Dissemination of Performance Testing Methods for Active Safety Functions in Road Vehicles

Support Action
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Roadmap for future research – testing of active safety functions in road vehicles

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Executive Summary

The ActiveTest initiative has the objective to disseminate performance testing methods for ICT-based safety functions ("active safety") in road vehicles.

Among other actions, the objective shall be fulfilled by issuing this report and road map for planning of future research topics. The report also compiles and analyses discussions from the three workshops held by ActiveTest. It points at some challenges in testing and at possible improvements of testing procedures.

Document Name

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Version Chart

Version	Date	Comment
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0.2	14.06.2012	Second draft
0.3		Third draft, 4.8 and 4.10 added
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Management Summary

ActiveTest is a support action aiming to increase road safety by supporting the introduction of ICT-based safety functions ("active safety"). The scope of the support action does not include research tasks with in-depth analysis and evaluation. However, the contacts at workshops and at other dissemination events have generated many ideas. As one of the tasks performed, the ActiveTest partners have compiled a number of topics suitable for future research.

This document also presents brief summaries of other existing initiatives for active safety testing. AEB, EuroNCAP, vFSS, ADAC, CAMP and the Harmonization Platforms all have produced valuable results. AsPeCSS and ASSESS are examples of European research projects with good progress.

The discussions within ActiveTest have mainly been focusing on active safety functions where the behaviour of other traffic participants can be predicted (e.g. by electronic perception) in a deterministic way. It is much more difficult to develop active safety functions for time scales where another traffic participant may significantly alter the dynamic state of his or her vehicle or body and thereby relax or aggravate a critical situation. That would require close integration of HMI expertise and also of accident and critical incident analysis.

ActiveTest has addressed active safety functions where the behaviour of other traffic participants or the driver's intentions may be predicted. Examples of such functions are autonomous emergency braking, electronic stability control, and detection of pedestrians.

There is a great challenge to develop performance test methods. The methods must really assess the effectiveness of the safety functions under test. Test scenarios have to be carefully selected for performance testing. A limited set of test cases shall give a comprehensive judgement of the traffic safety improvement. This can be compared to the established test protocols for crash testing, where a few crashes are used to judge the safety. A good performance in a test shall show that an active safety function increases safety in real traffic.

The advantage of ActiveTest has been the possibility to act as an open and independent initiative to bring out issues on performance testing. The aim to disseminate knowledge on performance testing connects well with the aim to propose some topic for future research.

The four main conclusions are

- The technological development is rapid
- Test harmonization is needed
- Research topics are identified
- Exchange of experience within the field are beneficial for all partners

Preface

ActiveTest is a support action within the ICT programme of the European Community's 7th Framework Programme for Research. The general objective of ActiveTest is to increase road safety by supporting the introduction of ICT-based safety functions ("active safety") which allow mitigation or even avoidance of accidents. These functions are necessary to reduce fatalities on European roads significantly. But there are presently no commonly accepted testing methods established.

The ActiveTest initiative has the objective to disseminate performance testing methods for ICT-based safety functions in road vehicles by:

- demonstrating performance testing of ICT-based safety functions
- disseminating the test programme developed in the eVALUE research project
- establishing an active dialogue with key stakeholder groups
- compiling an outlook for future research need
- contacting standardisation organisations for road vehicles with research results
- creating awareness of the need of standardised performance testing of ICT-based safety functions

This deliverable gives an outlook for future research needed.

The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 269904.

1 Introduction

ICT-based safety functions ("active safety") such as Electronic Stability Control (ESC) and Lane Departure Warning (LDW) have been introduced. The purpose is to try to avoid accidents through anticipation. The largest future improvements of road safety are expected to rely on such safety functions with the aim to prevent accidents from happening. The ICT-based functions are under rapid development and there is presently, and in contrast to passive safety, no generally accepted testing procedures in place. Road safety must improve further. (Figure 1) ICT-based safety has the potential to greatly reduce the number of road accidents.

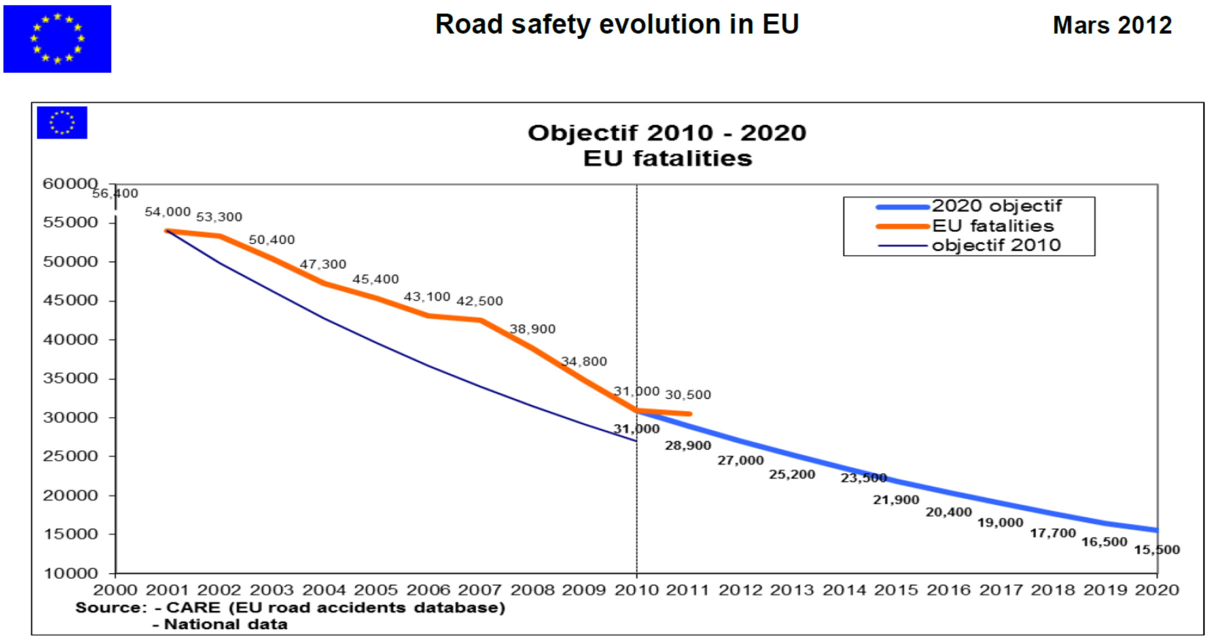


Figure 1 Road safety in the EU has improved, but needs further improvement [ec.europa.eu/transport/road_safety]

Safety measures to reduce the consequences of an accident ("passive safety") such as safety belts and airbags have been demonstrated in performance testing by different NCAPs all over the world. Such performance testing of passive safety has greatly contributed to road safety. Performance testing methods for active safety are necessary to improve the safety performance of the new safety functions in road vehicles. Performance testing will also increase the awareness of the users that ICT-based safety functions are beneficial for all road users. Several testing methods have been presented by standardization, industry and research projects. Tools are being developed to support performance testing.

Testing is also a very important activity during the development of new active safety functions. The test tools and the test methods can often be the same as for performance testing. The major difference is that development testing requires much more efforts. The new active safety functions have to be evaluated in many traffic scenarios. Also different driver reactions have to be considered. This leads to an extensive set of test cases.

A forum is needed for exchange of experiences and to compare principles from in-house testing at manufacturers with the results of research initiatives in Europe and overseas. ActiveTest provides a forum independent from industry, and thus neutral ground to allow for informal discussions. The intention is to focus on testing methods and rating approaches, not to address if the safety level of a vehicle is “good” or “bad”. Several national and international initiatives have started for performance testing of active safety functions. They are focusing on different functionalities and levels of detail, but share the objective to enable assessment and rating of active safety systems. This report compiles and summarises some of the initiatives in this field.

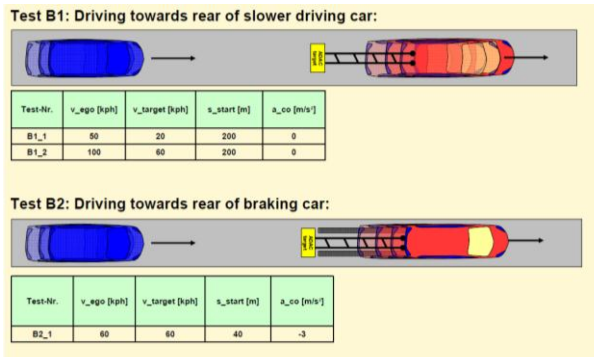
It is visible today that future research work will be required over the next years. This concerns e.g. topics such as reliable and comprehensive accident statistics taking the effect of active safety equipment into account, driver models as input for repeatable and validated testing procedures using driver robots as well as methods for the determination of the safety impact given by different safety functions. All the input received through the surveys and the discussions in the three ActiveTest workshops is also compiled and analysed. It will be used for pointing out possible updates and improvements of the test procedures.

2 Initiatives for testing of active safety

There are several on-going or recently finished initiatives and research projects devoted to defining performance testing methods for longitudinal active safety systems, e.g. forward collision warning (FCW) and autonomous emergency braking (AEB) systems. To the initiatives belong ADAC [ADAC], AEB [AEB], and vFSS [vFSS]. ASSESS [ASSESS] and AsPeCSS [AsPeCSS] are two research projects which have performance testing methods for longitudinal active safety systems as parts of their scopes. Additionally, standardization organizations such as ISO and SAE have released standards for performance testing of FCW systems [ISO,SAE] and an ISO standard for AEB is under development. NHTSA has defined three test scenarios for FCW systems in their NCAP confirmation test [NHTSA NCAP].

Examples of proposed test scenarios are shown in Fig. 1. Regardless of the databases which have been used to guide the initiatives and projects, most of them end up with a similar set of scenarios. All of them have scenarios where the vehicle in front is braking, travelling at constant speed, or is stationary. Besides those some of them also specify cut-in and junction scenarios as well as scenarios with vulnerable road users such as pedestrians and motorcyclists.

(a)



(b)

Figure 2 Examples of car-car scenarios proposed by ASSESS (a) and ADAC (b).

The common scenarios are summarized in Table 1 for comparison. Test vehicle (TV) speed and lead vehicle (LV) speed and deceleration are presented. The offset is the lateral mismatch between the centerlines of the two vehicles. Curvature tells the direction of the road. A curve is defined by its radius. The reaction, or driver model, specifies if the driver is passive or alert and how hard and fast (s)he presses the brake pedal.

Table 1. Scenarios and parameters proposed by different initiatives

Scenario	Parameter	ADAC	AEB	ASSESS	vFSS	NHTSA	SAE
Stationary LV (LV speed = 0) (LV dec. = 0)	TV speed [km/h]	20 30 40	10+10n[a] (n=0 … 5)	50 80	72[c] 25[d] 50[d]	72[e]	100[f]
	Offset	0	0 0 … 45°	0 50%	0	0	0
	Curvature	Straight	Straight	Straight	Straight	Straight	Straight
	Reaction	No	No	No Slow Fast	No	No	No
Slower LV (LV dec. = 0)	TV speed [km/h]	50 100	10+10n[a] (n=0 …	50 50	72[c] 90[d]	72[e]	60[f] 50[f]
	LV speed [km/h]	20 60	20	10 10	32[c] 50[d]	32[e]	10[f] 30[f]
	Offset	0	0	0 50%	0	0	
	Curvature	Straight	Straight	Straight	Straight	Straight	Curve Straight
	Reaction	No	No	No Slow Fast	No	No	
Braking LV	TV speed [km/h]	60	50[b]	50 80	72[c] 50[d]	72[e]	100[f] 100[f]
	LV speed [km/h]	60	50	50 80	72[c] 50[d]	72[e]	100[f] 100[f]
	LV dec. [m/s^2]	-3	-2 -6	-4 -7	-2.9[c] -6.2[d]	-2.9[e]	-1.5[f] -3.4[f]
	Offset	0	0	0	0	0	0
	Curvature	Straight	Straight	Straight	Straight	Straight	Straight
	Reaction	No	No	No Slow Fast	No	No	No

a: step increment until collision occurs **b:** at two different headways **c,e,f:** only for FCW testing **d:** only for AEB testing

One precondition which is not listed in the table but common in many of the test scenario specifications is the headway (time gap) which needs to be established between the TV and LV before the test sequence is initiated. As can be seen in the table there are both commonalities and differences. For example, ASSESS scenarios are the only ones covering different offsets, whereas SAE are the one considering scenarios in curves. Curved scenarios put more demands on the proving grounds since all of them have straight roads (naturally) but do not have many different radii for curves. NHTSA, SAE and some of the vFSS scenarios are only applicable for testing of FCW systems.

FCW systems are easier to test; if the required minimum time-to-collision has been passed without a warning issued, the test can be aborted. Thus a real vehicle can in principle be used as target (lead) vehicle. However, this way of testing may be a bit too simplified. First of all, in a situation where the FCW should avoid or mitigate a collision, the driver is in the loop. Therefore the HMI becomes very important: the warning modalities and their design. Also the driver reaction becomes important. An alert driver might be the difference between a collision or not. Additionally, support systems such as brake assist and well-designed brake/stability systems are not awarded.

2.1 AEB

An international group of insurer funded research centres is called RCAR (the Research Council for Automobile Repairs). Some RCAR members have formed a focus group, the so-called AEB group, with the aim of defining a set of test procedures that can be used by consumer test organisations such as Euro NCAP, IIHS and Thatcham. Thatcham is leading this group that also claims to be supported by a vehicle manufacturer and a tier 1 component supplier.

The AEB group states basing its test procedures on real crash scenarios taking into account both frequency and severity. Therefore, they use data sources that include insurance and national statistics as well as in-depth accident investigation. Test devices and tests able to represent these real world scenarios are developed by the AEB group. They publish their tests and share them with other working parties, for instance with the vFSS initiative.

Further information can be found under www.thatcham.org.

2.2 AsPeCSS

The main goal of the AsPeCSS project is to develop harmonised test and assessment procedures for forward looking integrated pedestrian safety systems that can be used for consumer rating and regulatory purposes. As such, the project is meant to stimulate wide spread introduction of these systems that have high potential to improve safety of pedestrians and, in case adequate detection technology becomes available, also for pedal cyclists.

The project is an FP7 funded project, started in September 2011 with a total duration of 2.5 years. The consortium comprises Industry (car manufactures, (first tier) suppliers), research organisations and universities. The geographical representation and the balance between (end) users, research and those involved in assessing, testing and regulations ensures a European-wide approach, which is the strength of this project by means of the complementarily of the partners and their multi-disciplinary aspects. It is well known that consumer rating programmes have a strong influence on manufacturers to build vehicles that consistently achieve high ratings, thereby enforcing introduction of new safety systems that address real world needs into vehicles. Moreover, it will raise the public awareness of the benefits of these integrated safety systems by means of easy understandable rating systems.

With this goal, the objectives of AsPeCSS are:

- To develop harmonised and standardised procedures and related tools for the assessment of forward looking integrated pedestrian safety systems. Such harmonisation shall be provided at European level and will also target a broader scope worldwide. As part of this:

- Develop a methodology for balancing direct active safety benefit, combined active-passive safety benefit, as well as direct passive safety benefit into one overall safety assessment (based on benefit estimations);

- Develop methods and means to adapt passive safety test conditions for scenarios with preceding pre-crash action;

- Develop test targets representing pedestrians for different sensor types.

- To gain acceptance for future implementation of test and assessment tools in scientific, industrial, regulatory or consumer rating procedures by extensive evaluation and validation;

- To set the bases and prepare similar activities focusing on the test and assessment of integrated protection systems dedicated to cyclists.

