ITS ACTION PLAN

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D4–Final Report
Action 3.4–Safety and comfort of the Vulnerable Road User

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MANAGEMENT SUMMARY

The overall objective of the action 3.4 of the ITS Action plan is 'to develop measures including best practice guidelines concerning the impact of ITS applications and services on the safety and comfort of the 'Vulnerable Road Users'. The objective of the present study, commissioned by the EC/DG MOVE is to establish state of art, to assess impacts, to identify and potentially prioritise most suitable ITS Services or application fields, to elaborate on potential measures and to recommend action in these. This document constitutes the final report (D4) of this assignment.

The Vulnerable Road User (VRU)
The following main categories of VRU are identified in this study:
- Pedestrians
- Cyclists
- Users of light powered two-wheelers (mopeds and scooters) (PWT)
- Motorcyclists
- The young/inexperienced car driver
- The older car driver.

It is noted that car drivers are often not regarded as VRU. Given their higher injury and fatality rates, and the existence of specific safety issues for these groups, it was deemed valuable to include them in the scope of this study.

Approach
As the most useful material appeared to be a mix of application-centred and accident-centred studies, it was decided to apply two methods of analysis and consequently synthesize the results:
- A top-down approach, which starts from an identification of the dominant safety issues for each of the identified VRU categories and searches for information on the (potential) impact of existing/experimental/conceivable ITS on these issues.
- A bottom-up approach, which starts from information on reported impacts of existing/experimental ITS applications on safety and comfort, and consequently filters on relevance to the VRU.

State of the art
Obviously, available solutions as well as on-going R&D has been focussing on cars and trucks and has been more limited for motorcycles, light PTWs, cycles and pedestrians – in that order. This has to do in the first place with technical and practical limitations, notably to the user interface, available space to install equipment without hindrance to the user, exposure to outside environmental conditions and the lack of a high-quality power source. There are also economical factors: if the bill is to be paid by the road user, the cost of the

ITS equipment has to be small compared to the cost of the transport means itself. Manufacturers of motorcycles, light PTWs and bicycles do not have R&D budgets anywhere near those of car manufacturers. As a result, few ITS solutions have been developed that target other traffic participants than the car or truck driver as primary user.

ITS Applications of specific relevance to the VRU

The positive message to convey is that most VRU are likely to profit from the indirect benefits that some ITS applications developed for passenger cars will bring to their safety. From a review of accident causes it can be concluded that there are a number of factors that have a large impact on the number and severity of injuries on the side of all or most types of VRU:

- Speed
- Alcohol
- Non-observance of the VRU by the vehicle driver
- Late and insufficient braking by the vehicle driver in cases of emergency.

Applications targeting the factors mentioned above are therefore of great interest to the safety of the VRU, in the first place:

- Intelligent Speed Adaptation
- Alcohol Ignition Interlock
- Pedestrian Detection Systems (PDS), combined with Emergency Braking (EBR) and to be enhanced with VRU Beacon Systems (VBS) in the future.

The following applications also have considerable potential for improving safety and comfort of the VRU:

- Adaptive Headlights
- Night Vision Warning systems
- Blind Spot Detection, in particular for trucks
- Cooperative Systems, in particular Intersection Safety (INS)
- Infrastructure based systems to reduce accidents on crossings: Intelligent Pedestrian Traffic Signals, Crossings Adaptive Lighting and Pedestrian Presence Warning systems.

It is emphasised that many ITS applications that have been investigated over the years are still not ready for real life deployment. Of many others, the impact on traffic safety is not clear or not ready for quantitative assessment. In general, systems that assist the car driver in the driving task will influence the behaviour of the driver. Whereas the primary effect is likely positive, adverse effects – e.g. less attention to a part of the driving task 'because the system will take care of it' – may reduce the net impact on safety. The difficulty to predict overall safety impact is that simulators, prototypes and test drives do not represent the way in which system and user interact in practice, and in particular do not reflect how this interaction will evolve over longer term. Improving the collection and registration of accident data across Europe, making detailed pre-crash data from in-vehicle systems available for

analysis as well as initiatives in support of naturalistic driving (observations), in which the behaviour of motorists is monitored in real life over a longer period, are likely to be very valuable for more effective and efficient development of safety-related ITS.

Comfort of the VRU

Whereas safety can be regarded the most important topic for this study, comfort to the VRU is also within the scope. In general, it is difficult to assess comfort objectively. The older road user deserves particular attention, as he has specific requirements / limitations when interacting with ITS. So far, few applications have been developed to assist him/her in his particular weaknesses. Moreover, the Human-Machine Interface (HMI) of mainstream ITS applications have not been developed to the requirements of the older user and are often not suited for use by the older driver.

As to pedestrians, cyclists, and drivers of PTWs, there are only few ITS-applications to support them directly as a road user. To a large extent their comfort depends on the road layout and local traffic regulations such as speed limits and restricted access for cars and trucks. An urban environment in which pedestrians and cyclists are regarded as prioritised road users, reduced speed limits apply and cars have a lower priority – as is practiced in some countries in inner cities and residential areas – makes a world of difference for the comfort of the VRU. ITS can play an important supporting role here, e.g. by stimulating speed limit compliance (ISA) and pedestrian-aware traffic signal control systems.

Recommended measures

A basic assessment of applications was done to identify the applications (or areas) to be prioritised for EU action. The following criteria were applied:
- Expected impact on VRU safety
- Technical maturity
- Cost/benefit
- Potential to stimulate deployment on the short or medium term by the EU
- Public acceptance

This lead to measures on three levels:
- Tier 1: Application specific measures
- Tier 2: Application-group specific measures
- Tier 3: Horizontal measures

An overview of recommended measures is presented in the tables below.

The following measures are deemed appropriate in the area of **Advanced Driver Assistance Systems** (ADAS):

1) Non-binding:
   a) Elaborate with EuroNCAP ways to attribute higher weight to ADAS that increases safety for the VRU, focusing on PDS+EBR and ISA, and including effectiveness for other modalities than pedestrians. This also requires the elaboration of functional criteria to assess VRU safety effectiveness.
   b) Elaborate with the insurance sector how car insurance premiums can be differentiated by safety properties / safety systems of the vehicle, with specific attention for PDS+EBR and ISA.
   c) Investigate the impact of mandatory ISA for specific categories of vehides, e.g. LCV, public transport, fleets of public organisations and elaborate a corresponding recommendation.
2) Financial
   a) Award subsidies for deployment of specific ADAS, focusing on PDS+EBR and ISA.
   b) Discuss with member states the introduction of fiscal incentives or national subsidies for ADAS that adds to the safety of the VRU.
3) Legislative:
   a) Stimulate consumer awareness to safety through mandatory quotation of EuroNCAP rating in car advertisements.
   b) Make EuroNCAP assessment mandatory for new vehicle types.

The following measures are deemed appropriate in the area of **cooperative applications**:

1) Non-binding instruments / Financial instruments
   a) Elaborate in consultation with road authorities a viable path for migrating to basic cooperative features in their infrastructure.
   b) Stimulate further research in the area of INS and VBS.
2) Standardisation
   a) Support the standardisation of vehicle-vehicle and vehicle to roadside applications / communications / application data.

The following measures are deemed appropriate in the area of **regulatory applications**:

1) Non-binding instruments
   a) Investigate, establish and promote best practice guidelines for the use of AII in rehabilitation programmes
   b) Investigate, establish and promote best practice guidelines for the use of AII in specific vehicle/user categories - considering HGV, LCV, public transport and

> novice drivers.
> 2) Standardisation
>   a) Organise standardisation of alcolocks.

The following measures are deemed appropriate in the area of solely *infrastructure-based applications*:

1) Non-binding instruments & Financial
   a) Establish best practice guidelines for the application of infrastructure based applications (in particular CAL, IPT and RPP).
   b) Perform further independent assessment of their safety impact and influencing factors.

The following measures are deemed appropriate in the area of *HMI*:

1) Non-binding instruments
   a) Elaborate with the industry the extension of existing HMI guidelines to cover cross-system/cross-application coordination as well as the specific requirements of the older driver.
   b) Elaborate with the industry a set of HMI guidelines for ADAS for motorcycles.

The following measures are deemed appropriate in the area of *accident data analysis*:

1) Non-binding instruments
   a) Elaborate further harmonisation of protocols and definitions on accidents reporting for enhanced causation analysis, in consultation with the Member States
   b) Elaborate safety performance indicators, including ones specific for the VRU, in consultation with the Member States, monitor the indicators and encourage Member States to set quantitative targets.
2) Financial support
   a) Enhance the accessibility of the CARE database to the general public, preferably via a web interface.
3) Legislation
   a) Given the importance of detailed pre-crash data for the development of effective safety systems, the feasibility of mandatory fitment of a dedicated data recorder ('black box') should be investigated, as well as an obligation to deliver anonymised data that may be available from other in-vehicle systems in case the vehicle was involved in a crash.

Open issues and next steps

On the basis of a limited analysis it proved feasible to identify priority areas and applications for the safety and comfort of the VRU, and to outline measures to be prioritised. Insufficient material was at hand and insufficient consultation was possible within the scope of this study to define a balanced and sufficiently elaborated set of measures 'ready for implementation'.

The following next steps are therefore suggested as a follow-up of this study:

- Discuss the identified measures with stakeholders from the industry, regulation bodies and relevant interest groups to get a founded assessment of costs, effectiveness and acceptance.
- Review and further elaborate 'best measures' on the short, medium and longer term.
- Publish the results for broad consultation.
- Review 'best measures' if appropriate.
- Bring measures forward for decision making at the appropriate level.

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1. Introduction

1.1. Background and scope of work

On 16 December 2008 the European Commission adopted the ITS Action Plan (COM (2008) 886) for road transport and interfaces with other modes. The Action Plan aims to accelerate and coordinate the deployment of Intelligent Transport Systems (ITS) in road transport. The ITS Action Plan includes measures in 6 priority areas. Action Area 3 is dedicated to road safety and security. Action 3.4 of the plan - to which this assignment relates - calls for special attention to the impact of ITS applications and services on the safety and comfort of Vulnerable Road Users (VRU).

This assignment was commissioned under a framework contract for "Technical, Legal and Organisational support for the Implementation of the ITS Action Plan". The scope of this study is defined as, [14]:

> Development of measures including best practice guidelines concerning the impact of ITS applications and services on the safety and comfort of the Vulnerable Road Users.

1.2. Purpose of this document

This document constitutes the draft final report (D3), meant for internal use by the principal. It includes the results from all tasks under the assignment as identified in the Inception Report, [1] and the Terms of Reference, [14]. This document is intended to provide the principal with an opportunity to preview the final results of the study, and to forward comments to be addressed in the Final Report (D4).

1.3. Structure of this document

Section 1 'Introduction', this section describes scope, purpose and structure of this document and lists the general terms and abbreviations used
Section 2 'Methodology' addresses the approach for this study and can be regarded as a further elaboration of the presented methodology in the Inception Report.
Section 3 'Demarcation of Scope' deals with the identification and classification of the *VRU* as well as the applied definition of *ITS*.
Section 4 'Findings per VRU category' reports on the intermediate results following from an analysis of specific safety and comfort issues per type of VRU.
Section 5 'Findings per ITS application' reports on the intermediate results of an assessment per ITS application.
Section 6 'Synthesis, recommended fields for action and measures' presents the synthesis of results from both approaches and identifies measures to be taken on EU-level.
Section 7, 'Conclusions', summarises the findings and recommendations from this study.

Annex A contains a list of ITS-applications referred to in this study, with the corresponding acronyms and brief descriptions. Please verify alphabetical order

Annex B provides details of the selection and assessment of most appropriate fields of action.

1.4. Terms and abbreviations

Terms and abbreviations used in this report are listed below, with a short description. For terms relating to specific ITS-applications, a more elaborate clarification is provided in ANNEX A.

Term	Abbreviation	Description
Adaptive Cruise Control Full Speed Range	FSR (or ACC-FSR)	The Adaptive Cruise Control Full Speed Range (FSR-ACC) system keeps a driver-set speed or, in case the vehicle in front is slower, a driver-set distance to this vehicle.
Adaptive Head Lights	AHL	Headlights that turn when the vehicle is cornering.
Advanced Driver Assistance Systems	ADAS	In-car (ITS) technology designed to support the driver of a vehicle with the driving task.
Alcohol Ignition Interlock	AII	Device that inhibits starting the vehicle if the driver is under the influence of alcohol.
Blind Spot Detection System for Cars	BSD-C	System that detects and warns for objects in the Blind Spot of the car.
Blind Spot Detection System for Trucks	BSD-T	As BSD-C but designed for trucks.
Crossings Adaptive Lighting	CAL	Equipment mounted at a pedestrian (zebra) crossing detects if a pedestrian is approaching/leaving the scene and that adapts the lighting accordingly.
Curfew Locks	CUR	System that denies use of the vehicle (ignition) within a specified time interval.
Driver Drowsiness Monitoring and Warning	DDM	System that monitors the condition of the driver and warns the driver when symptoms of drowsiness are observed.
EC Whole Vehicle Type Approval	ECWVTA	European regulation for vehicle approval, focused on safety for use on the road.
eCall	ECA	System consisting of an in-vehicle device that detects a crash and

Term	Abbreviation	Description
		automatically establishes a voice connection to the emergency centre and transfers data including location and identification of the vehicle.
Electronic Data Recorder	EDR	Black box for road vehicles, allows detailed analysis of accidents and driving behaviour [13].
Electronic Driver Identification Interlock	EDI	An EDI systems locks ignition unless a smartcard is inserted in an in-vehicle card reader, with a valid driver license [13]. A biometric system can be included to verify driver identity.
Electronic Stability Control	ESC	System to stabilize the vehicle within the physical limits and prevent skidding through active brake intervention and engine torque control [12].
Electronic Vehicle Identification	EVI	System to identify vehicles electronically, e.g. through an RFID tag attached to the vehicle [13].
Emergency Braking	EBR	System to avoid or mitigate longitudinal crashes by braking automatically when a collision is (almost) unavoidable.
European Automobile Manufacturers Association	ACEA	Association representing the interests of 16 European car, truck and bus manufacturers at EU level.
Heavy Goods Vehicle	HGV	Vehicle (truck/lorry) meant for goods transport, with a maximum allowed mass above 3.5 tonnes.
In Vehicle Safety Systems	IVSS	Electronic systems in the vehicle of which the main purpose is to increase safety of the occupants, or potential collision partners.
Intelligent Pedestrian Traffic Signals	IPT	A traffic signal control system that uses sensors such as an infra-red camera to determine the presence of pedestrians and adjusts the traffic signals accordingly.
Intelligent Speed	ISA	System that compares the actual speed

Term	Abbreviation	Description
Adaptation		of the vehicle with the local speed limit and advises the driver or controls the vehicle until the speed is reduced to the local limit. ISA applications can be roughly classified as intervening/non-intervening and as static/dynamic
Intersection Safety	INS	Intersection Safety assists the driver in avoiding common mistakes which may lead to typical intersection accidents. It covers these functions [12]: • Traffic light assistance • Right-of-way assistance • Left-turn assistance
Lane Change Assistant	LCA	The system enhances the perception of drivers in lateral and rear areas and assists them in lane change and merging lane manoeuvres.
Lane Keeping Support	LKS	A lane keeping system for passenger cars and commercial vehicles supports the driver to stay safely within the "borders" of the lane.
Laser Imaging Detection and Ranging	LIDAR	Optical technology that can measure the distance to, or other properties of a target by illuminating the target with light, often using pulses from a laser.
Light Commercial Vehicle	LCV	Vehicles meant for transport of goods, with a maximum allowed mass of 3.5 tonnes. Vans and pickups are in this category.
Night Vision and Warning	NVW	The aim of NVW is to extend the visible range for a driver in darkness, including obstacle detection and warning, as well as warning for vulnerable road users [12].
Normalised Fatality Rate	NFR	Number of casualties per billion km travelled
Pedestrian Detection System	PDS	Pedestrian Detection Systems use LIDAR, RADAR, or camera technology to recognize a pedestrian. The PDS warns the driver and may brake automatically if an impending impact is

Term	Abbreviation	Description
		anticipated. At low speeds the system is likely to avoid a collision, at higher speeds the collision speed is at least reduced as far as possible.
Powered Two-Wheelers	PTW	Motorcycles, mopeds and scooters.
Radio Detection and Ranging	RADAR	Object-detection system which uses radio-frequent waves to determine the range, altitude, direction, or speed of objects.
Radio-Frequency Identification	RFID	Technology to read an electronic identification from a tag/label attached to vehicles or equipment, using radio frequencies (e.g. 5.8 GHz).
Responsible/Injured Ratio	R/I Ratio	Ratio of accidents for which the involved category was legally responsible as a fraction of all accidents with injuries in which this category was involved.
Roadside Pedestrian Presence Warning System	RPP	The system detects that a pedestrian is close to a crossing (or bus stop) and warns upcoming motorised traffic with flashing lights or information on a display.
Seatbelt reminders or locks	SBR	A seatbelt reminder system gives a warning if the driver has not plugged in his seatbelts. It may be extended to passenger seats as well.
VRU Beacon System	VBS	The VRU carries a transponder that communicates movement data and facilitates detection/localisation by the roadside infrastructure of in-vehicle systems.
Vulnerable Road Users	VRU	Road users as defined in section 3.2
Wireless Local Danger Warning	WLD	WLD detects hazards via its own sensors and communicates the hazard information to other vehicles via vehicle-to-vehicle communication.

2. Methodology

2.1. Analysis

In the course of the assessment of input material, it was concluded that there are two possible approaches to assess the impact of ITS on the VRU:

- A top-down approach, which starts from an identification of the dominant safety issues for each of the identified VRU categories and searches for information on the (potential) impact of existing/experimental/conceivable ITS on these issues.
- A bottom-up approach, which starts from information on reported impacts of existing/experimental ITS applications on safety and comfort, and consequently filters on relevance to the VRU.

Both approaches have their pros and cons. Which approach is most efficient depends on the nature of the available sources. As the most useful material appeared to be a mix of application-centred and accident-centred studies, it was decided to apply both methods and consequently synthesize the results.

The top-down approach consists of the following steps:

- Identify subcategories of VRU with respect to modality and age
- Analyse areas of in-safety: the types of accidents in which the respective VRU are often involved, or suffer from more serious consequences compared to the average road user.
- Assess what (future) ITS applications could possibly influence the exposure, the crash risk or the damage relevant to the identified type of accident.

The bottom-up approach has the following steps:

- Identify (areas of) ITS applications with a likely impact on VRU safety and/or comfort.
- Search for, and analyse material that reports on the impact of ITS applications on VRU safety/comfort.

