



# Advanced driver assistance systems

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## CONTENTS

1	Overview	3
2	Vehicle technologies and road casualty reduction	5
3	ADAS - a definition	7
4	ADAS - known safety effects	7
4.1	Intelligent Speed Adaptation (ISA)	7
4.2	Seat belt reminders	10
4.3	Electronic stability control	12
4.4	Alcohol Interlock Systems	14
4.5	In-vehicle event data recorders	15
4.5.1	Crash data or event data recorders	15
4.5.2	Journey data recorders	18
4.6	Anti-lock braking systems in cars (ABS)	18
4.7	Autonomous emergency braking systems	19
4.8	Anti-lock braking for motorcycles	20
4.9	Lane support systems	20
5	ADAS safety measures - unknown safety effects	21
5.1	Emergency Brake Assist	21
5.2	Collision avoidance systems	22
5.3	eCall	25
5.4	Electronic driving licences	26
6	EC initiatives on safety related ADAS	27
7	ADAS - evaluating measures	30
	References	32

## 1 Overview

### Vehicle technologies and road casualty reduction

Vehicle safety is a key strategy to address ambitious long-term and interim goals and targets as part of an integrated Safe System approach (See [ERSO web text on Road Safety Management and Vehicle Safety](#)). Secondary safety or crash protection technologies continue to deliver large savings; in the last few years, primary safety or crash avoidance technologies have started to contribute to casualty reduction and hold potentially large future promise. At the same time, new in-vehicle technologies under development have the potential to increase as well as decrease crash injury risk through introducing new driver distraction and inadvertent behavioural change that may solve one problem but create another. The safety effects of some of the technologies that are being promoted widely in the name of safety have yet to be demonstrated. More promising safety technologies that address large road safety problems and where benefits have been demonstrated are being promoted in only a few countries or are being taken up at a lesser rate across EU countries. The European Commission's Cars 21 strategy (see Cars 21) envisages an automotive industry that is leading in technology (clean, fuel-efficient, safe, and connected) and where vehicle safety can and should be further improved, for occupants and unprotected road users. The European New Car Assessment Programme (EuroNCAP) is developing a new role in assessing the safety quality of e-Safety systems through Advanced EuroNCAP and a new road map is underway to allow emerging crash avoidance technologies to be included (albeit not supplanting crash protection measures) into the assessment scheme by 2015. With the rapid deployment of new technologies on to the market, evaluation of systems referring to the analysis of final and intermediate outcome data as well as other relevant data is essential before wide-scale deployment.

### Advanced driver assistance systems – a definition

Advanced driver assistance systems (ADAS) are defined here as vehicle-based intelligent safety systems which could improve road safety in terms of crash avoidance, crash severity mitigation and protection and post-crash phases. ADAS can, indeed, be defined as integrated in-vehicle or infrastructure based systems which contribute to more than one of these crash-phases. For example, intelligent speed adaptation and advanced braking systems have the potential to prevent the crash or mitigate the severity of a crash. This text discusses a variety of measures that are being promoted widely as ADAS, e-Safety or active safety measures, the knowledge about which is gradually evolving, including information on the costs and benefits of such measures.

### Advanced driver assistance systems – safety effects known

The evaluation of ADAS is a young science and their road safety performance is of principal concern to road safety managers. Outcomes can be evaluated in terms of deaths and serious injuries (final outcomes) or any activity which is causally linked to these e.g., the level of seat belt use (intermediate outcomes). In this web text an intervention is deemed to have a 'known positive safety effect' if there are results from more than one study done in a similar road safety context and, where the results are statistically significant and indicate a useful level of effectiveness. Research in the EU and elsewhere has confirmed that the following interventions are likely to make a large contribution towards meeting ambitious safety targets and goals (ETSC 2006 eSafety): Intelligent Speed Adaptation (advisory ISA, Speed Alert); seat belt reminders in all seating positions in new cars, electronic stability control, alcohol interlocks for repeat offenders and fleet drivers, anti-lock braking for motorcycles and event and journey data

recorders. All the above mentioned measures are at different phases of implementation. In some cases, the safety effects of measures are known but the available evidence does not indicate clear safety benefits.

## **Existing ADAS and those under development – safety effects unknown**

Systems such as smart keys for young drivers and eCall, that are starting to come on to the market, hold future promise. In general, most of the devices for improvement of braking and handling affect driver behaviour, and the questions of driver acceptance, risk compensation and driver reaction, when the system is activated, are important. For example, and not to be confused with Autonomous Emergency Braking Systems, Emergency Brake Assist is often cited as a safety related ADAS. Prospective studies have indicated some benefits, while a study of real accidents has indicated some benefit, though not statistically significant, when Emergency Brake Assist is combined with other measures. However, its contribution to road safety is, as yet, not demonstrated. Collision Avoidance systems offer future promise and are receiving much attention though, again, the safety effects are as yet unknown.

## **EC and national initiatives**

Over the last decade, the EU institutions have played an active role in promoting ADAS policy and research. A legal framework (Directive 2010/40/EU) was adopted on 7 July 2010 to accelerate the deployment of these innovative transport technologies across Europe. The EU is being encouraged to work towards the early implementation of systems which have proven safety benefits and give priority in long-term development to systems that have significant potential to improve safety. Sweden has been particularly active in promoting evidence-based ADAS in the national fleet through procurement and in-house travel policies and this approach is accepted internationally as best practice. An EU crash injury monitoring system needs to be established to evaluate the design, development and implementation of new in-vehicle technologies and their short, medium, and long-term impacts on road safety.

## **Consumer information**

Launched in July 2011, EuroNCAP Advanced is a useful and timely tool and comprises a complementary reward system to EuroNCAP's existing star rating system. It aims to provide advice to car buyers about the potential safety benefits offered by technologies which have a scientifically proven safety benefit. Cars are eligible for a EuroNCAP Advanced reward only if they have achieved a creditable three star rating in the overall rating scheme. EuroNCAP is looking into further developing its communication strategy to engage with the car buying public.

## **Predicting casualty reduction and evaluating measures**

Although some aspects of this are being addressed within the research domain there is no accepted, systematic approach to predict the impact on safety of a new e-Safety system or package of e-Safety measures. (See discussion in the TRACE project). An accepted scientific evaluation framework is needed urgently to identify, evaluate, deliver and monitor technologies which improve safety and to identify and discontinue work on those which introduce new safety risks. Measures described as e-Safety measures; need to be demonstrably effective safety aids before they are introduced widely.

## 2 Vehicle technologies and road casualty reduction

Vehicle safety is a key strategy used in addressing international and national road casualty reduction goals and targets. Vehicle safety addresses the safety of all road users and currently comprises measures for crash avoidance and injury prevention (or primary safety); reduction of injury in the event of a crash (crash protection or secondary safety) and those which assist post-impact care (to reduce the consequences of injury).

### Crash avoidance systems

There is large future promise of casualty reduction from crash avoidance technologies, as long as development is prioritised to provide maximum casualty reduction. Since driver behaviour can modify the performance of safety systems which aims for crash avoidance, assessment of the human-machine interface, while complex, is essential.

### Crash mitigation systems

These refer to active in-vehicle systems which aim to mitigate the severity of the crash. Examples include intelligent speed adaptation and advanced braking systems.

### Crash protection systems

Substantial and evidence-based improvements have been made in the last 20 years and research has identified continuing large scope for enhanced vehicle safety from improved crash protection which aims to reduce injury severity during the impact phase. Examples include improvements in occupant restraint systems which better reflect the different human tolerance thresholds of male and female occupants and of different age groups.

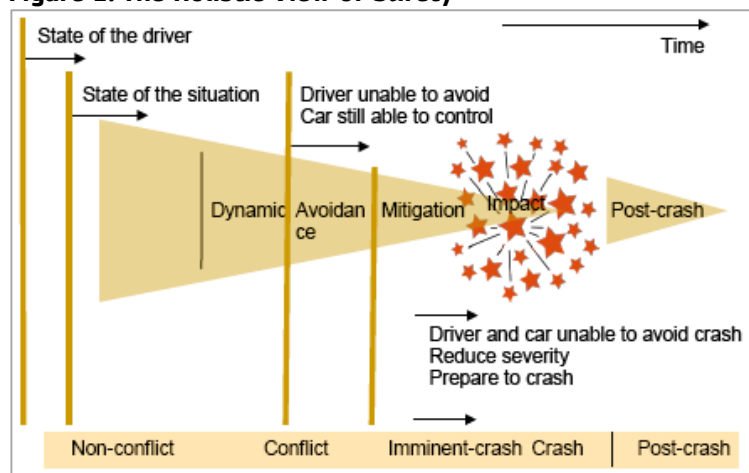
### Post-crash response systems

A new development is the deployment of systems such as eCall which aim to alert and advance emergency medical system support in the event of crash.