Further information can be found at www.aspecss-project.eu

2.3 ASSESS

The ASSESS project is funded under the Seventh Framework Programme of the European Commission and started in mid-2009 with 15 partners in total. The goal is to develop a relevant set of test and assessment methods applicable to a wide range of integrated vehicle safety systems in the longitudinal domain. More precisely, the focus is on pre-crash sensing performance and crash performance under conditions influenced by pre-crash driver and vehicle actions. This includes a study of the relevant driver behaviour as well as the development of a standardised target representing a vehicle. Additionally to the test tools for driver behaviour, pre-crash and crash evaluation, the project will deliver a methodology for the evaluation of the socio-economical benefit of active safety systems, considering the current road accident layout, the future trends and the performance level of the actual active safety systems under study.

The ASSESS project is partly based on the results of the eVALUE project with respect to the longitudinal domain. With its more focussed investigation of pre-crash functionality and related assessment, it shows an approach that can lead to the required level of detail with comprehensive protocols ready for implementation in the short term.

Further information can be found under www.assess-project.eu.

2.4 Euro NCAP

Euro NCAP has launched in 2010 its “Euro NCAP Advanced” award system for new and emerging safety technologies. It aims to provide car buyers with clear guidance about the safety benefits which these new technologies offer. The new reward system, complementing Euro NCAP’s existing star rating scheme, recognizes and rewards manufacturers who promote those new safety technologies which have a scientifically proven safety benefit. Many of the technologies are so new that no accepted standards exist to assess them. Euro NCAP has developed a methodology which allows the potential safety benefits of any new technology to be determined. Unlike Euro NCAP’s well established assessments involving physical tests at a crash laboratory, the new process is based entirely on the assessment of scientific evidence presented by the vehicle manufacturer.

In addition, for the first time Euro NCAP has tested the ESC performance of all cars crash-tested in 2009. 2009 was also the year when the ESC fitment was included as an essential part of Euro NCAP’s assessment leading to the overall award rating. Euro NCAP carried out “sine-with-dwell” tests according to the ESC Global Technical Regulation (GTR), which is based on the US regulation FMVSS126. During 2011, cars were evaluated with a pass/fail criteria based on this regulation. In the coming years, a deeper analysis will be defined. The “Beyond NCAP Assessment protocol” is available at the Euro NCAP web page www.euroncap.com.

2.5 vFSS

vFSS is a working group on Advanced Forward-Looking Safety Systems that was initiated mainly by German vehicle manufacturers and research organisations, later seeking international cooperation with other European and non-European vehicle manufacturers as well as research organisations and institutions worldwide. The aim of the working group is the development of test procedures for driver assistance systems (in particular advanced emergency braking systems) in order to ensure a robust assessment of such systems. The work is based on accident analyses and also addresses pedestrian safety issues. The ASSESS project is very much in line with the vFSS procedures on longitudinal safety systems, and the initiative is looking for harmonisation with as many initiatives as possible, e.g. CAMP-CIB and AEB.

2.6 ADAC

German motoring club ADAC, also a member of Euro NCAP, presented in 2011 results of a test series that investigated advanced emergency braking systems (AEBS). The ADAC AEBS test assessed the AEBS capability to reduce impact speed as well as when and how effectively the driver is alerted to an imminent collision in six current family and executive car models. According to ADAC, preventing a collision because of timely warning is always better than an autonomous emergency braking with unforeseeable consequences. As another important factor for enhanced driver safety, ADAC has identified system reliability. They conclude that most drivers will not accept false alarms even if they are no injury risk; unlike accidental emergency braking, which may be fatal. Their test also assessed the probability of false alarms or unnecessary emergency braking. Their full test report and description of procedures is available for download under http://www.activetest.eu/pdf/adac_aebs_report_en.pdf.

2.7 CAMP

The Crash Avoidance Metrics Partnership (CAMP) was formed already in 1995 in the USA between Ford and General Motors to accelerate the implementation of crash avoidance countermeasures in passenger cars to improve traffic safety. In the meantime, other companies and institutions have joined the partnership. It is engaged in cooperative research with the National Highway Traffic Safety Administration (NHTSA) to advance the safety research objectives of the Department's Intelligent Vehicle Initiative and also partly funded by the United States Department of Transportation (USDOT).

As a sub-project, the Crash Imminent Braking (CIB) consortium started in 2009 the investigation of “Objective Tests for Imminent Crash Automatic Braking Systems”. The purpose of the on-going project is to define minimum performance requirements and objective tests for crash imminent braking systems and to assess the harm reduction potential of various system configurations and performance capabilities. Further information can be found under www.nhtsa.gov.

2.8 Harmonisation Platforms

Because of the potential of Autonomous Emergency Braking systems in crash avoidance and injury mitigation, Euro NCAP intends to include assessment of AEBS in future protocols. Procedures will be defined by the Euro NCAP PNCAP group using information from a number of projects:

- *Advanced Forward-Looking Safety Systems (vFSS)*
  Cooperation between OEMs, research and insurance groups world-wide developing test and assessment methods for forward looking safety systems related to accidents with pedestrians and cars. vFSS also develops and applies methods and tools for prediction of system effectiveness.

- *Advanced Emergency Brake (AEB)*
  Cooperation between insurance organisations Thatcham and IIHS with support from research groups, a supplier and two OEMs. Aims and goals identical to vFSS.

- *Assessment of Integrated Vehicle Safety Systems (ASSESS)*
  EU FP7 Project consortium of OEMs, suppliers, test houses, research organisations and universities. Total 14 partners. Research on test methods for car – car accidents (no pedestrians) considering driver behavioural aspects (warning), pre-crash performance evaluation, crash performance evaluation and overall system effectiveness.

- *Allgemeiner Deutscher Automobil-Club (ADAC)*

  ADAC defined an evaluation method for AEBS considering the warning and autonomous braking actions, to inform consumers on the system performance. The method was applied to various systems offered to the market and reported in the media.

- *Assessment methodologies for forward looking Integrated Pedestrian and further extension to Cyclists Safety Systems (AsPeCSS)*

  EU FP7 Project consortium of OEMs, suppliers, test houses, research organisations and universities. Total 11 partners. Research on test methods for car to pedestrian accidents only.

In order to streamline input from the various projects to the PNCAP group, the so-called Harmonisation Platforms (HPs) have been established. The goal is to exchange information on key subjects, thereby generating a clear overview of similarities and differences on the approaches and results. These HPs are formed by different members of the previous projects. The projects run independently but via the HPs they are well informed of mutual developments. Three HPs have been established:

- HP1 Test scenarios
- HP2 Test targets
- HP3 Effectiveness analysis

3 Research agendas

Several organisations have compiled research agendas including testing “active safety”, “integreted safety” or “ADAS”.

3.1 ERTRAC

The European Technology Platforms ERTRAC (European Road Transport Research Advisory Council) have developed a scenario [ERTRACscenExSum] [ERTRACscen] for road transport in 2030 and the following years. One of the conclusions is that by 2030, a harmonized policy framework for the transport sector will be needed to achieve sustainable transport in Europe in the period 2030-2050.

ERTRAC lists four major challenges:
- energy and the environment
- urban mobility
- long-distance freight transport
- road transport safety

Four likely factors contributing to road transport safety risks are mentioned. The increasing number of vulnerable road users may increase the risks. New types of vehicles will also increase the risks by accident incompatibility between vehicles. The increasing number of elderly people will put new demands for safety. An increase in the mobility demand is also likely to increase the risks.

The three main actors with regard to road transport safety are the user, the road and the vehicles. All three play significant roles for the active safety [ERTRACscen]. Active safety (or ADAS Advanced Driver Assistance Systems) is regarded to be one of the technology factors influencing road safety. Safety is expected to increase when active safety systems are more widely spread. But also society is regarded as one of the factors for road safety. Customer awareness will lead to active decisions when purchasing vehicles with safety systems.

ERTRAC concludes three crucial applications for the R&D agenda to be structured around:
- passenger and freight transport/delivery inside urban areas
- freight transport outside urban areas
- interconnections between the two transport systems

ERTRAC have also presented a strategic research agenda [ERTRACsra] [ERTRACsraExSum]. The agenda claims that a European road transport system that is 50% more efficient than today could be achieved by 2030. ERTRAC lists the guiding figures for safety as a 60% reduction in fatalities and severe injuries, and a 70% reduction in lost goods. (See figure 3.)

	Indicator	Guiding objective
Decarbonization	Energy efficiency: urban passenger transport	+80% (pkm/kWh) *
	Energy efficiency: long-distance freight transport	+40% (tkm/kWh) *
	Renewables in the energy pool	Biofuels: 25% Electricity: 5%
Reliability	Reliability of transport schedules	+50% *
	Urban accessibility	Preserve Improve where possible
Safety	Fatalities and severe injuries	-60% *
	Cargo lost to theft and damage	-70% *

* Versus 2010 baseline

Figure 3 Guiding objectives for 2030 [ERTRACsra]

The SRA says that research is needed on ergonomically and sociologically/physiologically justified information & supporting Human Machine Interface. Also systems that support the driver to avoid or mitigate collisions need research. Modelling of the driver behaviour in critical situations and in the driving task is another research topic. Solutions to support the driver in case of impairment (distraction, drowsiness, illness) are encouraged. This can be supplemented by systems to monitor the status and the alertness of the driver.

An intelligent and adaptive infrastructure will provide an infrastructure that communicates its condition (e.g. road surface or traffic density). This information can be used as input signals to new active safety functions to warn the driver of risks and to enable a safer driving behaviour.

3.2 EUCAR

EUCAR is the European Council for Automotive R&D from major European passenger car and commercial vehicle manufacturers. EUCAR facilitates and coordinates pre-competitive research and development projects and its members participate in a wide range of collaborative European R&D programmes. The European automobile manufacturers are the largest private investors in R&D in Europe with over €26 billion investment per annum, or 5 % of turnover. EUCAR members are BMW, DAF, Daimler, Fiat, Ford of Europe, GM/Opel, Jaguar Land Rover, Porsche, PSA Peugeot Citroën, Renault, Scania, Volkswagen, Volvo Cars and Volvo Group. EUCAR is closely connected to ACEA, the European Automobile Manufacturers Association. [EUCARChalPrior]

At 27th May 2011 EUCAR published a paper summarizing R&D Needs and Trends with the title 'Challenges and Priorities for Automotive R&D' [EUCARChalPrior]. In this paper EUCAR lists the following six priority themes for strategic research in the automotive sector:

- Mobility and transport in urban areas, extra-urban corridors and interfaces
- Enhanced powertrains and alternative fuels
- Electrification of the vehicle
- Safety applications in cooperative systems
- Suitable materials in automotive applications
- Ecological and efficient manufacturing of vehicles, components and systems

Within the fourth priority theme 'Safety applications in cooperative systems' EUCAR addresses the need for advanced in testing of active safety systems. For tackling the challenges that the European Transport Safety Council has proposed (target of reducing road deaths by at least 40% between 2010 and 2020), EUCAR and CLEPA associate to anticipate the research needs in road safety. The long-term objective is realising both efficient mobility for all societal groups within the 'Vision Zero' concept, which means striving for a road transport system in which no-one is killed or severely injured anymore. Considering the breakthrough in technological developments supporting new products and services, five research priorities are emphasized in a common document [EUCARChalPrior] in order to ensure the achievement of the objectives by 2020.

- <u>Design of vehicle safety in terms of integrated safety:</u> research is required to improve and widen the accident data base, identify reliable pre-crash sensing strategies and redefine secondary safety systems, develop new sensor and integration technologies and develop advanced virtual analysis and testing methods.

- <u>Anticipation of the safety of new vehicle concepts:</u> research should focuses on definition of the specific safety requirements of new vehicle concepts, redefinition of primary and secondary safety systems, development of technologies to ensure crash safety for energy storage systems, advanced methods and tools for reliable modelling, experimental and virtual testing and energy management to ensure at all times the proper functioning of critical safety systems.

- Integration of communication vehicle-2-X in the safety design: research is needed into in-depth accident/ incident analysis in order to better understand the pre-crash phase, low-cost technologies for sensitive and reliable real-time vehicle-2-X technology implementation, mitigation strategies including warnings, interventions and behaviour-based feedback, qualitative and quantitative situation modelling, improved IT security for drivers and vehicles

- Understand, modelling and improvement of driver behaviour: accident research and naturalistic driving studies are needed to develop driver behaviour models as well as research into low-cost technologies for real-time detection of driver behaviour failures and HMI strategies for minimizing the distraction potential of in-vehicle information systems.

- Standardisation of methodologies for evaluating new safety systems: research is needed into advanced methods and tools for physical testing and advanced simulation tools for virtual testing, standardisation of test conditions for the tests of primary and secondary safety systems, definition of driver behaviour models for in-the-loop testing, development of field operational tests.

3.3 CLEPA

84 of the world's most prominent suppliers for car parts, systems and modules and 26 National trade associations and European sector associations are members of CLEPA, representing an industry with an annual turnover of 300 billion Euro, more than 3,000 companies, employing more than three million people and covering all products and services within the automotive supply chain. Founded in 1959 and based in Brussels, Belgium, CLEPA is recognized as the natural discussion partner by the European Institutions, United Nations and fellow associations (ACEA, JAMA, MEMA, etc). [CLEPA]

In 2006, CLEPA published a Strategic Research Agenda addressing the future of automotive research. [CLEPAStratResAgend] Within this agenda, CLEPA is focusing on four topics:

- Mobility
- Energy, Environment and Powertrain
- Safety, Security and Comfort
- Materials, Design, Processes and Manufacturing

In the third topic, CLEPA states that improving road safety can only be done through an integrated approach invoking all stakeholders. In terms of the vehicle, improving road safety means taking an intelligent approach, combining active and passive safety technologies and addressing every phase of driving, from normal situation driver support via preventive pre-crash actions to accident mitigation or avoidance of an accident. In order to ensure road safety in Europe, the development of safety technologies has to be accompanied by clear Europe-wide legislation focused on saving lives.

According to [EUCARChalPrior] there exists a common document from EUCAR and CLEPA, in which five research priorities are emphasized to ensure the achievement of the objectives by 2020.

3.4 EARPA

EARPA is an association of automotive R&D organisations, which brings together the most prominent independent R&D providers in the automotive sector throughout Europe. Its membership counts at present around 40 members ranging from large and small commercial organisations to national institutes and universities. EARPA is the platform of automotive researchers and is actively contributing to the European Research Area and the future EU RTD funding programmes. For focusing on answering specific needs, EARPA is currently divided in nine Task Forces. [EARPAPosPapSaf]

In 2012, the Task Force Safety of EARPA published a position paper addressing further advanced in road safety with respect to importance for European road and transport research [EARPAPosPapSaf]. According to this position paper, there exist four research areas, namely areas road user, vehicle, infrastructure and cross-cutting topics which should be focused on in the future.

Within the research area 'vehicle, EARPA addresses testing of active safety systems. Test methods for active safety functions are necessary to improve the safety performance of the novel safety functions. Efficient testing based on real traffic scenarios will also be used to increase the awareness of the benefits among all road users. Active safety testing of today is not at all as well developed and mature as passive safety testing ("crash testing"). Several subjects need further research to reach solid test methods with repeatable results for active safety. Driver models, traffic scenarios suitable for active safety testing, wireless communication environment and test targets are stressed.

The development of objective test and assessment methods to determine the safety performance for functions reducing risks at drowsiness and distraction of drivers are also stressed.

