Pedal	Haptic feedback into throttle to warn of excess speed into corners, built up areas, due to weather, road conditions, or slower traffic ahead. Achieved through inputs from – GPS, Advanced maps database, 'Extended Floating Car' data, ACC radar.
Adaptive Airbag Inflator	Airbag inflator with: - variable output - variable onset - controlled mass flow Occupant, position and crash severity adaptation , optimal use of occupant restraining distance.
Adaptive Airbag Tether	Airbag tether adaptive - pyrotechnic bolt design at tether attachment point.
Adaptive Airbag Venting	Adaptation of the airbag vent size to the occupant and impact. Pyrotechnic bolt design at can vent. Ventilation through airbag can. Occupant, position and crash severity adaptation; optimal use of occupant restraining distance.
Adaptive Cruise Control - Brake to Stop	Adapts vehicle speed to traffic conditions and brakes to a stop
Adaptive Cruise Control - Low Speed	ACC enhanced with a Stop & Go feature extending the operational envelope down to a stop. Will also enable 'car following' at lower speeds. Service brakes used to bring car to a halt, while Electric Park Brake could be used to hold the car to deal with engine stall, or driver exit. To start from stationary will require driver input i.e. pressing resume or the accelerator. Steering angle sensor used to give better path prediction at lower speed. Navigation link will restrict the feature to roads adjudged suitable, i.e. where pedestrians are not expected. The system could run as an extended ACC or as a separate queueing feature, which would require an extra switch.
Adaptive Cruise Control - Obstacle Detection / Front Alert	ACC provides an (audio) warning (chime) if the radar detects a potential forward collision scenario. The warning can be disabled by a button provided to the driver. Intermediate step to Frontal Collision Warning.
Adaptive Cruise Control - Stop & Go (1st Opportunity - Queue Assist) - ACC S&G or QA ACC	A Stop and Go ACC system extends the useful driving scenarios of ACC from the highway environment to more congested traffic scenarios characterized by heavy congestion with a frequent stationary and walking pace following pattern. The technical challenges associated with this increased functionality include addressing stationary objects, precise threat location for cut-in and overlap situations, and indefinite brake holding, as well as intuitive driver interaction regarding transition with standard ACC and driver override at traffic junctions / traffic lights. Adapts vehicle speed to traffic conditions, incl. slow traffic / traffic jam. ACC enhanced with a Stop & Go feature extending the operational envelope down to a stop. Also enables 'car following' at lower speeds. Top level Description - Queue Assist can be engaged as soon as the vehicle is moving (production ACC requires that the driver travels at a minimum speed of 40 KpH). The minimum cruising speed is 10 KpH - Queue Assist works down to zero speed (production ACC only works down to 26 KpH). - QueueAssist will therefore come to a complete stop if required. - Queue Assist reacts to stationary in path targets below a speed threshold as well as moving targets (production ACC only reacts to moving in path targets). - Queue Assist provides FA down to zero speed (production ACC only provides FA at speed above 26 KpH) Queue Assist operation - General operation over 20 mph is as for production ACC - If the vehicle ahead slows to a halt, QA will stop the car and hold it on the service brakes - The driver may press resume to creep forward (3m min) - When the vehicle ahead has moved off, pressing the resume button allows the vehicle to commence and follow mode is automatically entered if appropriate. - To allow for the limited field of view, QA will cancel automatically if target is lost at short range - For use in stop/go traffic on main roads

Feature	Description
Adaptive Cruise Control - Stop & Go (Full Feature) - Urban Cruise Control (UCC)	A Stop and Go ACC system extends the useful driving scenarios of ACC from the highway environment to more congested traffic scenarios characterized by heavy congestion with a frequent stationary and walking pace following pattern. The technical challenges associated with this increased functionality include addressing stationary objects, precise threat location for cut-in and overlap situations, and indefinite brake holding, as well as intuitive driver interaction regarding transition with standard ACC and driver override at traffic junctions / traffic lights. Operation would be similar to Low Speed Adaptive Cruise Control, but with automatic go. An extra short range sensor will allow the system to be used on all roads. The navigation link could be useful to process some targets (e.g. bridges), or to provide advance road curvature information. However this isn't essential.
Adaptive Cruise Control (ACC)	Adaptive cruise control is a comfort and convenience system designed to automatically allow an equipped vehicle to follow another vehicle in a highway environment. ACC will automatically slow to a predetermined headway setting and accelerate to the driver's desired speed, depending on the speed of the vehicle ahead. Today's technology, however, is limited in several respects. The driver is expected to intervene in scenarios where there is a significant difference in the two vehicles speeds and not rely on the ACC's automatic braking. It is also limited in its ability to correctly classify stationary objects and will not initiate braking for stationary objects or oncoming vehicles, and is automatically disabled at low vehicle speeds. Adapts vehicle speed to traffic conditions. Radar is used to detect a preceding car to which a fixed time headway is maintained by adjusting the cruise control speed and applying the brakes.
Adaptive Cruise Control (ACC) - Forward Collision Warning (FCW)	A Forward Collision Warning system is designed to warn the driver when there is a risk of a collision with another vehicle, at sufficient distance to allow the driver to avoid, or reduce the effect of, the potential collision. The warning will come in the form of an audible and / or visible indication via a unique human machine interface (e.g. head up display, stereo system, etc.). No tactile indication is planned at this time. These indications are intended to supplement the driver's normal diligence in operating the vehicle, which may be of particular effectiveness in situations with heightened workload (e.g. conversation with a second individual, distraction by roadside events, etc.) without being intrusive to the point of annoyance. These warnings may also reflect varying degrees (probability) of threat and some directionality as well. Forward (frontal) collision warning for use on highways. Driver warned by means of a coloured flash onto the windscreen. Sensor can detect stationary objects at a longer range allowing a higher performance, and offers a route to collision avoidance. Use of dynamic maps data to filter out spurious sensor information such as road signs and, through greater map accurancy predict the vehicles path from road curvature.
Adaptive Cruise Control (ACC) - Reduced Stopping Distance (RSD)	Utilize data from Adaptive Cruise Control system to reduce stopping distance in emergency brake situations. System combines functionality of brake assist with pre-emptive brake pressure build up and collision mitigation by braking. See also Pre-Crash Braking
Adaptive Damping	System provides optimised ride comfort amd handling performance by real time damping force control. The control logic can be changed between normal and sport modes.
Adaptive Headlamps (AFS) (follow drive direction)	Reactive-AFS: Only uses vehicle speed, steering input and turn signal to infer Driver's directional intent. Input analysis adjust beam pattern(s) and calculates headlamp swivel. Predictive-AFS: Utilizes Reactive-AFS inputs. Adds road geometry sensing inputs & analysis from: - GPS navigation system; or, - Forward road scene sensing/analysis from LDW (Lane Departure Warning) Beam pattern(s) & swiveling based on expanded analysis. Algorithm must allow for loss of predictive capability
Adaptive Headlights (AFS) (Generation II)	Front lighting system adapts to different situations. Examples for low beam: - Country Light (CL): Wider light pattern, esp. opposite site - Bending Light (BL): Light distribution following bends on the road - Adverse Weather Light (AL): Lower glare for meeting vehicles on wet roads - Town Lighting (TL): Short and wide light pattern for town driving
Adaptive Load Limiting Seatbelt Retractor	A seatbelt retractor, which can adapt the load limiting characteristics, based upon the status of any number of inputs, including: - Crash Severity - Occupant Classification (mass) - Occupant Position - Children in the rear seat
Adaptive Pretensioner	Adaptation of the pretensioning forces to occupant biometrics, occupant position and crash severity
Adjustable Lighting System for Switches with Day / Night Mode	-
Advanced Restraints - Stage 1	Consists of dual-stage front airbags, crash severity sensors, belt switches, driver seat track position sensor and passenger seat weight sensor.