### Integrated systems

The potential for in-vehicle systems to integrate crash avoidance, crash protection and post-crash objectives is being increasingly understood, as shown in Figure 1, as are vehicle to vehicle and vehicle to network communications.

**Figure 1: The Holistic View of Safety**



Source: Swedish Transport Administration 2010

New technologies for road safety have collectively been known as Intelligent Transport Systems (ITS) and transport telematics (although these cover a wide range of road and vehicle based systems), advanced driver assistance or driver support technologies and, more recently, ADAS, to reflect increasing use of electronic and telecommunication technology within the road transport sector. However, as noted by the European Commission, “not all new technologies for cars are for safety; they can be for comfort, professional use, traffic management. Safety is a precious public good; there may be a temptation to declare technologies as safety technologies to get policymakers interested in promotion and funding, while the normal business case should prevail.” (Tostman, 2006). Furthermore, new in-vehicle technologies have the potential to increase risk as well as decrease crash and injury risks (Rumar ed., 1999).

**Box 1: Examples of in-vehicle technologies**

Electronic Stability Control	Active Cruise Control with emergency brake
Blind Spot Monitoring	Brake Assist
Adaptive Headlights	eCall
Obstacle And Collision Warning	Advance hazard warning
Lane Departure Warning	Seat belt reminders

While many predictive studies on ADAS effectiveness have been carried out, research on the casualty reduction effects of systems in practice is just starting. Although attempts have been made to classify the impacts of ADAS safety measures, it is acknowledged to be a young science (Golias et al., 2002; ADVISORS, 2003; SUPREME, 2007; Thomas, 2008). Before measures are described as safety related ADAS, positive safety performance needs to be demonstrated before they are introduced widely.

Results of studies carried out to date are available on the safety effects website, [www.esafety-effects-database.org](http://www.esafety-effects-database.org) and it is important that such resources are kept up to date. These studies utilise a variety of approaches and it is necessary to evaluate the statistical robustness of the approaches used.

Based on current knowledge about safety impacts and feasibility, this web text accordingly discusses measures in two broad groups:

- Safety related ADAS - safety effects known
- Safety related ADAS – safety effects unknown

In this web text an intervention is deemed to have a ‘known positive safety effect’ if there are results from more than one study in a similar road safety context, where the results are statistically significant and where results indicate a useful level of effectiveness. The measures selected for discussion are those which are being promoted widely as safety related ADAS measures, the knowledge about which is slowly evolving, including information on the costs and benefits of measures.

Given the rapid development and implementation of ADAS technologies, the EuroNCAP Advanced assessment process is clearly a useful and timely next step. At the same time a scientific evaluation framework is needed urgently to identify, evaluate, deliver and monitor such

technologies. Work Package 5 of the EU-funded DaCoTA project proposed to establish a consistent approach to the evaluation of ADAS once they have been introduced to the market by specifying analytic approaches and new data needs. See [DaCoTA WP 5](#).

Little data exists at EU level to evaluation the effectiveness of ADAS technologies in terms of their final and intermediate outcomes that needs to be addressed urgently.

## 3 ADAS - a definition

Safety professionals understand ADAS as vehicle-based intelligent safety systems which could improve road safety in terms of crash avoidance, crash severity mitigation and protection, and automatic post-crash notification of collision; or indeed integrated in-vehicle or infrastructure based systems which contribute to some or all of these crash phases. More generally, some driver support systems are intended to improve safety whereas others are convenience functions.

## 4 ADAS - known safety effects

A wide variety of ADAS technologies are in use today, some of which are fitted to vehicles increasingly as standard equipment. Research on seat belt reminders, alcohol interlocks, intelligent speed adaptation (ISA) and electronic stability control (ESC) indicates that these measures offer significant safety potential. These technologies are, accordingly, being introduced increasingly into legislation into some national safety policies as well as governmental and organisational procurement policies which encourage fast-tracking of fitment of demonstrably-effective safety equipment.

### 4.1 Intelligent Speed Adaptation (ISA)

See also [ERSO Speed and speed management web text](#).

#### What is ISA?

ISA is a system which informs, warns and discourages the driver to exceed the statutory local speed limit or other desired speed thresholds below this limit at safety critical points. The in-vehicle speed limit is set automatically as a function of the speed limits indicated on the road. GPS allied to digital speed limit maps and speed traffic sign recognition allows ISA technology to continuously update the vehicle speed limit to the road speed limit. There are three types of ISA:

Informative or advisory ISA gives the driver a feedback through a visual or audio signal. A Speed Alert System is an informative version of ISA; it is able to inform the driver of current speed limits and speed in excess of these limits.
Supportive or warning ISA increases the upward pressure on the accelerator pedal. It is possible to override the supportive system by pressing the accelerator harder.
Intervening or mandatory ISA prevents any speeding, for example, by reducing fuel injection or by requiring a "kick-down" by the driver if he or she wishes to exceed the limit.

## What road safety problem does ISA address?

Excess speed contributes to around 30% of fatal crashes and is at the core of the road safety problem (TRB, 1998). Typically, 40% to 60% of EU drivers exceed the limit ([ERSO Speed and speed management web text](#)). Studies show that small differences in speed can have a profound effect on the occurrence and severity of road accidents and injuries. Research indicates that a 1% decrease in average speed corresponds with a 2% decrease in injury accidents, a 3% decrease in serious injury accidents and a 4% decrease in fatal accidents and vice versa. A 5% increase in mean speed will lead to a 20% increase in fatal accidents and vice versa (Elvik, 2009, Nilsson, 2004).

## How effective?

The EU-funded and SRA co-ordinated project PROSPER looked into ways that advanced assisted driving technology and technology relating to speed limitation devices can improve safety, and also at the barriers for the implementation of ISA. The PROSPER project calculated crash reductions for six countries. Reductions in fatalities between 19-28%, depending on the country, were predicted in a market-driven scenario for voluntary systems. Even higher reductions were predicted for a regulated scenario – between 26-50%. Benefits are generally larger on urban roads and are larger if more intervening forms of ISA are applied (Carsten & Tate, 2006). Trials with ISA have been carried out in many European countries: Austria, Belgium, Denmark, Finland, France, Hungary, the Netherlands, Spain, Sweden (ETSC, 2006 ISA) and the United Kingdom (Carsten et al., 2008) as well as in the USA, Canada and Japan. An earlier study in the Netherlands showed that ISA could reduce the number of hospital admissions by 15% and the number of deaths by 21% (Loon, van & Duynstee, 2001). Research has shown that ISA and physical infrastructure measures to reduce road speed are complementary rather than competing methods (PROSPER, 2006). The most recent results are shown in Table 1.

**Table 1: Expected road safety results from a range of ISA options**

	Advisory % reduction	Voluntary % reduction	Mandatory % reduction
Fatal accidents	5%	21%	46%
Serious injury accidents	3%	14%	34%

Source: Carsten, O. (2012) Personal communication of additional results to study Lai F., Carsten, O. and Tate, F. (2012) How much benefit does Intelligent Speed Adaptation deliver: An analysis of its potential contribution to safety and environment, Accident Analysis and Prevention 48 (2012) 63– 72

## Benefits to cost?

Benefit to cost ratios ranging from 2,0 to 3,5 and 3,5 to 4,8 have been calculated for two scenarios: market driven and regulation driven. The costs were based on the premise that by 2010, all new vehicles would be fitted with a satellite navigation system [and available and accurate speed limit maps (Carsten & Tate, 2006).

## Other benefits?

Other ISA benefits have been identified as fuel savings, CO2 savings and the potential to reduce journey time (managed motorways; reduction in incidents).

## Public acceptability?

Different trials using informative and supportive systems across Europe have shown that approximately 60-75% of users would accept ISA in their own cars. A MORI poll in the UK carried out for the FIA Foundation in 2002 indicated 70% support for warning ISA in urban areas, with 58% in support of non-over-rideable limiters on residential streets if that meant road humps



would be removed. Studies have shown that around 75% of drivers reported being more positive towards ISA after using it (Almqvist & Nygard, 1997; Lahmann et al., 2001).

## Next steps for implementation?

Continuing trials and further experimental studies are being carried out in the EU, North America and Australia, though few countries yet cite ISA in any form in their road safety strategies.

Sweden's National ITS Strategy for 2006-2009 and the current ITS strategy (2009) have targeted increasing implementation of ISA driver assistance systems. The Swedish Transport Administration leads by example and equips its whole fleet with ISA systems.