The protection potential of integrated active and passive safety systems exceeds passive-only safety systems without contributing to vehicle weight. The development of active safety systems should lead to a situation in which vehicles are able to avoid collisions. In crash scenarios where collision avoidance is not feasible or possible, then integrated active and passive safety systems should be capable of mitigating collisions and to reduce the injury severity of the occupants. Upon impact, crashworthiness will stay important to protect occupants by mitigating injuries, but passive systems can become more lightweight as they are required to function at lower impact speeds. Optimal occupant protection will be achieved by a good balance between active and passive measures. Research should address also assessment methods for overall vehicle safety, reflecting the benefits of both passive and active safety.

Test and assessment methods to prove the benefit of systems to protect vulnerable road users are also mentioned as an urgent research need.

3.5 iMobilityForum

The iMobility Forum succeeds the eSafety Forum. Its field of work includes ICT systems for resource-efficient and clean mobility in addition to the latter's focus on ICT-based safety technologies. The iMobility Forum is a joint platform open for all road stakeholders interested in ICT-based systems and services. Since its establishment in 2003, the iMobility Forum has successfully advanced on the implementation of 22 Recommendations. There is now a need to move increasingly towards deployment.

Its vision is to deliver a discussion frame for safe, smart and clean mobility with zero accidents, zero delays, no negative impact on the environment and connected and informed citizens, where products & services are affordable and seamless, privacy is respected and security is provided.

In order to work towards this vision, the Forum provides a platform for all ITS stakeholders in Europe to discuss, define, coordinate and support activities to further innovation, research, development, deployment and use of ICT based transport systems and services.

It is organized into several working groups:

- Implementation roadmap
    - Its objectives were to identify the technical and economic potential of the industry as well as the topics and timetable for infrastructure improvements by the public sector with regard to iMobility systems capable of affecting road fatalities in Europe.
    - Additionally, a comprehensive assessment was carried out to study the maturity and potential of all eSafety systems and resulted in the identifications of eleven priority systems. The Implementation Road Maps have been regularly updated and the time horizon has been extended from 2010 to 2020.
- International Cooperation
    - The ICWG will support “Inter-Continental” Co-operation, enhancing the tri-lateral EU-US-Japan cooperation through increased support to government-industry cooperation of the three regions, and building on this basis extending the cooperation to a world-wide forum, involving Canada, China, India, Brazil, Russia, Australia, Korea and Taiwan;
    - The ICWG will initially focus on the global harmonization and standardization of Cooperative Systems, extending the current tri-lateral work to a world-wide reach.

- Vulnerable Road Users
    - Vulnerable Road Users (VRU) are to be considered as all "non-motorised road users, such as pedestrians and cyclists, as well as motorcyclists and persons with disabilities or reduced mobility and orientation" [2012 Transport WP].
    - This comprises a series of heterogeneous sub-groups: Elderly (as pedestrian, cyclist, passenger, driver/rider), Child (as pedestrian, cyclist, passenger), Disabled (motor, sensorial, cognitive as pedestrian, cyclist, passenger, driver/rider), Cyclists and PTW riders.
    - The VRU WG aims at creating a forum encompassing all key stakeholders in the area of Vulnerable Road Users safety enhancement, and at contributing to the specific objectives and targets of the European Commission addressed within the "Horizon 2020" initiative.
- Automation
    - The group has a broad experience in different areas around the table with experience from national and EU projects like HAVEit, CityMobile, Cybercar, GCDC, SARTRE, to name just a few, but also representation of relevant organizations like EUCAR, CLEPA and EARPA. Thus a good basis for addressing the topic of automation from a wide perspective is achieved. Anyhow, depending on the outcome of the next steps it might need to strengthen the working group further by inviting relevant stakeholders from areas with so far weaker representation, including participation of relevant industry partners.
    - Early ideas:
        - To provide detailed recommendations to the EC
        - To provide a roadmap on deployment and a roadmap on technology readiness
        - To define different use scenarios to be considered during the definition of the roadmaps
        - To include HMI in the context of automation (more than just a screen, it covers as well the complex aspects of driver and system interaction and driver in the loop aspects)
        - To cooperate with legal issues and implementation WG

Other working groups:

- ICT for Clean and Efficient Mobility

- Digital Maps
- Business Models
- Legal Issues

3.6 ERTICO

ERTICO - ITS Europe represents the interests and expertise of around 100 Partners involved in providing Intelligent Transport Systems and Services (ITS). Its vision is to bring intelligence into mobility, working together in public private partnership towards zero accidents, zero delays, reduced impact on the environment and fully informed people, where services are affordable and seamless, privacy is respected and security is ensured.

Their activities typically focus on developing enabling technology and a common technical and business approach to Intelligent Transport Systems and Services (ITS). The implementation and market take-up of ITS are discussed in different user fora. All ERTICO initiatives are fully Partner-driven and seek to deploy ITS technologies Europe-wide and beyond in order to reap the full societal and commercial benefits.

Fields of activity are:

Safe mobility:

- Integrated road safety: provide all road users with relevant safety support from vehicle & infrastructure.
- Safe urban mobility: improve safety into the design of urban mobility services
- Road user behaviour: enable safety innovation through better understanding of road user behaviour.

Cooperative mobility:

- Vehicle-to-Vehicle, Vehicle-to-Infrastructure communication: connect vehicles with each other and link vehicles with nearby roadside equipment and transport infrastructure.
- Cooperative monitoring: provide real-time vehicle-based data about road, traffic and environment status and incidents.
- Cooperative safety applications: provide local hazard alerts, the safe intersection, wrong-way driver warning.
- Cooperative traffic management: use vehicles as “virtual loop detectors”, provide vehicle-traffic control interaction for smooth driving.

Eco mobility

- Eco-smart driving: support drivers to adopt and then maintain a fuel-efficient driving behaviour.
- Eco-freight and logistics: enable freight routing and logistic operations to optimise fuel consumption and green goods transport.
- Eco-traffic management: implement traffic control and management systems improving global traffic network energy efficiency.
- Eco-vehicles: integrate hybrid and electrical vehicles into the transport and energy network.

Info mobility

- Traffic and traveller information, to ensure evolution from real time traffic information to truly integrated multimodal transport planning & traveller information
- Geo-localisation, to provide ubiquitous localisation through GNSS / in-door geo-positioning and appropriate location referencing methods
- Freight and Logistics, to optimise overall supply chain by means of e-freight and intermodal interoperable logistics management
- Access and Demand management, to support interoperability of European electronic toll and road charging services

3.7 EPoSS

EPoSS, The European Technology Platform on Smart Systems Integration, is an industry-driven policy initiative, defining R&D and innovation needs as well as policy requirements related to smart systems integration and integrated micro and nano systems.

In their SRA, EPoSS defines the following major R&D objectives for the next 15 years with respect to active safety:

“Driver information on vehicle dynamic limitations (e.g. traction, curve speed, ground clearance); adaptive human machine interface (HMI) systems to interact with the driver based on the specific situation; a personalised safety system adapted to characteristics of the individual (e.g. weight, age, size); driver drowsiness monitoring to sense and predict dangerous driver situations (e.g. sleep recognition); road safety in cities (i.e. at low speed); pedestrian protection systems including reacting and avoiding strategies (e.g. backover avoidance); collision mitigation systems to automatically reduce impact severity; emergency braking systems for unavoidable accidents; vision enhancement systems including night vision and blind spot monitoring, and vehicle interaction systems to allow cooperative driving using car to car and car to infrastructure communication.

Driver assistance is support to the driver in guiding the vehicle. Consumer demands, technical limits, and legal issues all require the driver to retain full responsibility for the vehicle. Taking account of the human ability to deal with complex situations, a synergetic solution aimed at extending driver abilities is the midterm perspective for vehicle control. The major R&D objectives here are:

Lateral and longitudinal vehicle guidance systems (including lane-keeping and lane-change support, ACC stop & go, and ACC for urban areas); later, semi-autonomous driving for defined situations (e.g. automated parking, automatic following and guided driving); personalised driving based on individual driving patterns, constitution, and appropriate vehicle adjustments; active load-management systems controlling chassis systems and the suspension based on the weight distribution in the vehicle; adaptive human-machine interfaces for situation specific interaction (using e.g. force feedback, head up displays, and speech recognition systems), and adaptive light projection systems for a better illumination of the vehicle's forward scene (using, e.g., turning lights, projection, automatic high beam).

The objective is that the adaptive technical systems provide optimal driver support taking account of vehicle and driver capabilities and characteristics. EPoSS will build upon networked functionalities using numerous sensor inputs to collect information, (shared) computational power to analyse and interpret situations and decide on appropriate measures, and a variety of actuators for operations to assist the driver in a smart and situation-specific way."

EPoSS propose the following examples of smart systems:

"In terms of both Safety and convenience a first example employing the EPoSS approach will be a multifunctional smart system device based on CMOS technology integrating several functionalities such as lane warning, pedestrian detection, and road-sign detection, while keeping the ability to detect crossing vehicles, the status of incoming traffic, tunnels, bridges, mist, fog, rain, and ambient light intensity and operates as controller of several actuators.

Networking architectures and related processing with sensors mounted at different locations around the vehicle to detect different areas in a multi-stereo and multispectral approach at both visible and infrared wavelengths could make it possible to reconstruct the road environment and obstacles, thus providing the basis for novel safety, driver assistance and convenience functions. micro-optics with novel materials, micro-mechanics, microelectronics, advanced packaging, advanced processing (data fusion) and wireless communication links underlay such on-going developments."

3.8 European Roadmap of Electrification

The European Technology Platforms ERTRAC (European Road Transport Research Advisory Council), EPoSS (European Technology Platform on Smart Systems Integration), and

SmartGrids (SmartGrids European Technology Platform for the Electricity Networks of the Future) have compiled a roadmap [ElecRoad] on the electrification of road transport.

The roadmap lists six major technology fields:

- Energy Storage Systems
- Drive Train Technologies
- Vehicle System Integration
- Grid Integration
- Integration into the Transport System
- Safety

The exploitation of active safety measures for electric vehicles are mentioned in the roadmap. Two of the listed milestones for the transport system and two of the listed milestones for safety refer to active safety (see figure 4). Automated and cooperative driving based on active safety is envisaged for the transport system, and exploitation of active safety for electric vehicles is expected. The safety measures is one among six listed technology fields, but active safety applied for electric vehicles is still regarded as important. Plug in hybrid cars and electrical cars have to provide at least the same safety level as cars with conventional powertrains.

Transport System	**Semi-automated driving based on active safety systems and car-to-x communication.**	**Enhanced usage of car-to-x communication for automated and cooperative driving for zero-accident road safety and highly convenient driving. Integration of EV in multi-modal transport system.**
Safety	**Safety systems and functionalities following innovations in EV development. Enhanced exploitation of active safety measures for electric vehicles including safety of vulnerable road users.**	**Active and passive safety measures for EVs used in multi-modal transport. Updated safety systems to enhanced modular vehicle platform with multiple integrated functions.**

Figure 4 Description of milestones for the Transport System and for Safety [ElecRoad]

A dedicated roadmap was drafted for all the six major technology fields, including safety. It is estimated that research for active safety will be performed in the years 2012-2020. (See figure 5.) The ActiveTest partners estimate that active safety for electric vehicles still will be a research topic for some years after that period. The roadmap for transport system integration estimates research on automated and cooperative driving to continue up to 2018. (See figure 6.)

The roadmap recommends a close cooperation between the PPP European Green Cars Initiative with international partners for the fully electric vehicle. Among the recommended actions is to establish an intense exchange of information, people and technology with governments and industry in the U.S. and Japan.

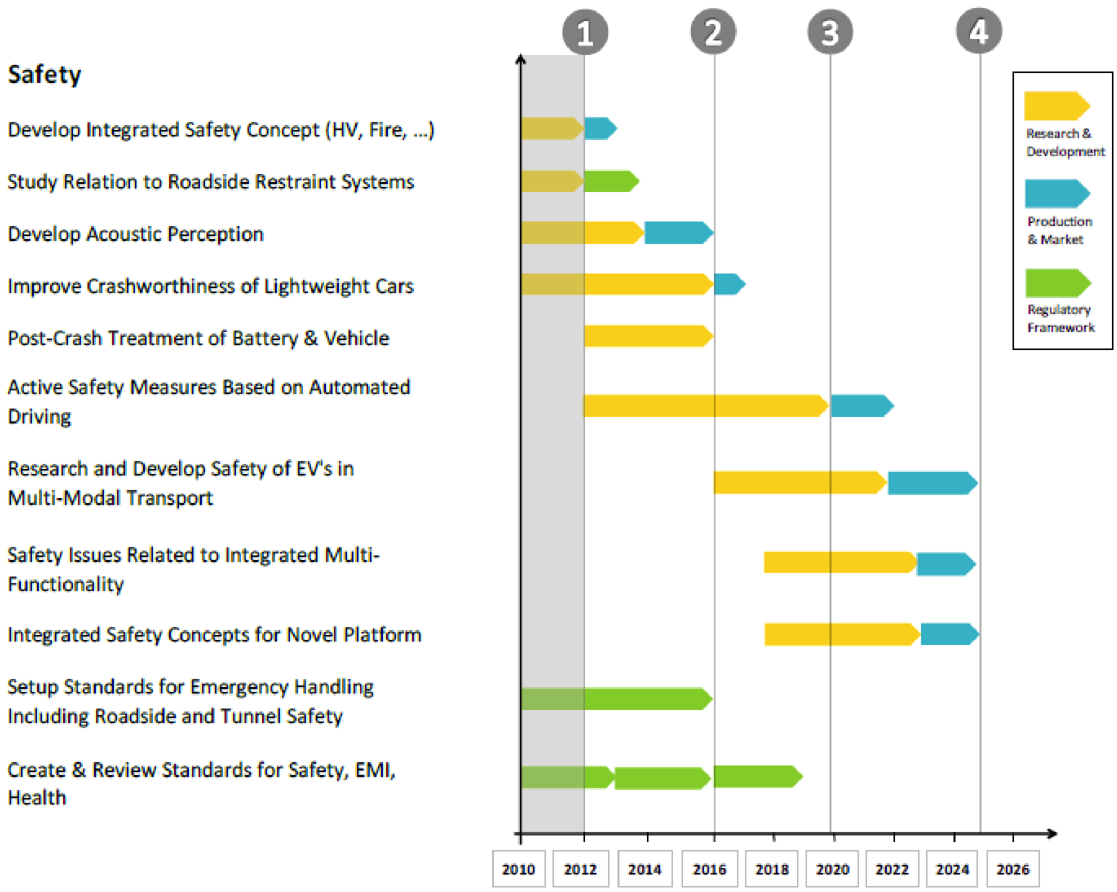


Figure 5 Roadmap on safety activities

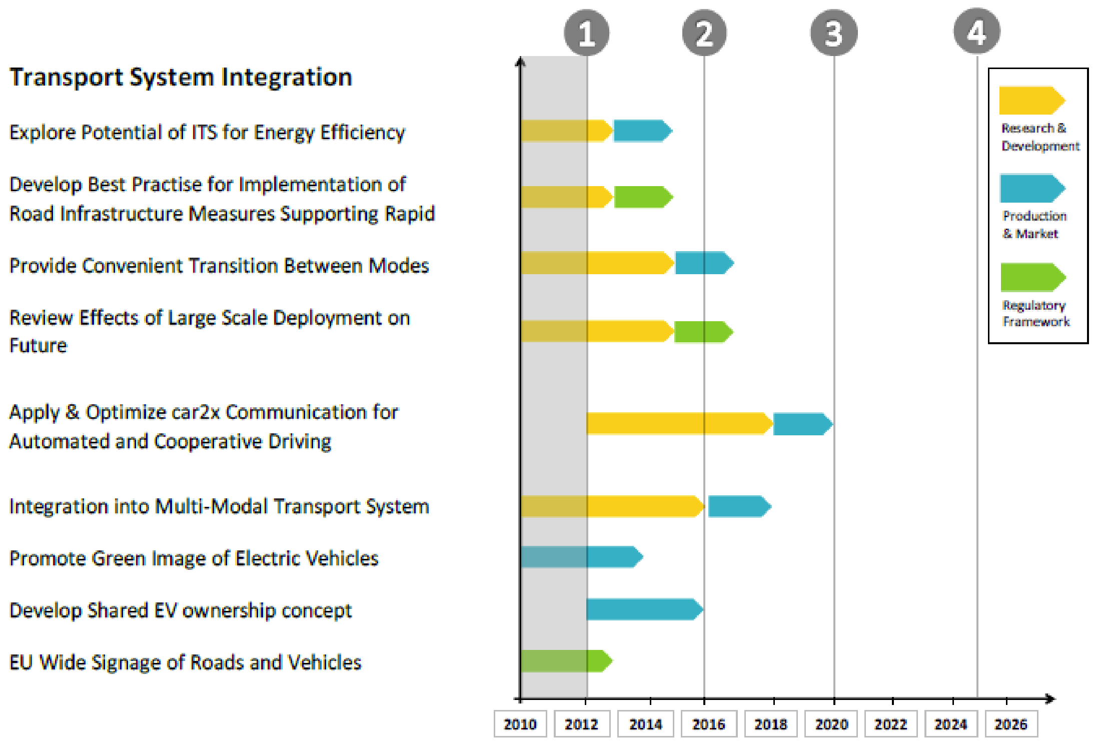


Figure 6 Roadmap on the traffic system integration activities

4 Future research topics for tests

Nineteen topics have been suggested by the ActiveTest project members. The topics were distributed to all participants in the ActiveTest network for review. Each topic is briefly described with background, objective and impact. The topics can be attributed to one or several of these four areas (cf. figure below):

- Analysis of drivers, accidents, and impact
- New systems and technologies
- Development testing
- Performance testing

These areas follow from the iterative way in which automotive safety systems are developed. First, target accident situations are identified. If suitable technologies exist, systems are developed to mitigate the situations. Then systems are tested during development and rating.