Advanced Restraints - Stage 2	Upgrade to achieve a more adaptive system. Variable venting in the airbags to reduce compromises made between belted and unbelted occupants. Variable load limiting seatbelts to optimize belt performance to occupant size. Improved weight sensing on driver and passenger side to allow implementation.
Advisory and Warning for: - Speed Limit - Road Exit - Intersection - Other regulation	-
Alarm - Inclination Sensing	Alarm system enhanced by tow-away sensing based on inclination sensing.
Anti-trap Power Windows	One-shut up power windows with obstacle detection and automatic reversing. Allows safe operation of 'one touch up' windows. Obstacles are detected enabling 'bounce back'.
Audio - Steering Wheel Controls	Steering wheel integrated controls for the In Car Entertainment System
Auto Locking	Vehicle automatically centrally locks when vehicle speed exceeds 7 kph.
Auto Reduced Guard	Prevent activation of double lock or alarm as long as a occupant is in the vehicle. Gives occupants the possibility to escape from vehicle. Adresses the 'forgotten' occupant (child, pet) use case.
Auto Tire Pressure	Automatic adaptation of tire pressure to load and speed
Auto-adjusting Headrestraints & D-rings	Adjust position of headrestraints and D-ring to stature of person. Requires biometric sensing. Uses the occupant sensor to judge the proportions of the occupant, and adjust the powered head rest and seat belts accordingly.
Autolight	Automatically switch light on in tunnels, twilight etc.
Automatic Activation of Hazard Warning	Automatic activation of hazard warning lights under heavy braking. Heavy braking triggers the hazard lights to signal sharp vehicle deceleration.
Automatic Headlamp Leveling	Adjust Headlamp Leveling depending on vehicle load. Required with HID lamps.
Automatic Re-locking	Automatic re-locking of the vehicle if it is accidently unlocked
Automatic Rollover Bar	Normally hidden roll-over bar that automatically deploys when the vehicle starts to roll over.
Automatic Stability Control (ASC)	-
Automatic Stability Control (ASC)	-
Automatic Trunk Release	Automatically release the trunk if an accidently locked occupant (child, pet) is sensed in the trunk. Provides the locked occupant the possibility to escape from the trunk.
Battery Back-up Sounder	Needed for Category I security system. Acoustic alarm is given when alarm horn is manipulated.
Battery Disconnect	Disconnect battery in case of front impact. B+ battery cut-off switch to prevent heat concerns after impact.

Feature	Description
Belt Pretensioner - Rear Seats	Seat belt pretensioner for the rear (outboard) passengers. Provides early restraint and limits belt loads when combined with load limiters.
Belt Tension Reducer	Electrically or mechanically reduce the seatbelt tension.
Beltminder - Driver	Warning issued to driver when driver seat belt is not engaged following ignition on (seat belt buckle switch).
Beltminder - Driver & Front Passenger	Warning issued to driver when front seat belts are not engaged following ignition, on occupied front seats (weight sensing on passenger seat).
Beltminder - Rear Occupancy Sensing	Addition of some sort of occupancy sensing for rear seats to eliminate spurious warnings.
Beltminder - Rear Passenger	
Bi-HID Lamps	Bi-xenon headlamps with xenon bulbs for low and high beams. A shutter that is moved electro-magnetically provides the desired light beam distribution.
Biometric Personal Settings	Personalization of the vehicle based on biometrics of driver (& passengers). Typical systems adjusted based on biometrics are Headrests, D-Rings, Seats, Pedals, Steering Wheel.
Black Ice Detector	As ambient temperature can be above 0 when black ice forms, infra red is used to sense road surface temperature. Can sense a 1 degree change within 0.1 seconds.
'Black Panel' Night-Time Instrument Lighting	Reduced instrument cluster illumination for night-time driving. Only the essential informations are displayed.
Blind Spot Detection (BSD)	A warning (visual and audible) at lane change, when risk for collision with vehicle in adjacent lane is imminent. Radar, optical or similar sensor at both sides of car senses the presence of another vehicle. Use sensors or cameras to detect vehicles or obstacles in the rear or side of the vehicle.
Brake Assist (BA)	The rate of brake pedal application by the driver is monitored and used to detect an emergency braking situation. If the driver applied pedal force/travel is insufficient to provide full braking, the system will automatically increase the brake pressure.
Brake Assist with Forward Collision Warning (Collision Mitigation by Braking - CMbB)	A Collision Mitigation system will make an autonomous brake application when it determines a collision with another vehicle is unavoidable in both high speed and low speed environments. The CM function assumes the driver has ultimate authority over vehicle control and will not interfere with any potential evasive maneuvers intended by the driver. Since the distance required to brake for avoidance usually exceeds the distance required to steer for avoidance, the system is limited to mitigation by braking only. This function can also include a panic brake assist function if a driver has applied an inadequate level of braking to avoid a collision or hesitates in full application. Using date from an Forward Collision Warning sensor (distance, closing speed, deceleration, likelihood of impact), the brake assist system can calculate the exact level of braking required and apply it. Early form of collision avoidance that requires driver confirmation (through hard and sudden brake application). A Forward Collision Warning system is designed to warn the driver when there is a risk of a collision with another vehicle, at sufficient distance to allow the driver to avoid, or reduce the effect of, the potential collision. The warning will come in the form of an audible and / or visible indication via a unique human machine interface (e.g. head up display, stereo system, etc.). No tactile indication is planned at this time. These indications are intended to supplement the driver's normal diligence in operating the vehicle, which may be of particular effectiveness in situations with heightened workload (e.g. conversation with a second individual, distraction by roadside events, etc.) without being intrusive to the point of annoyance. These warnings may also reflect varying degrees (probability) of threat and some directionality as well.
Brake by Wire – Electro-Hydraulic Brake (EHB)	Hydraulic pressure to actuate the calipers is generated by an electric pump. Travel sensors attached to the brake pedal generate a driver demand signal. Can compensate for changes in pad friction and hydraulics to give a consistent feedback and feel under all conditions. Combines electronic control (Brake by wire) with hydraulic actuation.
Brake by Wire - Electro-Mechanical Brake (EMB)	Electromechanical brake, motors activate brake disks. Electrical actuation of brakes with no hydraulic element.
Brake Lights - LED	Brake lights based on LED technology instead of filament bulbs.
Camera-Powered Headlamp Dimmer System	Using image sensing high beams are controlled, usually by fading them on and off. System helps drivers to use their high beams in the 75% of conditions where they should be but aren't.
Cargo Restraints	Devices to restrain cargo in the vehicle.
Child Protection Door Lock	Electronic Door Lock for Children (Switch in IP or Door area used to lock rear doors - similar to Power Windows Child Lock)
Child Seat Detection	Detect child seat to prevent airbag deployment.
Child Seat Presence & Orientation Detection	Detect the presence and orientation (forward-facing, rearward-facing) of a child seat on the front passenger seat.
Child-Lock Switch (separate lock / unlock)	Switch operated from driver to lock / unlock rear doors. Also controls interior door handle function.
CHMSL - LED	Center High Mounted Stop Lamp with LED's instead of filament bulbs
Collapsible Pedals from Footwell	Mechanical System - decouple pedals from engine compartment mechanics to prevent lower leg injuries.