**Table 2: Multi-modal ITS strategy and action plan for Sweden**

Action plan – Measures	Who is responsible	Time
<b>Vehicles/vessels, communication and physical infrastructure</b>		
<i>3.1 Deployment of systems and services</i>		
Alcohol interlock in all transport modes	Swedish Transport Agency	2011 -
Continued introduction of ISA	Public players and others	Ongoing
eCall	Government offices	2011-2013
ERTMS	Swedish Transport Administration	2008 – 2015
eNavigation	Swedish Maritime Administration and others	2010 -
<i>3.2 Pilot projects and field trials</i>		
Full-scale trials on selected ITS services	Swedish test arenas and others	2010-
Pilot project on "Pay as you drive"	Insurance companies and others	2010 – 2012
<i>3.3 Cooperative systems</i>		
Open in-vehicle platform architecture, including standard interfaces for the provision of ITS services	Automotive industry, Swedish Transport Administration	2011-
Introduction plan for multimodal transport cooperative services based on usefulness and safety.	Swedish Transport Administration, automotive industry, ICT industry	2011-12
Definition of uniform standard for road markings, road signs, etc.	Swedish Transport Administration and others	2010 - 2012
Development and trials on the road as sensor	Road maintenance authority	2011 -
<i>3.4 Communication</i>		
Specifications for communication between infrastructure and vehicles for cooperative systems.	Swedish Transport Administration, automotive industry, and ICT industry	2010 – 2014
Development and testing road safety services based on both short-range and mobile communication	Test arenas, etc.	2012 -
<i>3.5 Road charges</i>		
A national road charging system	Swedish Transport Agency and Swedish Transport Administration together with players involved	2010 – 2013
Implementation of EETS Directive	Swedish Transport Administration and Swedish Transport Agency	2010 -2014
Monitoring concept for road charging system	Swedish Transport Agency	2011 – 2013

Source: Swedish Road Administration, 2009

Australia's national road safety strategy 2011-2020 also proposes an implementation path for ISA systems.

**Figure2: Extract from Australia's National Road Safety Strategy 2011-2020**

13. Facilitate the implementation of Intelligent Speed Adaptation (ISA) systems:

- a. Encourage the development of digital speed limit maps.
- b. Examine the scope to require advisory ISA in all government fleets; and mandatory speed limiting ISA and/or other technologies for recidivist speeders and P-plate drivers.
- c. Initiate discussion with insurers to encourage voluntary fitting of ISA and recorders through lower insurance premiums, especially for young drivers.

While positive benefits to cost have been identified for ISA, a number of criticisms of ISA have hindered widespread implementation. A review - Intelligent speed assistance – myths and reality – discussed 'myths' regarding ISA and argued that ISA (and Speed Alert) technologies can work reliably (ETSC 2006, ISA).

The EU-funded SpeedAlert project coordinated by ERTICO was set up in 2004 to harmonise the in-vehicle speed alert concept definition and investigate the first priority issues to be addressed at EU level, such as the collection, maintenance and certification of speed data (SpeedAlert, 2001).

While there is considerable public support for ISA, an implementation strategy is needed to speed up the process of implementation of ISA in vehicles (PROSPER, 2006). This should include the mandatory development of speed limit maps by European, national and regional authorities (to date, Sweden and Finland have established speed limit databases although these are under development in the UK and the Netherlands). Also, awareness of ISA / Speed Alert has to be created. Authorities and organisations (e.g. fleet owners) can act as forerunners by implementing ISA in their vehicle fleets. Further harmonisation activities are needed on the international level. EuroNCAP planned to incorporate Speed Assistance Systems into its rating system from 2013.

## 4.2 Seat belt reminders

### What are they?

Seat belt reminders are intelligent, visual and audible devices that detect whether seat belts are in use in various seating positions and give out increasingly urgent warning signals until the belts are used. Based on the Swedish experience, the European Enhanced Vehicle- Safety Committee (EEVC) Working Group recommended in 2002 that seat belt reminders should (Kullgren et al., 2006):

- target part-time users, i.e. people who understand the value of a seat belt but sometimes do not use it.
- not affect the driveability of the vehicle.
- comprise a combination of visual and sound signals.
- use a signal based on multiple steps, i.e. build up progressively.
- be fitted to all seating positions.

EuroNCAP has developed a seat belt reminder protocol along these lines (though requiring only a visual signal for the rear seat in the absence of seat occupancy information) and encourages their installation. Cars meeting the specification receive points which contribute to the star rating.

## **What road safety problem do they address?**

Research studies indicate that the risk of dying in a crash could be reduced by about 60% by using the seat belt and by more, when belts and air bags are combined (WHO/World Bank 2004). While most drivers in EU countries wear seat belts in the fronts of cars, a significant proportion involved in crashes are unrestrained, even in countries with the highest seat belt use. Seat belt wearing levels in the rear seat are not high in most EU countries (ETSC, 2006 Seat Belt).

## **How effective?**

User trials and research in Sweden and the United States have shown that seat belt reminders with advanced reminder systems with visual and audible warnings were the most effective systems for increasing seat belt use (ETSC 2006, Seat Belt).

A Swedish study examined differences in driver's seat belt use in cars with or without different reminder systems and found that 99% of drivers used their seat belt in cars, with the most advanced reminders (in compliance with EuroNCAP criteria), 93% of drivers used their seat belt in cars equipped with "mild" reminders producing a visual and soft sound signal, 82% of drivers used their seat belt in cars without seat belt reminders. An observation study carried out in several EU countries in 2008 found a significant difference in seat belt wearing rate in cars with seat belt reminders. For all observations, the total seat belt wearing rate was 97,5% in cars with seat belt reminders, and 86% in cars without (Lie at al., 2008).

Earlier US studies found a 7% increase in seat belt use among drivers of cars with seat belt reminders, compared with drivers of unequipped vehicles (Williams, 2002). A driver survey found that of the two thirds who activated the system, three quarters reported using their seat belt and nearly half of all respondents said their belt use had increased (Williams, 2003).

Seat belt reminders can help part-time users to develop habits of belt use. However, they are likely to have little effect on hard-core non-users who actively choose not to buckle up. More aggressive solutions, such as interlock systems, may be needed to encourage this small, but important non-user group to belt up (ETSC 2006 Seat Belt).

It is estimated in Sweden that reminders in all cars could contribute to a further reduction of 20% of car occupant deaths.

## **Benefit to cost?**

A cost-benefit analysis for the mandatory introduction of audible seat belt reminders for front seats in 2004 was undertaken by ETSC in 2004. It was based on the assumption that roughly 50% of fatally injured front seat car occupants killed in the EU did not wear seat belts and that audible seat belt reminders for the front seat could increase seat belt wearing among front seat occupants to 97%. After twelve years of introduction, the costs would amount to about 11 million Euros while the benefit would be 66 million Euros. The benefit to cost ratio of seat belt reminders was estimated at 6:1 (ETSC, 2004). A Belgian study by the Belgian Policy Research Centre for Traffic Safety found that a seat belt reminder system would be beneficial to society even if it

prompted only 5-15% of non-users to fasten up over a period of ten years (Brabander & Vereeck, 2003).

## **Who uses them?**

Of all new cars tested by EuroNCAP in December 2010 almost 95% of the new car sales had a seat belt reminder specification for drivers, some 75% had a reminder for the passenger and 35% a system to monitor seat belt use in the rear seat.

In Sweden, where the fitment of seat belt reminders has been promoted actively by the lead agency, 96% of drivers wear seat belts and 95% of new cars are sold with seat belt reminders for the driver's seat compared with 88% in 2009. The percentage of the traffic volume in cars with seat belt reminders was about 41% in 2009 rising to 48% in 2010. Sweden has created a demand for this safety equipment nationally through its own in-house safety policy for staff travel and as one of the safety requirements of its road transport contracts. The Swedish policy has been targeting increases in new cars sold in Sweden with seat belt reminders.

## **Next steps for implementation?**

There have been calls for the mandatory fitment of seat belt reminders in all seats in Europe, given the great potential of this technology. In 2005, the CARS 21 High Level Group included EU regulation on seat belt reminders in its 10 year road map for the automotive industry in Europe.

In 2006, the European Automobile Manufacturers Association expressed its commitment within the European Road Safety Charter to continue to equip progressively passenger cars of categories M1 and commercial vehicles with seat belt reminders for the driver's seat

The European Transport Safety Council has called for the installation of seat belt reminders in rear seats as well as in front seats (ETSC 2006 Seat Belt).