The top-down approach is expected to add to the results of the bottom-up approach. It will help to identify areas where no or insufficient research results were found for firm conclusions, but where there is an area for improvement, and where ITS might be (part of) the solution.

2.2. Synthesis and elaboration of measures

As a next step, based on the results of the top-down and the bottom-up results, it is determined whether/how – in case of a reported positive impact – the expectations can be confirmed, the development, introduction or the penetration of the application can be

stimulated, or the effectiveness for the VRU can be improved. In case of a negative impact: determine whether/how the negative effects for the VRU can be mitigated.

For the elaboration of recommended measures, the following approach is taken:

1. Select the applications that were found to have a significant potential for the safety of the VRU
2. Prioritise applications on the basis of the following criteria
   - o Potential to save lives and reduce injuries of VRU
   - o Technical/organisational maturity
   - o Cost/benefit
   - o Potential to stimulate deployment on the short or medium term, by the EU
   - o Public acceptance
3. Elaborate appropriate measures for the prioritised applications, in view of the current development, deployment and legislative status.

It is noted that, measures may cover an entire group of applications, e.g. ADAS or Co-operative systems, or target overall improvement of VRU safety/comfort across all types of applications and systems. In other words, three types of recommendations are provided:
- Tier 1: Application specific measures
- Tier 2: Application-group specific measures
- Tier 3: Horizontal measures

Finally an outline of action for the further elaboration of the recommended measures is provided.

Note on comfort
The described approach has a clear focus on safety. Meanwhile, comfort of the VRU is also in the scope of this study. In general, it is difficult to assess comfort objectively: what is perceived as comfort by one user may be felt as a complete nuisance by the other. It is reported that – especially with respect to user interfaces of ITS – large differences between user groups exist. The older road user deserves attention, as he has specific requirements / limitations when interacting with ITS.

There is little scientific literature reporting on user comfort of ITS. Safety and comfort however often go together. In case of motorcyclists, discomfort could create a situation of danger, and therefore comfort should be considered as an important safety element. Systems that are felt to be non-comforting tend to be ignored (and thus not add to safety) and on the other hand that a system that is really believed to add safety is more likely to add to a perception of comfort. Of course, there are notable exceptions such as the comfort of phone calls while driving which does not add to traffic safety.

The approach taken for this study is that safety aspects are dominant in the description and selection of applications, but where applicable comfort is addressed separately.

3. Demarcation of scope

3.1. Introduction

This assignment is mainly concerned with traffic safety. Not all traffic safety aspects are to be considered however; the scope is clearly limited in two dimensions:

- The work should be dedicated to the Vulnerable Road Users, defined by the ITS Directive as: 'non-motorised road users, such as pedestrians and cyclists, as well as motor-cyclists and people with disabilities or reduced mobility and orientation', see [40].
- Attention is only to be paid to the impact of ITS. Measures/aspects that have no relation to ITS are to be ignored (or mentioned just briefly). This leads to the question what exactly falls under the definition of ITS.

The purpose of this Section is to elaborate a practical demarcation of the scope that can be used to determine what inputs and results are relevant to the work.

3.2. Identification of the VRU

In the Inception Report [1], the issue of a proper demarcation of the Vulnerable Road User (VRU) was already addressed. In literature car drivers and occupants are most often excluded from the definition of VRU, whereas the definition of the ITS Directive, see 3.1 would include those car users that qualify for 'reduced mobility or orientation'. In order not rule out important safety developments for cars beforehand, a broader scope was applied, including specific categories of car drivers.

Vulnerability can be associated with three or four different aspects:

1. The absence of a protective 'cage' around the traffic participant; this is applicable to all pedestrians, cyclists and drivers of Powered Two-Wheelers (PTWs).
2. Physical vulnerability. Increased chances of severe injuries when exposed to a given impact in a traffic accident; this is applicable to elderly and children. It is sometimes argued that women should be included as well, because vehicle safety design and testing is often tailored to physical characteristics of the average male. Women are generally stronger impacted in vehicle crashes compared to men. Vulnerability to rear impact crashes is particularly higher for female drivers (whiplash). Disabled are also a VRU group; due to the highly specialized approach requested to meet their needs this group of users is however not addressed in this study.
3. The ability/skills to safely participate in traffic; in fact this would apply to all road users with limited experience (in a specific modality). In particular it would apply to children who have limited oversight and understanding of traffic rules. It also relates to (very) elderly people who have a reduced ability to e.g. turn head and neck, assess speed of moving objects and reduced ability to evaluate complex

situations in a short time. Also people with little driving experience – recently acquired a driving license – can be regarded part of this category.

4. The traffic behaviour and attitude of the participant; this relates to e.g. drink driving, speeding, ignoring traffic regulations and signs. 'Behaviour' cannot be strictly separated from 'Ability and skills'. In essence the difference is that ability/skills cannot be improved or only gradually through training, whereas behaviour always has an element of free choice that can be directly influenced through communication and enforcement. From a moral point of view one could argue that behaviour in this sense is not related to vulnerability but comes down to a free choice of taking higher risks with one's own life as well as that of others. From a practical point of view, it would make sense to include this aspect as it results in a higher probability of getting injured or killed in traffic and of causing damage to others – if relevant reference will be made as to "impaired drivers".

A purely statistical approach defines all categories of road users that expose a significantly higher risk than average of becoming involved in a traffic accident as 'Vulnerable'. The first question to answer is how 'increased risk' is determined. The simplest method is to take the annual probability of getting killed or severely injured in traffic for a defined group of users. The drawback of this method is clearly that a there are large differences in exposure to traffic between groups: a higher exposure logically leads to more accidents. It is often more relevant to look at 'normalised crash rate', 'normalised fatality rate' or 'normalised injury rate' which represent the number of accidents, deaths or injuries per billion kilometres travelled. Unfortunately, such data are not always available: statistics are generally kept on accidents, but less often on travelled distances for specific categories of road users.

One may argue that a rate normalised over time spent in traffic instead of distance travelled maybe an equally valid method leading to quite different results. In general this moderates to some extent the great differences in fatality/injury rates between transport modalities. For the practical reason that data normalised by travel time are hardly available, rates per kilometre travelled are generally referred to in this document.

A simple classification of VRUs can be done by a matrix of age characteristics and transport modality as in Table 1 below. The table is too simple to present all relevant features and does not have the granularity normally required for safety research (usually 5- or 10-year segments) but serves to highlight the main categories of VRU. For all modalities except 'car', users of all ages can be regarded as VRU.

For the modality car, the inexperienced users (behaviour, skills) and older users (skills, physical vulnerability) represent categories that stand out with a higher average risk. Including these in the definition of VRU extends the definition from the ITS Directive which mentions non-motorised road users, motorcycles and 'people with disabilities or reduced mobility and orientation'. It is noted that this is a rude classification as young adults are not necessarily inexperienced or reckless drivers and that there are great differences between

driving skills of older drivers of a given(high) age. It is further noted that car drivers with a higher than average probability of becoming involved in a traffic incident may induce a higher risk for others than for themselves. For the scope of this task it is however convenient to have a simple definition and classification of the VRU; further nuances will be taken into account where relevant for conclusions and recommendations.

Table 1 Overview of VRU categories. Coloured cells indicate a VRU group; darker cells represent an assumed higher vulnerability.

	On foot	*Cycle*	*Light PTW*	*Motorcycle*	*Car*
Children			N.A.	N.A.	N.A.
Young adults					
Adults					
Elderly					

For the scope of this study, and after a scan of available material, it seems adequate not to distinguish all VRU categories by modality AND age, but to take modality as main classifier and address age categories specifically only for the modality 'car'. This leads to the following categories:

- I: pedestrians
- II: cyclists
- III: drivers of scooters and mopeds
- IV: motorcyclists
- V-A: young car drivers
- V-B: older car drivers.

Table 2 VRU categories in this study.

	On foot	*Cycle*	*Light PTW*	*Motorcycle*	*Car*
Children	I	II	III	IV	
Young adults					V-A
Adults					
Older adults					V-B

This does not mean that findings that are relevant to subcategories of these groups (I-IV) will be neglected; where relevant within the scope of this study they will be dealt with in the respective overarching category.

3.3. Identification of relevant systems and services

Although the term Intelligent Transport Systems is used widely throughout the transport community, the exact meaning is not obvious. The ITS Directive, [40], provides a definition, which leaves abundant room for interpretation: "Intelligent Transport Systems (ITS) are advanced applications which without embodying intelligence as such aim to provide innovative services relating to different modes of transport and traffic management and enable various

users to be better informed and make safer, more coordinated and 'smarter' use of transport networks"

. Clearly, some element of IT has to be part of the system, and at least part of the system should affect the transport means or transport infrastructure to classify as ITS. But this restriction does not provide a clear definition. Conventional traffic systems, e.g. an intersection traffic control system – although it may contain digital technology – is generally not regarded ITS. In-vehicle electronics does not automatically classify as ITS either.

The following three conditions seem to apply for what is often regarded as ITS:
- The system/service includes information technology
- The system/service includes an aspect of electronic data exchange with, or observation of, at least one other entity of type:
    - Vehicle
    - Road or roadside infrastructure
    - Driver or other traffic participant.
- The system/service has relevance to traffic / transport.

In the execution of the work, the checklist above will be applied. In cases of doubt, applications will be included.

4. Findings per VRU category ('top-down')

4.1. Introduction

Each of the following subsections addresses a VRU category. For each VRU category the following aspects are addressed:

1. *Accident statistics*. This subsection provides information on the absolute or relative frequency of accidents in which this VRU-category is involved, possible differences between countries and information on fatality or injury rates per billion km travelled.

2. *Characteristics and causes of accidents*. This subsection summarizes available information on specific subcategories, conditions, collision partners, roads and locations for which accident figures are reported to stand out.

3. *Possible areas of improvement*. From the specifics of accidents, generic areas of improvement are identified that would be effective in reducing – the severity of – traffic accidents.

4. *Relevant ITS-applications.* The identified areas of improvement may directly lead to ITS-applications, or be realised with a mix of ITS- and other solutions.

It is noted that positive safety effects can be sought in 4 different areas:

- Reducing the exposure to traffic, e.g. a navigation or real-time parking information service may lead to less distance travelled / less time spent in traffic
- Reducing the probability of accidents
- Reducing the severity of injuries if an accident happens
- Optimising assistance and care after an accident occurred. E-call is a well-known example of this category.

4.2. Pedestrians

4.2.1. ACCIDENT STATISTICS

According to an analysis by DG MOVE on the CARE database, pedestrians accounted for 20% of all traffic fatalities in 2009 in the EU. There are notable differences between member states, ranging from values around 10% in BE, NL, FI, SE to around 30% in RU, SK, PL and LT. In the period 2001-2009 pedestrian fatalities have reduced by approximately 33% while the total number of traffic fatalities has reduced 36%. Whereas this trend is to be regarded as positive, the number of pedestrian fatalities is still considerable.

Older adults (65+) have a disproportionate share of pedestrian fatalities, accounting for almost 36% in 2009. The pedestrian fatality rate strongly increases at higher age: from a small increase in the age group 65-69 to twice this value for ages 75-79. The main cause of this higher fatality is the higher physical vulnerability of the elderly.

Another group that stands out are children (<15), although to a far smaller extent than the elderly. Their share of pedestrian fatalities was around 5%, for the EU in 2009. The higher involvement of children is mostly caused by their limited ability to oversee traffic situations and comply with traffic regulations.

It is noted that fatality or injury figures per million inhabitants are a good measure for the 'size of the problem'. It does not provide full answers on the relative (un-)safety of a mode of transport or age group, as the figure depends on the amounts travelled, which may differ significantly between modalities and age groups. Figures that are normalised for distance travelled compensate for this effect. In [15] it is stated that for the EU on average, the fatality rate for pedestrians is 9 times higher than for passenger cars. For the Netherlands detailed figures are available, see [4] and [5]. In 2009 the traffic fatality rate was approximately 3.5 per billion traveller-km's over all modalities and ages, but almost 5 times higher (16.7) for pedestrians. For older people this rate was again 5 times higher: around 75. Looking at all crashes involving pedestrians– not only fatal crashes – the normalised traffic injury rate was 3 times higher for pedestrians compared to the average for all modes of transport. Here the figure for children as well as older adults (75+) is between 1.5 and 2 times higher than the average for all ages.

Similar to figures on the older drivers, a major increase in normalised fatality is observed from the age of 75; for ages between 65 and 75 the effect is quite small.

4.2.2. CHARACTERISTICS AND CAUSES OF ACCIDENTS

According to an analysis of the DG MOVE on the CARE database (2009 data), the accidents in the EU in which pedestrians are involved can be characterised quantitatively. Comparable figures for the Netherlands are provided between brackets, in case of major differences [5] with the EU average.

1. Over 69% of accidents happen in the urban area. This is of course related to the fact that the majority of walks is made in the urban environment.
2. A passenger car is involved in a majority – 75% - of accidents with pedestrians. In 8% a LCV or HGV is involved (20% for fatal crashes). Accidents with cyclists and mopeds account for 8%, and motorcycles for 5%.
3. A large portion of accidents, between 10% and 20% (in the Netherlands approximately 40%) take place on pedestrian crossings. The layout of the pedestrian crossing, the presence of traffic lights and the applicable priority rules have a significant influence on the safety. Generally speaking, crossings without any marking are safer than marked crossings. This is likely due to the fact that the markings provide the pedestrian with a false sense of security.
4. In general, as a result of their low speed, mass and lack of protective caging, pedestrians are generally the ones with the most severe injuries when involved in collisions with other modes of traffic. For collisions with cars, the chances of

survival for the pedestrian are strongly dependent on the collision speed. According to [6], the chance of survival is around 98% for a speed of 30 km/h, 80% at 50 km/h and only 40% at 80 km/h. The fatality risk increases sharply with speed between 50 km/h and 90 km/h.

5. New challenges are introduced by electrical vehicles as they produce little noise at low speeds and may thus not be observed by pedestrians. This is a particular issue for people with hearing problems or visual impairments (a relatively large fraction of older adults).

According to [3] a large portion of accidents with pedestrians happen in darkness: around 46% for the EU18 in 2005, with remarkably higher figures for Poland, Hungary and Estonia..

4.2.3. POSSIBLE AREAS OF IMPROVEMENT

From the brief analysis in the previous paragraph it can be concluded that significant safety improvements could be found in the following areas:

1. Better compliance with traffic rules by pedestrians themselves. Pedestrians may only walk on the road in the absence of pavements or verges. When there is no other option than to walk on the road, pedestrians should keep to the edge as much as possible, walk in single file and against the direction of traffic. Of course this can also be looked at from another angle: infrastructure in the urban environment should be designed for pedestrians as primary users, and traffic rules applied in such a way that pedestrians would largely comply spontaneously.

2. Where pedestrians do not share or cross the (part of the) roads that are used by faster modes of transport, the chances of serious accidents are small. The safety of the pedestrian will be improved if safe routes are available and known for frequently used destinations, especially those that are important for children (school) or older adults (e.g. shopping centre).

3. As the speed of the other means of transport involved in a collision is a determining factor in the severity of the accident for the pedestrian, measures to lower the speed of these road users at crossing facilities and locations where the road is shared with pedestrians are very effective. It also helps to reduce the chance of an accident. Conventional measures to improve compliance with speed limits include campaigns to inform drivers of the dangers of speeding and more intensive speed enforcement. Measures that help the driver to perceive pedestrians and possibly intervene in the driving task to avoid collisions. The system may warn the driver if the vehicle is on collision course with a pedestrian, increase the braking power for an emergency brake (Brake Assist) or even autonomously activate the brakes in case of imminent risk. This may or may not involve devices on the side of the pedestrian that facilitate his/her automatic detection. A specific concern is blind spot detection for trucks.

4. Improving the visibility of the pedestrian in darkness or twilight. This requires (better) lighting on pedestrian crossing facilities and situations where pedestrians share the road with other modes of transport. Crossings Adaptive Lighting (CAL) can significantly contribute to pedestrian visibility and so do improvements in the lighting system of vehicles, e.g. lights that turn with the curvature of the road, will also have a positive influence. Reflective elements on clothing will have a positive influence, but it seems unlikely that people will consistently use such when going for a walk. Technology that warns the driver or even activates the brakes is effective for this aspect as well.

5. Designing the front of vehicles in such a way that the impact on a pedestrian in case of a collision is minimised, e.g. by dynamic lifting of (the rear end of) the bonnet, or the use external airbags that may limit the severity of injuries on the side of the pedestrian.

6. Improving the layout and uniformity of pedestrian crossings, where applicable including measures to reduce vehicle speed, to improve traffic signal compliance or to warn fast traffic for the presence of pedestrians on or close to the crossing.

7. Improving the audibility of electrical vehicles: currently research is executed to find the best type of sounds that could be produced by electrical vehicles in order to be observed, whilst causing minimum annoyance.

4.2.4. RELEVANT ITS-APPLICATIONS

Some of the areas of improvement lead towards ITS applications. This is particularly the case for areas 3 and 4. Main applications of importance are:

- Related to area 3 (speed). ITS will become increasingly important here: speed measuring systems with feedback to the driver on roadside displays and in-car systems that remind the driver of local (legal or advised) speed limits, or even in-car systems that intervene to reduce the speed when above the local limit. The latter systems are all variants of Intelligent Speed Adaptation (ISA), see ISA. It is noted that ISA is not a solution that solves all issues; even when speed limits are fully respected serious accidents with VRU will take place.

- Related to area 3 and 4 (perception). Pedestrian Detection Systems warn for a forward collision with pedestrians and are nowadays often combined with brake assist and fully autonomous emergency braking functions, see PDS and EBR. Today's passive detection technologies (using LIDAR, RADAR or optical imaging technology) could in the future be complemented with an RFID transponder, in order to enable detection also when the line of sight is occluded during part of the approach (VBS). This requires that pedestrians are equipped with a 'tag'.

- Related to area 3. Blind Spot Detection Systems help to perceive VRU that are in the blind spot, i.e. not in the field of view of the driver or in the mirrors of the car. From a VRU perspective, this is mostly relevant for trucks, see BSD-T. It should be noted that accidents where the blind spot plays a major role, are reported as a major issue for cyclists and light PTWs, but not for pedestrians. This has to do with the

fact that, contrary to cyclists, pedestrians are mostly not closely along the side of trucks.

- Related to area 4 (darkness). Night Vision and Warning Systems, see NVW. In addition, Adaptive Head Lights, AHL, will likely lead to earlier detection of pedestrians 'around the corner' by vehicle drivers.
- Related to area 6 (pedestrian crossings). Intelligent Pedestrian Traffic Signal control, see IPT. These systems increase safety and comfort for pedestrians that require more than average time to cross the road, by extending the green time. They may also skip cycles when there is no pedestrian crossing the road (anymore) and thus increase acceptance and compliance by the motorist. Another kind of solution is a system that warns motorised traffic for the presence of pedestrians in the vicinity of the crossing, by flashing lights or warning signals on a display, see RPP. It may also be triggered by transponders carried by specific vulnerable groups (e.g. children going to school.