Collision Avoidance Systems	Automatic braking and steering to reduce crash impact. Independent from the driver, the car takes evasive actions to reliably avoid collisions. Requires Collision Sensing, Steer by Wire, Brake by Wire and Vehicle Path Prediction.
Collision Mitigation by Braking (CMbB) - Autonomous Braking w/ Warning & Adaptive Chassis Precursor	-
Compatibility - Bumper Airbag	Vehicle-to-Vehicle compatibility. Deploy bumper airbag on SUV's when impact is predicted. Of particular benefit for side impacts.
Compatibility - Nose Dipping	Means to ensure Vehicle-to-Vehicle compatibility. Lower the front suspension on SUV's when impact is predicted. Requires air suspension.
Continuous Damping Control (CDC)	Electronics used to continuously control damping characteristics over a wide range enabling optimisation to suit prevailing conditions. CDC is a semi-active damping system with single wheel control using five acceleration sensors and steering angle information. Vehicle movement is permanently calculated, the customer is provided with optimised balance of driving control and comfort via permanently self-adjusting damping characteristics.
Corner View	Using front bumper mounted cameras an image is presented on the cabin monitor that will give a left and right view at junctions, thus enhancing safety.
Cornering Brake Control (CBC)	Electronic brake force distribution whilst cornering which compensates over- or understeer.
Cornering Lamps integrated into Headlamp Units	Swivelling lamps integrated for headlamp units for better illumination when cornering.
Crash Recording & Messaging	Record restraints deployment & 'near deployment' situation. When restraints deployment, send message via telematics unit
Curve Over-speed Warning	-
Deployable Bonnet - Pedestrian Contact Sensor	When the pedestrian contact sensor, mounted in the front bumper, detects an impact an algorithm determines that pedestrian impact conditions have been met and triggers pyro-technic devices to lift the hood, at the rear edge, to deployed height to give required bonnet / engine clearance. A deployable hood system triggered by a bumper contact sensor to reduce the level of styling changes needed for pedestrian head impact protection (HIC < 650). Specific technologies include: Bumper Contact Sensor & Signal Processor, Pyrotechnic Hood Hinge (rear), Pyrotechnic Hood Latch (rear).
Deployable Bonnet - Pre-Crash Sensing	Through the use of pre-crash microwave sensor, pedestrians can be detected before impact, and counter measures such as deploayable bonnet initiated sooner, reducing pedestrian injuries.
Deployable Head Restraints	Pyrotechnically deployed head restraints to reduce whiplash. Pyrotechnic device used to deploy the headrest through 60mm of movement. This achieves a faster response than existing passive systems.

Feature	Description
Dial Controlled Multi Function Menu - Disassociated Controls	Reduces the need for switch gear, providing a clean and clutter free driving environment. The system uses a Rotary/push control situated between front passengers and a central high mounted screen to control a wide range of functions, including ventilation, navigation, hi-fi, internet.
Direction Indicator - Exterior Mirror	Integration of direction indicators in exterior mirror.
Direction Indicator - LED	Direction indicator with LED's instead of filament bulbs
Direction Indicator - Neon	Direction indicator with neon illumination devices instead of filament bulbs. Use of neon light for indicators, tail and stop lights gives even faster response than LED's, as well as the styling opportunities of LED systems. Supplemented by bulb units to meet regulations though.
Distributed Vehicle Security	Distributed vehicle security system - distributed architectures for the passive anti theft system (PATS). Improved distributed PATS immobiliser system using harder-to-change modules to increase time to drive away if system swap is theft method.
Double Locking	Decouple interior door handles from latch. Does not allow to unlock / open doors from the inside
Drive Away Assist	Stops the car rolling backwards on a hill by applying the brakes (EHB or electric parking brake)
Drive by Wire - Electronic Throttle Control - ETC	Electronic throttle control - Accelerator pedal not mechanically coupled with throttle.
Driver Vigilance System (driver awake)	Early detection of driver drowsiness by physiological indicators. Warning and / or stimuli to keep awake. Monitor driver's driving ability (eyelid ...). Linked to an occupant sensing system, variations from normal driving position and use of controls will be detected, indicating drowsiness. The driver is alerted by means of a vibrating pulse in the seat.
DTRL - Day Time Running Lamps	ACEA commitment
Dual Chamber Passenger Front Airbag	-
Dual Pretensioning	Two pyrotechnical pretensioner per seatbelt to increase restraining performance. Typical execution is buckle pretensioner and retractor or outer anchorage pretensioner. Offered in conjunction with high energy pretensioner.
Dynamic Traction Control	Allows the driven wheels to break traction up to a speed of 70 kph or a lateral acceleration of 0.4g to give the driving characteristics of a car fitted with a limited slip differential.
EHPAS - Electro-Hydraulic Power Assisted Steering	Electrical pump for power steering. Replaces mechanical with electrical PAS pump. Fuel economy benefit since pump will only be activated when steering assistance is needed.
Elecrical Parallel Actuator Steer-by-Wire	No physical connection between the steering wheel and the rack. The wheel provides inputs to an electric motor on the rack. Safety and packaging benefit from the elimination of the steering column. Safety and Dynamic benefit from ability to adjust wheel angle independently of the driver for IVD, Lane Keeping, Collision Avoidance. Requires 42 volts, with a 14 volt back up system for redundancy.
Electric Active Steering (EAS) - Active Front Steering (AFS)	Semi Steer-by-wire: Still with steering column but electronically controlled variable steering gear/transmission (steering angle reduction). Speed sensitive torque and damping (better comfort, higher stability, better agility), active return, series differentiation, fuel economy, package. Active influencing of steering angle in critical drive conditions. Modifies road wheel angle based on driver input while maintaining mechanical steering link. Closed loop system. Augmented steer angle does not require hand wheel input. Acceptable torque feedback to driver. Planetary gear set between steering and road wheels allows adjustment of steering angle independent of driver. This facilitates a range of functions like, lock to lock steering at parking speeds in just 1 turn of the wheel, as well as automatic angle corrections for stability control
Electric Brake-Pad Wear Indicators	Indicator for worn brake-pads.
Electric Hydrostatic Steering	A power-pack and an electronic torque / position sensor replace the power steering pump and steering gear control valve used on hydraulic power steering. Power pack consists of a switch reluctance motor driving a two-sided piston via a shaft with an Acme screw thread. A signal from the torque / position sensor along with inputs for vehicle speed, ignition status, .., are sent to control module. Control module tells the motor which way to turn and with what torque. Fluid displaced by the piston is then piped to the steering gear piston through hoses to provide power assist.
Electrical Belt Pretensioner	Activate belt pretensioner when safety critical situation is anticipated. Electrical belt pretensioners are resetable restraints; after activation no need to be exchanged. Requires pre-crash sensing (anticipatory sensing).
Electrical Heated Windscreen	Clear view through windscreen in cold, icy conditions before defroster is effective.
Electrochromic Exterior Mirror	Dimming of glass in reflectivity under glaring conditions.
Electrochromic Interior Mirror	Dimming of glass in reflectivity under glaring conditions.
Electro-Hydraulic Steer-By-Wire	A high resolution steering wheel position sensor is used as input to 3 microcomputers to provide the control signals to an hydraulic actuation system. Steering feel is provided by an electric motor behind the steering wheel. 3 times redundancy is provided.