## **4.3 Electronic stability control**

### **What is Electronic Stability Control (ESC)?**

Electronic stability control (ESC) is an active safety system which can be fitted to cars, buses, coaches and trucks. It is an extension of anti-lock braking technology, which has speed sensors and independent braking for each wheel. It aims to stabilise the vehicle and prevent skidding under all driving conditions and situations, within physical limits. It does so by identifying a critical driving situation and applying specific brake pressure on one or more wheels, as required. (SUPREME).

### **What road safety problem does ESC address?**

ESC addresses the problem of skidding and crashes due to loss of control of vehicles, especially on wet or icy roads or in rollovers.

### **How effective?**

Evaluation studies have shown that the fitment of ESC in cars has led to substantial reductions in crashes, deaths and serious injuries at the top end of the market. A Swedish study in 2003 showed that cars fitted with ESC were 22% less likely to be involved in crashes than those

without. There were 32% and 38% fewer crashes in wet and snowy conditions respectively (Tingvall, 2003). In Japan, a study showed that electronic stability reduced crash involvement by 30-35% (Aga & Okada, 2003). In Germany, one study indicated a similar reduction while another showed a reduction in 'loss-of-control' crashes from 21% to 12% (Breuer, 2002). UK research indicates that equipping a vehicle with ESC reduces the risk of being involved in a fatal crash by 25%. The research also shows a particularly high effectiveness for reducing serious crashes involving other loss of control situations such as skidding (33%), and rollover (59%) (Frampton 2007). Research at the US Insurance Institute for Highway Safety (2006) found that ESC led to a reduction rate of 32% of the risk of fatal multiple vehicle crashes and a reduced risk of single vehicle crashes by more than 40% (of fatal ones: 56%). A recent US study indicated a 5% overall reduction in all impacts and a 23% reduction in fatalities in passenger car crashes reported to the police (Sivinski, 2011). The FIA Foundation estimated in 2007 that equipping all vehicles with an ESC system could save over 500 deaths and 2500 serious injuries per year in the European Union.

## **Benefits to cost?**

A Norwegian benefit to cost analysis considered two scenarios for ESC fitment (Elvik, 2007). The first was that ESC continues to be fitted gradually through the vehicle fleet, but is not made mandatory. The benefit-cost ratio in this scenario was estimated to be 4. The second scenario was ESC retrofitted on all cars of whatever age producing a benefit-cost ratio of about 0,4.

## **Who uses ESC now?**

ESC has been on the market since 1995 and is standard equipment in many cars of the middle and upper price classes, but not yet in smaller cars. A country fitment rating is published by EuroNCAP which promotes its fitment as an important safety device. Sweden has been foremost in the national promotion of ESC and in 2006 over 90% of new cars sold in Sweden were fitted with electronic stability control.

## **Next steps for implementation?**

In the US, legislation was passed in 2007 making ESC mandatory standard equipment for all passenger cars, multipurpose vehicles, trucks and buses with gross vehicle rating of 4.536 kg or less from model year 2012. Since 2012, ESC has to be fitted mandatorily to all new EU registered car models.

An international group of experts agreed on a harmonised technical specification and test method for a Global Technical Regulation (GTR) on ESC systems intended to be fitted to cars and light vans. ESC is mandatory for new types of cars and vans from 2011 and for all new vehicles from 2014. In November 2007, the United Nations announced it would require trucks and heavy vehicles to be fitted with anti-skid Electronic Stability Control (ESC) from 2010.

## 4.4 Alcohol Interlock Systems

(See also [ERSO Alcohol web text](#))

### What are alcohol interlocks?

Alcohol ignition interlock systems are automatic control systems which are designed to prevent driving with excess alcohol by requiring the driver to blow into an in-car breathalyser before starting the ignition. The alcohol interlock can be set at different levels and limits.

### What road safety problem do alcohol interlocks address?

Excess alcohol contributes to about 25% of all road deaths in Europe. Alcohol interlocks address excess alcohol in the general driving population and are being increasingly used in commercial and public transport operations, as well as in repeat offender schemes.

### How effective?

Large scale quantitative research on alcohol interlocks in use has shown that they are 40 to 95% more effective in preventing drink and driving recidivism than traditional measures such as licence withdrawal or fines (ICADTS, 2001; SUPREME, 2007). A literature review (UK Department for Transport, 2004) showed a recidivism reduction of about 28-65% in the period where the alcohol interlock is installed compared with the control groups who were not using the alcohol lock. An EU study indicated that alcohol interlocks need to be fitted permanently to have an effect, for after removal of the lock recidivism increases again (Bax et al., 2001). Alcohol interlocks have an important role to play within rehabilitation programmes.

There has been no evaluation of the impact that alcohol interlocks used in commercial transport have on road safety but Swedish companies report that fitting alcohol interlocks prevented excess alcohol amongst fleet drivers. Some 23% of municipalities and 18% of county councils have stipulated the need for alcohol interlocks when purchasing new public and private transport vehicles. Some 70.000 alcohol interlocks are in use in Sweden in trucks, buses and taxis on a voluntary basis (Swedish Government Report).

A major US initiative is entering its second phase in an attempt to develop an in-car detection system that can be more widely used. The US Driver Alcohol Detection System for Safety Program is exploring the feasibility, the potential benefits of, and the public policy challenges associated with a more widespread use of non-invasive technology to prevent alcohol-impaired driving. Two specific approaches have been chosen for further investigation; tissue spectrometry, or touch-based, and distant/offset spectrometry, or breath-based sensors. Two of the sensors are designed to remotely measure alcohol concentration in drivers' breath from the ambient air in the vehicle cabin, and the third is designed to measure alcohol in the drivers' finger tissue through placement of a finger on the sensor. Prototype testing has indicated that there are potential technologies that ultimately could function non-invasively in a vehicle environment to measure a driver's BAC. Research vehicles are expected to demonstrate the technologies by the second half of 2013 (Ferguson et al., 2011).

### Benefits to cost?

The results of cost benefit analyses for implementing alcohol interlocks for drivers caught twice with a BAC between 0,5g/l and 1,3g/l and for drivers caught with a BAC above 1,3g/l in several countries are shown below (Vlakveld et al., IMMORTAL, 2005).

## **Box 2: Benefits to cost of alcohol interlocks in different countries**

- For the Netherlands, the reduction of 35 traffic fatalities annually is valued at 4,8 million per death, leading to a benefit of 168 million Euros. Benefit/cost ratio = 4,1
- For the Czech Republic, the 8 fatalities prevented are counted at 1,1 million Euro/death, leading to estimated benefits of 9 million Euro/year. Benefit/cost ratio = 1,6
- For Norway, the benefits are calculated as 5,5 deaths less per year a rate of 5. Benefit/cost ratio = 4,5
- For Spain, the reduction with 86,5 deaths/year at 800.000 Euro per death would imply benefits of 69 million Euro/year. Benefit/cost ratio = 0,7

Source: Vlakveld et al., IMMORTAL, 2005

## **4.5 In-vehicle event data recorders**

### **What are in-vehicle event data recorders?**

These devices can be used in cars and commercial transport as a valuable research tool to monitor or validate new safety technology, to establish human tolerance limits and to record impact speeds. Even data recorders can also be used to influence driving behaviour and facilitate forms of automatic policing (100% surveillance of all traffic offences). Offenders can be tracked more easily and fined automatically by means of devices such as Electronic Vehicle Identification – See EVI website. At the same time, the system can be used to reward safe behaviour (Schagen, van & Bijleveld, 2000) and to reduce insurance premiums (Wouters & Bos, 2000).

Two types of in-vehicle data recorders are currently used which can provide useful data for road safety purposes: crash data recorders and journey data recorders.

### **4.5.1 Crash data or event data recorders**

These collect data over a period before and after the crash and critical events. They are often based on the airbag control module and will cease to store information once the airbag has deployed (Langeveld & Schoon, 2004).

### **What road safety problem do they address?**

These devices are an important monitoring and research tool for road safety management, as illustrated below.

### Box 3: Usefulness of event data recorders or crash recorders

- Increased quality of crash data
- Increased accuracy of data
- Possibility to use information previously not possible to obtain
- Better evaluation of new safety technology
- Knowledge of injury thresholds for the design of a crashworthy road transport system
- Better understanding of injury causes and injury mechanisms
- Influence on crash involvement risk?
- Useful from legal aspects (insurance)
- Information used for "e-Call" systems
- Pre-crash data to investigate collision causation - Evaluation of active safety systems
- Crash data to investigate crashworthiness
- Evaluation of interior safety systems
- Calculation of injury risk versus impact severity
- Crash reconstruction

Source: Kullgren et al., 2006

### How effective?

#### Data recorders as enforcement devices

Research indicates that data recorders fitted to trucks and vans lead to an average reduction of 20% on the number of crashes and damage (Wouters & Bos, 2000). The effect derives from the driver's knowledge that traffic law infringements can, in principle, be detected by examination of the driving records.