4.3. Cyclists

4.3.1. ACCIDENT STATISTICS

According to the CARE database cyclists accounted for almost 7% of all traffic deaths in Europe. The fatality rate of cyclists – number of fatalities per billion km travelled – is considerably higher than for passenger cars. As an example: in the Netherlands, which is one of the most cyclist-friendly countries in Europe, the cyclist fatality rate is still about 5 times the value for passenger cars, and the rate for severely injured even equals 7 times the value for passenger cars, see [4].

The European Cyclist Federation (ECF) reports that the relative safety of the cyclist increases when more people use a bicycle [11]. In countries with little cycle use such as Spain, the fatality rate is up to 10 times higher than in countries such as Denmark and the Netherlands, where cycling is quite common, see also [20]. It is concluded that the accident risk of cyclists is reduced by a society which is more cycle-focused. It is expected that when car drivers are more accustomed to cyclists they consequently pay more attention. More importantly, in countries with a larger cyclist community, the realisation of cycle-friendly environments (restricted access for vehicles, separate bicycle roads/lanes, lower maximum speeds) is far more developed compared to countries where cycling is rare. This strongly reduces the risk of traffic conflicts and collisions.

4.3.2. CHARACTERISTICS OF ACCIDENTS AND CAUSES

The following characteristics are observed for accidents involving cyclists:
- On the average, accidents involving cyclists are evenly spread over the urban (53%) and non-urban area (47%), with notable differences between countries [10].
- Over 80% of cyclist fatalities involve a motor vehicle as collision partner, in most cases a passenger car, see [10].

- Just as for accidents between cars and pedestrians, the severity of injuries when a cyclist is hit by a car is strongly correlated to the collision speed. At speeds above 50 km/h, chances of survival drop sharply.
- Different from collisions with pedestrians, cyclists often hit the windscreen or the metal frame of the colliding vehicle, see [11].
- Some 4% of severe accidents with cyclists in the EU involve a heavy goods vehicle, where the bicycle was in the blind spot of the truck. A factor in the seriousness of a part of these accidents is the high open spaces between vehicle and trailer or between the axles where the cyclist may get overrun, see [16].
- A large portion of traffic accidents involving cycles takes place at junctions, notably crossroads. According to [10], the fraction of cycle fatalities at junctions is around 37%. This is the highest fraction when comparing modalities, and almost twice the value for passenger cars
- On the average, some 24% of all bicycle fatalities take place in darkness or twilight, [10]. A factor of importance is that a significant fraction of cyclists that travel in darkness have no or not adequately functioning lighting. In a Dutch investigation in 2007, 38% of cyclists were carrying insufficient lighting. This is a rather alarming figure, as in darkness cyclists without lighting are often seen very late by car drivers.
- The cyclist fatality rate per billion km travelled increases dramatically above an age of 75, see e.g. [16]. This is for a large part due to the fact that the consequences of a given collision impact are generally far greater for the elderly given their higher frailty.

4.3.3. POSSIBLE AREAS OF IMPROVEMENT

Improvements may be sought in the following areas:

1. Separation of traffic streams. In urban areas, major routes may be completely freed of motor-powered traffic. This is a likely key element in any urban policy to stimulate the use of the bicycle, but is not related to ITS. Outside urban areas, separate cycle roads/paths drastically improve safety, notably by reducing the risk of collisions with motorized vehicles.
2. Perception/observation of cyclists by car drivers, especially in darkness or limited visibility conditions. This is relevant where the road is shared between cyclists and cars, as well as on crossroads.
3. Perception/observation of cyclists by truck drivers, when the cyclist is in the blind spot. It is noted that this is also an issue with passenger cars, yet specific attention for trucks is justified from the reported frequency and severity of accidents.
4. Reducing the average speed of motorized traffic at locations where the road is shared between cyclists and motor vehicles. The ECF recommends to have 30 km/h as the standard speed limit in urban/residential areas- cfr [11]. It should be noted that speed limits are not strictly respected by all drivers. Infrastructural measures such as speed humps that make faster driving impossible or very uncomfortable are effective to achieve 'natural compliance'. An important

contribution can be expected also from measures that improve speed limit compliance.

5. Infrastructural design and traffic control at intersections.
6. Passive safety measures, leading to reduced severity of injuries when a cyclist collides with a passenger car. Outer airbags targeting the windscreen or dynamic lowering of the vehicle hood are expected to be very effective to reduce the number of cycle fatalities in this type of accident [11].

4.3.4. RELEVANT ITS-APPLICATIONS

ITS may play an important role in the following areas:

- Area 2: (perception & observation)
  - o In-vehicle (ADAS) systems that warn for a potential head-on collision with cyclists. This may be an integrated facility that also detects and warns for other types of road users, e.g. pedestrians, as well as fixed objects. See PDS. The option of enhancing detection by using RFID transponders (see VBS), as noted in 4.2.4 for pedestrians, seems promising for cycles/cyclists as well, [50]. For improving observation of cyclists under conditions of darkness, NVW and AHL are relevant.
- Area 3: (perception & observation by truck drivers)
  - o In-vehicle (ADAS) systems that warn for cyclists or pedestrians in the blind spot. This is especially relevant for trucks but also for passenger cars, see BSD-T and BSDC.
- Area 4: (speed)
  - o A contribution to speed limit compliance could be expected from Intelligent Speed Adaptation, see ISA. Several pilots have studied the effects of ISA on speed limit compliance. In general, it is reported that the more intrusive and more dynamic concepts of ISA, would be more effective. The more intrusive variants however have a user acceptance issue. The negative perception may be turned into a more positive one if the direct user benefits can be strengthened (e.g. lower insurance premiums, potential to avoid speeding tickets). See also 5.2.3.
- Area 5: (intersection safety)
  - o More intelligent intersection control systems enhance safety at intersections as they may react more dynamically and adequately on actual traffic supply, see IPT. IPT is primarily designed for pedestrians, but addition of similar functionality for cyclists is likely feasible. This will increase acceptance and traffic signal compliance by all traffic participants. Another application in this area is RPP, which warns upcoming traffic that a pedestrian is approaching / starting to cross the road.

4.4. Mopeds and Scooters

4.4.1. ACCIDENT STATISTICS

The safety characteristics of mopeds and scooters have resemblance with motorcyclists as well as cyclists. There are significant differences as well, justifying a separate category. Mopeds, scooters and motorcycles are often combined in one category 'powered two-wheelers' (PTWs). There are two main difficulties for a specific assessment of safety issues with light PTWs (mopeds and scooters) in Europe:

1. Mopeds and scooters are not uniformly defined across Europe. Member States tend to have different definitions of categories (in terms of maximum speed, maximum motor volume or maximum power), different requirements as to required driving licenses and mandatory use of a helmet. As a result, statements about light PTWs have different meanings from country to country.

2. As with bicycles, there are large differences in the use of light PTWs between Member States.

These differences are also reflected in national accident statistics that are difficult to aggregate on a European level.

According to the CARE database, moped fatalities constitute some 4% of all traffic fatalities in Europe (in older figures, [19], this was 5%). This seems a modest share, yet the normalised fatality rate is the highest of all modalities, even higher than for motorcycles. Dutch statistics over 2003-2006, see [4], indicate a fatality rate of 70 per billion kilometres travelled - compared to 66 for motorcyclists, 12 for pedal cyclists and 3 for car drivers. The corresponding figures in the UK in 2008 were 89 for mopeds & motorcyclists and 2 for car drivers, see [21]. Moped riders stand out even more if we also consider severe injuries: the severe injury rate (fatalities + in-patients) equals 800, almost twice the corresponding value for motorcyclists.

The group of young drivers, aged 15-17 is of special concern as their injury rate is even two times higher than for average moped riders.

4.4.2. CHARACTERISTICS OF ACCIDENTS AND CAUSES

The following characteristics of accidents in which mopeds and scooters are involved are reported, see [22]:

- In the major part of accidents with a moped/scooter, a passenger car is the collision partner.
- Frequent victims of crashes with mopeds/scooters are cyclists, other moped riders and pedestrians. Injuries suffered by car and van drivers involved in an accident with mopeds are rather rare.
- Diagnoses common for moped accidents include: not yielding, not yielding to straight-on traffic, and losing control over the bike. 22% of accidents were single accidents.

- Alcohol consumption was involved in 10% of accidents. This is slightly higher than the average value for all transport modes.
- Most of accidents involving mopeds/scooters take place in the urban area, and slightly more on junctions compared to road segments.
- Factors considered relevant for the high injury rate of moped riders has to do with their relatively low speed while sharing lanes with cars and trucks.
- Another factor is the limited protection of moped riders, in combination with a relatively high speed. Wearing a helmet has a major impact in reducing the severity of injuries. According to [23], the helmet reduces or avoids injury in more than two thirds of accidents with PWTs. Helmet usage is lower for moped users compared to motorcyclists, especially during summer months in southern European countries. [24] reports a compliance of 80% for mopeds in urban areas, and only 60% for moped passengers in Spain.
- Young drivers, aged 15-17 are overrepresented in accidents.
- In some countries it is quite common that mopeds are tuned for higher power/speeds than legally allowed. Risks increase if people with tuned mopeds, don't use a helmet, share cycle lanes designed for <25 km/h or have insufficient driving experience for a larger machine.

4.4.3. POSSIBLE AREAS OF IMPROVEMENT

From the previous paragraph we conclude that specific improvements for light PTWs may be sought in the following areas:

1. Creation of risk awareness, awareness of traffic regulations and proper driver training. This is a specific challenge for the young drivers.
2. Mandatory use of a helmet for all types of PTW.
3. Improving compliance with speed limits, through enforcement and/or by creating risk awareness
4. Reducing drink driving, through enforcement and by creating risk awareness.

The areas of improvement listed for cyclists are relevant for this category as well, see 4.3.3. For the heavier types of PTW, the areas of improvement for motorcycles apply as well.

4.4.4. RELEVANT ITS-APPLICATIONS

The specific areas of improvement for light PTWs mentioned in the previous paragraph do not lead to any straightforward ITS application. However, the ADAS applications deemed relevant for cyclists and motorcyclists are also likely to improve the safety of the light PTW driver; notably BSD-T, BSDC, ISA, NVW, AHL, INS and AII .

4.5. Motorcycles

4.5.1. ACCIDENT STATISTICS

According to the CARE database, motorcycle fatalities constituted 15% of all road fatalities (16% reported in [7] for the EU-14 in 2006). This is a very high figure in view of the fact that the number of kilometres driven with motorcycles is relatively low. It is reported that for motorcyclists the NFR is between 7 (Finland) and 25 times (UK and France) times higher than for car occupants, see [8] and [9], with an EU average of 18, [15].

Whereas road fatalities have reduced strongly (by 36% on average) for almost all modalities over the last 10 years, the number of motorcycle fatalities in Europe has increased by only 6% in the same period, against an increase in vehicle park of almost 15%. This trend was also visible in the United States, both in absolute numbers as in fatality rates per distance travelled [17].
In the Netherlands, the number of motorcycles strongly increased over the past 30 years (from 100.000 to 600.000), whereas the total number of kilometres travelled by motorcycle gradually *decreased*, see [4]. Apparently, the average motorcyclist in the Netherlands travels considerably less kilometres than 10 years ago. It seems the motorcycle is increasingly used for a limited part of the mobility demand of motorcycle owners. It is likely that this trend exists in other EU countries, but no figures were at hand.

In 2009, some 21% of motorcycle fatalities concerned young drivers (<25) while drivers between 25 and 45 years of age accounted for another 56%. The share of women is low, around 6% in spite of the growing number of women motorcyclists. [7].

4.5.2. CHARACTERISTICS OF ACCIDENTS AND CAUSES

According to [7], some 40% of all accidents with motorcycle fatalities take place in the urban area. This is a high percentage compared to passenger cars (20%). Another 55% happens on interurban secondary roads. Fatalities on motorways constitute less than 4%; this is two times less than for passenger cars.

During summer months the number of motorcycle fatalities is about three times higher than in winter, [7]. This is not really surprising, as many motorcyclists only drive with good weather conditions.

The following types of accidents involving motorcycles are reported to be most common in various national and European studies, [9]:
1. Accidents at an intersection: 29% of motorcycle fatalities occur at junctions (compared to 16% for passenger car occupants), mostly on crossroads and T- or Y-junctions [7]. Often a right-of-way violation is involved, where in many cases the error is made by the car driver failing to notice the motorcycle.

2. Accidents during an overtaking manoeuvre, often caused by a car driver having a motorcycle in the adjacent lane blind spot, or not observing the upcoming motorcycle when overtaking on single carriageway roads.
3. Single motorcycle accidents, due to loss of control. This type of accident often takes place in curves. Excess speed and/or locally deteriorated road surfaces are common causes for this type of accidents.

The following causes or influences play a notable role in motorcycle accidents, according to [9]:

1. Conspicuousness. In a large part of accidents, the motorcycle is not observed or perceived by a car driver. According to [18], this would apply to 33% of all crashes with motorcycles. This is mainly due to its smaller size, and the fact that perception of car drivers is 'tuned' to the observation of cars rather than motorcycles. It is assumed that so-called 'Look but Fail to See' errors are involved in a major part of these accidents, see [25]. Another factor is the situational higher speed of motorcycles: a car driver is often surprised by the sudden approach of a motorcycle that seemed far away an instance ago. More often than not, car drivers are at fault in collisions with motorcycles. For the motorcyclist impaired perception occurs as a result of occlusion by the helmet, and reduced stability when looking over the shoulder. This is however not reported to be a major cause of accidents.
2. It is reported that alcohol is involved in 25% of all motorcycle accidents with fatalities.[18] reports a value of only 5% however, for a large number of crashes analysed in 2000 and 1999.
3. Speeding. It is reported that non-compliance with speed limits or inadequate speed is far more common for motorcyclists than for car drivers. Some studies suggest that for 40% of fatal accidents with motorcycles, the motorcyclist was riding considerably faster than the speed limit.
4. Driving attitude and behaviour. This relates to sensation seeking, risky behaviour and also includes over-confidence of the motorcyclist to adequately react when other traffic participants would act unexpectedly. It is noted that risky behaviour does not apply to all categories of motorcyclist and has a correlation to young age.
5. Driving skills and experience. It is observed that the risk of an accident is much higher for motorists that use their motorcycle infrequently.
6. Inherent instability related to the concept of a two-wheeler. Especially in combination with a slippery road, deteriorated road surface, inadequate speeding and/or unexpected traffic events this will strongly increase the risk of serious accidents.

4.5.3. POSSIBLE AREAS OF IMPROVEMENT

From the previous paragraph we conclude that the improvements may be sought in the following areas:

1. Better detection/perception of motorcycles by car drivers

2. Improving compliance with speed limits, through enforcement and/or by creating risk awareness
3. Reducing drunk driving, through enforcement creating risk awareness, and through ITS, see next paragraph.
4. Improving risk awareness and driving skills with the young/less experienced riders
5. Better information on dangerous road, traffic or weather conditions to the motorcyclist.

4.5.4. RELEVANT ITS-APPLICATIONS

It is felt that ITS has a role to play in areas 1-3. Most important is area 1. This would in the first place target the drivers of passenger cars instead of the motorcyclist: car drivers may be supported by systems that automatically detect approaching motorcycles head on, or in the blind spot of the vehicle.

- Area 1 (perception).
  - o In-vehicle systems that warn for approaching head-on traffic in particular when turning left (turning right for UK/Ireland), forward collision warning, see also INS.
  - o Blind Spot Detection systems are likely to reduce the risk that a car driver will initiate an overtaking measure that will lead to a collision with a motorcycle, see BSD-C.
- Area 2 (speed limit compliance).
  - o It is imaginable that adapted versions of ISA could be developed for motorcycles as well. Apart from the technical challenges, it is reported [8] that the introduction of the more intrusive versions of ISA will not be welcomed by the motorcycle driver – it is expected that the aversion of the motorcyclist to intrusive versions of ISA would be even stronger than for car drivers. The Federation of Motorcyclist Associations (FEMA) indicates that this 'aversion' of motorcyclists is mostly based on the conviction that intervention on brakes/throttle during cornering or other manoeuvres is difficult to handle for the driver and is more likely to cause danger than to solve a safety problem. Non-intrusive forms of ISA should not have this issue.
  - o More intensive speed enforcement may be part of the mix to increase speed limit compliance (awareness, assistance, enforcement).
- Area 3 (drink driving).
  - o Alcohol Ignition Interlock Systems, AII, could be developed for motorcycles as well.
- Generic
  - o ABS is available on some models. ABS will increase the effectiveness of braking and help to keep control of the vehicle when strong braking is required.

Motorcycle ADAS could improve the safety of the biker as well. There is however a number of obstacles that will likely lead to a lower coverage and slower uptake compared to passenger cars:

- The HMI requirements (of the motorcycle are hugely different from passenger cars. The driving task requires more instantaneous attention and the possibilities to provide visual or audio information in a safe manner are limited due to the position of the dashboard, the helmet and the background noise experienced by the motorcyclist.
- The impact of systems that intervene in the driving task is quite different from passenger cars and requires specific R&D. As was noted for ISA, stability is critical on a motorcycle and imposes very different constraints compared to 4-wheeled vehicles.
- Generally speaking, motorcyclists are not always enthusiastic for systems that take over parts of the driving task as this can induce a loss of vehicle control. A large part of the community will not be willing to pay extra for such technology if optional. In general however, the motorcycle community is very risk-aware, and would be interested in systems that would really be suited for motorcycles and shown to reduce risks.
- The motorcycle industry is much smaller than the car industry and strongly fragmented. Individual companies have limited means for safety-related R&D, and will target on improvements the biker is willing to pay for.

In spite of these obstacles, ITS certainly has a role to play to increase motorcycle safety in the future. [17] identifies E-Call (ECA) night vision (NVW) alcohol interlock (AII), blind spot detection (BSDC) and collision warning systems as suitable applications for the motorcycle – once sufficiently developed for motorcycles.

4.6. Inexperienced/young drivers

4.6.1. ACCIDENT STATISTICS

Young inexperienced car drivers have a strongly increased risk of getting involved in a traffic accident. In the Netherlands 20% of passenger cars involved in serious accidents were driven by young drivers (age 18-24), whereas their share of driving licenses was only 7.8%, [38]. Judging from this figure the fraction of young drivers of all traffic casualties would be 5.4%. An older report lists a figure of 37% for all car driver casualties and 18% of all driver injuries in Ireland in the year 2000, [49].