Electro-Mechanical Steering Column Lock	-
Electronic Brake-Pad Wear Prediction	-
Electronic Ignition Switch - Electronic Switching Unit	See also Electro-Mechanical Steering Column Lock. Needed for Push-Button start of vehicle
Electronic Stability Program (ESP) Interactive Vehicle Dynamics (IVD)	Enhancement to ABS & TCS with additional modulator control valves and sensors for steering angle, yaw rate, lateral acceleration and brake pressure and usually a pre-charge brake pressure device (e.g. active brake booster). Corrective brake modulation and reduced engine torque to avoid under or oversteer.
Electronic Stability Program Interactive Vehicle Dynamics - AWD	ESP for All-Wheel-Drive Variants
Electrorheologic Damping	Electrorheologic active suspension damping. Uses magneto-rheological fluid, which can alter its characteristics with the application of a magnetic field. Current flows through a coil in the piston to create the magnetic field. When energised tiny ferrous particles in the fluid clump together to form strings that act to firm up the damping.
ESP - Understeer Control Logic (UCL)	ESP with undesteer control logic features a new control program. Apart from countering oversteer, the system works effectively in the event of severe understeer or loss of grip of the front wheels. Correction us achieved by reducing engine torque and applying brakes to reduce speed. Control of understeer works on two wheels on one side, or on all four wheels at once according to severity of understeer. As it may involve strong decelerations, the stop lights are illuminated at more than 0.8 m/s^2.
External Crash Indication	Telematics: Send signal when restraint system elements have been activated.
Facia Airbag	Facia's plastic skin can inflate by 6 inches to provide further occupant protection.
Feature Control - Tactile Feedback	Controls provide tactile feedback that makes operation more intuitive and enjoyable. Could be employed for audio and climate control features, for example, in ways that do not require the driver to take their eyes off the road.
Flash to Pass	When tipping the direction indicator it will provide 3 flashes (for overtaking).
Follow Me Home	Headlamp-off delay. Perimeter illumination by headlamps, rear lamps, rear view mirror integrated puddle lamps.
Forward Collision Warning (FCW)	A Forward Collision Warning system is designed to warn the driver when there is a risk of a collision with another vehicle, at sufficient distance to allow the driver to avoid, or reduce the effect of, the potential collision. The warning will come in the form of an audible and / or visible indication via a unique human machine interface (e.g. head up display, stereo system, etc.). No tactile indication is planned at this time. These indications are intended to supplement the driver's normal diligence in operating the vehicle, which may be of particular effectiveness in situations with heightened workload (e.g. conversation with a second individual, distraction by roadside events, etc.) without being intrusive to the point of annoyance. These warnings may also reflect varying degrees (probability) of threat and some directionality as well.

Feature	Description
Forward Collision Warning with Threat Assist HMI	A Forward Collision Warning system is designed to warn the driver when there is a risk of a collision with another vehicle, at sufficient distance to allow the driver to avoid, or reduce the effect of, the potential collision. The warning will come in the form of an audible and / or visible indication via a unique human machine interface (e.g. head up display, stereo system, etc.). No tactile indication is planned at this time. These indications are intended to supplement the driver's normal diligence in operating the vehicle, which may be of particular effectiveness in situations with heightened workload (e.g. conversation with a second individual, distraction by roadside events, etc.) without being intrusive to the point of annoyance. These warnings may also reflect varying degrees (probability) of threat and some directionality as well.
Four Point Seatbelt	-
Front Lights - LED	Super-bright high performance LEDs used for front lights. Headlamps may have active cornering beams with no moving parts - achieved by activating more LED lighting elements.
Gear Change and Clutch by Wire	-
GPS Assisted Driving Control	GPS and advanced maps data is used to enable basic anticipatory measures. Ahead of bends it will change down gears, apply brakes, and apply acceleration on exit, all according to corner severity and vehicle speed. Will slow the vehicle on approach to intersections, and with a link into traffic data, on approach to congestion.
GPS based Adaptive Headlamp Aiming	Manipulation of light distributions based on vehicle dynamics and guided by GPS. Illuminates upcoming bends and reverse curves. A development of Adaptive Headlamps using GPS to better guide around bends, humpback bridges etc.
Handsfree Phone via Bluetooth or Wireless Equivalent	Provides wireless, hands-free remote control and use of the customer's own Bluetooth or equivalent enabled cell phone.
Heading Control	-
Headlamps - Auto Dipping	Automatically dip from high beam to low beam. Using 'camera-on-a-chip' technology, the system dips the headlamps from full to dipped beam when it senses a DC voltage light source (headlamps or tail lamps), returning to full beam when the source disappears. AC voltage, such as street lamps or shop windows, are ignored. Depending on the application, gradual dimming may be possible.
Headlamps - Adaptive Aiming - Steering Angle Based (AFS)	Manipulation of light distributions based on steering angle (bending light). Manipulation of light distributions to allow the curvature of a bend to be illuminated, raise beam for M-Way use and provides additional beam patterns for changing road / environment scenarios. AFS is expected to be legal in 2003 for USA and 2005 for Europe. Sensor data on speed, steering angle, ambient light type, rain etc is used to modify beam patterns through electro mechanical control of light source and optical devices.
Headlamps - Adaptive Beam Height Control	Adaptive beam height control to optimize visual range according to driving situation. Provides: a) Static correction: to compensate for difference in vehicle loading, b) Dynamic correction: during braking and acceleration c) Speed adaptation: <30 kph: Dipped beams are lowered to reduce high-level output in urban driving (beam range 55 m) >30 kph: Dipped beams return to nominal position (beam range 77 m)
Headlamps - Adaptive Focusing	Manipulation of headlamp focus based on vehicle speed?
Heat Stroke Warning	This feature could be developed in conjunction with 'Interior Occupant Alert', to provide a solution to the problem of children suffering, often fatal, heat stroke from being left unattended in a hot vehicle. Would utilise the heart beat sensor from 'Interior Occupant Alert' to detect an occupant, and then a temperature sensor. Some kind of alarm is issued when conditions are detected that could result in heat stroke.
Heated Side Screens	Electrically heated side screens for fast demist. Similar to heated front front screen and backlit.
HID - Projector	Projector technology for High Intensity Discharge Lamps.
HID - Reflector	Reflector in lieu of projector technology for HID lamp.
HID Lamps	High Intensity Discharge Headlamps. HID light source employing arc principle in a xenon gas, initiation and burn controlled by electronic module. Combines better light output with extremely uniform light levels and improves field of vision. Also combines lower electric power consumption with life expectancy five times higher than halogen.
High Energy Pretensioner	Apart from taking out the belt slack, those pretensioner also guide to occupant in a better restraining position. Help to prevent knee impact on instrument panel (EuroNCAP) by starting rotation of the occupant earlier.
High Intensity Back-up Lamps	Back-up lights with high intensity to increase rearward visibility when driving in reverse gear.
Hill Ascent Control - HAC	Similar to Hill Descent Control
Hill Descent Control - HDC	Downhill assist control uses engine braking combined with throttle and brake control to improve directional control during decent on steep or slippery surfaces.
Hill Holder	Use sensors and actuators to assist start when parking on a hill.
Improved Tuneable / Reliable Column Ride Down Mechanism	Improvements to current mechanism. Controlled steering column ride-down provides upper torso energy management contribution and compensates for intrusions.
Inflatable Curtain - 3rd Row	Inflatable curtain covering the third passenger row.
Inflatable Curtain Deployment in Oblique Frontal Impacts	Deployment of the inflatable curtain in oblique frontal impacts to reduce risk of head injuries.