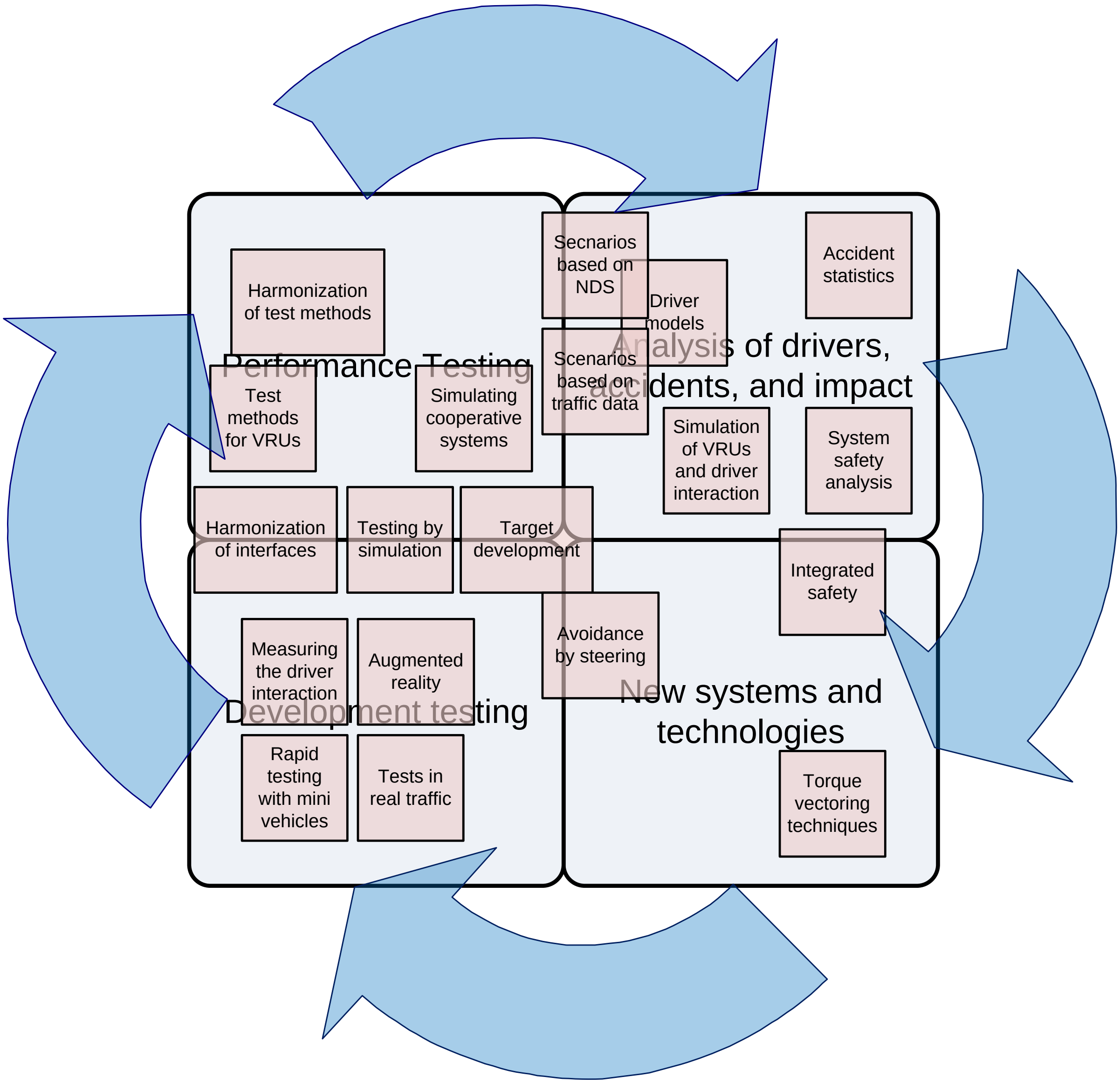


Figure 7 The iterative development of safe vehicles with research topics

It can further be distinguished between topics that are related to functions or systems which are already in the market and technologies that are under development. The following table shows the distinction of the research topics, which are likewise structured in the following sub-chapters.

Table 2. Research topic differentiation

Research topics related to technologies that are already in the market	**Research topics related to technologies that are under development**
Accident statistics	Integrated safety
Driver models	Rapid testing through use of miniature vehicles
Harmonization of test methods	Simulation for safety functions based on co-operative systems
Scenario development based on traffic data	Augmented reality
Target development	Scenario development based on naturalistic driving data
Test methods for Vulnerable Road Users	System safety analysis
Testing of ADAS functions by simulation	Accident avoidance by steering
Homologation by simulation	Torque vectoring techniques
Test methods for Vulnerable Road Users	Active safety functions enabled by Galileo GNSS
Analysis of the driver-vehicle interaction	
Tests in real traffic	
Harmonization of test equipment interfaces	

4.1 Research topics related to technologies that are already in the market

4.1.1 Accident statistics

Background: The uses of accident statistics with respect to active safety systems are two-fold: analyzing accident data to find the most important accident scenarios to mitigate/avoid, and in hindsight analyze the safety impact of systems that have been introduced on the market.

Today, accident data reporting is not accurate enough. The information provided by the police or medical facilities is often brief, if available at all. Different accident scenarios are classified differently in different countries. For example a vehicle that runs off road after evading an animal could be classified either as an animal or a run off road accident.

To get better accident data, crash or event data recorders can be used. These boxes work in the same way as the black boxes in aircraft, and record the important data during the last seconds before an accident/incident.

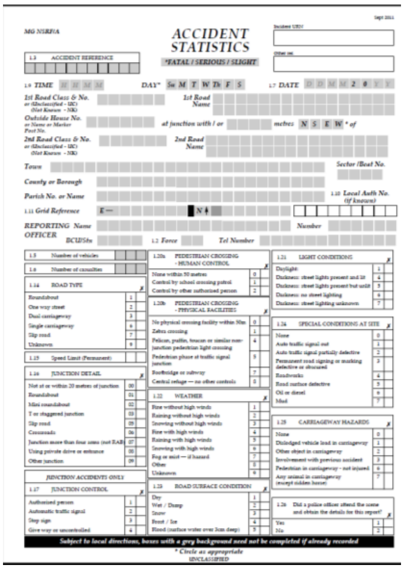

ACCIDENT STATISTICS
*FATAL / SERIOUS / SLIGHT

Figure 8 Example of the first page of the UK Police National Stats Form for accident reports

Objective: To investigate ways of improving the quality of data in accident databases. Particularly critical incident recording as performed and started analysing in late field operational test projects such as EuroFOT shall be taken into account. Correct triggering of recording (to reduce data amount) is to be investigated and defined. Inspection, evaluation and drawing of correct conclusions are subject to the establishment of critical incident research experts and potentially a European competence centre.

Impact: Accident data of better quality will give the possibility to better analyze and understand the safety impact of specific active safety systems. Additionally, key incident and/or accident-prone scenarios/situations could more easily be extracted from the data.

4.1.2 Driver models

Background: Driver models are gaining importance. The reason for this can partly be explained with the advent of active safety systems. Driver models are used to fine tune the systems, and to evaluate the safety impact of these systems. Additionally driver models can be used to assess macroscopic effects, e.g. traffic flow. It is fairly easy to evaluate the driver capability when it comes to operational capabilities i.e. steering and braking by performing experiments. There are physical limits on how fast a driver can react, how much pressure can be put on the brake pedal, or how much torque can be exerted on the steering wheel. Strategic and tactical driver models are much harder to anticipate since the larger time scale offer some much more levels of freedom, possibilities, for the driver. Here driving simulators and FOTs could offer viable ways forward.

In future active safety and convenience systems, driver models will be important since the level of control will be shared between the driver and the system, see the figure below. During the same driving occasion, the driver can choose from different levels of automation depending on e.g. the traffic conditions. In urban congested areas the drive can be fully automated at low speed, and in rural areas the drive can be partially automated. The hand-over to the driver during automation level switches becomes important.

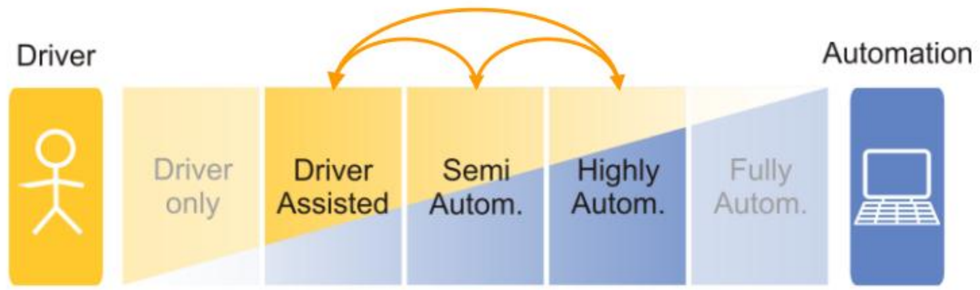


Figure 9 Level of automation according to HAVEit

Objective: The goal is to develop driver models which can be used during verification and validation of active safety functions. Driver models can be divided into strategic, tactical, and operational, where the difference is the time. Strategic is e.g. related to route choices, tactical to lane changes, and operational to steering and braking.

Impact: Driver models can be used to support design, verification, and validation of active safety systems. The models controls driving robots which mimic human driving behaviour, either in the test vehicle or other vehicles involved in the test scenario, e.g. a lead vehicle which is braking.

4.1.3 Harmonization of test methods

Background: Different active safety systems are introduced by different OEMs. The specification of these systems are similar, but never the same due to different system tuning related to branding image, the technical solution implemented, the price of the system and the development stage. Each OEM also develops own methods how to test and assess their own system. These methods consist of test scenarios, test tools, parameters, thresholds and key performance indicators for certain test results. Additional differences come from the combination of objective tests with some subjective evaluation and criteria (normally related to user comfort and acceptance).

All these different effects deliver different systems in the market with different performance levels. From a verification point of view, the test methods required by each of the systems may be different. However, from a validation point of view, holistic test methods are required. When these methods are derived from real-life accident analysis and evaluate the safety impact of the functions, it is possible to validate different systems with a commonly representative methodology.

Attending to these needs for validation test methods, different collectives have been and are working in the development of new test methods. The collectives might represent entities with different objectives: OEMs, TIER1s, research organisations, public bodies, insurance companies and, therefore, they might have different objectives with the validation procedures. The next picture shows the different associations and the harmonization efforts taken to provide commonly accepted test methods for Autonomous Emergency Braking systems.

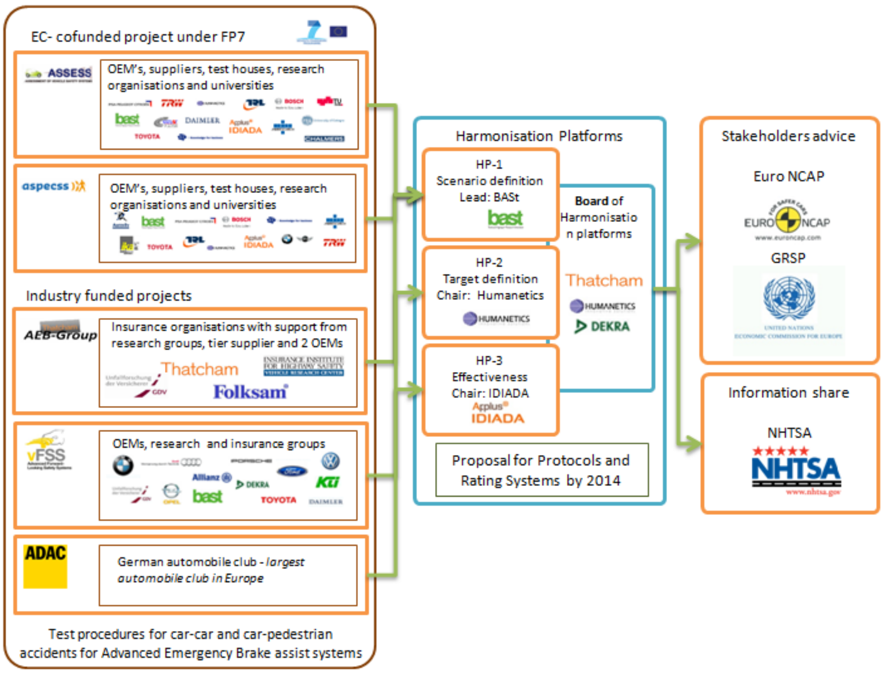


Figure 10 Harmonization platforms for AEB systems in Europe, source: AsPeCSS project

Objective: The goal is to harmonize the different test methods and to introduce a common basis for all possible development solutions of one system. In order to achieve this, associations working in new test methods and different stakeholders (OEMs, TIER1s, research, public bodies, insurance companies, end-users associations) must exchange information about their needs and interests in the validation process.

Impact: Harmonized test methods would reduce testing costs and could be performed by independent institutions. Such methods would provide a possibility to compare different systems from different OEMs up to a certain degree. These methods would support to standardise active safety systems. The standardisation would allow a faster widespread of the functions in the market and at the same time, as comparisons would be possible, system developers would be challenged to improve their systems for competitive reasons.

4.1.4 Scenario development based on traffic data

Background: Traffic data has been collected in accident data bases. The collected information can show which traffic scenarios are most accident-prone and in best need of active safety functions to reduce the risk of accidents.

Traffic data has also been collected in field operational tests (FOTs) and researchers have drawn conclusions from experiments in driving simulators. The collected information can be used to identify traffic scenarios with a great probability of accidents occurring.