In the Netherlands, the risk per kilometre travelled is about 4 times higher compared to car drivers between 30 and 60 years of age. Comparable figures are reported for other countries where drivers are fully licensed for independent use of a vehicle after passing their test.

A worrying trend is that in the last 20 years the injury rate for the young male driver has not followed the decreasing trend for the average driver.

4.6.2. CHARACTERISTICS OF ACCIDENTS AND CAUSES

In general, drivers are assumed experienced after 6 years of driving a vehicle or 100.000 km's. With less experience the chance to get involved in various types of accidents is simply higher – although large individual differences exist. According to [38], the following more specific factors are relevant for accidents involving young drivers:

1. The use of alcohol and/or drugs. Although young drivers are less often found to be drunk driving than average, the effect of alcohol is strongly detrimental to driving skills for drivers with little experience. A problem of increasing importance is the use of drugs in traffic. It should be mentioned that this problem is strongly correlated to young male drivers. Given de diversity of drugs that are used no adequate automated detection methods are currently available.

2. Young drivers are relatively often involved in single accidents, see [38]. For young male drivers single accidents constitute about 50% of all accidents in which they are involved, compared to only 25% on average. For young female drivers the corresponding fraction is 33%.This indicates that young (inexperienced) drivers make more errors in controlling the vehicle, which is also related to choosing an appropriate speed

3. Relative high exposure to increased risk situations: driving at night, in the weekend, driving with distraction from other passengers or mobile phone use.

4. Young drivers are generally less risk-averse and tend to overrate their driving skills.

4.6.3. POSSIBLE AREAS OF IMPROVEMENT

Improvements can be sought in the following areas:

1. Improved training, with more focus on risk perception, and monitoring/feedback also after acquiring a driver license
2. Gradual licensing schemes
3. Reducing allowable alcohol limits and increasing compliance
4. Reducing the use of drugs in traffic
5. Support in respecting appropriate driving speed
6. Reducing the use of mobile phones while driving
7. Discouraging use of the vehicle under increased risk conditions / Reducing the use of the vehicle at night especially during weekend nights

4.6.4. RELEVANT ITS-APPLICATIONS

- Related to area 1 and 2: mandatory use of eco- and safe-driving coaching devices during first 100.000 km giving real-time advisory feedback and off-line follow-up (most likely running on navigation system or phone)
- Related to area 3: the fitment of Alcohol Interlock Ignition systems. It should be noted that other measures, i.e. not relating to ITS, are reported to be more important to reduce drink driving. According to [44], lower blood alcohol limits

(BAL), random breath testing, a lower BAL for youths and gradual license schemes are all more effective against drunk driving. Still Alcohol Ignition Interlocks may be a valuable component in an overall alcohol strategy.

- Related to area 4: given the diverse nature of drugs that deteriorate driving skills, no automatic detection technologies are available as yet.
- Related to area 5: Intelligent Speed Adaptation (ISA)
- Related to area 7: Pay As You Drive (PAYD) schemes. PAYD may differentiate vehicle insurance premiums by time and location of travel, and by driving characteristics (speed, acceleration, braking etc.)
- Related to area 7: mandatory use of Curfew Locks, see CUR, disabling the start of the vehicle late at night (typically between 1AM and 6AM)

4.7. Elderly drivers

4.7.1. ACCIDENT STATISTICS

From the CARE database the following conclusions can be drawn on accidents involving older road users (ages>64):

- The portion of older adults in road fatalities is about 21%. The trend of reduction between 2001 and 2009 was lower than for the average driver (25% compared to 36%).
- The fatality rate (road traffic casualties per year, per million inhabitants) is notably higher than average for older adults: +25% for the age group 65-74 and even +75% for the age group 75-84[1].
- In around 27% of road fatalities with older adults, they are involved as car driver. Fatalities with older drivers constitute app. 27% x 21% = 5.7 % of all road fatalities.

The fatality rate reported above clearly indicates that the elderly driver has an increased annual risk to become a victim of a traffic accident. When taking into account that the number of kilometres travelled by older drivers is much lower than average, the difference is even much greater. [16] indicates that the fatality rate in terms of killed drivers per billion driver kilometres was about six times higher for the age 75+, and almost three times higher for the age group 65-74, than for ages 50-59 (figures from 1996-1998 in the Netherlands). From more detailed figures it can be concluded that a clear increase in traffic fatalities is apparent from the age of 65 and that it shows a steep increase from an age of 75. It is likely that the right 'leg' of the fatality/age curve gradually shifts to higher ages, with the general trend of decreasing vitality at high age.

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[1] This applies to the average for the EU, there are considerable differences between the countries.

The next step is to find the causes of the higher fatality of the older driver. The analysis in [2] shows there are two important elements:

- The frailty of the elderly: from the age of 65 the vulnerability (number of fatalities per 100 people injured in traffic) increases from a value in the order of 1, to a value above 4 at the age of 85.
- A higher 'error rate' of traffic decisions: the R/I ratio (ratio of the number accidents in which someone of the age class was involved and found legally responsible divided by the number in which someone of the age class was involved but 'innocent') raises from a value of 0.85 at the age of 50-59, to a value of 1.5 at the age 65-74 and even 3.0 at ages >75. It is noted that R/I information is largely dependent on police reporting. This registration has a considerable inaccuracy as it is often not possible to determine responsibility at the scene of the accident. Prejudice towards the older driver is suggested by some experts to play a role as well. Without building on the absolute figures, the great differences between types of accidents provide valuable insight in the situations and manoeuvres that are a greater problem for the older driver.

One may conclude that as car driving at higher ages leads to steeply increased chances of becoming involved in accidents, it should be discouraged. If we compare with other modalities however, car driving is – for older people as well as other age groups– substantially safer than riding a bicycle, a moped or going on foot, judging from the injury rates per billion kilometres travelled (public transport being still by far the safest means). From a point of view that freedom of movement is a fundamental right, that mobility adds to quality of life and that the choice of modality is an individual choice, improving the safety for the older driver should be a priority anyway.

Two different paths can be followed when seeking to improve the safety of the older driver:

1. One may look for ways to reduce the impact on the body for a given accident type
   - this is for a large part not specific to the older driver and an on-going development in vehicle safety. There may however be types of protection that would target specific vulnerabilities of the older people. Such improvements are mainly in the area of vehicle protection systems, but ITS can play a role as well.
2. One may look for ways to eliminate/reduce traffic situations that are apparently difficult for the older driver, or seek ways to assist the driver to make fewer errors in such situations. In order to determine what kind of assistance would be effective, one needs to have a closer look at the type of accidents in which older drivers are overrepresented.

4.7.2. CHARACTERISTICS OF ACCIDENTS AND CAUSES

As mentioned above, according to [2], older drivers are often legally responsible for the crashes they are involved in. The R/I ratio (responsible/involved and injured) increases

from a value of 1 at ages 60-64 to a value of 3^2 for ages 75+. There are remarkable differences though, per type of accident. Types of accidents in which the older driver is over-represented, or the older driver is more often legally responsible are presented in Table 3.

Table 3 R/I ratio for types of crashes in which the older driver is overrepresented.

According to [2], based on data from the NL Ministry of Transport (1994-1998).

Type of crash / manoeuvre	Age group		
	60-64	65-74	75+
At intersection	1.2	1.7	3.4
Not yielding	1.5	2.0	4.2
Fatigue/illness	1.8	2.7	5.7
Turning left	1.6	2.3	7.1
Turning round	1.5	2.3	8.3
Joining/exiting through-traffic	1.5	2.7	3.5

The physical and mental condition of the older driver plays an important role in the higher crash rates of the older driver. These may be distinguished in:

- Functional limitations, related to age. This includes vision, cognitive functions (ability and speed to process complex information) and motor functions (e.g. ability to rotate the neck)
- Specific disorders more common at higher ages. Examples are various eye disorders, dementia, Parkinson, stroke, angina pectoris, and diabetes.
- Medication. Older adults often suffer from one or more illnesses/disorders and often have medication. Multiple medications are quite common. Medication has a potentially strong impact on the ability to drive, depending on type, combined use, the illness itself and personal characteristics.

It should be noted that these negative effects do not automatically lead to more accidents: the older driver may compensate with many years of driving experience, and with adapted behaviour such as avoiding inconvenient road and weather conditions and not being tempted to violate traffic rules. These compensations are mostly on the 'strategic' and 'tactical' level and have little effect on the operational level when vital decisions have to be taken in (fractions) of seconds. This explanation is suggested by [2] for the fact that the steep increase in accident rates starts at a much higher age than the gradual deterioration of perception and cognitive functions: to a certain level the loss of 'operational capability' can be compensated for, but a certain minimum is necessary to participate safely in traffic.

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[2] It is noted that an R/I ratio of 3 means that the involved was reported liable in 75% of the cases and not liable in 25% of the cases.

4.7.3. POSSIBLE AREAS OF IMPROVEMENT

Three major areas for improvement can be identified:

1. Improving road design, to reduce the complexity of perception and processing. This particularly applies to intersections. It primarily relates to the physical road design, e.g. presence and appearance of traffic signals, road lighting, road markings and number of left-turn lanes.
2. Assisting the driver in perceiving other road users, processing and selecting information, and controlling the vehicle, and notably being informed/reminded on the appropriate driving speed
3. Warning the driver and eventually taking control over the vehicle in case of an abrupt physical problem of the driver while driving the vehicle.
4. Enhanced care-taking in case of vehicle breakdown or incidents

4.7.4. RELEVANT ITS-APPLICATIONS

ITS may play a significant role in areas 2 and 3.

Area 2 (driver assistance)

According to [2], functionality particularly useful for the older driver can be derived from their particular problems/weaknesses. See Table 4 below.

Table 4 Identification of desired ADAS functionality for the older user, according to [2]. Note: the last row was added by the authors.

Specific problem/weakness	Desired functionality	Relevant ADAS
Perception of moving objects and contrast sensitivity; estimating speed of other road users, perceiving depth, reading signs	Draw attention to approaching traffic, especially at intersections	Collision warning systems Lane Keeping Support / Lane Change Assistance In-vehicle signing systems
Peripheral vision, flexibility of head and neck; overlooking other road users	Observe road users in the driver's blind spot	Blind spot and obstacle detection systems
Selective attention, overlooking traffic signs and signals	Assist driver to focus on relevant information	In vehicle signing systems
Speed of information processing and division of attention	Provide prior knowledge on upcoming traffic situations, e.g. traffic signs, lane use	Pre-information from navigation or co-operative system

In addition, ISA can be effective to remind the older driver of the appropriate speed, even if speeding is not a common cause of accidents for this group. This can be implemented by in-vehicle signing, and may also add significantly to the comfort of the older driver.

Some of the ADAS mentioned above is not yet available on the market at all. Almost all applications available are not or not sufficiently tuned to the needs of the older user. It is not yet possible to indicate the impact such systems will actually have on the crash rates of the older drivers. It is fair to assume that such systems will at least add to the comfort of the older driver, provided that the design has been tested and optimised for this user group. It is emphasised that the HMI requirements of the older driver are quite different from the average driver. The design of the HMI should be adapted to his/her limitations in processing and select the most urgent/important information for presentation. A further challenge is to present the information in such a way that it is noticed and understood by the older driver, with a minimum distraction from the driving task.

Area 3 (assistance in case of stroke, unconsciousness)

- Systems in the vehicle may monitor the driver's behaviour and detect anomalies. Such systems are of course not specific for older drivers. The course and speed of the vehicle may be input to such systems, as well as direct observation of the driver. In the first stage the driver will be warned through visual and sound signals of increasing intensity. If no reaction is observed, the system takes control over the vehicle, reduces the speed, parks it safely alongside the road and triggers the e-call, see also DDM and ECA.
- E-call will be of particular benefit to the older drivers, given their increased chance of being involved in an accident or losing control of the vehicle due to abrupt physical conditions.

4.8. Generic VRU safety: distraction

4.8.1. DESCRIPTION

Many accidents in which passenger cars are involved include an element of reduced attention to the road / traffic scene by the driver. In some cases accidents can be completely attributed to driver distraction. More often, accidents might have been avoided or the impact speed would have been lower if the driver was paying more attention. Though accident statistics do not allow a quantitative assessment of this issue, it is widely recognised that driver distraction is an important safety issue of which the VRU are the usual victim.

There are several forms of driver distraction:
- Driving task related: e.g. while looking in the mirrors one is not able to perceive the traffic in front of the vehicle.

- Non-driving task related – e.g. the use of a mobile phone, a conversation with the passengers or external distraction from outside of the car (e.g. billboards).

Not all distraction is bad for traffic safety. Recent research shows that it is relatively harmless or even beneficial to perform a minor secondary task in order to achieve prolonged high performance on longer trips. A conversation in a low workload scenario is generally valuable to keep car driver alert.
In a high workload scenario however distraction is dangerous as it reduces the chances of timely and adequately responding to external threats.

In general, drivers are able to prioritise and modulate workloads. This process is not 'error-free' however, and the driving task may change from a situation of low workload into a high workload in a very short time.

4.8.2. POSSIBLE AREAS OF IMPROVEMENT

The following areas of improvement can be identified:
1. Banning activities that cannot safely be combined with the task of driving. A well-known example is the use of the mobile phone. A lot of effort has already been spent on public awareness campaigns and dedicated enforcement.
2. Disabling functions or applications that cannot be safely combined with driving, or not above a certain speed.
3. Measures to keep the driver alert in low workload scenarios.
4. Measures to warn the driver when a collision with an object or VRU is close and the driver does not respond adequately.

In general measures to reduce the speed will always have a positive effect as well, as the time to react is increased and the impact of a potential collision is reduced.

4.8.3. RELEVANT ITS-APPLICATIONS

Relevant ITS-applications are seen in areas 2 and 3.
People will always be distracted of the forward road scene due to external events or driving related events.

- Related to area 3. The industry is looking into 'keep alert' applications for use in low workload scenarios. This is a research area for the future. DDM is also relevant, but is corrective rather than preventive and focuses on drowsiness rather than distraction.
- Related to area 4. Forward collision warning systems are very helpful in this area. This functionality is not listed separately in this study but largely covered by PDS and EBR. It is noted that there is room for improvement of the detection capability of current generations of these systems, including better detection of cyclists and mopeds.

5. Findings per ITS application ('bottom-up')

5.1. Introduction

This chapter presents the results of the 'bottom-up' approach. It identifies existing and envisaged ITS applications that have proven or potential safety impacts on VRUs or that add to their comfort. Per application an assessment is made of:

- The expected penetration between now and 2020
- The safety and comfort impact on each VRU category

Finally, measures to improve the impact of the applications are described, and steps elaborated to realise these measures.

Table 5 presents an overview of a basic assessment of the safety impact of the applications for each of the defined VRU-categories. The applications are sorted by category:

- ADAS
- Cooperative systems
- Regulatory and enforcement applications
- (Solely) infrastructure based applications
- Other ITS applications

Table 5 Expected safety/comfort benefits of applications for distinct categories of VRU as a result of a basic assessment. The ITS applications are sorted in groups (ADAS, Cooperative, Infrastructure-only, Regulatory and Other).

	Acronym	Category					
	Application or application area	**Pedestrians**	**Cyclists**	**Drivers of scooters and mopeds**	**Motorcyclists**	**Young drivers**	**Older drivers**
	AHL	(+)	(+)	(+)		(+)	(+)
	PDS / EBR	++	?	?		(+)	(+)
	ESC					++	++
	FSR				(+)	(+)	(+)
	LCA				(+)	(+)	+
II	LKS , LDW				(+)	+	+

	Acronym	Category					
	NVW	+	+	+	+	+	+
	DDM				(+)	+	+
	BSD-C	(+)	(+)	(+)	+	+	+
	BSD-T	(+)	++	+	+		
	ISA	++	++	+	+	++	(+)
Cooperative Systems	VBS	+					
	INS	+	+	+	+	+	++
	WLD				(+)	+	+
Regulatory Applications	All	++	++	++	++	++	++
	SBR					+	+
	EDI	I	I	I	I	I	I
	EVI	I	I	I	I	I	I
	EDR	I	I	I	I	I	I
Infrastructure based Applications	CAL, IPT, RPP	++	(+)				
Other ITS	ECA				(+)	+	+
	SAT					+	+

Legend:

++:   strong positive impact reported

+:   positive impact reported

(+):   some positive impact likely

?:   impact expected, but unknown

I: indirect effect

The next sections provide per application category:

- A general description of the common application characteristics
- Relevance of applications for the safety (and comfort) of distinct VRU categories
- Expected future penetration, i.e. the installed base / fraction of vehicles (or roads in case the application has no in-vehicle component) equipped by a certain time horizon
- Potential impact of the applications on road safety
- Expected road safety benefits of the applications
- A synthesis of what applications are most suited to improve road safety per VRU category, and the expected impact at unchanged conditions
- Possible measures to stimulate development and deployment of most appropriate applications

5.2. Advanced Driver Assistance Systems (ADAS)

5.2.1. DESCRIPTION

Driver assistance systems support vehicle drivers in the driving process. These can either assist, inform or warn drivers, or sometimes intervene in the actual driving process. ADAS development is led by the automotive industry. Significant advances have been made in recent years to make ADAS market ready, resulting in several ADAS market introductions in recent years. For example:

- FIAT launched the first haptic LKS in 2008
- NVW was introduced by BMW in 2008
- PDS has been launched by Volvo in several 2010 and 2011 models
- Mercedes introduced DDM in 2010.

It is noted that new ADAS is usually introduced by one or a few leading manufacturers on selected / top end models. Successful features that consumers appear to be willing to pay for and that do not involve major cost are subsequently adopted by the other manufacturers and extended to a wider range of models. The time between the first introduction and availability on all new cars may take several years (cf. ABS). This process can be influenced by awareness campaigns, fiscal measures, type approval requirements and by inclusion in NCAP ratings.

5.2.2. RELEVANCE FOR THE VRU

Driver assistance systems in the first place aim at supporting the driver task (comfort) or preventing the vehicle driver from getting involved in an accident and/or reducing the severity of the impact.

In the recent past, driver assistance systems have been developed with the aim to avoid collisions with less protected VRUs, e.g. NVW, PDS and EBR. These applications improve road safety for VRUs. The pedestrians are the main category that is targeted by currently available applications, but they will be beneficial to other categories of VRU as well.

There is an enormous safety potential for PDS/EBR systems, as the impact speed would be considerably reduced in case of earlier braking and when applying more braking power than would be engaged by the driver. It is noted that current PDS technology is not yet proven effective in all possible collision scenarios with pedestrians *(re: Adaptive headlights do contribute as well)*. Improvements are expected from the use and fusion of information from different sensors, see e.g. [39]. Due to different detection characteristics and accident scenarios, the safety impact of current generation PDS for other types of VRU than pedestrians is currently limited.