### Box 4: Value of crash data recorders based on past experience

- Significant improvement in crash reconstruction
- Legal security
- Attentive driving
- Direct or indirect reduction in crashes and damages
- Reduction of fuel consumption and vehicle maintenance
- Real data for vehicle safety design
- Real data for tuition and training
- Legal (data privacy) concerns that can be overcome
- Limited interest from original equipment manufacturers in Europe

### Box 5: Main aims of event data recorders based (VERONICA, 2006)

- Provide reliable information
- On vehicle crash causation
- Via wireless format in the vehicle
- For further processing by certified experts
- For dedicated road safety, legal, security and crime fighting application

Source: VERONICA, 2006

#### Data recorders as research and monitoring tools

The increasing use of intelligent systems presents challenges for monitoring using traditional methods, Data recorders can serve as a useful tool in assisting the monitoring of intelligent



primary safety systems entering the market as well as crash protective devices such as restraint systems in real crashes.

## Benefits to cost

The benefits and cost ratios of Crash Data Recorders have been estimated for the Netherlands (Langeveld & Schoon, 2004).

## **Who uses them?**

Crash Data Recorders have been used for many years in cars and commercial transport. In the US, the car manufacturer GM has been using them since the 1970s to evaluate the performance of airbags in crashes. In the UK, police fleet cars have been fitted with black boxes. In Germany a crash recorder called UDS by Mannesmann/VDO has been on the market for more than 15 years. Crash Data Recorders are also promoted by insurance companies giving drivers a reduction in insurance premium if they are fitted.

### **Box 6: Examples of event data recorder use in “large fleet” projects**

Since 1990s - GM and Ford cars (more advanced in late 90s)  
Since 1995 - Volvo DARR in Volvo cars – approx 500.000 cars fitted- and in Saab cars  
Since 1992 - Folksam CPR project - 220.000 cars fitted with Crash Pulse Recorders  
Since 1995 - UDS in Austria, Switzerland and Germany

Source: Kullgren et al., 2006

## **Next steps for implementation?**

The EC project VERONICA made various recommendations on the next steps for implementation of Crash Data Recorders in the EU. The project reviewed the standardisation of procedures and tools to retrieve the data, the use of the data collected (for crash research, by the police to check driving conditions, or in legal applications to help in the determination of the responsibilities in a crash) and questions concerning the ownership of the data. It recommended the targeting of various road user groups, commencing with the commercial transport sector; that a UN ECE Working Group be established to prepare a technical specification and that the EU should introduce a Directive rather than a Regulation to give Member States flexibility in implementing Crash Data Recorders.

### **Box 7: Target groups for use of event data recorders from the enforcement and insurance points of view**

- Hazardous goods transport
- Coaches and buses
- Commercial vehicles
- Vans
- Emergency service vehicles
- Motorcyclists
- Young drivers

Source: VERONICA, 2006

It is important to ensure that data from recorders will be collected and stored in such a way that it is available to designers of both cars and road-side objects, and especially to the responsible bodies for the road transport system (Kullgren et al., 2006).

## 4.5.2 Journey data recorders

These collect data during driving. Journey data recorders can provide information regarding driving behaviour and any law infringements, they can be used to monitor driving in relation to insurance costs and the information can be used for traffic management purposes. They can also be an important source of research data regarding the risks of normal driving and the nature of traffic conflicts.

### Benefits to cost?

The benefits and cost ratios of Journey Data Recorders have been estimated as 20:1 for the Netherlands (Langeveld & Schoon, 2004).

### Who uses them?

Tachographs are used in commercial vehicles to monitor drivers' hours of work, speeds and to track cargo. One further example in use is the SAGA system developed in Iceland, which allows for monitoring and reporting on vehicle position and use, speeds relative to posted limits as well as other aspects of driver behaviour. The system is currently used in vehicle fleets of 70 companies leading to significant registered reductions in crashes (OECD & ECMT, 2006).

### Next steps for implementation?

The OECD and ECMT addressed the issue of how journey data recorders might be employed to reduce young driver risk and concluded that economic incentives such as lower insurance premiums could be employed to encourage their use (OECD & ECMT, 2006).

In addition it was suggested that parents might be able to insist that certain technology be placed in vehicles used by their children. The need for the introduction of an EU Directive was highlighted by VERONICA.

## 4.6 Anti-lock braking systems in cars (ABS)

### What are anti-lock braking systems (ABS)?

The main purpose of ABS is to prevent skidding where loss of steering and control result from locked wheels when braking hard. Such systems are now fitted to many new cars. This is intended to provide additional steering in an emergency situation, not to decrease stopping distances.

### Casualty reduction effect?

A meta-analysis of research studies shows that ABS give a relatively small, but statistically significant reduction in the number of crashes, when all levels of severity and types of crashes are taken together. There are statistically significant increases in rollover, single- vehicle crashes and collisions with fixed objects. There are statistically significant decreases in collisions with pedestrians/ cyclists/ animals and collisions involving turning vehicles. ABS brakes do not appear to have any effect on rear-end collisions. However, while injury crashes decrease (-5%), fatal crashes increase (+6%) (Elvik et al., 2009). One study, however, indicates that anti-lock brakes may not contribute to crash prevention at all (Cummings & Grossman, 2007).

As with other forms of braking, the effectiveness of anti-lock braking depends upon road user behaviour. A German study found that ABS brakes can lead to changes in behaviour in the form of higher speeds and more aggressive driving (Ashenbrenner et al., 1987). It has also been suggested that the results to date may also be partly due to lack of knowledge or incorrect assumptions amongst car drivers about how ABS brakes actually function (Broughton & Baughan, 2000).

## 4.7 Autonomous emergency braking systems

### What are they?

Autonomous emergency braking (AEB) systems detect approaching vehicles or other road users and apply braking to either prevent a collision occurring or to reduce the impact severity. Early systems were relatively slow in analysing the information from the camera or LIDAR sensors and these systems were therefore only able to brake sufficiently to avoid a collision with a relative velocity of around 15 kph. These systems were therefore commonly termed “City-AEB” or “low speed AEB”. More recent systems can operate faster and can therefore detect obstacles at greater travel speeds.

Early systems were only able to detect cars however object recognition of more recent systems now includes PTWs, pedestrians and cyclists although to a lower level of precision and there are no systems currently available that claim to reliably detect other road user types.

EuroNCAP stresses that AEB systems are support systems and may not be effective in all circumstances: “It should be noted however that AEB is a support system that should not be overly relied upon by the driver. In more challenging situations, AEB activation may not be sufficient or not timely enough to avoid a crash completely, although the resulting impact speed may be significantly reduced. Good occupant protection remains vital to avoid serious consequences.”

### Casualty reduction effect

A meta-analysis (Fildes et al, 2015) based on accident data from six countries identified that vehicles equipped with City-AEB systems were effective in preventing 38% of front to rear collisions. A further analysis of collision claims (IIHS 2013) examined two Volvo models and found reduced collision claim frequencies of 9%-20%. More recently it was observed that AEB in conjunction with forward collision warning systems reduced rear end collisions with injury by 44% (Ciccino, 2016), however the reduction from FCW systems alone was not significant.

### Next steps for implementation

From 1 November 2013 all new types of goods vehicles over 7.500 kg must be equipped with AEB systems and all new goods vehicles after 1 November 2015. From 2018 all new vehicles must be equipped with systems with more stringent requirements. EuroNCAP test protocols include an assessment of AEB and examine performance under several conditions.

## 4.8 Anti-lock braking for motorcycles

### What are they?

Anti-lock braking systems are in-vehicle devices which aim to prevent the locking of wheels during braking when under emergency conditions, so preventing the motorcyclist from falling off their vehicles.

### Casualty reduction effect?

A German study concludes that in 93% of cases where the motorcyclist fell off the vehicles, ABS would have avoided the crash or at least reduced the severity of the accident. This provides an estimated reduction in fatal and severe injuries to motorcycle drivers by 8 to 10% in Germany (Winkelbauer, 2006). Another prospective estimate also suggests that ABS might reduce the number of crash victims by at least 10% (Spörner & Kramlich, 2000).