Inflatable Seat Belts - Rear Seats	Seat belts which inflate like an airbag in case of an severe impact. Inflatable lap belt may substitute rear pretensioner. Airbag is fitted inside the belt,to provide forward protection to front/rear occupants. Belt is fully retractable,although a little thicker (8-10mm). Could replace side / IP bag (not for driver). An integrated seat is required.
Instant Mobility System with Tire Pressure Monitoring	-
Integrated Fuel & Battery Cut-Off	Post Crash: Cut-off of fuel pump and battery.
Integrated Vehicle Driving Control - Phase 3	IVDC with active steering and braking stability function: I ntegrates ESP, EHB, with AFS (SAS - EPAS with nonlinear gears, SbW)
Integrated Vehicle Driving Control - Phase 4	IVDC combined with Active Safety: Based on information on traffic situation, weather conditions, (3D-) road characteristics and the estimated vehicle dynamics state a High-Level function provides an adequate intervention by brake, ..., steering.
Integrated Vehicle Driving Control (IVDC) - Phase 1	Interaction of dampers, brakes, EPAS. Overall vehicle control using synergies of all chassis control systems resulting in better overall dynamic. Philosophy espoused by concept is to regard the vehicle as one dynamic system through integration of the many electronic systems that impact dynamic behaviour.
Integrated Vehicle Driving Control (IVDC2) - Phase 2	Link steering, suspension and brakes for AWD vehicles - On-road and off-road vehicle dynamics
Intelligent Tire	Polarised magnetic elements in sidewall allow a sensor mounted alongside to detect dynamic distortion and hence vehicle attitude & motion. Augments ABS & yaw sensors making a potential improvement in functionality of ABS/TC/ESP(IVD) systems.
Interior Occupant Alert	Provide the owner with a warning of some sort, when approaching the vehicle, if an intruder is detected. May be linked with Passive Entry / Start.
Interior Scanning for Convertible Vehicle	Allow scanning for vehicles with roof open
Interlock Steering Column Lock - ISCL	Steering column lock with interlock functionality for vehicles with automatic transmissions (US only?)
Intersection Collision Warning	Extension of forward collision warning . Warning if collision in intersection is imminent
IPS - Intelligent Protection System (Minimum Level)	Adaptive restraints system optimized for European requirements consisting of: - Dual stage frontal airbags - Upfront impact sensor - Pretensioner and load limiter front belts
ISOFIX Child Seat Mounts - Front Passenger Seat	Standardized mounting mechanism for child seats.

Feature	Description
ISOFIX Child Seat Mounts - Rear	Standardized mounting mechanism for child seats.
Lane Change Aid (LCA)	Network of sensors and image cameras around the vehicle provide the driver with a warning if the indicator signal is used whilst the system detects another vehicle in a potentially hazardous situation. Improve driver awareness during intentional or unintentional lane change or merging maneuvers to reduce vehicle-to-vehicle accidents.
Lane Departure Warning (LDW)	Alerts driver when coming adrift from road lane. Warning for unintended road / lane departure due to driver falling asleep or other lack of attention. A video camera detects unintended crossing of road markings and generates a warning with "rumble-strip" character. Improve driver awareness during unintentional lane/road departures to reduce accidents.
Lane Keeping Aid (LKA)	Corrections to steering angle made automatically to keep the vehicle in the lane. Achieved by combining Steer by Wire and Lane Departure Warning
Left Occupant Alert	Provide owner / driver of vehicle with warning of some sort when locking vehicle whilst human being is still in the vehicle
Leg Airbags	Airbags designed to reduce leg injuries.
Load Independent Deceleration	Deceleration of vehicle independent from vehicle loading.
Load limiter - Lap Belt	Front seat safety belts equipped with a second load limiter for the lapstrap section of the belt. Intended to provide more effective protection of the pelvis by avoiding fractures of the iliac wing type.
Load Limiting (Clevis) Pedal	Impact load limiting pedal. Part of passive safety big bang bundle.
LRD - Baseline Passenger Airbag & Occupant Classification System	Standard passenger airbag combined with an occupant classification system that meets the dynamics restraining requirements and Out-Of-Position requirements.
LRD - Driver Low Risk Deployment Airbag	Low risk deployment driver airbag that meets the Out-Of-Position deployment requirements without the need for an occupant classification system. Increased airbag size and reduced gas leackage for improved airbag/occupant interaction and increased upper torso energy absorption without Out-of-Position deterioration.
LRD - Passenger Low Risk Deployment Airbag	Low risk deployment front passenger airbag that meets the Out-Of-Position deployment requirements without the need for an occupant classification system.
LRD-bag	Low Risk Deployment airbag, primarly for the front passenger. LRD bag works with smart venting / bypass venting. Can potentially replace the passenger seat weight sensor. Meets out of position requirements (of FMVSS208) without sensing
Mobile.com 2nd Gen.	-
Mobile.com 3rd Gen. - Color Display & Multimedia	-
MSR - Engine Torque Regulation	Engine torque regulation on overrun function avoids the risk of locking the driven wheels by controlling the engine torque when the driver llifts of the accelerator or during deceleration on low-grip surface.
My Connected World - Entertainment	Supported Features: - Wireless Download Music/Maps/Data to Vehicle from Home PC - Wireless Download Music/Maps/Data to Vehicle from Handheld - Wireless Downloads of Maps from Vehicle to Handheld (final leg functionality)
My Connected World - General	Apply short range wireless technologies to seamlessly integrate consumer handheld devices with on- and off-board vehicle services. Increase customer security by wirelessly providing advanced vehicle and environmental information to handheld. Employ intelligent personalization services enabling the vehicle to exercise its knowledge of driver preferences and needs (scheduling, environment, etc) to enhance the driving experience Provide a flexible, defined hardware and software infrastructure able to readily accept new wireless consumer devices and software updates that emerge after <CC> and throughout the product lifecycle.
My Connected World - Personal Settings	Supported features: - Environmental Control by Wireless Handheld or Voice - Ergonomic Settings by Wireless Handheld or Voice - Entertainment Settings by Wireless Handheld or Voice - Individualized Programmable Entertainment such as Morning Drive with CNN News and Evening Drive with Light Music - Voice Mechanism for Selecting from Multiple Profile Availability in Vehicle (several MCW devices in car) - Providing Personal Medical Info to Rescue Personal by Wireless or Vehicle Speakers - Seamless Personalization Wherever Wireless Access Available, at Vehicle, Office, Home, Hotel etc. (Stage 2)
My Connected World - Security	Supported Features: - Passive & Remote Vehicle Access Through Wireless Handheld - Passive & Remote Home Access Through Wireless Handheld (Phase 3) - Remote Vehicle Monitoring through Wireless Handheld
My Connected World - Stationary Wireless Service	Supported Features: - Wireless Order/Payment at Fast Food Restaurant/Gas Station/Toll Booth/Parking Lot etc. (Phase 2-3) - Wireless Traffic Info such as Road Conditions/School Zone etc. (Phase 2-3)
My Connected World - Vehicle Service	Supported Features: - Vehicle Maintenance Reminder and Automatic Service Appointment such as 10,000 Mile Maintenance - - Download Different Drive Tunes such as Race Track Tune for Weekend (Phase 3) - Remote Prognostics and Diagnostics
My Connected World - Virtual Assistant	Supported Features: - Seamless Scheduling Assistance at Vehicle, Office, Home, etc. - Destination Entry on Handheld then Wireless Link to Vehicle - Smart Recommendation Based on Individual Activities such as Favorite Restaurant (Phase 2) - Hands-free Mobile Phone, Integration with Phone Book
Navigation - Safe Route Information	Geographic areas regarded as 'unsafe' in terms of personal security can be identified by the navigation system, and routes planned to avoid them.