5.2.3. PENETRATION AND IMPACT

When assessing the safety impact of new technology for passenger cars, it should be kept in mind that the average age of an EU car is 8.2 years, and that more than one third of the passenger car fleet is older than 10 years [51]. Consequently, even if all new vehicles are equipped with a specific feature, it would still take some 8 years before a penetration of 50% is reached. The expected relative reduction of fatalities / injuries – i.e. as a fraction of all traffic fatalities/injuries – therefore seems low on the short/medium term, even for likely effective applications.

5.2.3.1. PENETRATION

Some studies indicate that a high *penetration* by 2020 for passenger cars is only to be expected for ESC, estimated in the range 55-75% [12][30]. (E-Call is also expected to have a high penetration by 2020, but this application is not regarded ADAS and treated in the Subsection 'Other ITS'). Other applications are expected to have a penetration in the order of 5 to10% by 2020, see [12]. The expected high penetration of ESC is due to mandatory fitment from 2014 in all new vehicles. By the same regulation, [41], Lane Departure Warning (can be considered part of LKS, Lane Keeping Support), will however also become mandatory in new trucks and buses from 2015 and in new vehicle types from 2013.

The Implementation Road Maps monitoring report from the e-safety forum, [48], also performed an assessment on the penetration of ADAS and IVSS. The results are presented in Table 6.

Table 6. Penetration of in-vehicle systems according to [48]. The first part refers to unchanged policy, the second part to a situation where strong implementation support by the EC would be given.

Business as usual		% new cars equipped		
Approximate equivalent in this study	IRM name	2010	2015	2020
ESC	ESC	high	very high	very high
PDS (partial overlap)	Obstacle & collision warning	very low	low	medium
EBR	Emergency braking	very low	low	medium
BSD-C, BSD-T	Blind spot monitoring	very low	low	low
AHL	Adaptive head lights	low	medium	medium
LDW / LKS	Lane departure warning	very low	low	medium
Implementation support		% new cars equipped		
Approximate equivalent in this study	IRM name	2010	2015	2020
ESC	ESC	high	very high	very high

PDS (partial overlap)	Obstacle & coll. warning	very low	medium	high
EBR	Emergency braking	very low	medium	high
BSD-C, BSD-T	Blind spot monitoring	very low	low	medium
AHL	Adaptive head lights	low	medium	high
LDW / LKS	Lane departure warning	very low	medium	very high

The technology for ISA is mature and has been proven to be effective in various trials and pilot deployments [12][32][33]. ISA can be implemented as an autonomous in-vehicle application (though requiring regular updates) or as a cooperative application that receives speed information locally. The latter has the advantage of higher accuracy but will take far longer to deploy. Deployment in an I2V environment also requires the adoption of a standard for the exchange of speed limit information, and the commitment of road authorities to implement and operate an ISA-enabled infrastructure.

5.2.3.2. EFFECTIVENESS

According to eIMPACT, [12], the *potential effectiveness* of the individual technologies, expressed as a fraction of total traffic fatalities (and separately for severe injuries) that they would prevent when every vehicle would be equipped, ranges from 1.5% to 16.5%. It is emphasised that this definition of effectiveness leads to low figures for applications that are in fact very effective for a specific type of accidents.

The highest effectiveness, above 15%, is reported for ESC[3] and LKS (LDW). EBR and ISA (referred to as SPE, Speed Alert) are also attributed a fair effectiveness in reducing road fatalities, i.e. between 5% and 10%.

A detailed study on the potential of PDS / EBR, see [45], suggests that 40% of fatalities and 25-30% of severe injuries suffered by pedestrians can be avoided. These figures do in fact not contradict the eIMPACT results, as pedestrians only account for 17.5% of all casualties and eIMPACT reports effectiveness as a fraction of total road traffic casualties and injuries. This may serve as an illustration that some systems that are very effective in mitigating accidents of a distinct type or for a certain group may have a comparatively modest effect on the total number of traffic casualties and injuries.

The potential reduction by FSR ranges from 0.5% to 12.9% of vehicle-vehicle collisions, depending on the road type. FSR might have an adverse road safety effect if used in dense traffic or on other roads than main roads because FSR so far is not perfect in detecting pedestrians and vehicles outside the field of view [31].

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[3] In literature much higher figures on the effectiveness of ESC can be found. The difference can be explained from the fact that these figures are relative to the scenarios in which ESC is effective: loss of control at high speeds or on slippery roads. These scenarios are only a fraction of all traffic accidents with injuries.

As to ISA, the estimations cover a range from 7% to 20%, in [12[32][33][34]. SWOV [32] estimates the potential reduction of fatalities (again: when all vehicles would be equipped) between 18% and 59%, for different types of ISA. This source further suggests that

- The more intrusive the implementation, the stronger the impact of reducing traffic speed. The high figure (59%) applies to a combination of dynamic speed limits and where non-compliance with speed limits is inhibited by the system.
- Intrusive variants of ISA generally have low user acceptance.
- Dynamic speed limits may however add to user acceptance, if the variable limits are felt to be reasonable. A well-known example is the direct environment of a school, where a low speed limit will be widely accepted during the short period that children are entering or leaving the school, but should be set to 'normal' outside these periods when no children are around.
- Repeating speeding offenders seem to be least likely to support ISA [32].

A number of other applications (DDM, WLD, INS and NVW) are reported to have an expected effectiveness between 2.5% and 5%. No figures for AHL are available.

5.2.3.3. *EXPECTED IMPACT*

The *expected impact* on road safety is now calculated by multiplying the effectiveness with the expected penetration rate for a certain time horizon. According to [12] and [30], ESC stands out with a reduction of road fatalities by 7%-15% in 2020. [12] further expects a value of 5% for ISA and 3% in 2020 (all for 'high scenario'). Other applications have an expected lower impact.

In terms of injuries INS, EBR and LKS are expected to give a reduction of 7 to 9%; LCA and ISA by 4 to 7%; and WLD, NVW, FSR and DDM between 2 and 4%, see [12].

A 'safe systems approach' which is the most prominent vision on road safety nowadays, will lead to lower speed limits, notably in residential areas (30 km/h zones). A pilot with ISA in Tilburg (the Netherlands), [42], showed that these are the areas for which ISA is likely to have strong public support. These are also the areas where the safety of VRU will benefit most from improved speed limit compliance. This improves the business case for ISA considerably.

5.2.4. SYNTHESIS

The safety impact of ESC is considerable, and stands out because of high penetration as a result of mandatory fitment in new vehicles, [41]. LDW (part of LKS) will for the same reason also acquire high penetration by 2020. However, these applications mainly target motorists in general and will only benefit VRU through side effects on the VRU young and older driver groups.

When focusing on the safety of the VRU, the following applications are of specific relevance.

- PDS with EBR
- NVW
- ISA.

These applications will be focused on in the elaboration of measures in the next section.

All driver assistance applications have the potential to increase driving comfort of all drivers and in particularly the older driver. It is noted that if the requirements of the older driver are not taken into full account in the HMI, some applications may not be of any use to this user category.

5.3. Co-operative ITS

5.3.1. DESCRIPTION

Co-operative ITS applications typically rely on communication / data exchange between vehicles (V2V), and/or between vehicles and the infrastructure (V2I). While regular driver assistance applications need to rely on autonomous detection of other traffic participants, traffic participants in cooperative systems can pro-actively exchange reliable data on current and intended position, speed and heading and assess the situation accordingly. This greatly helps to classify when a collision is possible, likely or imminent, and allows for a correction of their movement / behaviour if required. V2I communication allows the infrastructure to better accommodate traffic and allows road operators to warn vehicle drivers for specific local road, weather and traffic conditions, potentially on a personalized basis.

A specific development in cooperative technology from which pedestrians (and other VRUs) could profit is a microwave transponder carried by the VRU, which can send relevant data (e.g. speed and direction) to the in-vehicle system. At the same time the transponder can be localised accurately by the in-vehicle system. When sufficiently mature, this technology – called VRU Beacon System (VBS) throughout this document – would enhance the effectiveness of Pedestrian Detection / Emergency Braking Systems, as these systems currently cannot detect road users out of the line of sight of the vehicle sensor, see [50].

5.3.2. RELEVANCE FOR THE VRU

Cooperative applications can be beneficial to most VRUs. Co-operative systems can increase VRU safety by reducing common traffic regulation incursions, such as red light ignoring and speed limit violations, and by enhancing traffic safety at crossings.

5.3.3. PENETRATION AND IMPACT

5.3.3.1. PENETRATION

According to eIMPACT [12], the penetration of listed cooperative applications for passenger cars in 2020 would still be low (<5%). This is largely due to the fact that

investing in the vehicle component is difficult to justify when the supporting roadside infrastructure is not yet deployed and vice versa. It requires coordination and considerable investments to make the cooperative vision come true.

eIMPACT did not assess the market penetration of VBS. VBS is currently in the concept phase, and penetration in 2020 is therefore expected to be very low.

5.3.3.2. EFFECTIVENESS

The potential impact on road safety varies between the cooperative applications. INS and WLD each have a potential to reduce fatalities by an estimated 4%, assuming every vehicle would be equipped, [12][34].

INS can contribute significantly to the reduction of injuries (-7%). According to [35] INS can prevent between 30% and 60% of all injuries at intersections, between 16% and 36% of total fatalities at intersections. WLD has the potential to reduce injuries by 3%, [12][34].

VBS holds the promise of timely detection of all VRU by all cars and trucks. It can therefore be expected to have a high potential impact on fatalities and injuries.

5.3.3.3. IMPACT

The safety impact expected for 2020 is low for most cooperative applications (<1%) [12][34]. This is due to an expected low penetration by 2020. Penetration may of course be influenced by stimulating policies.

5.3.4. SYNTHESIS

In general, cooperative systems, as is the case with Advanced Driver Assistance applications, are developed by the automotive industry and have a primary focus on comfort and safety of the occupants of the car. In recent years, there has been a shift in attention towards the safety of the other road users as well. The inclusion of external safety in the EuroNCAP rating played a considerable role in this process. The VRU will in the future benefit from the effects of cooperative applications such as improved red light and speed limit compliance, and systems that detect and warn for VRUs on potential collision course. Widespread deployment of cooperative systems would therefore benefit VRU.

INS has considerable potential to increase the safety of the VRU.

Although in the conceptual phase, VRU Beacon Systems (VBS) holds great promise for the safety of VRU. It requires however a technical solution that is harmonised, and requires adoption by VRUs as well as a commitment from the automotive sector to install VBS-enabled driver assistance applications, notably PDS/EBR.

5.4. Regulatory and Enforcement ITS

5.4.1. DESCRIPTION

Regulatory and enforcement applications stimulate or impose compliance with road traffic regulations, and aim at either warning drivers of a (potential) incursion, preventing a driver from starting a car, or making enforcement easier and more effective. An example of such an application is the Alcohol Ignition Interlock that has been put into legislation in Finland, Sweden, Belgium and Denmark.

5.4.2. RELEVANCE FOR THE VRU

Regulatory applications can play an important role in reducing the chances of accidents, notably with VRU. In particular the Alcohol Ignition Interlock (AII) and Electronic Driver Identification Interlock (EDI) can prevent recurring offenders from causing accidents.

5.4.3. PENETRATION AND IMPACT

One in four traffic accident deaths on EU roads is caused by drink-driving (approximately 10 000 per year), and more than 1 out of every 4 deaths among young men (aged 15-29 years) in the EU is due to alcohol (often caused by road traffic accidents, homicide, violence, etc.) [26]. Another study suggests that about 10,000 traffic deaths in the EU each year are people different from the intoxicated driver; this includes pedestrians, passengers and non-drinking drivers [27].According to [33], 16% of fatalities could be saved when alcohol compliance would be 100%.

Based on the foregoing, if implemented in all vehicles, AII could potentially save about 10,000 traffic fatalities in Europe and have a very high impact on the number of fatalities and injuries in the VRU-category of Young Drivers. Wide-scale deployment in the Young Drivers category would have a proportionally higher impact.

It should be noted that:
- An AII needs to be well integrated in the vehicle electronics to prevent tampering. This will add significantly to the costs, especially if it is to be implemented only for dedicated user groups.
- AII only measures the level of intoxication by alcohol. Intoxication by other drugs, or any form of other drowsiness cannot be detected but could also severely hamper the driving ability.

Seatbelt reminders and Ignition Interlock systems have been around since the 1970's. Seatbelt reminders are now factory fitted in most cars. Seatbelt interlock systems are uncommon. The mean wearing rate for seat belts in the European Union is 76% for front seat occupants and 46% for rear seat occupants [28]. The wearing rate for front seat occupants can be increased to 97% if all cars have audible seat belt reminders [28]. The ETSC estimates that in the first year after its introduction, a mandatory seat belt reminder

for the front seats will have an effect on 10% of front seat car occupant fatalities, and 11% of all fatalities, [28][33]. This corresponds to 483 fatalities, a moderate road safety impact. Obviously the VRU categories of Young and Older Drivers would be the only VRU to benefit from such a measure.

No information on the impact of the Electronic Driver Identification Interlock (EDI) is available. The impact is expected to be quite limited as it aims at prohibiting inappropriate use of the vehicle and would only be effective in controlling the relative small number of recurring offenders, and because an EDI-lock can be circumvented relatively easily unless very advanced and expensive EDI are deployed combining electronic registration with biometric identification.

EVI would improve effectiveness of traffic enforcement by more efficient and reliable vehicle identification and would help against vehicle theft and fraud. The impact on traffic safety seems rather limited. EDR would provide data for more detailed and reliable analyses of road accidents causation. R&D on traffic safety (systems) would greatly benefit if such data would be available on a large scale. Nowadays, accident data registration mostly depends on police registration which has a varying quality. Privacy and liability issues may however stand in the way of the common use of EDR data. It should be noted that some existing vehicle systems already collect detailed movement data, but vehicle manufacturers are not willing to make these data available for whatever third party use. Alternative ways of data acquisition via e.g. a smartphone seems promising, especially for VRU that suffer even more from bad registration.

5.4.4. SYNTHESIS

Considering the large number of alcohol-related fatalities and injuries of both car drivers as well as other road users, AII can have a significant effect on road safety. Of the VRU, in particular the Young drivers will benefit from AII. Other VRU however will also benefit since they are often the victims of drink driving by another road user. If made mandatory for new cars AII would have a very high impact on road safety in general, and for Young Drivers in particular. It is however unlikely that popular support for such a measure can be attained.

A more realistic scenario is the use of AII for recidivist drink drivers as part of a rehabilitation programme, and the voluntary or mandatory implementation of AII on public transport vehicles, HGV, public body vehicle fleets and company fleets. Both types of use are operational in some countries. No assessment of the effectiveness is available for application on specific groups as listed above however.

Seatbelt reminder systems (SBR) are already widely used in European cars and have proven an effective way of increasing seatbelt use. A seatbelt reminder is a cost-effective measure to reduce fatalities and the impact will be considerably increased if audible SBR is to be extended to the passenger and rear seats as well.

5.5. Solely-infrastructure based applications

5.5.1. DESCRIPTION

Intelligent Pedestrian Traffic Signal Control (IPT) falls in this category. State-of-the-art traffic light management systems use advanced sensors to monitor crossing behaviour of pedestrians. If pedestrians are slow to cross the road, the green light period for pedestrians is extended.
On the other hand, traffic lights are only to be switched to red for the nearing motorized traffic if the pedestrian activating the system is still present at start of the cycle. This would significantly enhance acceptance and compliance from a motorist perspective

These systems provide a clear benefit to children, people with disabilities and older adult pedestrians. It provides them with the time they effectively need to cross a road. No research however is available concerning the road safety impact of IPR, though it is likely that IPT would reduce the risk for pedestrians of being hit by a car. Furthermore, such systems add for sure to the comfort of the older adult pedestrians.

Research on impacts would provide better insight into the effectiveness of IPT in increasing road safety in general, and for the VRU in particular.

Another relevant infrastructure-based ITS application is Roadside Pedestrian Presence Warning, that warns upcoming traffic for the presence of pedestrians close to the crossing, see RPP. Such systems have been deployed in Sweden and are reported to result in an average speed reduction of 2.2 km/h on 50 km/h roads. This reduction, as well as the increased attention of the motorist when passing the crossing, is likely to increase crossing safety, see also [43].

Finally Crossings Adaptive Lighting (CAL) is worthwhile to mention. The lighting on a (zebra) crossing is automatically switched on when a pedestrian is approaching. This reduces the chance that the pedestrian is not or late observed by the driver, and saves energy as well.

5.5.2. SYNTHESIS

IPT, RPP and CAL are mature applications and deployed in some countries. The positive safety effect on pedestrian safety for specific deployments has been demonstrated, [43]. The effect on total casualties and injuries would strongly depend on the number of crossings that would be equipped with such technologies.

5.6. Other ITS

5.6.1. ECALL

ECall is a vehicle-based system that automatically establishes a voice connection with, and sends digital location and vehicle information to, emergency services in case of a crash. Twenty-five European countries have signed the eCall Memorandum of Understanding, committing themselves to the establishment of national public service answering point (PSAP).

ECall does not prevent accidents but mitigates the effects of severe accidents. Various researches have assessed the potential impact of eCall with varying results. According to [28], the potential of eCall to improve road safety is quite limited, very low for injuries (near 0%) but significant in avoiding fatalities (about 3%, or about 500 fatalities).

Of the VRU, the Young and Older Drivers would benefit most from eCall. Other VRU would benefit indirectly when involved in a severe accident with a car or truck, as emergency services will arrive faster and better informed at the scene.

If not installed in the majority of vehicles, the impact of eCall however will be limited. The ongoing promotion of eCall by the EC will likely lead to a situation in which eCall is pervasive in European vehicles. Although the impact of eCall on the other categories of VRU will be quite limited, the Young and Older Drivers will benefit

5.6.2. SATELLITE NAVIGATION SYSTEMS

Satellite navigation systems have become a commodity product over the past decade. It has both positive and negative impacts on road safety:
- Navigation systems shorten the travel time by 18% when driving unfamiliar terrain and as such reduce the risk of accidents to drivers [29].
- A navigation system reduces the activity of searching. Drivers can devote more attention to driving [29].
- Navigation systems can help to avoid inappropriate traffic flows on sensitive road segments, e.g. keep truckers away from build-up areas or school environments –at least when this is utmost needed

However:
- 64% of drivers operate their navigation systems while driving. This can lead to critical driver distraction.
- Personal navigation devices can have an impact on the driver's field of view if inappropriately installed (In case of an accident nomadic navigation devices can become lethal projectiles.
- Map errors incidentally lead to accidents when drivers follow faulty instructions.