Objective: A positive test result in a test of an active safety function should imply that the function actually improves traffic safety. It will be important to find representative scenarios both for development testing and for performance testing. This requires tools to pre-process the high amount of data recorded. Preferably, the recording of data is triggered only in critical incidents (cf. topic 4.1.1).

Research based on accident data bases, field operational tests and driving simulator experiences can define the scenarios most suited for testing of active safety functions. The connection between critical incidents and factually occurring accidents is to be investigated, in order to derive clues as to the improvement potential of preventive safety in everyday road traffic.

It should be investigated if the subsystem detecting and extracting critical incidents could be a low cost device or even a pluggable (i.e. nomadic) device which uses the vehicle sensors with little to no maintenance requirements.

Figure 11 Accident investigation by the California Highway patrol [chp.ca.gov].

Impact: The scenarios used in active safety testing will be based on the most relevant information related to accidents. A good result at a test will indicate a high probability for a high reduction of accidents.

4.1.5 Test target development

Background: There is often an unacceptably high risk to perform tests of active safety functions using real vehicles and road users in a scenario. An unexpected behaviour of the safety function under development could cause harm. This has triggered a development of “balloon cars” and other test targets which are possible to crash into with minimum danger to humans. However, new sensor principles are applied and new safety functions require new ways of testing. This calls for a further development of test targets. The development can be compared to the research previously needed to find harmonized crash test dummies.

Objective: Test targets are needed for cars, pedestrians, two-wheelers and animals. The objective is to develop test targets which can be harmonized, and are suitable for many types of sensor systems.

A target has to be recognized by one or more of the sensor systems; radar, lidar, vision and perhaps IR. Targets should also be perceived by the driver as a real object, when a human driver is part of the function under test. “A pedestrian target should look and behave almost like a real pedestrian.” if a true reaction from a driver is expected.

Both static and moving test targets are needed. For some scenarios, the target can be positioned without requirement of further movement. Whereas, for other scenarios the target will be positioned at the start position, and then operated in a controlled movement with precise speed and position, e.g. path following. The propulsion system for a target should preferably be possible to use together with several types of targets. In the future, certain degrees of randomness could be applied to the target movement to introduce some indeterminate behavior. Perhaps some of the parameters could be randomized, or a scenario is randomly selected from a set of predefined scenarios.

Figure 12 Examples of targets

Impact: Well-performing test targets are necessary for safe and efficient testing. A failure of a test must not lead to a dangerous situation for the test engineers. The test engineers also expect the targets to be easy to configure, run and maintain.

4.1.6 Testing of ADAS functions by simulation

Background: Driving assistance functions are intended to perform in many diverse real world scenarios. However, limited resources do not allow a deep development testing / validation process. In other disciplines, such as passive safet, much of the verification activities for crashworthiness and restraint systems are performed using cost-efficient computer simulations. Models of the driver and the vehicle are used. The models and the simulation results are validated using a few real crash tests.

Objective: To investigate the possibility to use computer simulations to partly verify/validate active safety systems; both during development and during performance evaluations. One important aspect is how well the sensor operation can be modelled. Sensor characteristics need to be accurately modelled, including how it is affected by e.g. vehicle movements and other disturbances (glare and unintended radar echoes).

Stochastic simulations considering many different environmental and system-related parameter settings can be simulated with limited efforts and quickly provide illustrative results.

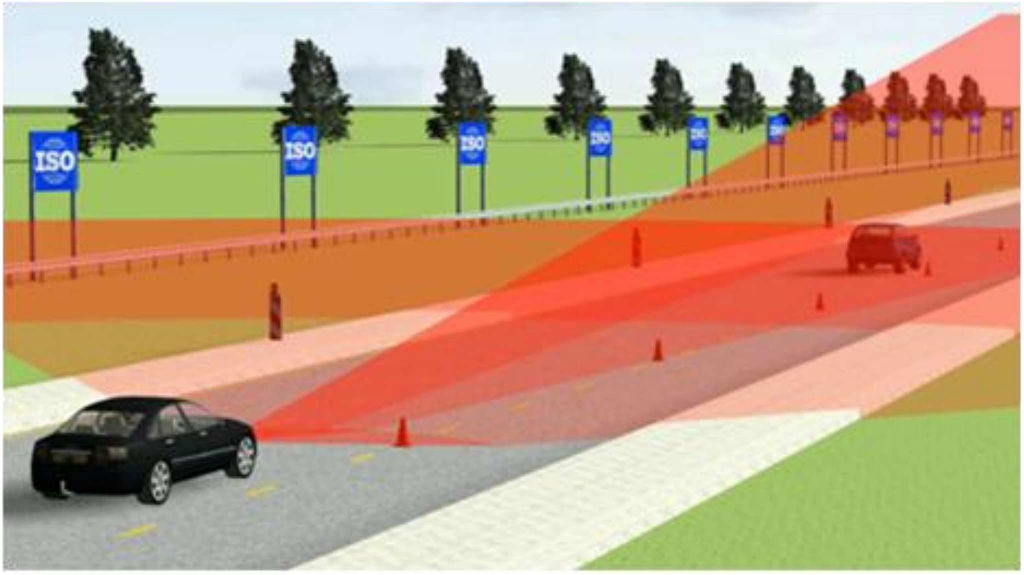


Figure 13 PreScan tool from TNO

Impact:

These simulations can provide qualitative data about possible scenario performance for a given system and the requested sensor performance, algorithm performance and braking system performance.

This can provide ADAS concept studies, sensors benchmarking, algorithm development, sensitivity analysis and robustness validation.

4.1.7 Homologation by simulation

Background: With the European Union setting ambitious targets to halve the number of road deaths on Europe's roads by 2020, the uptake of active safety systems such as ABS and ESC had to be made mandatory for all new vehicles. According to the regulation, not only is fitment necessary, but also that the effectiveness of the systems must meet certain performance criteria for vehicle response and stability. Traditionally the check is made by means of real testing of a vehicle for a variety of manoeuvres, both open and close loop.

Due to the increasing number of variants it is critical to organize ad perform real testing test for each of them. On the other side, the high level of correlation that is possible to reach with modern simulation tools, make their use a very promising possibility in order to reduce the number of tests while keeping the control on the performance of each vehicle variant.

Objective:

In opening up the possibility to use simulation for homologation assessment, it is also necessary to control accuracy and quality of the process and therefore requirements for the use of the simulation are given. The objective is to define a robust procedure that, adopted through all the phases of the homologation by simulation, allows fulfilling objective criteria for the vehicle model validation. This procedure should also become a reference to follow for all projects where simulation replaces real testing for homologation purposes.

Impact:

The possibility to verify and homologate the safety performance through simulation provides manufacturers with an alternative to vehicle testing and also ensures the safety systems are working to specification for each variant.

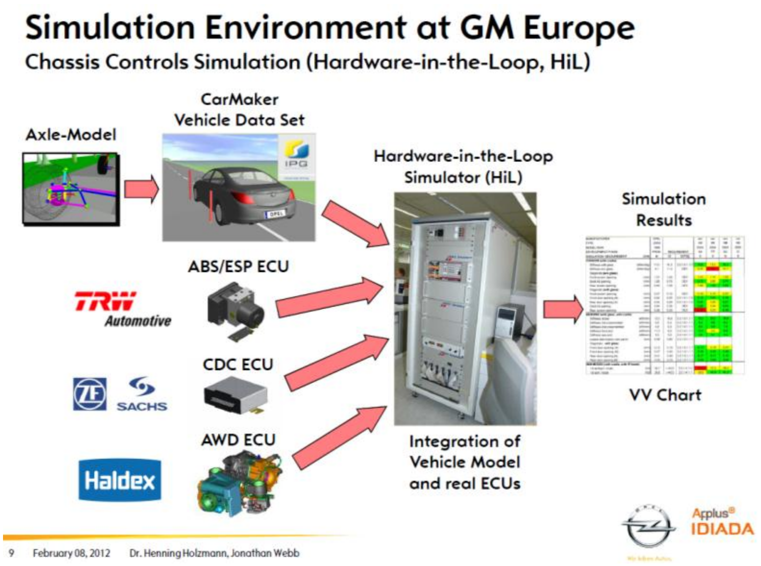


Figure 14 Simulation environment presented by Opel-IDIADA during ActiveTest 2nd workshop

4.1.8 Test methods for Vulnerable Road Users

Background: The numbers of fatalities and serious injuries in road accidents have decreased during recent years, but are still at an unreasonably high level. The number of accidents on rural roads has decreased but there are still a fair number of urban accidents. Vulnerable road users are exposed in accidents in urban traffic scenarios. The need to reduce greenhouse gas emissions may lead to increased use of “soft transport modes” (walking, bicycling etc.).

ERTRAC [ERTRACsra] have identified five parts important for the safety of vulnerable road users:

- Intelligent traffic systems for VRU safe mobility management
- Improved VRU active safety systems for accident avoidance
- Safety systems for the protection of (motor)cyclists in collisions with motor vehicles.
- Safety systems for single vehicle motor-cyclist accidents
- Mitigation of secondary impact

All the systems aimed to protect pedestrians, cyclists and motorcyclists have a common limitation: the time criticality of the triggering event. VRUs have the ability to change their trajectory very fast, when compared with other road users (passenger cars, heavy goods vehicles...). For this reason, VRU detection algorithms have two main limitations when compared with other detection algorithms:

- They need to monitor the position and velocity of the subject during longer periods and judge the probability of the predicted next position. This leads to complex algorithms with long calculation times.

- They need to delay the triggering of the warning signals and the activation of the autonomous emergency braking system until the confidence that the VRU will be in a critical position with a very high probability. If this is not considered, the systems will provide a very high rate of false alarms which will not be acceptable from a end-user point of view.

Objective: Methods to test how active safety systems improve safety for vulnerable road users are needed. Test methods shall be developed for relevant scenarios with pedestrians and two-wheelers. An important request for these test methods is that they are able to test efficiency (activation of the systems when really needed) and specificity (non-activation of the systems when it is not needed, false alarms) of the systems under tests at the same time and without detriment of one against the other.

The test methods need to be based on traffic scenario regarded as representative for many of the accidents. Both urban and interurban scenarios are expected to be equally important. Examples are bicycles in road crossing, pedestrians at zebra crossings and motorcycles advancing in queues between cars and trucks. But also rural scenarios can be of importance. Examples are pedestrians on the road at night, and bicycles crossing country roads.

Figure 15 Pedestrians and bicycles are vulnerable in urban traffic

Impact: Test methods for active safety functions for vulnerable road users will support the development of efficient active safety. Proper test methods will ensure that the functions developed will lead to a reduction of accidents.

The lead time and the development cost of the active safety functions can be reduced if the performance targets are clear.

The public awareness of the benefits and acceptance of active safety functions for vulnerable road users can be increased if the test results are clearly stated to explain the increase in safety.

4.1.9 Analysis of the driver-vehicle interaction

Background: In the operation of almost all active safety systems the driver is to some degree part of the control loop. Either the driver is expected to respond/react to some warning (optic, audio, or haptic) or should have the possibility to override the system. Therefore it is important to analyse how the average driver react in typical critical scenarios. Dangerous situations should be evaluated using driving simulators whereas less harmful ones could be performed in real traffic with certain restrictions and permissions.

Additionally, to better understand human nature and develop new systems with respect to driver drowsiness and inattention, knowledge can be gathered by e.g. measuring brain activity, heart rate, perspiration, tracking eye movement and blink duration/frequency.

It is also important to highlight the particular case of emergency braking systems for protection of vulnerable road users, as they are currently in research and development and HMI performance will play an important role. A market introduction of AEB systems for vulnerable road users is expected in the following years. In order to optimise warning and braking systems the behaviour of vulnerable road users and the interaction with the driver needs to be understood better.

Objective: A specific goal is to find out how drivers interact with active safety systems, and more generally how drivers act and behave during driving, with respect to e.g. fatigue and attention/distraction.

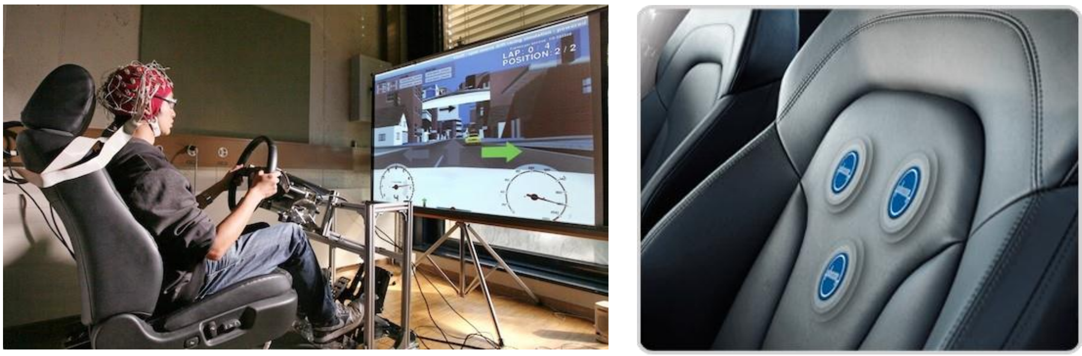


Figure 16 Measuring the brain activity [Nissan] or the heart rate [Plessey] of the driver

Special focus is in the investigation of VRU behaviour and especially on the driver VRU interaction. As many of the VRU pedestrian accidents are caused by mis-interpretation of the criticality of the situation, it is important to better understand the perception of VRU and drivers. Based on this knowledge, detailed models for simulation and test tools are to be developed, which can be used for the development and improvement of active safety systems.

Impact: The collected information can be used to device new or improve active safety systems that keep the driver aware of the surrounding critical events and allow him to react to avoid the accident. This potentially could reduce the number and consequences of road accidents.

4.1.10 Tests in real traffic

Background: The bulk of testing activities before a new active safety system is released on the market is performed in real traffic. A fleet of cars are driven, perhaps with actuators disabled, in real traffic collecting data on potential system activations. This will validate and even improve the effectiveness of the active safety function by exposing it to the diversity (and also non-predictability) of real-world traffic and road conditions. Artificially designed routes with extra difficulties is only one of a variety of choices, ensuring greater diversity in real traffic is another one. The purpose is also to fine-tune the relationship between true and false positives.

A false positive (false alarm) is strictly not allowed for intervening functions e.g. for autonomous braking systems. A false positive in functions giving information (e.g. a lane departure warning system) may to a certain degree be tolerated. A false negative (missed alarm) will noy cause any additional hazard for intervening functions since they may be compared to the absence of the system. A false negative for functions givning information may result in a confused driver if the driver detects a dangerous situation for which the function did not warn.

Objective: To improve the effectiveness of the active safety function by exposing it to the diversity (and al-so non-predictability) of real-world traffic and road conditions. But also to improve the testing for false positives in real traffic by being able to partly control traffic in such a way that more potential false positive situations occur compared to at normal driving. To achieve this, specific routes need to be precisely characterized with respect to speed limits, traffic lights, and other infrastructure. Also communication and synchronization between vehicles becomes important.

A set of well-known reference routes in different traffic environments should be estabilished to be able to run and repeat non-critical tests in a real traffic environment. Detailed knowledge about the road and the road environment will help to analyse the results from tests. The interaction between the vehicle, the driver and the active safety function can be studied in real traffic environment.

Impact: The cost of development testing could be significantly reduced. Availability of equipment and tools for non-critical test scenarios in real traffic will be a supplement to the use of computer simulations, driving simulators and tests at test tracks.

4.1.11 Harmonization of test equipment interfaces

Background: At the moment test equipment for active safety systems are growing rapidly. Data loggers, external sensors, drive robots, and self-propelled targets, all need to be synchronized and sometimes actively interact with each other.