Next Generation Active Roll Control (ARC)	-
Next Generation Tire Pressure Monitoring	-
Night Vision	Driver vision enhancement during nighttime driving, thermal image camera output transposed on windscreen. Extended view beyond headlight range during night time driving. Infra-red camera (or similar) detects objects invisible to human eyes and displays a virtual image using a head up display just below line of sight.
Occupant Classification Sensing - Gen 2	Occupant classification system including child seat detection.
Occupant Classification Sensing (OCS) - Gen 3	Occupant sensing system capable to distiguish between 5 %-ile, 50%-ile and 95%-ile female / male. Needed for restraints system adaptivity to 5 - 50 - 95%-ile.
Occupant Classification System (OCS)	Classify front occupants according to their statur (size, weight) and taylor restraints deployment to achieve optimum restraining performance.
Out of Position Deployment - Frontal Occupants	Sensors to monitor the passenger seat to determine type & position of occupant for airbag deployment decision-making. Spin-off features: auto mirror / head rest adjust, adaptive climate control etc. Upgrade will include dynamic position sensing that refreshes data on occupant positions much faster than currently.
Out of Position Deployment - Rear Occupants	Aimed at supporting 'rear side impact airbags'. Use of Out of Position Sensing technology will prevent the possibility of an airbag deploying whilst the occupant is resting their head against the door.
Overhead Bag	Low risk deployment passenger airbag. Installation of the overhead bag is in the front part of the roof. Gives about the same level of protection to unbelted and belted front seat passengers as today's type of airbag. Passenger airbag deploying from the headlining.

Feature	Description
Overhead Bag - Rear Seats	Airbags deploying from the headliner to restrain rear occupants to: - reduce impact risk to front seats - reduce neck loads.
Panic Alarm Bottom on Remote Control	Integrate Panic Alarm Bottom on Remote Control Key
Passenger Airbag Deactivation (PAD) - Switch	Key-operated manual cut-off switch for the passenger airbag. Deliberate action by user to deactivate the passenger airbag. Passenger airbag deactivation for transportation of rear facing child restraint system.
Passenger Occupancy & Position Detection - Camera	Two cameras are used to detect front passenger occupancy and position.
Passenger Occupant Detection System	Seat integrated bladder that senses the presence of a front passenger. Signal leads to deactivation of the passenger front & side airbag plus pretensioner if seat is empty. Deactivation is for all pyrotechnical restraining devices dedicated to the front passenger.
Passenger Presence Detection - Beltminder Strip	Front passenger presence detection by means of the seat-integrated beltminder strip. Deactivation of passenger front and side airbag plus deactivation of pretensioner.
Passenger Presence Detection - Beltminder Strip	Front passenger presence detection by means of the seat-integrated beltminder strip. Deactivation of passenger front and side airbag plus deactivation of pretensioner.
Passenger Presence Detection - Force & Weight Sensor	Detect presence of passenger on the front seat and surpress passenger front & side airbag plus pretensioner deployment if seat is empty (all deployable restraining devices dedicated to front passenger).
Passive Entry - Face Recognition	Passive Entry that does away with the smart card, using face recognition technology to identify the owner.
Passive Entry - Finger Print Recognition	Replace the smart card with finger print recognition technology. As the surface of the electrode is touched, 65,000 sensors measure the distance between it and the skin to an accuracy of 0.01mm. A digital map with a resolution of 20 dots per mm is used to search for 12 to 24 different characteristics to confirm the identity.
Pedestrian Protection	Pedestrian protection - compliance possible in 3 different ways: a) Changes to the front design b) Technology c) Clever engineering
Perimeter Lighting	Approach light - Illumination of outer door area and tailgate area.
Peripheral Threat Alert	Provide the owner with a warning of some sort, when approaching the vehicle, if a potential assailant is hidden within the immediate proximity of the vehicle? A network of external sensors is required.
Personal Communicator Device	Hand held device able to remotely communicate with the car, to enquire about security status, occupant status and many other things. In addition to the RKE functions, the device will enable passive entry/start, a car locator, vehicle status check (doors, locks, alarms, children or pets left in the vehicle), car data (VIN, etc.), clock, potential telematics applications, and trip/fuel computer. The Car Locator feature will provide directions back to the owners car if lost. · May use GPS for position information. Hand held device may link into Passive Entry / Start. VPC G1: - including Passive Entry & Passive Go and Interior Occupant Sensor VPC G2: - Touch display - Blue tooth - Rechargeable - Enhanced security feedback - Interior imaging
Personal Security	A module based scalable technology platform for integrated or non-integrated security features: From Passive Entry & Passive Go up to advanced integrated PDA / Cell Phone / Remote features that allows brand unique differentation on HMI. Bundle content: - Passive Entry, Passive Start, Heartbeat Sensor, Standard Range RKE Functions, PDA / Cell Phone Interface, Telematics Personalization - Super Fob HMI: L-R Companion - Biometrics HMI: DFAP
Phone - Voice Control	Speaker independent and multilingual control of the phone system. Requires the user to issue commands using specific sentences. Advanced Voice Portal project will include 'word spotting', enabling the user to speak using a normal conversational style. See also Voice Activated Controls'.
Post Crash Signaling / Messaging (Event Notification Signal)	External indication of crash / severe impact. Different execution possible: - Hazard warning - Telematics - Emergency Call - Fuel Cut-off - Battery Cut-off - Central Unlock - Interior Light Illumination
Posture Enhancing Seat	The cushion slides backward, while the vehicle is on the move, until the correct posture is achieved. Correct posture requires an upright spine, which is unnatural, hence automatic action.
Pre-Brake Light Signalling	Using data from an Forward Collision Warning (FCW) / Pre-Crash Sensor (distance, closing speed, deceleration and likelihood of impact), the brake lights can be illuminated before the driver has applied the brakes. Gives warning to other road users that the vehicle is likely to perform an emergency brake.
Pre-Crash Body Structure Adaptation	Before an expected accident the bodywork is re-configured to enhance crash performance. Must be reversible in case the driver makes a recovery. Extendable front bumper could be used to increase crush space. (See also 'Compatibility - Bumper Airbag')
Pre-Crash Braking	Using data from an Forward Collision Warning (FCW) / Pre-Crash Sensor (distance, closing speed, deceleration and likelihood of impact), the brakes are locked on if an obstruction is detected 10 meters in front of the vehicle and speed is such that an impact is inevitable. Collision Mitigation: A Collision Mitigation system will make an autonomous brake application when it determines a collision with another vehicle is unavoidable in both high speed and low speed environments. The CM function assumes the driver has ultimate authority over vehicle control and will not interfere with any potential evasive maneuvers intended by the driver. Since the distance required to brake for avoidance usually exceeds the distance required to steer for avoidance, the system is limited to mitigation by braking only. This function can also include a panic brake assist function if a driver has applied an inadequate level of braking to avoid a collision or hesitates in full application.
Pre-Crash Interior Re-configuration	Before an expected accident the interior is re-configured to enhance occupant safety. Must be reversible in case the driver makes a recovery. The ability to move the power seats into an optimal crash position, close the sunroof, and even deploy the interior door panels to protect occupants during a side impact.