Research suggests a slight to moderate overall safety benefit of satellite navigation, although results are not unambiguous, [29][30]. The road safety benefits for VRU are even

less clear but it is certain that satellite navigation systems can considerably contribute to the comfort of all drivers, including the Young and the Older Drivers. An interesting possibility is to combine navigation systems with coaching applications with real-time and offline feedback.

The HMI of current satellite navigation systems are poorly adapted to the needs of the Older Drivers. User interfaces in general contain too many features, and displays and character sizes are too small. Improving this aspect of satellite navigation systems could enhance road safety, and would certainly improve driving comfort for the Older Drivers.

5.7. HMI aspects

Issues with the user interface of ITS applications were already identified for specific types of VRU and some specific applications. Whereas for all IT applications HMI is a determining factor for effectiveness, in the case of ITS, it is also crucial to safety.

The design of a HMI is crucial for the effectiveness and safe use of ADAS or traveller information systems. Systems with complex HMI or systems that e.g. provide too much information at one time, may not be effective and even have a detrimental effect on traffic safety as they might require the driver to take his eyes of the road regularly or distract attention from driving when interpreting the information. This problem is aggravated when the number of applications that interact with the driver without coordination is increased. The need for an overarching HMI, which optionally disables applications and filters and prioritises information in situations of high workload is becoming more and more apparent. It is noted that this problem has been addressed a long time ago, and EC and industry effort have lead to the establishment of a European Statement of Principles on HMI in 1999, which was revised in 2006 and updated in 2008 [46]. It is however noted that ADAS, defined as systems that require immediate action from the driver, are outside the scope of this SoP although part of the results may be valuable for ADAS as well. ADAS HMI is specifically addressed by the ADAS Code of Practice, produced by the PReVENT project and endorsed by ACEA, [47], which has however a much broader scope than HMI. In general these documents are providing valuable guidance for the design of in-vehicle systems. The following issues are reported to persist however:

- It is reported that a 'one size fits all' approach may not be fully appropriate. The Older Driver in particular may strongly benefit from systems that add to the comfort of driving and help to make the right decisions while driving, whereas systems of today often fail in this respect. Generally speaking, to serve the older driver, systems are required to better coordinate, filter and prioritise messages from different applications to the user and should present visible messages with larger icons and fonts.
- In practice, the principles and code of practice mentioned above are not applied throughout the industry. In particular nomadic devices, including navigation systems and smart phones and their applications which are used in the vehicle,

follow different design constraints. This problem is difficult to tackle as the involved industry is mostly outside the automotive sector. A standardised safe fitting and connection in the vehicle for nomadic devices might be a viable way to solve this problem.

- It is noted that HMI requirements for motorcycles are quite different and more stringent compared to passenger cars. More work in this area is recommended.

6. Synthesis, recommended fields for action and proposed measures

6.1. Introduction

This section synthesizes the results of the bottom-up and top-down approach, and elaborates recommended measures, see also the methodology section (2.2).

In the bottom-up approach a number of application areas (or individual applications) were found that are likely to bring significant benefits to the safety and comfort of the VRU. In the top-down approach (quantitative) results were found for the expected effectiveness and impact of specific applications. It should be kept in mind that in most cases the quantitative results are not based on statistics of the proven benefits, but on analyses and simulations. They consequently have a considerable degree of uncertainty.

This remainder of this section starts with an overview of the relevant policy instruments of the EU (6.2). Subsequently the most appropriate fields of action / applications from a VRU-perspective are identified (6.3). For each of these fields objectives are formulated and suitable measures on EU-level that should help to realise these objectives (6.4). Finally, next steps towards the execution of the measures are presented (6.5).

6.2. Relevant instruments of the EU

The policy instruments available to the EU can be divided in a number of main categories:
- legislative instruments (regulations and directives)
- financial support (e.g. subsidizing research or deployment)
- standardisation (development of standards)
- non-binding instruments (recommendations and opinions, organising co-operation, concertation across member states or industries)

Enforcement instruments (verification of compliance to legislation, including sanctions and legal action) are sometimes listed as an additional category but can also be regarded as part of the legislative toolbox. European standardisation is largely carried out by standardisation bodies that are independent of the EU, yet the EU can influence the process and focus through policy, legislation and financial incentives.

An overview of the instruments and examples in the different phases of the product/service life cycle is presented in Table 7.
.
In general, legal instruments have a strong impact once fully adopted, yet may take many years to prepare and implement. Non-binding instruments can be implemented much faster, yet will only be effective if sufficiently supported by the Member States and other main stakeholders.

Table 7   Overview of policy instruments available to the EU, in different phases of the product/service life cycle. Examples are given for the types of measures in the different phases.

Type of instrument	Life cycle phase		
	Development (examples)	Deployment (examples)	Continuous Improvement (examples)
Non-binding instruments		• Disseminate best practices across the public sector or industries • Organise public awareness campaigns on EU level • Voluntary agreements on common approaches with member states or industry sectors • Voluntary agreements on generic requirements for public procurements	
Financial	• Subsidize R&D, • Include in focus of Research Programmes	• Subsidize deployment • Subsidize assessment/ certification • Fiscal incentives • Insurance incentive	• Finance R&D for continuous improvement
Standardisation	• Organise, subsidize, stimulate development of standards in specific areas	• Organise, subsidize, stimulate development of standards in specific areas	
Legal	• Research to support legislation	• Mandatory fitment (for specific groups). Mandatory assessment or certification • Mandatory implementation of infra-measures to Member States • Mandatory information in commercial communication	• Adapt existing regulations / directives

6.3. Selection of most appropriate specific fields of action

Table 8 summarizes all results for the specific categories of road users considered, based on the findings of the previous sections. The indication of the potential benefit assumes

that the relevant group of users is fully equipped. The applications that have specific potential for the VRU are marked with coloured rows.

Table 8 Safety/comfort benefits of applications for distinct categories of VRU

	Acronym	Category					
	Application or application area	Pedestrians	Cyclists	Drivers of scooters and mopeds	Motorcyclists	Young drivers	Older drivers
Advanced Driver Assistance Systems	AHL	(+)	(+)	(+)		(+)	(+)
	PDS / EBR	++	?	?		(+)	(+)
	ESC					++	++
	FSR				(+)	(+)	(+)
	LCA				(+)	(+)	+
	LKS , LDW				(+)	+	+
	NVW	+	+	+	+	+	+
	DDM				(+)	+	+
	BSD-C	(+)	(+)	(+)	+	+	+
	BSD-T	(+)	++	+	+		
	ISA	++	++	+	+	++	(+)
Cooperative Systems	VBS	(+)	(+)	(+)			
	INS	+	+	+	+	+	++
	WLD				(+)	+	+
Regulatory Applications	All	++	++	++	++	++	++
	SBR					+	+
	EDI	I	I	I	I	I	I
	EVI	I	I	I	I	I	I
	EDR	I	I	I	I	I	I
Infrastructure based Applications	CAL, IPT, RPP	++	(+)				
Other ITS	ECA				(+)	+	+
	SAT					+	+

Legend:

++:   strong positive impact reported

+:   positive impact reported

(+):   positive impact likely

?:   impact expected, but unknown

I: indirect effect

In fact all applications listed have at least some (expected) positive impact for a category of VRU. This does not necessarily mean that new or additional EU measures would be appropriate. The principles formulated in Annex II the ITS Directive, [40], should be useful as a guideline, although they only apply to specific types of measures.

In a first selection step, applications were ruled out that are e.g. already subject to on-going EU action or target other road users than VRU. The latter does not necessarily mean that these applications do not have potential to add to the safety and comfort of the VRU, it is just that the benefits to the VRU are considered of secondary importance compared to the main purpose/effect of the application. Seat-belt reminders for all seats may serve as an example: all car occupants benefit from this measure, including the young and the older driver that have been identified as VRU. Any policy on SBR would however consider the safety benefit to all car occupants; there is no need for a specific focus on the VRU here.
The full list of criteria applied and a short motivation per application are to be found in ANNEX B. The applications ruled out for specific measures are indicated with the uncoloured rows in Table 8.

In a second step a number of criteria were applied to the remaining set, to select the applications to be prioritised on the basis of a number of criteria. The first criterion (VRU safety potential) is given a weight of 4, the potential to stimulate deployment on the short- or midterm a weight of 3, public acceptance a weight of 2 and the remaining aspects each a weight of 1. Results are summarised in Table 9. A motivation is provided in ANNEX B. It is emphasised that this is not a scientific evaluation, and partly depends on subjective assessments and priorities.

Table 9 Assessment of applications to be prioritised

	Application or application area	Potential to save life and reduce injuries of VRU	Technical maturity	Cost/benefit	Potential to stimulate deployment on the short or midterm by EU	Public acceptance	Overall score

Relative weight		4	1	1	3	2	
Advanced Driver Assistance Systems	AHL	+?	+	+	+/-	+	8
	PDS / EBR	++	+/-	+	+/-	++	13
	LCA	+/-	+/-	+	+/-	+	3
	LKS	+/-	+/-	+	+/-	+	3
	NVW	+	+/-	+	+/-	+	7
	DDM	+/-	-	+	+	+	4
	BSD-C	+/-	+/-	+	+/-	+	3
	BSD-T	+	-	+	+	++	9
	ISA	++	+	+	+	-	11
Cooperative Systems	VBS	+	--	+	-	+	2
	INS	++	--	+	-	+	6
	WLD	+/-	--	+	-	+	1
Regulatory Applications	All	+	+	+	+	+/-	7
Infrastructure based Applications	CAL, IPT, RPP	+	+	+	-	++	8

A preliminary conclusion from this exercise is that the following application areas deserve prioritised attention (score >= 10) in defining measures:

- PDS + EBR
- ISA.

A group of secondary priority (scores 5-10) would consist of:

- AHL
- NVW
- BSD-T
- INS
- All
- CAL, IPT, RPP

The prioritised groups are marked in darker shades in Table 9.

6.4. Recommended measures

6.4.1. OVERVIEW

In this subsection recommended measures are presented. As was indicated in 2.2, three levels of measures are distinguished:

- Tier 1: Application specific measures
- Tier 2: Application-group specific measures
- Tier 3: Horizontal measures

The first two levels of measures are discussed per application group in the following subsections. Horizontal measures are discussed in 6.4.6.

Table 10 Selected applications versus relevant policy instruments

	Application Acronym	Generic instrument			
		Legislation	Financial	Standards	Non-binding
Advanced Driver Assistance Systems	AHL		X		X
	PDS / EBR		X		X
	LCA	(LDW in place)	X		X
	LKS , LDW		X		X
	NVW		X		X
	DDM		X		X
	BSD-C		X		X
	BSD-T		X		X
	ISA	(?)		X	X
Cooperative Systems	VBS		X	X	X
	INS		X	X	X
	WLD		X	X	X
Regulatory Applications	All			X	X
Infrastructure based Applications	CAL, IPT, RPP		X		X
Horizontal aspects	HMI				X
	Accident data	X	X		X

6.4.2. ADAS

Various types of the selected ADAS applications are already available on selected models of vehicles. In the last 5 years new applications have reached the market, as well as improved/extended versions of existing ones. The penetration is still low for most applications. It is observed that safety is getting ever more attention from consumers and becoming a field of competition between vehicle manufacturers. Traditionally, the automotive industry has focused on the safety of the occupants of the vehicle. More recently, the safety of other road users, including the VRU, is also targeted in the development of safer designs and driver assistance systems. A good EC strategy therefore seems to encourage consumer attention for safety-related ADAS, in particular for those applications that have positive impact on the VRU, and stimulate further development and deployment by the market.

It is important but difficult to find the appropriate balance between passive safety measures and ITS. Passive measures of course have a much longer history in safety design and are generally easier to evaluate. For the industry car safety is important as such, but the focus is strongly influenced by the marketing potential of safety features. EuroNCAP ratings are an important driver for setting the priorities. If for instance, an extra 'star' can be gained with a pop-up hood and not with ADAS technologies such as PDS or EBR which might be more effective to increase VRU safety, a suboptimal trigger might be provided to the market. Ideally, EuroNCAP should fully include the effectiveness of a vehicle type to avoid accidents and to reduce the accident impact in safety assessments. This is of course much easier said than done. In general it is very difficult to quantify the effectiveness of systems that avoid accidents in a real life environment. It is also important that the assessment criteria of EuroNCAP remain clear, avoid dispute and evolve along a stable and predictable path to serve as a guideline for the automotive industry. Still, further increasing the influence of EuroNCAP on the automotive market, while improving the balance of safety assessment elements (occupant safety versus safety for other traffic, passive versus active measures) seems a policy from which all will benefit.

Developing legislative measures to promote the deployment of specific ADAS is complicated by the fact that current developments in market and technology are likely to outpace the legislative process. It should be noted that, while throughout this document ADAS has been dealt with as individual applications, similar applications are often identified different names, and identical names are used for not fully identical functionality and levels of sophistication. Furthermore, underlying detection and vehicle control subsystems can serve more than one function. It is likely that ADAS will further evolve into packages of functionality that do not respect the boundaries of current application definitions. This will also reduce the costs per application. It is therefore recommended to elaborate policies in terms of functionality rather than systems.

Mandatory fitment, for specific ADAS applications, in all vehicles or selected types/groups is a potentially very effective instrument. It however requires that the application is mature

and the required quality can be specified and certified, and that the total overall costs are in balance with the 'proven' safety benefits. This stage has not been reached today for most ADAS, but may be expected within a few years.

The objective of the EU in the area of ADAS to improve safety and comfort for the VRU should be primarily focused on giving the right stimulus to the market and trigger further consumer awareness.

In line with this objective, the following measures are deemed appropriate:

The following measures in the area of ***ADAS*** are deemed appropriate:

1) Non-binding:
   a) Elaborate with EuroNCAP ways to attribute higher weight to ADAS that increases safety for the VRU, focusing on PDS+EBR and ISA, and including effectiveness for other modalities than pedestrians. This also requires the elaboration of functional criteria to assess VRU safety effectiveness.
   b) Elaborate with the insurance sector how car insurance premiums can be differentiated by safety properties / safety systems of the vehicle, with specific attention for PDS+EBR and ISA.
   c) Investigate the impact of mandatory ISA for specific categories of vehicles, e.g. LCV, public transport, fleets of public organisations and elaborate a corresponding recommendation.
2) Financial
   a) Award subsidies for deployment of specific ADAS, focusing on PDS+EBR and ISA.
   b) Discuss with member states the introduction of fiscal incentives or national subsidies for ADAS.
3) Legislative:
   a) Stimulate consumer awareness to safety through mandatory quotation of EuroNCAP rating in car advertisements.
   b) Make EuroNCAP assessment mandatory for new vehicle types.

It is felt that at this stage that 1b), 1c), 2a) and 3a) would be effective to stimulate the further development and deployment of vehicle safety systems – whereas on the longer term mandatory fitment could be considered if there are considerable safety benefits, and the market fails to achieve significant penetration for a given application.

Note on PDS/EBR

In the last few years Pedestrian Detection Systems (with Brake Assist and Emergency Braking) systems have reached the market. This technology can be regarded as a major breakthrough, and it targets a major accident scenario. It is noted that versions currently available still suffer from the limitation of line-of-sight to the pedestrian during a short period before the collision.

It is also desirable that in the future similar technology will become available that avoids collisions with cyclists and PTWs. It is noted that further development of PDS should take into account also potential adverse effects as a result of adapted behaviour of the driver (paying less attention to traffic when confident that PDS will intervene if necessary) or false positives that could impose a risk to following traffic by unexpected strong braking.

Note on ISA
A much studied and trialled application is Intelligent Speed Adaptation (ISA). The effectiveness is widely acknowledged, whereas it is expectedly much greater for systems that intervene compared to purely informative approaches. The great advantage of ISA is that – unlike enforcement measures – it targets speed limit compliance at all time, on any road. Both informative and intervening variants of ISA can be considered mature. Remaining issues exist around the availability and distribution of reliable speed limit data, especially concerning the urban areas. It is important that the EC undertakes initiatives to improve the availability of speed limit data. This aspect is however already addressed in Area 1.3 of the ITS Action Plan.

At this point a mandatory fitment for all vehicles seems a bridge too far for public acceptance. It is however quite imaginable for specific user groups, e.g. commercial vehicles, public transport, coaches etc. It is suggested to investigate the impact of making ISA mandatory for specific vehicles, e.g. public transport, coaches, LCVs.

Meanwhile it seems worthwhile to stimulate voluntary deployment of ISA, through fiscal/financial incentives and by underpinning the possible contribution to driver comfort.

6.4.3. COOPERATIVE SYSTEMS

Cooperative systems are still in a stage of development. Some applications have a high potential to improve traffic safety. Deployment is more difficult than for ADAS as it requires equipment in the vehicle as well as on the roadside. As communication between vehicles and the roadside infrastructure should work regardless of location and brand of the vehicle, it requires more co-operation and standardisation/harmonisation, involving in-vehicle systems manufacturers as well as manufacturers of roadside equipment.

From the cooperative applications, INS and VBS were selected for potential for the VRU.

At this point, the objective of EU action should be to accelerate the further development and standardisation of applications.

The following measures in the area of **cooperative applications** are deemed appropriate:

1) Non-binding instruments / Financial instruments

6.4.4. REGULATORY APPLICATIONS / ALCOHOL

The strong effect of alcohol on driving capability is widely accepted. In many EU countries, continuous awareness campaigns have made drunk driving socially inacceptable. Still alcohol is a factor in a considerable fraction of accidents. There seems to be a minority of drivers that are not influenced by such campaigns: recidivism is common for drunk driving and offenders often have an addiction.

Alcohol Ignition Interlock (AII) systems are in principle very effective, as they simply deny the use of the vehicle if the driver is detected to be under influence of alcohol. A strong effect on traffic safety could be expected if all vehicles would be equipped with AII. On the other hand, such a measure seems impractical, not easily accepted by the public and not very cost-effective as the problem of drunk driving is limited to a minority of drivers.

Targeting only recidivist drunk drivers is more cost-effective, yet has the disadvantage that only a part of the target group will be affected (the chance of getting caught for drunk driving is relatively small in most countries). The effect of such an approach also depends on the legal procedures and supportive actions taken to get the recidivist on the right track. Some Member States currently have successful AII programmes in place. As the programmes differ in various aspects, it seems worthwhile to share best practices for a broader uptake in the rest of the EU.

An AII programme may be extended to other types of users than recidivist drunk drivers. Candidates are:
- Public transport, *given societal role and exposure to other road users*
- Commercial vehicles (HGV)
- Young/inexperienced drivers. Alcohol use is reported to have a much stronger influence on driving capability of the younger driver.

The first two categories may have the advantage of easier public acceptance, yet will not have a great impact as the associated number of accidents involving alcohol is rather small.