A Swedish study (Rizzi, 2009) has evaluated the effectiveness of antilock brake system (ABS) technology on motorcycles in reducing real life injury crashes and to mitigate injury severity. Induced exposure analysis showed that the overall effectiveness of ABS was 38% for all injury crashes and 48% for severe and fatal crashes, with a minimum effectiveness of 11% and 17% respectively. Since the launch of the Swedish Transport Administration's study results in June 2009, Swedish importers have increased the number of motorcycle models with ABS as standard and the share of new motorcycles with ABS has gone from 15% in 2009 to 60% in 2010 (Swedish Roads Administration, 2011).

### Next steps for implementation?

Typically, these systems are available on more expensive models of motorcycle. In 2004, the Association des Constructeurs Européens de Motorcycles (ACEM) made a commitment to equip the majority of PTW advanced braking systems by 2010 and has set a further objective of 75% of new models to be equipped with ABS or offered as an option by 2015. An Advanced Braking System is a braking system in which either an antilock brake system and/or a combined braking system is present. As a result of the 2004 commitment, ACEM reports that 35% of the motorcycles sold by the ACEM manufacturers are equipped with ABS.

## 4.9 Lane support systems

### What are they?

Lane Keeping Warning Devices are electronic warning systems that are activated if the vehicle is about to veer off the lane or the road. Their effectiveness strongly depends on the reaction of the driver and on the visibility of the road markings. Times to collision in safety-critical lane changes are normally much less than one second. Since mean driver reaction time is about one second, there is not sufficient time for a driver to respond to a warning before crashing. Because there is insufficient time for reaction to a warning, lane change and merging crashes can probably only be avoided by intervening systems known as Lane Keeping Assist. This is an automatic system which keeps the vehicle in its lane except if the turning indicator is activated and depends only on the visibility of the marking. The technical and operational feasibility of such systems has still to be demonstrated. Most existing systems are warning only systems.

Simultaneous highway safety lane marking is key to the effectiveness of this measure and has been highlighted by EuroNCAP and iRAP in Roads that Cars Can Read (2011).

## **Casualty reduction effect?**

There have been few evaluations of the real-world effectiveness of lane support systems owing to the challenge of isolating the effect from that of other equipment on the vehicles. Sternlund (2016) reported a reduction of 30% in head-on or single vehicle crashes in a small sample of Swedish vehicles. Nodine (2011) conducted a field trial with 16 vehicles equipped with Lane Departure Warning Systems and found a 33% reduction in near-crash events related to lane change and a 19% in those related to road departure. Birrel (2014) conducted a similar trial with 33 participants and observed a 12% reduction in lane deviations; however, this was not statistically significant. No evidence for a reduction in collision rates with Lane Keeping systems has been identified.

## **Next steps for implementation?**

The EuroNCAP consumer testing protocols evaluate the presence of Lane Departure Warning and Lane Keeping Support systems. It rewards manufacturers that fit the systems as standard and gives additional reward when a Blind Spot monitoring system is fitted.

## **5 ADAS safety measures - unknown safety effects**

This section, which is not intended to be exhaustive, discusses a range of new technologies that are being promoted currently by the European car industry and EU institutions amongst others as promising safety measures. These either are being fitted widely, ready for implementation or are under development. While safety benefits have been predicted for such measures – some very high, others much lower – their effects and/or feasibility have still to be scientifically demonstrated. Such technologies may even lead to disbenefits where some vehicles are equipped but not others. For example, those designed to improve braking could generate a rear impact phenomenon. A car with improved braking could avoid a situation (typically a frontal impact) but there is no guarantee that a following vehicle would have the same capability and hence has a risk of an impact due to less advanced braking provision. Thus, their usefulness (or not) to road safety is not yet known.

### **5.1 Emergency Brake Assist**

#### **What is Emergency Brake Assist?**

Emergency Brake Assist in emergency situations is a technology which comes as standard on new cars forms part of an EU legislative package on pedestrian protection (originally as a substitute for more stringent tests aimed at better crash protection). Emergency Brake Assist aims to address the problem of insufficient pressure being applied to the brake by drivers in emergency situations, so increasing stopping distances. Car manufacturing trials have shown that brake assistance systems could help by providing full braking effect, where the driver does not press hard enough on the pedal. In marketing material, Daimler Chrysler indicate that for a car braking at 100km/h, Emergency Brake Assist can reduce the normal stopping distance by 45%. Emergency Brake assistance systems can use the ABS capability to allow heavy braking

without the risk of wheel locking, but they have to distinguish between emergency and normal braking as well as respond appropriately to reduced brake pressure.

## **Casualty reduction effect?**

In general most of the devices described for improvement of braking and handling interfere with driver behaviour, as well as the matter of driver acceptance, risk compensation and driver reaction, when the system is activated, are important (especially for old drivers). There is no standard method to assess the safety performance of these devices, which makes it difficult to estimate their potential benefits; moreover, under the same name very different systems can be found, as each manufacturer has its own specification.

While a prospective estimate has been made for Emergency Brake Assist to reduce fatal and serious injuries among pedestrians by 10%, the same study noted that the casualty reduction effect of Emergency Brake Assist has yet to be scientifically established (Hardy & Lawrence, 2005). A Swedish study of real-world pedestrian crashes found that the isolated effects of Emergency Brake Assist on pedestrian safety were not significant enough (Strandroth et al., 2011).

## **5.2 Collision avoidance systems**

A considerable amount of research is addressing safety systems of the future. Much work is being carried out on technologies such as collision avoidance systems but their usefulness in addressing high-risk crash scenarios typical of most European roads as well as their feasibility has yet to be determined.

Research on collision warning and collision avoidance systems is taking place in Japan, the United States and in the European Union within the European Commission's H2020 research programme. Very large estimates of the safety potential of such systems have been claimed following laboratory studies, but the range of technical and behavioural issues involved in many of the concepts require full on-road assessment. To be practical, most of the proposed systems require a well-controlled traffic situation, such as that found on motorways where the casualty reduction potential is relatively low. For an overview of key issues (Rumar ed., 1999) see OECD, 2003 Road safety: impact of new technologies and EuroFOT, which is carrying out large field trials.

Several systems are at various stages of development and implementation:

### **Forward Collision Warning**

Is a system which comprises a visual and audible warning that the driver is too close to the vehicle in front. The warning depends on how long the distance is between the vehicle in question and the vehicle ahead. The level of warning changes from "safe" to "critical" as the following distance decreases.

### **Reverse Collision Warning System**

Is a visual and audible system which warns drivers about the likelihood of collision with an object or person behind the vehicle by means of sensors in the rear bumper. The warning intensifies when the distance between the vehicle's rear and the object decreases.

## **Adaptive Cruise Control (ACC)**

Enhances automatic cruise control found in many new vehicles by automatically maintaining a fixed following distance from the vehicle in front. The distance to the preceding vehicle is measured by radar, laser systems or both. When the speed of the vehicle in front is slower than the adjusted speed, the ACC system adjusts vehicle speed to allow a safe distance to the lead vehicle.

## **Attention assist**

These systems monitor driving behaviour, often by measuring steering wheel motion. They alert the driver when it appears he/ she may be fatigued or sleepy.

## **Vision enhancement**

This group of technologies aims to support the driver in the detection of obstacles or other vehicles during night-time. Adaptive headlight systems adjust according to the heading direction of the vehicle in order to provide better illumination around bends. Night-vision cameras can provide additional visual information to the driver using either a separate screen or head-up display technologies.

## **Multi-collision brake**

These systems automatically apply full braking and activate the hazard lights following a collision that has deployed the airbag. The intention is to avoid a secondary collision with another vehicle or obstacle. Should the driver consider the braking is likely to increase risk it is possible to defeat the system by depressing the accelerator.

## **Vehicle automation**

Following the public interest in autonomous vehicles by commercial groups such as Google and Uber many vehicle manufacturers have indicated they are developing driverless vehicles. The US Society for Automotive Engineers has developed a classification and terminology for automation which is shown below in Table 3.

**Table 3: SAE classification and terminology for vehicle automation**

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/	Monitoring of Driving Environment	Fallback Performance of Dynamic Driving Task	System Capability (Driving Modes)
<b>Human driver monitors the driving environment</b>						
<b>0</b>	<b>no Automation</b>	The full-time performance by the human driver of all aspects of the dynamic driving task, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
<b>1</b>	<b>Driver Assistance</b>	The driving mode-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task	Human driver and system	Human driver	Human driver	Some driving modes
<b>2</b>	<b>Partial Automation</b>	The driving mode-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task	System	Human driver	Human driver	Some driving modes
<b>Automated driving system ("system") monitors the driving environment</b>						
<b>3</b>	<b>conditional Automation</b>	The <i>driving mode</i> -specific performance by an <i>automated driving system</i> of all aspects of the dynamic driving task with the expectation that the <i>human driver</i> will respond appropriately to a <i>request to intervene</i>	System	<b>System</b>	Human driver	Some driving modes
<b>4</b>	<b>high Automation</b>	The <i>driving mode</i> -specific performance by an automated driving system of all aspects of the <i>dynamic driving task</i> , even if a <i>human driver</i> does not respond appropriately to a <i>request to intervene</i>	System	System	<b>System</b>	Some driving modes
<b>5</b>	<b>full Automation</b>	The full-time performance by an <i>automated driving system</i> of all aspects of the <i>dynamic driving task</i> under all roadway and environmental conditions that can be managed by a <i>human driver</i>	System	System	System	<b>All driving modes</b>

Source: 2014 SAE International.