Pre-Crash Restraints Deployment	Use of pre-crash sensing technology to improve the response of restraints through raising their state of readiness prior to deployment. Use of Electric Seat Belt retractors would give resetable Pre-tensioning. May make meeting legislation easier. (See also Pre-Crash Sensing). Before an expected accident restraint devices are deployed to enhance occupant safety. Must be reversible in case the driver makes a recovery. An electric seat belt pretensioner that tensions the belt before impact, or a deployable knee protector are possibilities.

Feature	Description
Pre-Crash Sensing (PCS)	Anticipatory sensing in pre-crash phase. Enabler for refined active and passive safety systems. Use of pre-crash sensing technology to improve the response of restraints through raising their state of readiness prior to deployment. May make meeting legislation easier. Using data from an Forward Collision Warning (FCW) / Pre-Crash Sensor (distance, closing speed, deceleration and likelihood of impact), the brakes are locked on if an obstruction is detected 10 meters in front of the vehicle and speed is such that an impact is inevitable. Through the use of pre-crash microwave sensor, pedestrians can be detected before impact, and counter measures such as deployable bonnet initiated sooner, reducing pedestrian injuries.
Pre-Crash Sensing (PCS) - Closing Velocity (CV) Sensing	Closing velocity sensing by means of short range radar or lidar to improve roboustness of impact sensing and improve deployment times of restaining devices to improve overall performance of the restraints system.
Pre-Crash Vehicle Compatibility	Before an expected accident the ride height is adjusted, either upward or downward, using the Active Body Control (air suspension) system, to ensure crash compatibility. Will require Phase 3 of Crash Detection (Image processing) to determine the size of the target vehicle. (See also 'Compatibility - Nose Dipping')
Pre-Emptive Brake Pressure Build Up	When rapid movement from throttle to brake is detected hydraulic pressure is built up in readiness for before the driver is actually depressed the pedal.
Pressure Controlled Airbag Vent	Occupant and crash severity adaptation. Optimal use of distance. Alt. 1: Ventholes, that remain closed until pre-defined opening pressure is reached (during inflation, emergency vent) Alt. 2: Ventholes, that close at increased pressure
Protection for 2 seat vehicles	Investigation into rear impact protection for 2 seater vehicles. Will Anti-Whiplash seats work within the package space? Are airbag based head restraints effective?
Puddle Lamp	Illumination of outer door area when approaching the vehicle. Typically, the puddle lamp is integrated in the exterior mirror. May also include the illumination of the area on the tailgate / luggage compartment (when unlocked) - license plate illumination may be used for this purpose. Other execution: Headlights, interior lights and license plate illumination can be activated via remote control to further improve safety for entry and exit of the vehicle.
Pyrotechnical Fuse	Protect Battery Cable
Rain Sensitive Wipers	Activate front wipers based on rain intensity utilizing rain sensor.
Rear Impact Protection	Occupant protection for rear impacts. Requires rear impact sensing. Activate belt pretensioner during rear impact to reduce whiplash effect.
Rear Lamps - LED	Rear lamps with LED's instead of filament bulbs. LED array ilo Bulbs, allows dual functions, such as Stop/Tail by driving LED at low / high intensity. Significantly faster rise times than Bulbs. Slim package and long life - low / no maintenance. LED lighting provides styling opportunities. Subject to performance and style demands, LED's may be used with and without reflectors. Illumination time is instant instead of 200 milliseconds for conventional bulbs.This gives drivers an extra 5.5m in which to respond at 60mph.Also provides new styling opportunities,and cuts power consumption.
Rear Lamps - Neon	Rear lamps with neon illumination devices instead of filament bulbs. Use of neon light for indicators, tail and stop lights gives even faster response than LED's, as well as the styling opportunities of LED systems. Supplemented by bulb units to meet regulations though.
Rear Seat Safety "Package"	-
Rear Side Impact Airbag Deactivation	Deactivation of rear side impact airbag by means of key or switch
Remote Immobilization	Remote de-activation of stolen vehicles keys by service center. Offered as telematics service. Stolen vehicle keys can be disabled such that a start of the vehicle is not any longer possible.
Remote Vehicle Shut-Down	Remote vehicle shut-down of stolen vehicles initiated by service center. Offered as telematics service.
Retractable Pedals	Active retraction of pedals in case of frontal impact
Road Friction Detection - AWD	System provides warning for slippery road surfaces, more accurate than temperature warning. Also, additional input to enhance functionality of other systems like ACC. Uses ABS sensors as main input. Use of the Dynamics Sensor Network and new algorithms to determine friction levels at each wheel- - If friction levels are too low, due to ice, snow, water, oil etc, the driver is warned. - Likely to provide an input for 'Crash Anticipation – Dynamics Sensor Network'.
Road Friction Detection - FWD	System provides warning for slippery road surfaces, more accurate than temperature warning. Also, additional input to enhance functionality of other systems like ACC. Uses ABS sensors as main input. Use of the Dynamics Sensor Network and new algorithms to determine friction levels at each wheel - If friction levels are too low, due to ice, snow, water, oil etc, the driver is warned. - Likely to provide an input for 'Crash Anticipation – Dynamics Sensor Network'.
Road Sign Recognition	Using image processing technology the system will recognize triangular and circular shaped road signs, and then present the image to the driver within the IP cluster.
Rollover Prevention - Non-active	Active use of the ESP to prevent rollovers. An additional rollsensor is needed to identify risks for rollovers. When needed, the ESP system will apply the brakes to stabilize the vehicle. Upgrade to ESP software, use tires/brakes to slide.
Rollover Protection - Convertible	The addition of a reliable sensor to detect a vehicle rollover situation can be used to deploy restraint systems appropriately. Typically, the deployable roll bars are activated.
Rollover Protection - Convertible	Convertible rollover protection with lamella bag & rops development, including reinforced A-ring structure.
Rollover Protection (Curtain airbags)	Use curtain airbags to reduce injuries in rollover accident. Operates as an energy-absorbing device in a rollover. Needs longer 'up time to deflation' and the addition of an rollover sensor. Provides head protection for complete duration of rollover event.
Rollover Protection (No Head Contact)	-
Rollover (Active Seat Back Movement)	-
Route Guidance - Overspeed Advice / Road Dangers Warning / Black Spot Warning	Advanced maps provide a means of geographic referencing. Used to advise or warn the driver of too high speed for a bend. Using 'probe vehicle' data, dynamic map databases will allow warnings to be given for ice, accidents etc, based on the experiences of probe vehicles ahead. 'Black Spot Warning': Warns the driver that they are driving on a section of road regarded as an accident black spot. Achieved by means of either an advanced navigation map database, or via the Concierge system.
Run Flat Tires	Run Flat Tires with supporting ring inside the wheel requires pressure monitoring to tell the driver that a puncture has occurred and ESP. Advanced design incorporating a unique tyre and wheel provides run flat capability, without the disadvantages of conventional systems i.e poor ride, high rolling resistance.
SCC A-Pillar	See-through A-Pillar as shown on the Volvo Safety Concept Car. Customer will perceive A-pillar as transparent.
Seat Integrated Belts	Seat belts integrated into seats
Seat Pan Airbag	Seat cushion integrated airbag for pelvis energy management. The seat pan airbag is an expanding inflatable device located under the seat cushion foam in place of the vehicles anti-submarine pan. In the event of a collision, it is inflated by a small airbag gas generator to provide an instantaneous reaction surface for the occupants upper legs and pelvis. (See also 'active seat ramp')
Self Adjusting Load Limiter	-
Self Guided Vehicle	Intelligent Driver Support uses systems like ACC and Lane Departure Warning in an integrated way. Camera image is linked to a logic system that is able to actively steer the car to avoid lane departure.