A gradual licensing scheme, inhibiting young drivers to drive at night in the weekends, combined with Electronic Driver Identification and/or curfew locks might be effective to reduce the number of accidents where alcohol and drugs play a role. This is considered out of the scope of this study however, as this is basically a procedural measure.

The objective of the EU in this area should be to work towards an effective yet socially acceptable implementation of alcolocks.

The following measures in the area of *regulatory applications* are deemed appropriate:

1) Non-binding instruments
   a) Investigate, establish and promote best practice guidelines for the use of AII in rehabilitation programmes
   b) Investigate, establish and promote best practice guidelines for the use of AII in specific vehicle/user categories - considering HGV, LCV, public transport and novice drivers.
2) Standardisation
   a) Organise standardisation of alcolocks.

6.4.5. SOLELY INFRASTRUCTURE BASED APPLICATIONS

CAL, IPT and RPP were reported to have a positive impact on the safety and comfort of pedestrians. The applications can be considered mature and are already applied in some Member States. Decisions on the implementation of such systems are within the competency of the respective (urban and regional) road authorities.

The objective of the EU in this area should be to promote the use of these systems across Member States and road authorities by establishing best practice guidelines and independent assessment of effectiveness.

The following measures in the area of solely *infrastructure-based applications* are deemed appropriate:

1) Non-binding instruments & Financial
   a) Establish best practice guidelines for the application of infrastructure based applications (in particular CAL, IPT and RPP).
   b) Perform further independent assessment of their safety impact and influencing factors.

6.4.6. HORIZONTAL ASPECTS

HMI

HMI is of great importance to the usability as well as the safety impact of ITS, see also 5.7. The importance of HMI has been recognised long time ago, and this has led to the formulation of a European Statement of Principles on HMI and the ADAS Code of Practice that also partly deals with HMI. Although these efforts have been very useful, some issues are reported to persist:

- For usability for the older driver, specific requirements on HMI have to be taken into account. To the benefit of all users, additional guidelines to coordinate HMI across applications would seem helpful.
- In practice, the principles and code of practice mentioned above are not applied throughout the industry. This problem is difficult to tackle as the involved industry is mostly outside the automotive sector. A standardised safe fitting and connection in the vehicle for nomadic devices might be a viable way to solve part of this problem.
- It is noted that HMI requirements for motorcycles are quite different and more stringent compared to passenger cars. More work in this area is recommended.

The objective of the EC in this area should be to extend the voluntary guidelines to cover these aspects, and to promote the use across all relevant industries.

The following measures in the area of **HMI** are deemed appropriate:

1) Non-binding instruments
    a) Elaborate with the industry the extension of existing HMI guidelines to cover cross-system/cross-application coordination as well as the specific requirements of the older driver.
    b) Elaborate with the industry a set of HMI guidelines for ADAS for motorcycles.

ACCIDENT DATA COLLECTION

For the development of effective systems and supportive policies enhancing traffic safety it is extremely important that accurate and detailed data on accidents causation are collected. Without such data, time and money may be spent on solutions that do not target the most important issues/causes, or will fall short of expected impact.

With good and uniform data it is also better possible to define safety Key Performance Indicators to benchmark Member States. This enables clear safety targets for Member States and is likely to lead to more effort when targets are not met.

Accident data are collected in all Member States and considerable progress has been made to harmonise definitions, aggregate these data on a European level and make them available through the CARE database. Still there is much room for improvement in the following areas:

- The accessibility of the CARE database for can be largely improved. National statistics institutes have shown that it is possible to open up complex databases to the public through a web interface.
- Availability of accident details. Development of ADAS and cooperative systems require details on the causes and conditions of accidents. These are only systematically collected in a few countries. The German GIDAS database serves as a good example.

- Improve the quality and uniformity of data and definitions, e.g. for important characteristics such as 'severely injured'. Key is of course that the source of accident data is willing and able to use these definitions consistently.
- In-vehicle systems may collect detailed pre-crash (and exposure) data. In fact, some existing technologies such as ABS systems already collect relevant data. An obstacle to open up these data for public use are privacy concerns, and concerns of the industry that such data may be used against the interest of their clients. There is a large public interest of the use of these data for the analysis of accident causes and circumstances, which would be very beneficial to the development of safety-related ITS. By anonymising data, it should be possible to overcome privacy concerns. Alternative ways of data acquisition via a smartphone or navigation system, also seem promising, especially for VRU that suffer even more from bad registration.

The objective of the EC in this area should be to enhance the quality and uniformity of relevant safety data across the Member States, and stimulate continuous improvement through monitoring of uniform safety performance indicators.

The following measures regarding *accident data analysis* are deemed appropriate:

1) Non-binding instruments
   a) Elaborate further harmonisation of protocols and definitions on accidents reporting for enhanced causation analysis, in consultation with the Member States
   b) Elaborate safety performance indicators, including ones specific for the VRU, in consultation with the Member States, monitor the indicators and encourage Member States to set quantitative targets.
2) Financial support
   a) Enhance the accessibility of the CARE database to the general public, preferably via a web interface.
3) Legislation
   a) Given the importance of detailed pre-crash data for the development of effective safety systems, the feasibility of mandatory fitment of a dedicated data recorder ('black box') should be investigated, as well as an obligation to deliver anonymised data that may be available from other in-vehicle systems in case the vehicle was involved in a crash.

6.5. Actions by the EC

In the preceding paragraph several measures related to ITS have been identified that, once implemented, are likely to add to the safety and comfort of the VRU. At this point uncertainty exists in the area of the effectiveness of some of the identified measures, the costs to various stakeholders on the short and longer run, the public acceptance and the best way to implement the measures. There is also little basis to prioritise the measures.

It is therefore suggested to take the following steps:
- Discuss the identified measures with stakeholders from the industry, regulation bodies and relevant interest groups to get a founded assessment of costs, effectiveness and acceptance.
- Review and elaborate 'best measures' on the short, medium and longer term.
- Publish the results for broad consultation.
- Review 'best measures' if appropriate.
- Bring measures forward for decision making at the appropriate level.

7. Conclusions

State of the art

Obviously, available solutions as well as on-going R&D has been focussing on cars and trucks and has been more limited for motorcycles, light PTW'S, cycles and pedestrians – in that order. This has to do in the first place with technical and practical limitations, notably to the user interface, available space to install equipment without hindrance to the user, exposure to outside environmental conditions and the lack of a high-quality power source. There are also economical factors: if the bill is to be paid by the road user, the cost of the ITS equipment has to be small compared to the cost of the transport means itself. Manufacturers of motorcycles, light PTWs and bicycles do not have R&D budgets anywhere near those of car manufacturers. As a result, few ITS solutions have been developed that target other traffic participants than the car or truck driver as primary user.

ITS Applications of specific relevance to the VRU

The positive message to convey is that most VRU are likely to profit from the indirect benefits that some ITS applications developed for passenger cars will bring to their safety. From a review of accident causes it can be concluded that there are a number of factors that have a large impact on the number and severity of injuries on the side of all or most types of VRU:

- Speed
- Alcohol
- Non-observance of the VRU by the vehicle driver
- Late and insufficient braking by the vehicle driver in cases of emergency.

Applications targeting the factors mentioned above are therefore of great interest to the safety of the VRU, in the first place:

- Intelligent Speed Adaptation
- Alcohol Ignition Interlock
- Pedestrian Detection Systems, combined with Emergency Braking and to be enhanced with VRU Beacon Systems in the future.

The following applications also have considerable potential for improving safety and comfort of the VRU:

- Adaptive Headlights
- Night Vision Warning systems
- Blind Spot Detection, in particular for trucks
- Cooperative Systems, in particular Intersection Safety (INS)
- Infrastructure based systems to reduce accidents on crossings: Intelligent Pedestrian Traffic Signals, Crossings Adaptive Lighting and Pedestrian Presence Warning systems.

It is emphasised that many ITS applications that have been investigated for years are still not ready for real life deployment. Of many others, the impact on traffic safety is not clear or not ready for quantitative assessment. In general, systems that assist the car driver in the driving task will influence the behaviour of the driver. Whereas the primary effect is likely positive, adverse effects – e.g. less attention to a part of the driving task 'because the system will take care of it' – may reduce the net impact on safety. The difficulty to predict overall safety impact is that simulators, prototypes and test drives do not represent the way in which system and user interact in practice, and do in particular not reflect how their interaction will evolve over long-term usage. Improving the collection and registration of accident data across Europe, making detailed pre-crash data from in-vehicle systems available for analysis as well as initiatives for naturalistic driving, in which the behaviour of motorists is monitored in real life over a longer period, are likely to be very valuable for more effective and efficient development of safety-related ITS.

Comfort of the VRU

Whereas safety can be regarded the most important topic for this study, comfort to the VRU is also within the scope. In general, it is difficult to assess comfort objectively: what is perceived as comfort by one user may be felt as a complete nuisance by the other. ADAS should support the driver and make driving easier, safer and more comfortable. The user interface of ADAS applications often determines whether this is actually the case.

The older road user deserves particular attention, as he has specific requirements / limitations when interacting with ITS. So far, few applications have been developed to assist him/her in his particular weaknesses. Moreover, the HMI of main stream ITS applications have not been developed to the requirements of the older user and are often not suited for use by the older driver.

As to pedestrians, cyclists, and drivers of PTWs, there are only few ITS-applications to support them directly as a road user. To a large extent their comfort depends on the road layout (e.g. breadth of sidewalks, availability of cycle paths and type of crossings) and local traffic regulations such as speed limits and restricted access for cars and trucks. An urban environment in which pedestrians and cyclists are regarded as prioritised road users, reduced speed limits apply and cars have a lower priority – as is practiced in some countries in inner cities and residential areas – makes a world of difference for the comfort of the VRU. Such a more quiet and forgiving traffic environment is of particular benefit to the (very) young as well as the older road user. ITS can play an important supporting role here, e.g. by stimulating speed limit compliance (ISA) and pedestrian-aware traffic signal control systems. It is reported that in such an environment the public support for ISA is also remarkably stronger than for general application.

From the analysis of safety issues for each of the VRU categories, the identified relevant ITS Applications, their expected effectiveness and deployment status a set of most appropriate areas for EU action was defined. For each area measures were defined in view to the generic instruments available to the EU.

Recommended measures

The following measures are deemed appropriate in the area of ***ADAS***:

1) Non-binding:
   a) Elaborate with EuroNCAP ways to attribute higher weight to ADAS that increases safety for the VRU, focusing on PDS+EBR and ISA, and including effectiveness for other modalities than pedestrians. This also requires the elaboration of functional criteria to assess VRU safety effectiveness.
   b) Elaborate with the insurance sector how car insurance premiums can be differentiated by safety properties / safety systems of the vehicle, with specific attention for PDS+EBR and ISA.
   c) Investigate the impact of mandatory ISA for specific categories of vehicles, e.g. LCV, public transport, fleets of public organisations and elaborate a corresponding recommendation.
2) Financial
   a) Award subsidies for deployment of specific ADAS, focusing on PDS+EBR and ISA.
   b) Discuss with member states the introduction of fiscal incentives or national subsidies for ADAS that adds to the safety of the VRU.
3) Legislative:
   a) Stimulate consumer awareness to safety through mandatory quotation of EuroNCAP rating in car advertisements.
   b) Make EuroNCAP assessment mandatory for new vehicle types.

The following measures are deemed appropriate in the area of ***cooperative applications***:

1) Non-binding instruments / Financial instruments
   a) Elaborate in consultation with road authorities a viable path for migrating to basic cooperative features in their infrastructure.
   b) Stimulate further research in the area of INS and VBS.
2) Standardisation
   a) Support the standardisation of vehicle-vehicle and vehicle to roadside applications / communications / application data.

The following measures are deemed appropriate in the area of ***regulatory applications***:

1) Non-binding instruments
   a) Investigate, establish and promote best practice guidelines for the use of AII in rehabilitation programmes
   b) Investigate, establish and promote best practice guidelines for the use of AII in specific vehicle/user categories - considering HGV, LCV, public transport and novice drivers.
2) Standardisation

> a) Organise standardisation of alcolocks.

The following measures are deemed appropriate in the area of solely *infrastructure-based applications*:

1) Non-binding instruments & Financial
   a) Establish best practice guidelines for the application of infrastructure based applications (in particular CAL, IPT and RPP).
   b) Perform further independent assessment of their safety impact and influencing factors.

The following measures are deemed appropriate in the area of *HMI*:

1) Non-binding instruments
   a) Elaborate with the industry the extension of existing HMI guidelines to cover cross-system/cross-application coordination as well as the specific requirements of the older driver.
   b) Elaborate with the industry a set of HMI guidelines for ADAS for motorcycles.

The following measures are deemed appropriate in the area of *accident data analysis*:

1) Non-binding instruments
   a) Elaborate further harmonisation of protocols and definitions on accidents reporting for enhanced causation analysis, in consultation with the Member States
   b) Elaborate safety performance indicators, including ones specific for the VRU, in consultation with the Member States, monitor the indicators and encourage Member States to set quantitative targets.
2) Financial support
   a) Enhance the accessibility of the CARE database to the general public, preferably via a web interface.
3) Legislation
   a) Given the importance of detailed pre-crash data for the development of effective safety systems, the feasibility of mandatory fitment of a dedicated data recorder ('black box') should be investigated, as well as an obligation to deliver anonymised data that may be available from other in-vehicle systems in case the vehicle was involved in a crash.

Open issues and next steps

On the basis of a limited analysis it proved feasible to identify priority areas and applications for the safety and comfort of the VRU, and to outline measures to be prioritised. Insufficient material was at hand and insufficient consultation was possible within the scope of this study to define a balanced and sufficiently elaborated set of measures 'ready for implementation'.

The following next steps are therefore suggested as a follow-up of this study:
- Discuss the identified measures with stakeholders from the industry, regulation bodies and relevant interest groups to get a founded assessment of costs, effectiveness and acceptance.
- Review and further elaborate 'best measures' on the short, medium and longer term.
- Publish the results for broad consultation.
- Review 'best measures' if appropriate.
- Bring measures forward for decision making at the appropriate level.

8. Bibliography

[1]   Inception report – Action 3.4 ITS Action Plan; Algoé & Rapp Trans; Version 1.3; February 2011.

[2]   Assisting the older driver, R. Davidse, December 2007.

[3]   Traffic Safety Basic Facts – Pedestrians, ERSO, 2008.

[4]   Traffic statistics database Netherlands, SWOV/I&M/CBS, updated for 2009, www.swov.nl

[5]   SWOV factsheet Voetgangers, SWOV, April 2010, www.swov.nl.

[6]   Pedestrian fatality risk as a function of car impact speed, Rosen, E. and Sander, U.; Accident Analysis and Prevention 41 (2009) 536-542, 2009..

[7]   Traffic Safety Basic Facts – Motorcycles and Mopeds, ERSO, 2006.

[8]   SWOV factsheet Motorrijders, SWOV, December 2010.

[9]   Rider / Driver behaviours and road safety for PTW, Deliverable D1 of EU 7FP project 2-BE-SAFE, January 2nd 2010.

[10]   Traffic Safety Basic Facts – Bicycles, ERSO, 2007.

[11]   Halving injury and fatality rates for cyclists by 2020, European Cyclist Federation, June 2010.

[12]   eIMPACT - Impact assessment of Intelligent Vehicle Safety Systems, eIMPACT Consortium, 2008.

[13]   SWOV-Factsheet Intelligente Transportsystemen (ITS) en Verkeersveiligheid; SWOV, July 2010.

[14]   Task specifications to award a Specific Contract under the Framework Contract TREN/G4/FV-2008/475/01 – Technical, legal and organizational support for the implementation of the ITS Action Plan – Development of appropriate measures including best practice guidelines concerning the impact of ITS applications and services on the safety and comfort of Vulnerable Road Users, EC DG MOVE Unit B4, December 2010.

[15]   Draft report on European road safety 2011-2020, 2010/2235(INI), Committee on Transport and Tourism, European Parliament, Feb 8th 2011.

[16]   SWOV factsheet Fietsers, SWOV, juli 2009.

[17]   Motorcycle safety and Intelligent Transport Systems; Dodge, Linda D. and Halladay, Michael; Research and Innovative Technology Administration and Federal Highway Administration, 2007.

[18]   Intelligent Transport Systems and Motorcycle Safety; Bayly M., Regan, M. and Hosking, S.; Monash University Accident Research Centre; Report No. 260; July 2006.

[19]   Annual Statistical Safety Report 2007, SafetyNet, February 2008.

[20]   Making cycling irresistible: lessons from the Netherlands, Denmark and Germany; Pucher, J. and Buehler, R.; Transport Reviews, Vol. 28, No. 4, 495-528, July 2008.

[21]   Office for National Statistics, Social Trends, Issue 40, 2010.

[22]   Factsheet Brom- en Snorfietsen, SWOV, March 2009.

[23]   The Safety of Vulnerable Road Users in the Southern, Eastern and Central European Countries (The "SEC Belt"); Avenoso, A and Beckmann, J.; ETSC; 2005.

[24]   Barómetro de Seguridad Vial 2004, FITSA, 2004.

[25]   Car Drivers' Attitudes and Visual Skills in Relation to Motorcyclists; Department for Transport, Road Safety Research Report No. 121; Crundall, D., Clarke, D. and Shahar, A., University of Nottingham; 2010.

[26]   Alcohol-related harm in Europe - Key data; European Commission, 2006.

[27]   Reducing Drinking and Driving in Europe; Institute of Alcohol Studies, London, July 2007.

[28]   Cost Effective EU Transport Safety Measures; European Transport Safety Council, 2003.

[29]   SWOV Fact sheet - Safety effects of navigation systems; SWOV, January 2009.

[30]   Schatting van verkeersveiligheidseffecten van intelligente voertuigsystemen; SWOV, 2010.

[31]   SWOV-Factsheet Advanced Cruise Control (ACC); SWOV, 2010.

[32]   SWOV-Factsheet Intelligente Snelheidsassistentie (ISA); SWOV, 2010.

[33]   ETSC Position - Communication Action Plan for the Deployment of Intelligent Transport Systems in Europe (COM 2008 886); ETSC, 2009.

[34]   Final study report CODIA - Co-Operative systems Deployment Impact Assessment; CODIA, 2008.

[35]   Final Report - Project Evaluation and Effectiveness of the Intersection Safety System; PReVENT/INTERSAFE, 2007.

[36]   Legislative instruments of the European Union, a brief guide to understand EU legislation, EASPD, www.easpd.eu.

[37]   Saving 20000 lives on our roads – A shared responsibility – European Road Safety Action Programme, COM (2003) 311 final, EC, 2003.

[38]   SWOV-Factsheet Jonge Beginnende Automobilisten, SWOV, februari 2010.