Most vehicle manufacturers expect automation systems to be progressively introduced as engineering capabilities improve. The systems are expected to become available for an increasingly wide set of driving scenarios.

Safety is a key issue for automation systems. The transfer of control between vehicle and human together with the opportunities for distraction, inattention and loss of driving skills means that automated vehicles have the potential to introduce new risks into the driving environment. The prevention of these new risks and the further mitigation of existing road risk are key targets in order to capture the safety opportunities offered by increasing automation.

Typically 95% of accidents are initiated by a driver error in response to road traffic, road, other vehicle or road user factors. There is a common expectation that vehicle automation will improve



safety figures by “taking the driver out of the loop” and thereby preventing driving errors. Automatic Emergency Braking and other systems are shown to reduce accidents in some driving situations and can be considered stepping stone technologies to higher levels of automation. However, the technology roadmap for vehicle automation (ERTRAC, 2015) identifies the key automation technologies to be introduced up to 2025 will focus on highway automation and automated parking systems. These systems are not anticipated to address current road safety problems in Europe where 69% of fatalities were vulnerable road users.

## 5.3 eCall

### What is eCall?

Post-crash care is a key Safe System strategy to help reduce the consequences of injury through fast and efficient care. (See [ERSO Post-Impact Care web text](#))

eCall is a system that provides an automated message to the emergency services following a road crash which includes the precise crash location. The in-vehicle eCall is an emergency call (an E112 wireless call) generated either manually by the vehicle occupants by pushing a button or automatically via activation of in-vehicle sensors after a crash. When activated, the in-vehicle eCall device will establish an emergency call carrying both voice and data directly to the nearest emergency services (normally the nearest 112 Public Safety Answering Point, PSAP). The voice call enables vehicle occupants to communicate with the trained eCall operator. At the same time, a minimum set of data will be sent to the eCall operator receiving the voice call. The minimum set of data contains information about the incident including time, precise location, vehicle identification, eCall status (as a minimum, indication if eCall has been manually or automatically triggered) and information about a possible service provider (CEC, 2005).

### What road safety problem does eCall systems address?

These systems aim to reduce the time between when the crash occurs and when medical services are provided. The aim is to reduce the consequences of injury to prevent death and disability, particularly in single vehicle crashes. A Swedish study into survivability in fatal road traffic crashes concluded that 48% of those who died sustained non-survivable injuries. Out of the group who sustained survivable injuries, 5% were not located in time to prevent death, 12% could have survived had they been transported more quickly to hospital and a further 32% could have survived if they had been transported quickly to an advanced trauma centre (Henriksson, 2001). Additionally, many emergency service providers may receive several calls for each incident, for which they may have to respond several times and it is anticipated eCall may enable them to manage responses more effectively.

### How effective?

The potential effectiveness of eCall is highly dependent on the availability and efficiency of the nearest emergency medical system call centre.

A prospective Finnish study has estimated that such a system might reduce between 4-8% of road deaths and 5-10% of motor vehicle occupant deaths in Finland (Virtanen et al., 2006). The study assumed that all vehicles were equipped with the eCall terminal and that each terminal would function properly. The study was unable to evaluate the impact of the precise location

information given by eCall on the swifter arrival of rescue units at the crash site in the evaluation of decrease in road traffic deaths. The overall impact of the system which involves additional players has not been evaluated.

The Finnish study noted that through “the comparison of the 4–8% decrease in traffic accident fatalities arrived at in this study with the figures of other European studies one can see that the results are similar to the German (5%) and Dutch (7%) estimations. The estimations in Sweden (2–4%) and Great Britain (2%) are smaller and the estimate for the whole EU area (5–15%) greater than the estimate in this study. The American estimation for the decrease in traffic accident fatalities based on field studies was smaller (2–3%) than in this study. The estimate made by the doctors was, however, greater (9–11%)”.

The European Commission believes that a pan-European eCall is estimated to have the potential to save up to 2.500 fatalities annually in the EU when fully deployed (COM(2005) 431 of 14.9.2005: Bringing eCall to Citizens (Bouler, 2005). The eMERGE project study estimated that eCall will allow for a reduction of crash response time of about 50% in rural areas and up to 40% in urban areas. When medical care for the severely injured is available earlier after the accident, the death rate and severity of trauma can be significantly reduced.

## **Benefits to cost?**

The benefits to cost ratio (BCR) of eCall in Finland have been found to be in the range of 0,5 (minimum estimate) to 2:3 (maximum estimate). A UK benefit to cost analysis concluded that universal fitment of eCall would result in more costs than benefits (McClure & Graham, 2006).

## **Next steps for implementation?**

Various manufacturers supply eCall systems on demand e.g. Volvo, BMW and PSA. Various eCall systems have been tested in the EU-supported eMERGE project in Germany, Italy, the Netherlands, Spain, Sweden and the UK.

The implementation of a pan-European emergency eCall system for road vehicles requires standardisation activities related to: (1) the communication protocol by which the minimum set of data (MSD) will be sent via the mobile telecommunication network (e.g. GSM) to the public service answering point (PSAP) (expected to be ready by mid-2008), and (2) the content and format of the MSD. A new WG15 eSafety has been formed within CEN to cover these and other eSafety initiatives emanating by the Commission or CEN members countries. Market deployment of eCall is expected to take place rapidly over the next few years.

eCall implementation is also high priority of the European Commission. According to a Eurobarometer study over 70% of the respondents say that they would like to have eCall in their next car. eCall deployment is supported by the industry, European Parliament, user organisations and by some Member States.

## **5.4 Electronic driving licences**

The concept of an electronic driving licence which comprises a smart card for driving access has been long anticipated. The driving licence is a smart card containing personal information about the driver, including which vehicle types or even individual vehicles he or she is authorised to

drive. The smart card serves as an ignition key access, allowing the start of a vehicle if there is correspondence between the card and the vehicle unit (Goldberg, 1995; Myhrberg, 1997; Rumar ed. 1999).

## 6 EC initiatives on safety related ADAS

There has been a decade of EC initiative on safety related ADAS. While the European Commission's Enterprise Directorate has responsibility for safety initiatives, the Transport and Energy Directorate leads on road safety strategy.

The eSafety Initiative launched in 2002 was a joint initiative of the European Commission, industry and other stakeholders and aimed to accelerate the development, deployment and use of Intelligent Integrated Safety Systems that use information and communication technologies in intelligent solutions, in order to increase road safety and reduce the number of accidents on Europe's roads.

The eSafety Forum (now the iMobility Forum) provided a platform for consensus among stakeholders, High-Level Meetings with Industry and Member States defining strategy and Working Groups: Solution-oriented, reporting to the Forum.

A safety effects database lists a variety of studies which have attempted to identify the effects of new technologies.

There have been several European Commission Communications on ADAS. Examples are as follows:

- Information and Communications Technologies for Safe and Intelligent Vehicles" COM (2003)542 Final, 15.9.2003 focussed on 3 priorities: eCall (Pan-European eCall); RTTI (Real-Time Traffic & Travel Information) and HMI (Human-Machine Interaction).
- On 1 June, 2005 the Commission adopted the initiative: i2010: European Information Society 2010 for growth and employment. The Intelligent Car was one of the i2010 Flagship Initiatives. The objective was to improve the quality of the living environment by supporting ICT solutions for safer, smarter and cleaner mobility of people and goods. The three pillars comprised 1) The eSafety Initiative (2) RTD in Information and Communications Technologies and (3) Awareness raising actions.
- Bringing eCall to Citizens COM (2005)431 Final 14.9.2005 provided for the fitment of "eCall" from 2010 onwards. This technology will call the emergency services in case of an accident, using 112 to send accident data, including the car's location. Many Member States need to upgrade their infrastructure to enable the emergency services to receive and process the Call data.
- Bringing eCall back on track - Action Plan COM (2006) 723 final
- Safe and efficient in-vehicle information and communication systems: Update of the European Statement of Principles on human machine interface, Commission Recommendation of 22 December 2006. The updated European Statement of Principles (version 2006) summarises the essential safe design and use aspects to be considered for the human machine interface (HMI) for in-vehicle information and communication systems. Member States should perform a continuous evaluation and monitoring of the impact of the European Statement of Principles of 2006 and report to the Commission about the

dissemination activities carried out as well as the results of the application of the 2006 Principles within a period of 18 months from their publication.