Objective: To define standardized connectors and communication protocols for the exchange of real-time information between different test equipment used during testing of active safety systems. Especially important is to have a common view on time; both for precision control of traffic scenarios, and post-analysis of data.

Figure 17 Steering robot (ABD) and GPS (OxTS, GeneSys, or iMAR)

Impact: Time greatly reduced for test on proving grounds.

4.2 Research topics related to technologies that are under development

4.2.1 Integrated safety

Background: Today active and passive safety features in a vehicle are developed and tested mostly independently of each other. Integrated safety features are not taken into account as an essential part in the vehicle development process.

Objective: Integrated safety has been characterized under earlier development phases by extending the activation of already existing passive safety features. This is the case for features applied to passive components such as the pre-crash tightening of the safety belt, or the pre-crash headset that shifts forward to mitigate the whiplash damage resulting from a rear-end collision at lower speed. The active hood that is activated by an impact sensor belongs also to this category.

The next development step of integrated safety shall aim at implementing preventive safety functions that can take advantage of an infrastructure system that provides road-to-vehicle communication and communication systems that enable transmission of information vehicle-to-vehicle. Ultimately a synergic effect on overall safety could be obtained by using such information to enhance safety performance in traffic scenarios involving not only one vehicle and a potential obstacle but rather a fleet of vehicles and potential obstacles. A typical traffic scenario that could be avoided or mitigated is the series of collisions with many cars involved.

Impact: A positive increase of vehicle safety will be provided by integrated safety features, road infrastructure and communication facilities. Integrated safety features not only help to increase the overall safety of a vehicle, but could also have a positive influence on further characteristics such as vehicle weight, design and final overall costs.

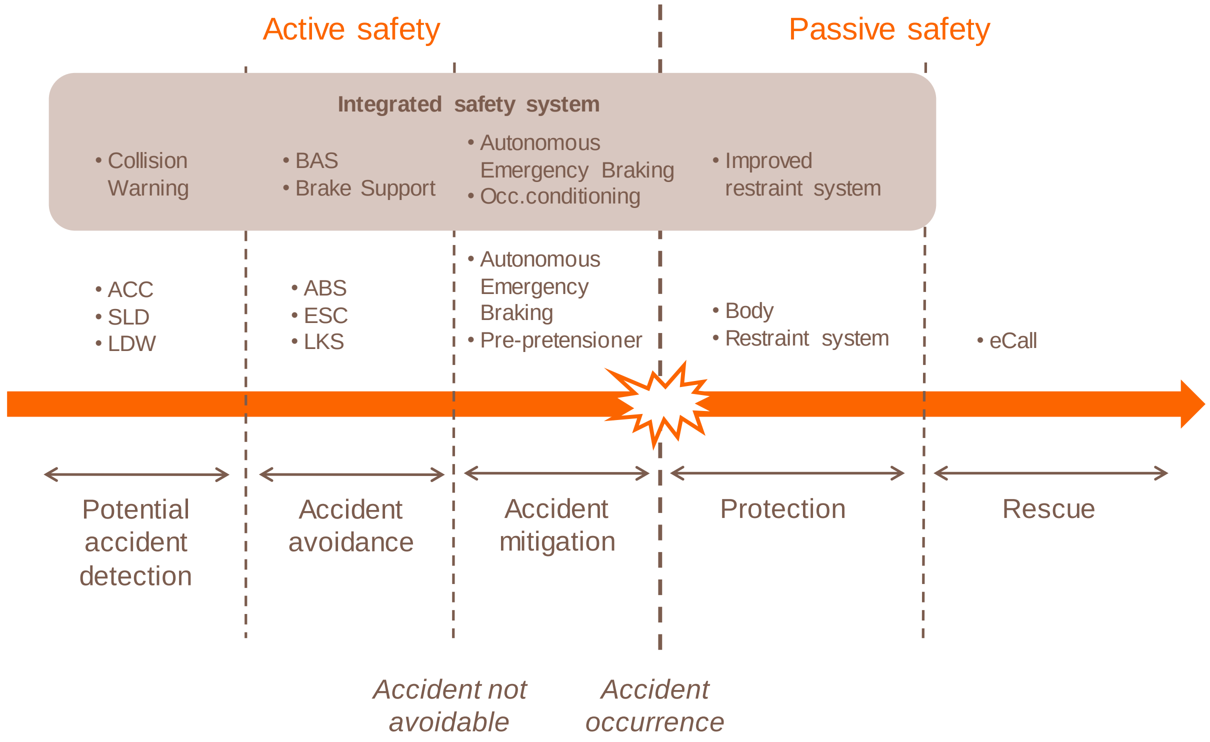


Figure 18 Phases of safety

4.2.2 Rapid testing through use of miniature vehicles

Background: During the concept phase, new potential active safety systems are evaluated in driving simulators or on the test track. These are very good methods but they are not cost efficient. Rapid prototyping using scaled miniature vehicles could be an alternative.

Such a test facility requires limited computational resources even for a complex scenario with many vehicles. The tests can be performed indoors in a limited space, and thus becomes e.g. weather independent.

A scaled lab is especially useful for active safety systems based on wireless communication, in e.g. intersection or oncoming scenarios.

A challenge is to realistically mimic the vehicle dynamics and sensor capabilities in a scaled environment.

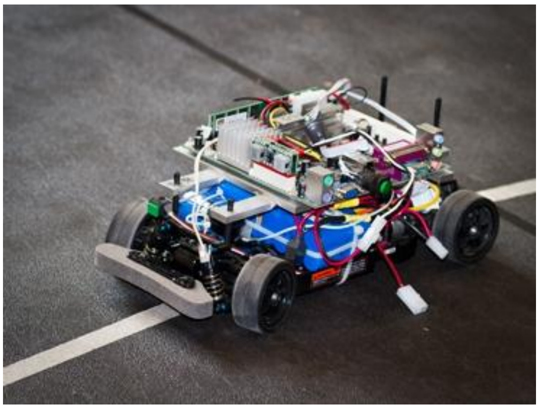


Figure 19 Multi-vehicle lab of MIT

Objective: The aim is to develop a scaled environment where several miniature vehicles can interact in a realistic way. Sensor performance and vehicle dynamics must be adapted to the scaled systems.

A pseudo GPS positioning system must be present in indoor facilities, and an accurate reference positioning system should be available as well to support the evaluation of experiments.

Manual control (steering, braking, etc.) shall be realised preliminarily to driver behaviour studies.

The final objective is the realisation of an adequate platform of sensors and other equipment with characteristics comparable to realistic traffic situations. A preliminary analysis is necessary to select appropriate parameters and scenarios. It is obvious that there are limitations to the feasibility of complete environment emulation and to anticipate at this stage the width of information that can be extracted. The next step is to explore the methods to extrapolate obtained emulation results to realistic traffic scenarios.

Impact: New promising active safety systems can be evaluated without spending too much resource on expensive and time-demanding tests in driving simulators or on the test track.

4.2.3 Simulation for safety functions based on cooperative systems

Background: The active safety functions available in road vehicles today use information from sensors of the own vehicle. Yaw rate, wheel rotation, speed, steering angle and vision information are examples of information which is fed into the active safety functions. The sensors are continuously developing to allow cost-efficient monitoring of information important to the safety of the vehicle.

Road vehicles will soon be connected by wireless to other vehicles and to the infrastructure. It will be possible to receive information from other actors in the traffic environment and to act accordingly. It can be expected that the information from the traffic environment also will be used in active safety functions. One example is that the position, speed and direction of surrounding vehicles can be monitored by wireless. This is today made by vision and radar sensors combined with algorithms to identify the other vehicles.

Future autonomous emergency braking may partly depend on cooperative systems. This is an example of where a simulated target vehicle can trigger the braking action of a real test vehicle on the track.

Objective: Development facilities and proving grounds have to be able to simulate wireless signals from other actors in the traffic environment. It will not always be feasible to drive real target vehicles at the proving ground. The objective would be to simulate a wireless environment where the systems of the vehicle under test receives wireless signals and responds as if real physical “dummies” and target vehicles were present.

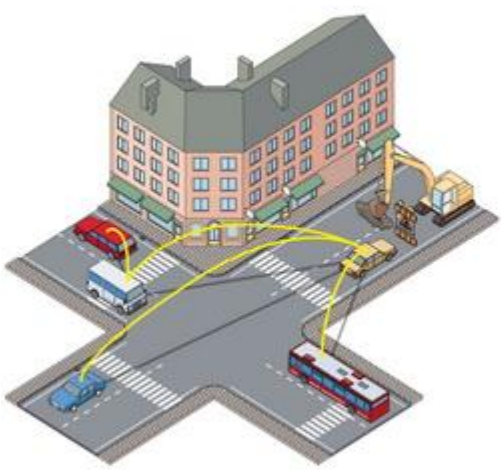


Figure 20 Exchanging traffic information in a cooperative system [www.safespot-eu.org]

The contents of a message sent from a simulated target must contain reliable data on position, orientation and time. GNSS satellite data (Galileo, GPS or other) need to be available with high precision. This cannot always be guaranteed, especially in scenarios where occlusion of satellites may occur. Techniques and measures to provide reliable position data for the simulated targets are needed.

Propagation of radio waves in the frequency bands used require a more or less free line-of-sigth. This means that messages may be lost when vehicles are separated by buildings, trees or other large vehicles. Simulation of radio wave propagation cannot be realistically made with limited efforts.

Disturbances is the communication will be possible to simulate by including an algorithm in the sending or the receiving node to drop certain messages by random or in a specific sequence.

Impact: The simulation of a wireless traffic environment will facilitate testing of active safety functions based on wireless connections. This is necessary to demonstrate the safety of future cooperative safety functions. It will also be quicker and less expensive than actually bringing real vehicles, target vehicles and pedestrians together to reconstruct a traffic scenario.

The safety will also be increased since the risk of hitting other vehicles during the test will be dramatically reduced.

One limitation of simulating the environment by wireless connections is that a human driver will not see the other partners in the traffic scenario. It will be enough to test the active safety systems reacting on wireless inputs. But it will not be enough to put the driver in the loop as the other vehicles will be invisible to him.

4.2.4 Augmented reality

Background: Some driving scenarios are too dangerous or too costly to reproduce on the test track. Therefore, it is beneficial to perform tests in a partly simulated environment. This can be accomplished by augmented reality where the field of view w.r.t. the driver or the sensor is augmented by simulated/purely virtual objects. Compared to a pure driving simulator test, the driving experience is more realistic due to non-simulated vehicle dynamics. As such, the probe effect of augmented reality-based test is smaller than for driving simulator studies. Since the test persons is actually driving a real car, there is a risk of harm to the person or the vehicle which would intrinsically induce a more natural driving behaviour.

Objective: The goal is to develop techniques for the use augmented reality in tests of active safety systems. It is challenging to add virtual objects in the field of view with realism. Head and car movements need to be handled in real-time to give any sense of reality. Virtual objects need to be synchronously presented to both the driver and the active safety system. Possible technologies are VR helmets or see-through displays.

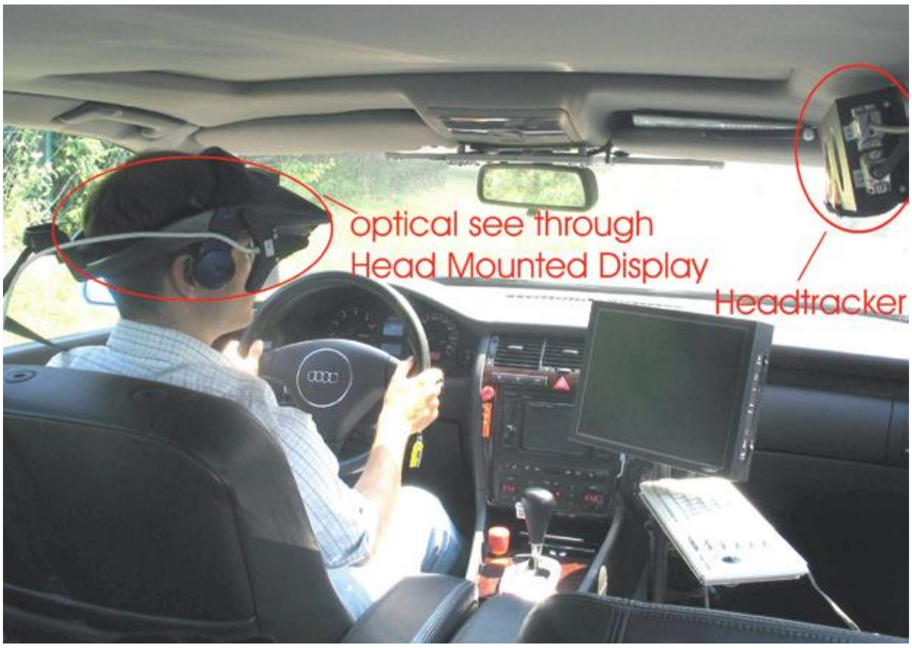


Figure 21 Example of equipment for augmented reality

Impact: Tests, which otherwise are too dangerous to perform with human drivers, can be performed. Sensors can be tested for a variety of driving situations.

4.2.5 Scenario development based on naturalistic driving data

Background: Today development and testing of safety systems is mainly based on accident data. For accident data development of different data bases has started some years ago. There are intentions to generate detailed data bases on European level or in-depth data bases such as the German GIDAS data base.

The disadvantage of accident data bases is that only cases are considered in which an accident happens. It is quite difficult to reconstruct accidents and find the root cause for an accident to happen. Especially accidents which are caused by the driver cannot by analysed in as much detail as necessary.

Naturalistic driver behaviour needs to be understood in order to reduce accidents cause by the driver and develop the necessary safety system.

Objective: The goal is to create a database of critical scenarios by means of naturalistic driving data. This data base would include not only accidents, but also critical situations, which can lead to accidents due to driver errors such as driver distraction.

Impact: The data base will support the development of new active safety systems and increase active vehicle safety in critical driving situations. The systems will detect the driver's behaviour and act appropriate in order to mitigate or avoid critical situations which have the potential to lead to accidents.

4.2.6 System safety analysis

Background: Coupled functions and complex traffic scenarios require thorough understanding of the risks associated to them. One example would be when future autonomous driving vehicles are mixed with manually driven vehicles and pedestrians in urban environments. The traffic scenario will then be quite complex. It will not be a trivial task to identify the all hazards and to estimate the risks. A hazard and risk analysis should identify all hazardous situations, evaluate the risks and analyze how different safety functions can influence each other. Test procedures and test cases have to be developed to cover all potential hazards.

The system safety will be depending on proper handling of all hazards associated with the scenario. Driver actions, vehicle functions, failure of a vehicle, failure of the infrastructure, weather conditions, traffic density and other factors need to be judged.

Objective: The goal is to develop a method to identify hazards and estimate risks for complex traffic systems and thereby understanding the need for new active safety functions. Principles for reducing the unacceptable risks should be proposed. Methodology used for development of functional safety in electronic systems in road vehicles may be applied for the traffic system.

Figure 22 Hazardous situations in complex traffic scenarios can be difficult to comprehend

Impact: The methods for system safety analysis will support the understanding of complex traffic systems and help the introduction of novel active safety systems.

Examples of future complex traffic scenarios where safety analysis would be beneficial are:

- Scenarios where new vehicles incorporating active safety functions are mixed with older vehicles without those active safety functions. What new risks will occur depending on the mix of vehicles?
- Scenarios where vulnerable road users are exposed to vehicles with active safety functions to protect pedestrians and bicyclists. Will major risks be significantly reduced by the active safety functions?
- Scenarios where an old infrastructure developed for a small flow of vehicles suddenly is used for a large flow of vehicles. How can active safety functions be developed and what safety integrity level will be needed?