[39]   Improvement of the Classifier Performance of a Pedestrian Detection System by Pixel-Based Data Fusion, Lietz, H., Thomanek, J. e.a., University of Chemnitz, 2010.

[40]   Directive on the framework of deployment of ITS in the field of road transport and for interfaces with other modes of transport, European, Parliament and Council, July 7th 2010,

[41]   Type approval requirements for the general safety of motor vehicles, their trailers and systems, components and separate technical units intended therefore, Regulation no. 661/2009, European Regulation, 2009.

[42]   Intelligent Speed Adaptation : results of the Dutch ISA Tilburg trial : summary, Dutch Ministry of Transport, Water Management and Public Works; RWS/AVV, Besseling H. and van Boxtel, A; 2001.

[43]   Evaluation of the effectiveness of enhanced information at pedestrian crossings, Anund A., and Söderstrom B., Swedish National Road and Transports Institute VTI, Linköping; 2010.

[44]   Reducing drink driving in Europe, Anderson P. on behalf of the Institute for Alcohol Studies, Deutsche Hauptstelle fur Suchtfragen, 2008.

[45]   Pedestrian injury mitigation by autonomous braking, Källhamer J., Autoliv Research, 2009.

[46]   Commission recommendation on safe and efficient in-vehicle information and communication systems: Update of the European Statement of Principles on Human-Machine Interface, C(2008)1742 final, EC, May 2008.

[47]   Code of practice for the design and evaluation of ADAS, Deliverable of RESPONSE3/PReVENT integrated project, EC DG INFSO, contract FP6-507075, August 2009.

[48]   Implementation Road Maps, Monitoring Report 2010, eSafety Forum, EC DG INFSO, July 2010.

[49]   Young driver accidents 2000, National Roads Authority Ireland, ISBN 1 900293 65 X, 2000.

[50]   Ko-TAG, Cooperative Sensor Technology for Traffic Safety Applications; Schwarz D., Kloeden H., Rasshofer R.; Proc. 8th International Workshop on Intelligent Transportation Systems, TU Hamburg-Harburg, pp. 31-34, Hamburg, Germany, March 22nd/23rd, 2011.

[51]   European Motor Vehicle Parc 2008, ANFAC, March 2010,

ANNEX A Glossary of relevant ITS applications

Abbreviation	Full name	Description	Deployment status
AHL	Adaptive Head Lights	Headlights that are controlled electro-mechanically. The headlights are directed into the bend as soon as the vehicle begins cornering. Vehicle speed, yaw-rate and steering wheel angle can be used as input.	Available, available in high-end car models.
AII	Alcohol Ignition Interlock	An alcohol ignition interlock device is a mechanism, like a breathalyzer, installed to a motor vehicle's dashboard. Before the vehicle's motor can be started, the driver first must exhale into the device, if the resultant breath-alcohol concentration analysed result is greater than the programmed blood alcohol concentration, the device prevents the engine from being started [13].	Several countries have piloted IDD (Sweden, USA, the Netherlands).
BSD-C	Blind Spot Detection System for Cars	System that detects objects or traffic participants in the Blind Spot. It may be combined with LCA.	Existing technology, available in high-end car models.
BSD-T	Blind Spot Detection System for Trucks	System that detects objects or traffic participants in the Blind Spot (using cameras or other detectors) and warns the driver accordingly. The major added value is a reduced chance of accidents when the truck driver takes a right turn (left for UK/Ireland) without observing cyclists/pedestrians next to it.	Under development, not yet mature.
CAL	Crossings Adaptive Lighting	Equipment mounted at a pedestrian (zebra) crossing detects if a pedestrian is approaching. The lighting of the scene is automatically switched on and off by the presence of pedestrians.	Available, deployed in some countries.
CUR	Curfew Locks	System that denies use of the vehicle (ignition) within a specified time interval.	Technology available, no deployment for regulatory purposes as yet.
DDM	Driver Drowsiness Monitoring	The Driver Drowsiness Monitoring and Warning system monitors the condition of the driver with respect to symptoms of	Final development phase

Abbreviation	Full name	Description	Deployment status
	and Warning	drowsiness. When it diagnoses the driver as 'hypovigilant' (i.e., 'drowsy', or 'sleepy'), the type of warning issued depends on the criticality of the traffic situation, i.e., the estimated momentary risk. Warnings can range from alert sounds to seat belt vibration. The expected reaction of the driver is to pull over and take a rest or another measure (e.g., going home by train) [12]. The system gives the warning based on onboard driver physiology monitoring sensors and vehicle and driver sensors. The following parameters are measured [12]: • The eyelid activity • Pressure the driver applies on the steering wheel. • Lateral position relative to the lane • Road geometry, presence and location of surrounding vehicles (video-based), GPS-derived measures.	
EBR	Emergency Braking	The aim of EBR is to avoid or mitigate longitudinal crashes (braking only). The system reacts if a vehicle approaches another leading vehicle. The system reacts in three steps: § Optical and acoustical warning, if the approach could lead to an accident. § Autonomous partial braking, if the distance is reduced further. § Autonomous full braking, if an accident appears inevitable. Input is the distance and the relative speed to a leading vehicle [12].	Available on a limited number of brands/models.
ECA	eCall	The Pan-European in-vehicle emergency call system is known as eCall. The eCall system is based on either the automatic detection of an accident with a sensor or a manual emergency call made by pushing a button. In both cases a normal voice communication is	The ITS Directive mandates that eCall standards be completed by 2012, and that any public eCall system introduced after that time must comply with those

Abbreviation	Full name	Description	Deployment status
		opened to the emergency centre, and accident vehicle location and identification as well as possible accident severity information is transmitted automatically [12].	standards. There is no requirement yet for mandatory fitment of eCall in new vehicles.
EDI	Electronic Driver Identification Interlock	An EDI systems locks ignition unless a smartcard is inserted in an in-vehicle card reader, with a valid driver license [13]. A biometric system can also be used to identify the driver.	Conceptual stage
EDR	Electronic Data Recorder	Black box for road vehicles, allows accident analysis and driving behaviour recording [13].	Existing technology, complex privacy issues.
ESC	Electronic Stability Control	The aim of ESC is to stabilize the vehicle within the physical limits and prevent skidding through active brake intervention and engine torque control [12] ESC compares the driver's intention with the vehicle's response, determined by measuring lateral acceleration, rotational speed (yaw velocity) and individual wheel speeds. ESC then breaks individual front or rear wheels and/or reduces excess engine power as needed to help correct under-steering or over-steering [12].	ESC is already widely deployed in newly manufactured vehicles.
EVI	Electronic Vehicle Identification	System to identify vehicles electronically, e.g. through an RFID tag attached to the vehicle [13].	Basic technology is available, but solutions do not meet all requirements. Member States are hesitant to introduce mandatory EVI given public concerns over privacy.
FSR (or ACC-FSR)	Adaptive Cruise Control Full Speed Range	Adaptive Cruise Control Full Speed Range (FSR-ACC) keeps a driver-set speed or, in case the vehicle in front is slower, a driver-set distance to this vehicle. The system is activated by the driver. When the vehicle comes to a standstill, it only starts again after a command by the driver. The system is deactivated either by a driver input	FSR is commonly available on upscale private cars of major car manufacturers.

Abbreviation	Full name	Description	Deployment status
		("deactivate") or by a driver intervention (braking). From deactivation a "resume" is possible activating the previous values for desired speed and distance [12]. The goal of the system is to keep a safe headway and extend the operating range of the conventional cruise control by making it usable in more traffic situations than in free flow driving and by providing this functionality at all speeds, from standstill to stop&go traffic to high speed driving. When a deceleration is required that is stronger than the system limit (around 4 m/s2) the driver is warned, e.g. by an audible signal. Within the deceleration limit rear-end crashes are avoided in following traffic. An avoidance of other standing obstacles is not tackled by the system [12].	
INS	Intersection Safety	Intersection Safety assists the driver in avoiding common mistakes which may lead to typical intersection accidents. It covers these functions [12]: • Traffic light assistance: preventing red light ignoring. This ends in an urgent acoustic warning if the situation becomes critical. • Right-of-way assistance: The right-of-way assistance pays special attention to lateral traffic. The system warns the driver if violating a right-of-way but also if somebody else is expected not to give the right-of-way to the case vehicle. • Left-turn assistance: The left-turn assistance warns the drivers about potential collision with other vehicles with crossing path.	Conceptual phase
IPT	Intelligent Pedestrian Traffic Signals	A traffic signal control system that uses sensors such as an infra-red camera to determine whether a pedestrian is using a pedestrian crossing. Such a system can	Market-ready but deployment is still quite limited.

Abbreviation	Full name	Description	Deployment status
		extend the green period for pedestrians that are less mobile and need more time to cross to the other side.	
ISA	Intelligent Speed Adaptation	System that compares the actual speed of the vehicle with the local speed limit and advises the driver or controls the vehicle until the speed is reduced to the local limit. ISA applications can be roughly classified as intervening/non-intervening and as static/dynamic. Intervening means that the system actually takes control of the gas pedal. Within intervening systems one may distinguish between fixed or voluntary systems (can be turned off by the driver). Static means that only the formal local speed limits are applied, dynamic means that time-dependent variable speed limits can be applied, e.g. 30 km/h just before school starts/ends, 50 km/h otherwise.	The non-intervening strictly informative type is already quite common as a feature of navigation systems. Intrusive variants have been tested in several pilots and are expected to be more effective, but are not yet commercially available.
LCA	Lane Change Assistant	The system enhances the perception of drivers in lateral and rear areas and assists them in lane change and merging lane manoeuvres through three functions [12]: • rear monitoring and warning: to improve driver attention and decrease the risk of collision in the rear area of the vehicle, particularly in case of limited visibility or critical workload of driver attention; • lateral collision warning: to detect and track (in general moving) obstacles in the lateral area and to warn the driver about an imminent risk of accident (e.g. collision); • lane change assistance with integrated blind spot detection: to assist the driver in lane change manoeuvres while driving on roads with more than one lane per direction. Vehicle-to-vehicle accidents are the main	LCA is currently available on some high-end car models

Abbreviation	Full name	Description	Deployment status
		category of accidents that benefit from the system. In particular, when sensor data detect an obstacle in the lateral and rear area of a vehicle, including the blind spot area, the system gives to the driver visual (i.e. lamps) or acoustic (i.e. alarm) information using a warning module, in order to stimulate the driver reaction. The illustration below outlines the scope of a LCA system [12].	
LKS	Lane Keeping Support	A lane keeping system for passenger cars and commercial vehicles supports the driver to stay safely within the "borders" of the lane. It determines the vehicle position relative to lane markings and combines this with recognition of driver intention or behaviour (e.g. taking turning lights into account or via analysing the motion of the vehicle via ESC) to check for unintentional lane departure. The system is for use on motorways and rural roads, and works under various road- and driving conditions [12]. It either • warns the driver by sound or by a steering wheel with haptic feedback • actively steers the vehicle	Various upscale private car models of major car manufacturers are factory-fitted with LCA.
NVW	Night Vision and Warning	The aim of NVW is to extend the visible range for a driver in darkness, including obstacle detection and warning, as well as warning for vulnerable road users [12]. The visible range for the driver in darkness is extended without disturbing on-coming drivers by using an "invisible high beam". This is achieved by using an infra-red camera looking forward and displaying its view on a screen in the vehicle. The display shows the area in front of the vehicle with a longer range of visibility than with the normal low-beam headlights. It detects and warns for obstacles and vulnerable road users if a critical driving situation is detected.	A few upscale private car models of major car manufacturers are factory-fitted with NVW.

Abbreviation	Full name	Description	Deployment status
PDS	Pedestrian Detection System	Pedestrian Detection Systems use LIDAR, RADAR and/or camera technology to detect a pedestrian. The PDS warns the driver and may brake autonomously if an impending impact is anticipated (EBR). At low speeds the system is likely to avoid a collision, at higher speeds the collision speed is at least reduced as far as possible.	This technology is on the market since a few years. Available for a number of Volvo and Lexus models. The market penetration is still marginal (<<1%).
RPP	Roadside Pedestrian Presence Warning System	The system detects that a pedestrian is close to a crossing (or bus stop) and warns motorised traffic with flashing lights or information on a display. The detection may also (apart from detecting any human in the vicinity through IR sensors) configured to be triggered by transponders carried by children going to school.	Available, deployed in Sweden.
SBR	Seatbelt reminders or locks	Seatbelt reminders detect whether the driver and passengers have plugged in their seatbelts. If this is not the case the driver will be warned when starting the vehicle or the vehicle will refuse to start (lock) [13].	Seatbelt reminders are already installed in many vehicle models. Seatbelt locks are in the conceptual stage.
VBS	VRU Beacon System	The VRU carries a simple device that facilitates detection by the roadside infrastructure or in-vehicle systems, see [50].	In development phase.
WLD	Wireless Local Danger Warning	WLD supports the driver in safe driving by inter-vehicle communication. The system detects hazards via its own sensors and communicates the hazard information to other vehicles via vehicle-to-vehicle communication. Also, information from the roadside can be integrated via infrastructure-to-vehicle communication [12]. The WLD safety impact analysis covers the following applications [12]: • (Detection) and warning of obstacles (other vehicle) on the road. Detection and warning of reduced friction or reduced visibility due to bad weather.	Several trials have been carried out; some road authorities consider the technology ready for use.

ANNEX B **Selection of fields of action and measures**

Criteria for first selection of most appropriate application areas

For the purpose of this study the following criteria were applied to select areas of action:

- Is the area specifically targeting the VRU, or are there specific impacts for the VRU? *If not, the application (area) is not selected as a potential priority area.*
- Is a major VRU safety benefit expected from further development or deployment of the application (area)?. *If not, the application (area) is not selected as a potential priority area. .*
- Is the EU/EC the appropriate level to mandate, trigger or stimulate development or deployment in that area? *If not, the application (area) is not selected as a priority area for EU/EC policy.*
- Is the area already in focus and covered by on-going and EU action? *If so, the application is not selected as a priority area, as there is no reason to ask for actions that already take place.*

Applications ruled out from first selection

This 'rules out' the following applications:

- ESC. This measure is reported to be very effective, yet does not target the VRU, and has no specific VRU aspects. In addition, the area is already covered by on-going EU action, in particular Directive [40].
- EDI, Not specific to the VRU.
- EVI. Not specific to the VRU.
- EDR. Important for improving analysis of behaviour and accident data, but not specific for the VRU.
- E-Call. Already covered by on-going EU action on various aspects, and not specific to the VRU. An exception would be the extension of E-Call to motorcycles; this is however already subject to on-going elaboration by the EC.
- FSR. Does not target a specific need or problem of the VRU. It is noted that FSR does add to the comfort of the driver, including the young and older driver.
- SAT. Navigation systems add significantly to the comfort of driving. As to safety, there are both positive and negative effects. Apart from HMI issues with older drivers, the application has little specific importance for the VRU.
- SBR. Seat belt reminders add to the safety of all drivers (and potentially passengers). In our VRU definition, the young and older driver also benefit from this application. There are however little effects that are specific to the VRU.

Assessment of applications to be prioritised

Table 11 Assessment of applications to be prioritised

	Application or application area	Potential to save life and reduce injuries of VRU	Technical maturity	Cost/benefit	Potential to stimulate deployment on the short or midterm by EU	Public acceptance	Overall score
Relative weight		4	1	1	3	2	
Advanced Driver Assistance Systems	AHL	+?	+	+	+/-	+	8
	PDS / EBR	++	+/-	+	+/-	++	13
	LCA	+/-	+/-	+	+/-	+	3
	LKS	+/-	+/-	+	+/-	+	3
	NVW	+	+/-	+	+/-	+	7
	DDM	+/-	-	+	+	+	4
	BSD-C	+/-	+/-	+	+/-	+	3
	BSD-T	+	-	+	+	++	9
	ISA	++	+	+	+	-	11
Cooperative Systems	VBS	+	--	+	-	+	2
	INS	++	--	+	-	+	6
	WLD	+/-	--	+	-	+	1
Regulatory Applications	All	+	+	+	+	+/-	7
Infrastructure based Applications	CAL, IPT, RPP	+	+	+	-	++	8

Motivation for the weight factors:
- The safety potential for the VRU is given the highest weight factor as this is the core scope for this study.

- The potential of the EU to influence the deployment of an application is given the second highest weight factor followed by public acceptance. Both are regarded important factors for successful measures.
- Technical maturity is given a weight of 1. Although technical maturity is in the end essential for any successful deployment, it is felt that significant measures can also be taken if the application is still in the developing stage, or subject to on-going major improvements. Of course the nature of measures would be different compared to a fully mature application.
- Cost/benefit is also given a weight of 1. This aspect is in general also very important, but it is felt that costs will strongly depend on the scale of roll-out and will develop over time. A high cost in the development phase therefore should e.g. not be a showstopper for a promising application.

Motivation for the scores:
- Potential to safe life and reduce injuries for the VRU. A '++' score is awarded to applications that are reported to have a major impact for at least one VRU category. A '+' score is awarded for applications that have a considerable impact for at least one VRU category, or a fair impact for multiple VRU categories. '+/-' is assigned to applications that have some impact for one or more VRU categories.
- Technical maturity. A '+' is assigned to applications that are available and deployed, and which do not require major improvements to fulfil their objectives.' +/-' means that the application is available and deployed on some scale, but is still undergoing major extensions or improvements. A '–' indicates that an application is not yet on the market, while '—' indicates an application that is still in a conceptual phase.
- Cost/benefit. Cost benefit estimates of [48] and [12] were applied to assess the C/B ratios of individual applications. All applications with a reported benefit/cost ratio above 1.5 is given a '+'.
- Potential to stimulate deployment on the short or medium term, by the EU. Applications that are fully vehicle based and have clear potential to become mandatory in the EU (for certain types/groups of vehicles), are awarded a '+'. Other fully vehicle-based systems are awarded '+/-'. Cooperative applications and solely infrastructure based applications are awarded '-' as they depend on implementation decisions by a large number road authorities in the Member States. The influence of the EU on such decisions is smaller, and the sheer number of entities involved would hamper a fast roll-out.
- Public acceptance. Little information exists on the public acceptance of various applications. It should be noted that public acceptance is not a static thing, but evolves over time, with broader deployment and as a result of awareness and marketing campaigns. In general it is difficult to assess public acceptance for completely new applications. For this assessment it was assumed that applications that have safety benefits for all, but affect authorities or only a minority of users in terms of obligations/investments, will easily be accepted. These applications are awarded a '++'. PDS/EBR is also awarded a '++' as it provides a very visible and

understandable safety benefit. Other ADAS and cooperative systems are awarded a '+'. Regulatory applications are generally never very popular. AII is awarded '+/-' and ISA '-'. It should be noted that public acceptance for these applications can actually be quite good, if only specific 'high risk' target groups are addressed.