- CARS 21
- New Commission strategy for long term viability of European car industry 7.2.07.
- EC Communication Brussels, 16.12.2008 COM(2008) 886 final: Action Plan for the Deployment of Intelligent Transport Systems in Europe
- 2008/0263 Proposal For A Directive Of The European Parliament And Of The Council laying down the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other transport modes Brussels, 16.12.2008, COM(2008) 887 final
- 'eCall: Time for Deployment (2009)
- ITS Directive (2010) and ITS Action Plan (2008)

A new legal framework (Directive 2010/40/EU) was adopted on 7 July 2010 to accelerate the deployment of innovative transport technologies towards coordinated implementation of ITS in Europe. It aims to establish interoperable and seamless ITS services while leaving Member States the freedom to decide which systems to invest in. The specifications and standards for ITS road safety and security applications shall include the definition of the necessary measures for the harmonised provision of an interoperable EU-wide eCall, including:

- the availability of the required in-vehicle ITS data to be exchanged,
- the availability of the necessary equipment in the emergency call response centres receiving the data emitted from the vehicles,
- the facilitation of the electronic data exchange between the vehicles and the emergency call response centres.
- to provide ITS based information services for safe and secure parking places for trucks and commercial vehicles, in particular in service and rest areas on roads, based on:
  - the availability of the road parking information to users,
  - the facilitation of the electronic data exchange between road parking sites, centres and vehicles.
- to support the safety of road users with respect to their on-board Human-Machine- Interface and the use of nomadic devices to support the driving task and/or the transport operation, as well as the security of the in-vehicle communications.
- to improve the safety and comfort of vulnerable road users for all relevant ITS applications.
- to integrate advanced driver support information systems into vehicles and road infrastructure which fall outside the scope of Directives 2007/46/EC, 2002/24/EC and 2003/37/EC.
- to integrate different ITS applications on an open in-vehicle platform, based on:
  - the identification of functional requirements of existing or planned ITS applications,
  - the definition of an open-system architecture which defines the functionalities and interfaces necessary for the interoperability/interconnection with infrastructure systems and facilities,
  - the integration of future new or upgraded ITS applications in a "plug and play" manner into an open in-vehicle platform,
  - the use of a standardisation process for the adoption of the architecture, and the open in-vehicle specifications.
  - to further progress the development and implementation of cooperative (vehicle- vehicle, vehicle-infrastructure, infrastructure-infrastructure) systems, based on:

# Advanced driver assistance systems

- the facilitation of the exchange of data or information between vehicles, infrastructures and between vehicle and infrastructure,
- the availability of the relevant data or information to be exchanged to the respective vehicle or road infrastructure parties,
- the use of a standardised message format for the exchange of data or information between the vehicle and the infrastructure,
- the definition of a communication infrastructure for data or information exchange between vehicles, infrastructures and between vehicle and infrastructure,
- the use of standardisation processes to adopt the respective architectures.

## Road safety action program

Towards a European Road Safety Area (2011) Policy orientations on road safety 2011-2020 set the following key actions:

- Within the context of the implementation of the ITS Action Plan and of the ITS Directive, the Commission will cooperate with the Member States with a view to:
- Evaluate the feasibility of retrofitting commercial vehicles and private cars with
- Advanced Driver Assistance Systems.
- Accelerate the deployment of e-Call and examine its extension to other vehicles.

## Research

A range of EC funded research projects related to ADAS includes Prevent, eIMPACT, TRACE, AIDE, DaCoTA, EuroFOT, CASPER, SCORFF, VADER, UDRIVE.

A specific road map for the development of ITS road safety applications has been set out by the European Transport Safety Council (Rumar, 1999).

## Box 8: Summary of recommendations for EU actions

- It is clear from the current situation that the EU needs to establish a long-term strategy on ITS with a view to road safety. It also needs to develop its role in giving advice to industry regarding the design, development, implementation and evaluation of new products. It is important to ensure that the potential benefits to the community are maximised and that any disadvantages are minimised. The key issue is how such a process should be developed and designed.
- Priority should be given to the development of ITS that address identified road safety problems, rather than to promoting technologies for their own sake. Other general aims than safety are, of course, legitimate as long as safety is not hampered.
- The EU should encourage the early European-wide implementation of those ITS which have proven safety benefits.
- The EU should give priority in long-term development to systems that have a significant potential to improve safety.
- The EU should ensure that ITS introduced on the market is monitored and evaluated from a safety point of view.
- The European Statement of Principles on Human Machine Interface for In-Vehicle Information and Communication Systems, as presented by the European Commission in 1998, represents an initial, non-mandatory approach to design and installation. The Statement of Principles needs to be made more specific and should define a procedure that should be followed to ensure compliance with these principles; a certification process through which products can be shown to have complied with these principles; an EU certification process for ITS functions which are very critical from a safety point of view. Steps to move beyond the current knowledge embodied in the Statement of Principles are recommended below.
- A mandatory certification procedure to approve ITS applications in terms of system safety should be developed at a European level (reliability issues and the availability of adequate fallback procedures need to be addressed, as a system failure might put the road user in a very dangerous situation). The existing procedures for ensuring system safety should also be adopted at the international standards level, through ISO.
- Specifically, the need for standardisation and quality assurance of relevant control algorithms and protocols should be addressed.
- Implementing ITS requires special consideration for safety in the transition phases - which may last several decades- during which car fleets, driver abilities, and ITS functions and interfaces will be very varied. The EU should establish a monitoring system to evaluate the design, development and implementation of ITS and their short, medium, and long-term impacts on traffic safety, that is, the overall safety effect of ITS on the traffic system

Source: Rumar, 1999

## 7 ADAS - evaluating measures

### Systematic evaluations

There have been various attempts to record and classify ADAS measures by their impacts, e.g. studies included in the iMobility safety effects database (Golias et al., 2002; ADVISORS, 2003; SUPREME, 2007) and currently in EuroFOT. However, various problems need to be addressed both in the assessment of existing and new systems. No systematic methods currently exist to evaluate new systems. While systems are under development, they are not yet mature. It is not possible to predict eventual casualty reduction based on experimental studies, field trials or simulators for most new systems (Thomas, 2008). Further naturalistic driving studies and the establishment of a European in-depth crash injury database are urgently required to evaluate current measures as well as identify future problems and solutions.

## **Human - Machine Interaction issues**

While the European Statement of Principles (Commission of the European Communities, 2006) was updated in 2006, there is a need for a test regime to provide objective assessment and guidance. Needs defined that the test regime:

- Is technology-independent, i.e. does not depend on a particular technology being employed in a system design
- Uses safety-related criteria
- Is cost effective and easy to use
- Is appropriate for a wide range of HMI
- Is validated through real-world testing
- At the same time, many driver assistance technologies are vehicle specific. That is, they apply to the vehicle in which they are fitted without knowledge of the level of assistance afforded to the surrounding vehicles.

In a market-driven implementation of new vehicle technologies, it is likely that nomadic devices will be freely available for purchase without the device being tried and tested in every vehicle in the fleet. The implications of retrofit of such devices could be problematic since the response of the vehicle to the technology in question might not be predictable. There needs to be a clear policy for handling nomadic devices, such that no gross assumptions are made to the effect that any single device will offer the same benefit to all vehicle types and make/models and they will not interfere with vehicle systems or add to the load on the driver. A clear framework is needed urgently to identify, evaluate, deliver and monitor technologies which improve safety and to identify and discontinue work on those which cost lives. Before measures are widely introduced, they need to be demonstrably effective in their safety performance.

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## Notes

### 1. Country abbreviations

	Belgium	BE		Italy	IT		Romania	RO
	Bulgaria	BG		Cyprus	CY		Slovenia	SI
	Czech Republic	CZ		Latvia	LV		Slovakia	SK
	Denmark	DK		Lithuania	LT		Finland	FI
	Germany	DE		Luxembourg	LU		Sweden	SE
	Estonia	EE		Hungary	HU		United Kingdom	UK
	Ireland	IE		Malta	MT			
	Greece	EL		Netherlands	NL		Iceland	IS
	Spain	ES		Austria	AT		Liechtenstein	LI
	France	FR		Poland	PL		Norway	NO
	Croatia	HR		Portugal	PT		Switzerland	CH

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