4.2.7 Accident avoidance by steering

Background: Braking has become commonplace as collision avoidance/mitigation technique in active safety systems. In specific situations when braking would be insufficient to avoid a collision, steering could be employed to perform an evasive manoeuvre. Generally, at higher speeds, avoidance by steering can be more efficient than braking to absolute stop. However, compared to braking, automatic steering needs longitudinal view of the oncoming traffic situation and the lateral situation of all traffic.

So far, most of the activities addressing autonomous emergency steering systems have focussed in the development of real-time vehicle models which can precisely determine the steering actions requested to avoid impacts against stationary or moving obstacles. This can be easily tested with typical vehicle dynamics scenarios. However, it is still missing knowledge on how to evaluate the performance of the detection algorithms for oncoming and lateral traffic.

Objective: To develop active safety systems that use steering to avoid or mitigate collisions; either by supporting the driver, or autonomously steer the vehicle. Steering support during an evasive manoeuvre can be performed by stiffening the suspension and adding torque. Steering can be used to divert to a “free space” during an impending collision, or to steer the vehicle back during a lane departure.

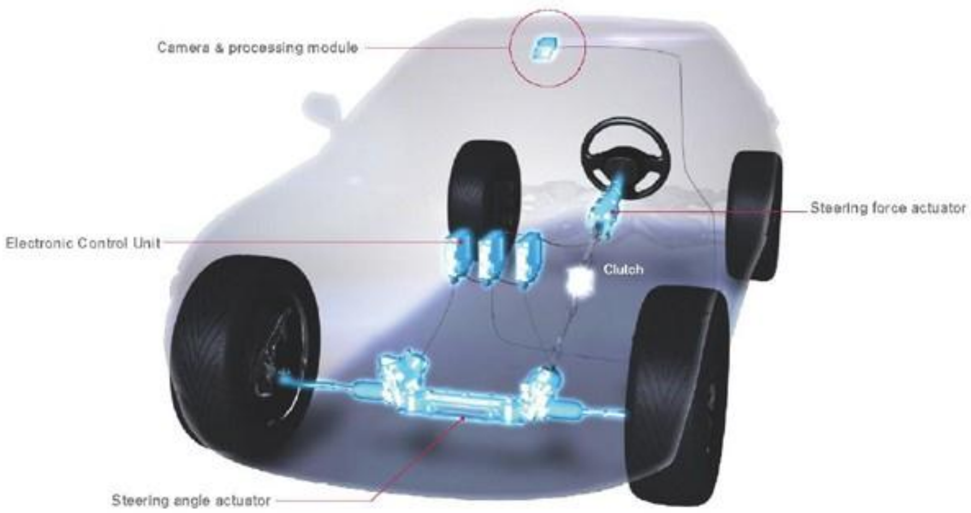


Figure 23 Steer-by-wire from Nissan, which enables autonomous emergency steering

Impact: Collision avoidance/mitigation systems have the potential to reduce the number of fatal accidents at high speeds, and reduce the severity of injuries during accidents.

4.2.8 Torque vectoring techniques

Background: The idea and implementation of torque vectoring are both very complex. The main goal of torque vectoring is to independently vary the torque being sent to each wheel. A torque vectoring system needs a specific electronic monitoring system on top of the standard traditional components (differential, motors). This electronic system is in charge of telling the actuators when and how to vary the torque output. In comparison to Electronic Stability Control systems, torque vectoring includes the possibility of distributing more additional torque to any the wheels (accelerating), while ESC is intended to brake (decelerate) independently any of the wheels.

This torque transferring ability improves handling and traction in almost any situation. When the torque can be actively distributed individually to the different wheels of the vehicle, responsiveness is increased, traction in corners is improved, and oversteer and understeer can be caused / mitigated.

The technology has slowly developed and is now being implemented in a small variety of production vehicles. The most common use of torque vectoring in automobiles today is in all-wheel drive vehicles. New electric vehicles and, specially, those equipped with in-wheel motors, allow new possibilities for torque vectoring techniques.

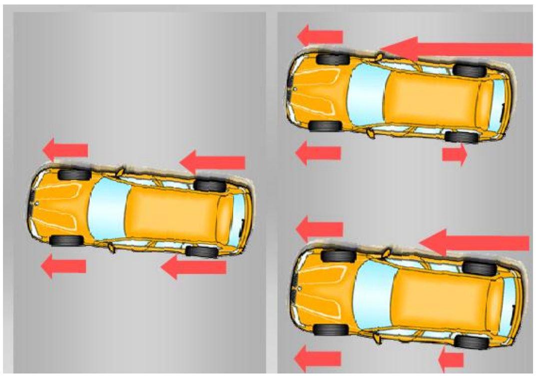


Figure 24 Torque vectoring (Dynamic Performance Control) by BMW

Objective: To improve the handling of the vehicle by individual control of the torque for each wheel. The torque can be controlled by braking wheels independently, having an active differential, or having an individual electric motor in each wheel, which could be the case in future electric vehicles.

However, torque vectoring is not excessively spread as it is mainly aimed for handling purposes. For safety purposes, the functionalities offered by ESC should be sufficient. For this reason, it is proposed to derive new test methods with complex dynamic scenarios which are able to demonstrate / validate the potentials of torque vectoring techniques.

Impact: To improve the handling and control of the vehicle while allowing customizable different vehicle behaviours.

4.2.9 Active safety functions enabled by Galileo GNSS

Background: The European global navigation satellite system (GNSS) Galileo is currently being built by installing the required satellites in their orbital positions. One of the key features and advantage as compared to the established US GPS is a service called Safety of Life that provides in addition to the current position a warning in the case the system should not be used for exact positioning any more, e.g. due to a failure or inaccuracy resulting from a bad signal reception. This service could allow to base active safety functions only or to a large extent solely on the Galileo positioning signal. Expensive positioning by sensors installed on board of vehicles might become obsolete.

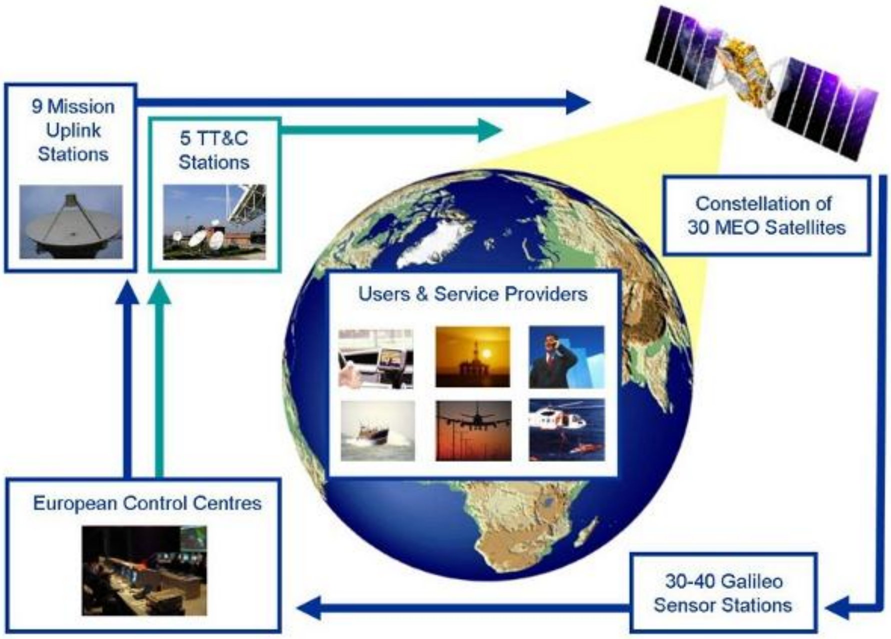


Figure 25 Galileo GNSS system overview

Objective: To investigate possibilities of active safety functions that are merely built on the Galileo positioning signal. The required accuracy is of highest importance in this regard. Furthermore their interrelation with other safety functions and sensors should be analysed. Application in the individual vehicle might be a first step, while a second step could be the establishment of a traffic control system that monitors each vehicle, its position and destination, thus being able to analyse and optimise traffic flow. A comparison could be the traffic control system for aircrafts, while this is mainly executed manually.

Impact: Simplification of safety systems and functions, related cost savings and consequently penetration rates which ultimately leads to higher safety in traffic. A general traffic control system could increase traffic flow significantly by providing optimal routes for individual cars taking into account the total traffic around and designated destinations.

5 Discussions at ActiveTest workshops

5.1 Workshop 1

Workshop 1 addressed particularly Collision Warning and Autonomous Emergency Braking systems and also specific definition issues related to test targets.

1. **Development of test scenarios specially" vehicle to pedestrian" scenarios**

The final goal is to assign to the active safety functions aiming at preventing or mitigating the effect of car-to-pedestrian accidents their fare contribution in the assessment of the overall safety. The term Collision Warning and Autonomous Emergency Braking applies to vehicle-to-vehicle scenarios as well as to vehicle-to-pedestrian scenarios. Meanwhile more attention was given to vehicle-to-vehicle scenarios, due to the fact that these functions are already on the market or about to be introduced on the market.

Focus should be set on the development of test scenarios and test procedures reflecting realistic traffic situations involving pedestrians and cars. Development of measuring equipment as well as test metrics and rating methods are a part of this process.

The development of vehicle-to-pedestrian scenarios and the implementation of associated test procedures require the settlement of issues related to the detection of pedestrian targets. The characterization of (a) standard pedestrian(s) must comply with realistic traffic conditions. The first step is to extract from available traffic accident data bases the most relevant test scenarios.

2. **Development of standard test targets that are compatible with current and future sensor technologies**

The assessment of object position, distance speed and size is implemented at the present time with various sensor technologies such as: short-and long-range radar, mono and stereo camera, infrared camera, multi-beam and scanning lidar, ultrasound, laser, etc.
A standard test target shall be independent of the sensor technology implemented but shall simulate the real object that shall be detected: car, truck, motorcycle, bicycle, pedestrian or infrastructure element. Thus the definition of the standard target shall always specify basic parameters such as shape, and size. The next step is the definition of the characteristics of the test target that are related to the discriminating quality of the object in relation to the traffic environment.

3. **Estimate the impact of active safety functions on road safety**

Estimations of the benefit of driver assistance safety systems for road safety have been presented in the context of two research projects, namely, FP6 projects TRACE and eIMPACT. To estimate the impact of the safety functions provided by the current systems entering the market, the figures presented earlier need to be validated.

To achieve this goal will necessitate the execution of Field Operational Tests as well as a cost benefit analysis, as it is currently done in projects such as euro FOT and Tele FOT.

4. **Address driver behavior (reaction, reaction time etc.)**

Further development of test scenarios and test procedures for the assessment of overall safety requires the integration of the driver reaction and behavior. Focus could be put on the development of mechanisms enabling to take into account the driver reaction and behavior for a more realistic set-up of test scenarios and test procedures.

5. **Integration of passive safety systems to earlier detection of critical traffic situations**

By sharing sensor data and by using sensor fusion, the performance of passive safety systems can be improved if sensor data from active safety functions becomes available. As an example, during an automatic braking maneuver, the optimal braking force cannot be applied because the driver is out of position. By using data provided by the AEB system it is possible to apply pre-tensioning of the seat belt to adjust the position of the driver. The out-of-position can also be reduced in e.g. curved roads by having predictive belt functions based on combined GPS position data and a map with the road curvature. These functions are partly already on the market and shall be extended in the future with new or improve applications.

5.2 Workshop 2

Workshop 2 addressed particularly handling and stability assessment procedures and homologation/performance testing of ESC systems.

1. **Define objective test methods that correctly discriminate safety performance among vehicles without considering other aspects more related to driving feeling and quality perception.**

It is very difficult to objectively compare different vehicles, especially within different vehicle segments. Several metrics and maneuvers can be defined, but they are not able to explain the behavior of all tested vehicles.

The present ESC procedures for regulation purposes were set-up to establish basic requirements that any vehicle fitted with an ESC system could fulfill. Consequently the manoeuvers associated to these procedures are not intended for assessment but to verify an ESC system installed in a vehicle complies with the basic requirements.

Find an approach for test procedures where appropriate test data result is compared with data from a defined path profile. Such procedures would require access to a robot driver corresponding to a standardized normal driver behavior. Thus the necessity to establish the characteristics of the:

- Robot driver
- Path profile
- Safety performance indicator(s)

2. Feasibility of simulation-based homologation of ESC systems.

Different project cases were presented giving a good understanding of how to link all simulation and testing activities. The implementation of the simulation process would require the definition of tools for software and hardware in the loop simulations. There remains some concern regarding the need of cooperation between ESC system suppliers and those following the simulation-based homologation work progress for access to relevant information. Further study is needed to define the combination of items and steps required by the homologation process such as:

- The combination of models and the characterization of all components affecting handling and stability of the vehicle. One important discussion was the need of grouping vehicle variants. Due to the amount of vehicle variants for the same model, it is impossible to tune an ESC system for all of them.
- The specification of the accuracy levels required in each of the steps of the process and identify the relevant performance indicators.

The simulation-based process shall eventually accelerate the development of ESC systems and ultimately provide better vehicle performance with reduced development costs, especially when a vehicle is provided with a large number of variants.

Meanwhile to be realized, the collaboration of vehicle manufacturers, ESC system suppliers, system integrators and validators is a necessity. It is imperative that they participate together along the whole process.

3. Study of the feasibility of simulation-based performance testing

Performance testing of active safety functions according to the test procedures for longitudinal, lateral and stability domains is expensive and time-consuming. Simulation-based performance testing could be used as a complement to bring down the scope of physical tests.

The experience acquired in developing the requirements for simulation-based homologation of ESC could give some guidance in the development of simulation-based procedures for performance testing of active safety functions.

5.3 Workshop 3

Workshop 3 addressed the activities concerning the development and the assessment of active safety functions in vehicles for the protection of Vulnerable Road Users (VRU).

1. Development of test scenarios addressing the avoidance and/or mitigation of accidents involving vehicles and vulnerable road users

The conditions affecting the probability of an accident to occur have to be accounted for in test scenarios addressing accidents involving vehicles and VRUs. There exist already test scenarios based on estimated walking speed, running speed for adults and children and for cycling speed. Must special tests scenarios be developed for elderly VRUs? Their behavior differs from other groups and their number in the traffic is constantly increasing.

Furthermore, there is still a polemic regarding the VRUs to be addressed in the test scenarios. A question which has been raised is if VRUs shall include powered two-wheeler riders beside cyclists and pedestrians.
Pedestrian detection and auto-brake speed reducing systems (pedestrian detection with auto-brake) offers a great potential in the realization of different accident scenarios with different car speeds and pedestrian sizes.

2. Development of test procedures for the assessment of safety functions addressing the protection of vulnerable road users.

Adequate safety performance indicators are essential to characterize the behavior of the tested vehicle according to the safety function being tested. The choice of safety performance indicators must be a part of the development process of the test procedures and has to take into consideration various aspects such as:

- Test track conditions
- Temperature conditions
- Data collection system
- Visibility conditions
- Subject vehicle type and configuration: passenger car, truck, commercial vehicle
- The target VRU involved: adult, child

The purpose of these test procedures is to assess the overall safety performance of the subject vehicle based on its capability to detect the VRU and avoid/mitigate a potential traffic accident. The final challenge is to ensure the reproducibility of the testing procedure while respecting the required ambient conditions, and the technical aspects concerning track, brakes, tires, dummy and measuring equipment.