Sequential Brake Light	Brake lights change intensity according to deceleration and / or flashes under hard braking. The lamps emit a brighter light under severe brake pressure to better warn other road users.
Shift By Wire	No physical connection between shifter and gearbox. Use of an electronic connection in conjunction with Electric Park Brake will allow automatic park brake application for instance.

Feature	Description
Side Curtain Airbags	Airbag device that deploys from the cantrail to protect heads of occupants in a side impact. Also prevents ejection from vehicle in a rollover. Further advances allow operation as an energy-absorbing device in a rollover – needs longer inflation time and the addition to vehicle of a rollover sensor
Side Impact - Dual Chamber Thorax-Pelvic Bag	Seat integrated side impact airbag with dual chamber protecting thorax and pelvic. Features thread vent.
Side Impact - Single Chamber Thorax-Pelvic Bag	Seat integrated side impact airbag with single chamber protecting thorax and pelvic.
Side Impact Airbags - Front	Categorized as thorax (chest) and combination (head & thorax OR thorax & pelvis) airbags.
Side Impact Airbags - Rear	Thorax side impact airbag for protection of outboard rear passengers. Airbags emerge from rear door panel or the outer bolster of the rear seats to protect rear seat occupants in a side impact. Use of Out of Position Sensing technology will prevent the possibility of an airbag deploying whilst the occupant is resting their head against the door.
Silicon Membranes Airbag	-
Simplified HMI (SHMI) - Multifunctional Instrument Cluster	Instrument cluster with analogue gauges and possibility to overlay incremental informations via virtual, mirrored-in display. The virtual display overlays the analogue instruments. Display needs a 45º 50% reflective mirror to generate the virtual image for the user. The display can be mirrored in from the top and is not visible for the user during driving. Depending on the anti reflex lens (front lens) the display can also be mirrored in from the bottom.
Single Sensor Interior Scanning	Use one sensor to implement interior scanning. Interior scanning detects intrusion in the vehicle interior.
Situation Awareness Support	-
Smart Anti-Whiplash Seats	Uses the occupant sensor to determine the distance between the head rest and the occupants head. The head rest is then powered forward to meet the head, thus reducing whiplash injuries. More effective than current anti-whiplash seats.
Smart Head Restraints - Active Headrests	Active head restraints, which tilt forward in a rear impact to reduce whiplash. Pure mechanical system without electronic control and electric actuation.
Smart Steering Column Device - SSCD	See also Electro-Mechanical Steering Column Lock
Steer by Wire	Mechanically decouple steering wheel and tires. No physical connection between the steering wheel and the rack. The steering wheel provides inputs to an electric motor on the rack. Requires 42 volts with 14 volts back-up system for redundancy. Safety and packaging benefit from elimination of steering column. Safety and dynamic benefit from ability to adjust wheel angle independently from driver for ESP/IVD, Lane Keeping, Collision Avoidance.
Tailbag	-
Telematics - IVR (Interactive Voice Recognition)	Voice based telematics services: e.g. Emergency call, breakdown, help services
Telematics - Back-Up Power Supply	Backup power supply for telematics unit for placing calls after loss of telematics power (battery / wiring may be damaged during impact).
Telematics - Bring Stolen Vehicle to Stop	Remote vehicle shutdown
Telematics - Disable Stolen Vehicle Keys	Remote immobilization function: Vehicle keys that have been stolen and are notified to a service center will remotely be disabled for the use with the vehicle.
Telematics - Emergency Call	When activated a call is put through to a service center giving the position and vehicle details. Access is given to the emergeny services. Activated by airbag deployment for accidents or via the navigation screen / dedicated switch in the header console.
Telematics - GPS based Vehicle Tracking (Crash, theft, navigation)	Proposal to use GPS technology to provide a tracking service for stolen vehicles. Developed by the Volvo led 'Security Big Bang' project. Ford are developing a proposal for on-line service provision to support vehicle tracking. Remote engine shutdown could be incorporated.
Telematics - Mobility Services	Prevent getting stuck due to (1) Fuel Run out (2) Accidental Lock-out (3) Flat Battery
Telematics - Remote Location	Telematics service
Telematics - Safety/Security Service Provider	Integration of Advanced Restraints and Next Generation Telematics to provide an enhanced crash notification system. The system will provide location, time of crash, crash severity, number of occupants and seatbelt usage to the response center. The second part of this project will consist of remote vehicle shutdown and immobilization that will limit the maximum speed of a vehicle and once turned off, prohibit restart.
Telematics 2	Reference to the next generation of telematics systems: - Off-Board Navigation - Internet Connectivity
Tinted Glass - Dynamic Glass Darkening	Using electrochromic glass, the windows are darkened on securing the vehicle, to conceal personal belongings (& protect for heating up of the interior)
Tire Pressure Monitoring (TPM) (ABS Software)	Use ABS software to detect flat tire. Only gives reading after time delay (no pre-warning). Compares the speed of each wheel to the other three and detects when tyre pressure falls by 15 or 20%. System does not work when car is stationary.
Tire Pressure Monitoring (TPM) (Sensors)	System detects slow leaks or a mismatch between the speed of the vehicle and the tyre pressures. Use sensor technology to monitor tire pressure. Accurate to changes of less than 1%. A pressure, temperature and acceleration sensor in installed in the wheels. Driver gets warned in the event of any leakage or incorrect inflation.
Towing Stability Control	Stabilize trailer during towing operation.
Tracker	Stolen vehicle tracking by commercial 'tracker' system.
Traction Control System (TCS)	For starting from rest and accelerating in low grip conditions. Whenever a spinning driven wheel is detected, that wheel is braked to transfer torque to other driven wheel. At the same time, the engine torque is reduced.
Tyre Condition Sensing	Sensors for fitment inside their tyres, that will provide warning information on tyre condition. Pressures sensors mounted inside the tyre will support 'Tyre Pressure Monitoring', as well as record the distance travelled by the tyre.
Unbelted Occupant Control	The low header rail will require a new restraints technology to address the potential for occupants to hit the rail during the impact.
Urban Collision Warning	-
User Friendly Seat Belts	Improvements to belt comfort / usability that reduce customer complaints whilst maintaining restraining performance. Could include buckle presenters (buckle rises up from its location so users doesn't have to reach as far.
Variable Assist Power Steering	Speed sensitive steering forces
Variable Load Limiting Belts - Rear Seats	Simple variable load limiting retractors based on size of occupant, improving restraint performance for small occupants.
Variable Speed Limiter	Driver can set a speed that the car can not exceed, in the same way as for cruise control. Cancelled by a cancel command or by a kickdown. Requires electronic throttle control and a cruise/limiter selector switch to implement.
Variable Volume Driver Front Airbag	-
Variable Volume Passenger Front Airbag	-
Virtual Sirene - Emergency Data Transmission	Use vehicle to vehicle communication opportunities to give advanced warning for approaching rescue vehicles.
Volume/Shape Airbag	Volume and shape adaptation by pressure activated tear-seam tether.
Wet Weather Braking	Use rain sensor to activate the EHB brakes in wet conditions to gently hold the brakes on in order to keep the discs dry. Could also be used to determine safe braking distances during ACC operation, in the wet.
Wiper / Headlight Link	When wipers are switched on, the headlights will automatically be switched on.
Wireless Heated Windscreen	Instant heated windshield - Silver sputtering on surface 2 of laminated glass - no visible heating wires. Can include infra-red reduction. Heating element also acts as IR filter