3. Development of dummy targets that simulate the behavior of vulnerable road users (pedestrian, cycle and motorcycle riders) in critical traffic situations.

The dummy targets that can be used for the tests required for the assessment of overall safety in vehicles must be adapted to realistic traffic situations. An estimation of pedestrian (adult, child and elderly) speed while walking and running has been done and can be used in test scenarios. The test scenarios involving cyclists or powered two-wheeler riders require especially adapted target dummies. There exist so called autonomous vehicles for certification of active safety systems (AVCASS, UFO, and others) intended for pedestrian dummies and other small low speed targets and balloon cars. The development of similar systems could result in adequate platform for testing cyclist and motorcyclist dummies.

4. Integration of passive safety protection devices and active safety functions

Pedestrian detection and auto break speed-reducing systems provide a potential platform for protection of VRUs. Legs, arms, shoulders and head are among the most frequent body part injuries. Such knowledge could be useful to optimize the integration of passive safety protection devices and active safety functions. A co-operation between car manufacturers, suppliers and biomechanics laboratories could be an interesting approach to the development of integrated safety in automobiles. In that context, the same considerations should be observed in the design of integrated safety in trucks and other types of heavy vehicles.

6 Conclusions

Rapid technological development

The development of active safety functions has been rapid during the past years. New safety functions have been introduced in cars and trucks. For cars, the introduction of new functions is mainly in the high-end cars. But we can notice that the first active safety functions have been carried-over from the high-end cars to cars in the medium price range. At the same time new innovative safety functions are demonstrated by research initiatives.

There are several research agendas for sustainable transport and automotive technology. All of these mention active safety functions as a research topic to consider. The automotive safety topic is expected to be addressed in future European research, both at national level for individual member states and as European co-operation.

Test harmonization needed

Vehicle manufacturers, suppliers and researchers are cooperating to develop and harmonize test methods for active safety. There are several groups working on different topics. The need for harmonization has been identified and harmonization platforms exist. But work within industry, standardisation and research still has to be aligned.

Research topics identified

The ActiveTest roadmap for future research has identified research topics spanning the whole traffic system; i.e. the vehicle, the driver and the infrastructure. Sometimes the active safety aspect can be addresses as a main topic. Sometimes the safety aspects are integrated in broader research topic spanning a wide scope within sustainable transport.

The main research topics for testing of active safety in road vehicles can be described in four areas:

- Analysis of drivers, accidents and impact
- Performance testing
- Development testing
- New systems and technologies

Exchange of experience beneficial

The contact network created during the ActiveTest support action has shown that there is a need for an open and independent initiative for exchange of experience. Test methods for active safety functions can to a large degree be regarded as pre-competitive. This makes it possible for industry to participate. Among the specific research questions suggested are

- Testing of “false positives”
- Follow-up on automatic braking
- Follow-up on vulnerable road users
- HMI, How can active safety functions best communicate with the driver?
- Test environments

We propose to continue with discussions (workshops) of these important issues.

7 References

[ASSESS] www.assess-project.eu

[AsPeCSS] www.aspecss-project.eu

[ERTRACscen] ERTRAC Road Transport Scenario 2030+
"Road to Implementation"
October 2009
Download at www.ertrac.org

[ERTRACscenExSum] ERTRAC Road Transport Scenario 2030+
"Road to Implementation"
Executive Summary
October 2009
Download at www.ertrac.org

[ERTRACsraExSum] ERTRAC Strategic Research Agenda 2010
Towards a 50% more efficient road transport system by 2030
Executive summary
October 2010
Download at www.ertrac.org

[ERTRACsra] ERTRAC Strategic Research Agenda 2010
Towards a 50% more efficient road transport system by 2030
Technical Document. Background document to the SRA Executive Summary
October 2010
Download at www.ertrac.org

[ElecRoad] European Roadmap, Electrification of Road Transport
2nd Edition June 2012
ERTRAC/EPoSS/SmartGrids
Download at www.ertrac.org (other sites are available)

[EUCARChalPrior] EUCAR Challenges and Priorities for Automotive R&D
27th May 2011
Download at http://www.eucar.be/publications/Challenges_Priorities/view

[EARPAPosPapSaf] EARPA Position Paper
Further Advanced in Road Safety Importance for European Road Transport Research
17th October 2012
Download at http://www.earpa.eu/earpa/22/position_papers.html

[CLEPA] About CLEPA
Website: http://www.clepa.eu/about-us/

[CLEPAStratResAgend] CLEPA Strategic Research Agenda
The Future of Automotive Research
Research & Development - Trends for the next Decades
November 2006

[EPoSS] STRATEGIC RESEARCH AGENDA of The European Technology Platform on Smart Systems Integration, Version 2, March 10, 2009

Annex A. Standards and Regulations

Within the International Organization for Standardization (ISO) there are two technical committees (TCs) with activities related to active safety systems. In TC 22 - Road Vehicles, there is a subcommittee (SC 9) responsible for standards related to vehicle dynamics and road-holding ability. Examples are standards for braking as well as lateral, yaw and roll stability. The second relevant committee is TC 204 in which one working group (WG 14) is working with standards related to vehicle/roadway warning and control systems. Examples are standards for FCW, ACC and LDW systems.

SAE International also has some committees working on standards related to active safety systems. The most relevant committee is the Safety and Human Factors steering committee within the Vehicle Safety Systems group. Other relevant SAE groups and committees are: Safety Systems Component Advisory group, Truck and Bus Brake Systems committee and Highway Time Forum Steering committee.

The National Highway Traffic Safety Administration (NHTSA) in the US has proposed three test procedures for FCW, LDW and ESC systems which are related to US NCAP (New Car Assessment Programme) assessments. Euro NCAP has a specific test protocol for ESC systems, and other active safety systems can be rewarded (Euro NCAP Advanced) by using the Beyond Euro NCAP Assessment Protocol. ESC systems are rewarded if fitted in the assessed vehicle in the Australasian NCAP (ANCAP). Other NCAP organizations are: Japan NCAP (JNCAP), China NCAP (C-NCAP) and Korea NCAP (KNCAP).

ISO 3888-1:1999 Passenger cars -- Test track for a severe lane-change manoeuvre -- Part 1: Double lane-change

ISO 3888-2:2002 Passenger cars -- Test track for a severe lane-change manoeuvre -- Part 2: Obstacle avoidance

ISO 4138:2004 Passenger cars -- Steady-state circular driving behaviour -- Open-loop test methods

ISO 6597:2005 Road vehicles -- Hydraulic braking systems, including those with electronic control functions, for motor vehicles -- Test procedures

ISO 7401:2003 Road vehicles -- Lateral transient response test methods -- Open-loop test methods

ISO 7975:2006 Passenger cars -- Braking in a turn -- Open-loop test method

ISO/TR 8725:1988 Road vehicles -- Transient open-loop response test method with one period of sinusoidal input

ISO/TR 8726:1988 Road vehicles -- Transient open-loop response test method with pseudo-random steering input

ISO 9815:2010 Road vehicles -- Passenger-car and trailer combinations -- Lateral stability test

ISO 9816:2006 Passenger cars -- Power-off reaction of a vehicle in a turn -- Open-loop test method

ISO 11012:2009 Heavy commercial vehicles and buses -- Open-loop test methods for the quantification of on-centre handling -- Weave test and transition test

ISO 11026:2010 Heavy commercial vehicles and buses -- Test method for roll stability -- Closing-curve test

ISO 12021:2010 Road vehicles -- Sensitivity to lateral wind -- Open-loop test method using wind generator input

ISO 13674-1:2010 Road vehicles -- Test method for the quantification of on-centre handling -- Part 1: Weave test

ISO 13674-2:2006 Road vehicles -- Test method for the quantification of on-centre handling -- Part 2: Transition test

ISO 14512:1999 Passenger cars -- Straight-ahead braking on surfaces with split coefficient of friction -- Open-loop test procedure

ISO 14791:2000 Road vehicles -- Heavy commercial vehicle combinations and articulated buses -- Lateral stability test methods

ISO 14792:2003 Road vehicles -- Heavy commercial vehicles and buses -- Steady-state circular tests

ISO 14793:2011 Road vehicles -- Heavy commercial vehicles and buses -- Lateral transient response test methods

ISO 14794:2011 Heavy commercial vehicles and buses -- Braking in a turn -- Open-loop test methods

ISO 15037-1:2006 Road vehicles -- Vehicle dynamics test methods -- Part 1: General conditions for passenger cars

ISO 15037-2:2002 Road vehicles -- Vehicle dynamics test methods -- Part 2: General conditions for heavy vehicles and buses

ISO 16234:2006 Heavy commercial vehicles and buses -- Straight-ahead braking on surfaces with split coefficient of friction -- Open-loop test method

ISO 16333:2011 Heavy commercial vehicles and buses -- Steady-state rollover threshold -- Tilt-table test method

ISO/AWI 16552 Heavy commercial vehicles and buses -- Stopping distance in straight-line braking with ABS -- Open loop and closed loop test methods

ISO 17288-1:2011 Passenger cars -- Free-steer behaviour -- Part 1: Steering-release open-loop test method

ISO 17288-2:2011 Passenger cars -- Free-steer behaviour -- Part 2: Steering-pulse open-loop test method

ISO/TS 20119:2002 Road vehicles -- Test method for the quantification of on-centre handling -- Determination of dispersion metrics for straight-line driving

ISO 21994:2007 Passenger cars -- Stopping distance at straight-line braking with ABS -- Open-loop test method

ISO/AWI 11270 Lane keeping assist systems

ISO 15622:2010 Intelligent transport systems -- Adaptive Cruise Control systems -- Performance requirements and test procedures

ISO 15623:2002 Transport information and control systems -- Forward vehicle collision warning systems -- Performance requirements and test procedures

ISO 17361:2007 Intelligent transport systems -- Lane departure warning systems -- Performance requirements and test procedures

ISO 17386:2010 Transport information and control systems -- Manoeuvring Aids for Low Speed Operation (MALSO) -- Performance requirements and test procedures

ISO 17387:2008 Intelligent transport systems -- Lane change decision aid systems (LCDAS) -- Performance requirements and test procedures

ISO 22178:2009 Intelligent transport systems -- Low speed following (LSF) systems -- Performance requirements and test procedures

ISO 22179:2009 Intelligent transport systems -- Full speed range adaptive cruise control (FSRA) systems -- Performance requirements and test procedures

ISO/AWI 22839 Intelligent Transport System -- Forward Vehicle Collision Mitigation Systems - Operation, Performance, and Verification Requirements

ISO 22840:2010 Intelligent transport systems -- Devices to aid reverse manoeuvres -- Extended-range backing aid systems (ERBA)

ISO/NP TR 26682 Crash and Emergency Notification Reference Architecture

ISO/NP 26684 Cooperative Intersection Signal Information and Violation Warning Systems (CISIVWS)

J2399_200312 Adaptive Cruise Control (Acc) Operating Characteristics and User Interface

J2400_200308 Human Factors in Forward Collision Warning Systems: Operating Characteristics and User Interface Requirements

J2478 (WIP) Proximity Type Lane Change Collision Avoidance

J2536_200401 Anti-Lock Brake System (ABS) Road Test Evaluation Procedure for Trucks, Truck-Tractors and Buses

J2802_201001 Blind Spot Monitoring System (BSMS): Operating Characteristics and User Interface

J2808_200708 Road/Lane Departure Warning Systems: Information for the Human Interface

J2830_200807 Process for Comprehension Testing of In-Vehicle Icons

J2909_201005 Light Vehicle Dry Stopping Distance

J2926 (WIP) Rollover Test Methods

U.S. DOT/NHTSA - NCAP Lane Departure Warning Test Procedure, Document ID: NHTSA-2006-26555-0125

U.S. DOT/NHTSA - NCAP ESC Test Procedure, Document ID: NHTSA-2006-26555-0126

U.S. DOT/NHTSA - NCAP FCW Test Procedure, Document ID: NHTSA-2006-26555-0128

UNECE Regulation No. 13-H - Rev. 1 - Amend. 2 - Braking of passenger cars

Euro NCAP ESC Test Protocol

Beyond NCAP Assessment Protocol

Annex B. List of Acronyms

ABS	Antilock Brake System
ACC	Adaptive Cruise Control
ACEA	European Automobile Manufacturer Association
ADAC	German motoring club, member of the Euro NCAP Allgemeiner Deutscher Automobil-Club
ADAS	Advanced Driver Assistance Systems
AEB **AEB group**	Autonomous Emergency Braking Group of RCAR members with the aim of defining a set of test procedures that can be used by consumer test organisations such as Euro NCAP,IIHS and Thatcham.
AEBS	Advanced emergency Braking Systems
AFS	Adaptive Front-Lighting System
AsPeCSS	Research project, the main goal is to develop harmonised test and assessment procedures for forward looking integrated pedestrian systems. Assessment methodologies for forward looking Integrated Pedestrian and further extension to Cyclists Safety Systems
ASSESS	Project funded under the Seventh Framework Programme of the European Commission. Assessment of Integrated Vehicles Safety Systems
BOS	Beginning of Steer
BSD	Blind Spot Detection
BSM	Blind Spot Monitoring
CAMP	Crash Avoidance Metric Partnership
CIB	Crash Imminent Braking
CLEPA	European Association of Automotive Suppliers
CM	Collision Mitigation
CMbB	Collision Mitigation by Braking
CMBS	Collision Mitigation Braking System
CMOS	Complementary Metal Oxide Semiconductor

CWS	Collision Warning System
ERTRAC	European Road Transport Research Advisory Council
ESC	Electronic Stability Control
EUC	Equipment Under Control
EUCAR	European Council for Automotive R&D from major European passenger car and commercial vehicle manufacturers
EuroNCAP	Provides motoring consumers – both drivers and the automotive industry – with a realistic and independent assessment of the safety performance of some of the most popular cars sold in Europe
EWB	Electronic Wedge Brake
FCW	Forward Collision Warning
FIR	Far Infrared
FOV	Field of View
GNSS	European Global Navigation Satellite System
GPS	Global Positioning System
GTR	Global Technical Regulation
GVWR	Gross Vehicle Weight Ratio
HMI	Human Machine Interface
HUD	Head-Up Display
ICT	Information and Communications Technology
IEC	International Electro technical Commission
IIHS	Insurance Institute for Highway Safety
IR	Infrared
ISO	International Standardisation organisation
ISO	International Standardisation organisation
ITS	Intelligent Transport Systems and Services
IVBSS	Integrated Vehicle-Based Safety System
IVDC	Interactive Vehicle Dynamic Control

IVIS	Integrated Vehicular Information System
JAMA	Japan Automobile Manufacturers Association
LCDAS	Lane Change Decision Aid System
LCW	Lane Change Warning
LDW	Lane Departure Warning
LDWS	Lane Departure Warning System
LKA	Lane Keeping Assistance
LRR	Long Range Radar
LSF	Low Speed Following
LV	Lead Vehicle
MIT	Massachusetts Institute of Technology
NCAP	New Car Assessment Program
NHTSA	National Highway Traffic Safety Administration (U.S. Department of Transportation)
NIR	Near Infrared
OEM	Original Equipment Manufacturer
Radar	Radio Detection and Ranging
RCAR	Research Council for Automobile Repairs
RCS	Radar Cross Section
SAE	SAE International is a global association of more than 128,000 engineers and related technical experts in the aerospace, automotive and commercial-vehicle industries.
SBW	Steer by Wire
SRA	Society for Risk Analysis
SRR	Short Range Radar
SV	Subject Vehicle
SWA	Steering Wheel Angle
TC	Traction Control

	Technical Committee (ISO)
TLC	Time to Line Crossing
TNO	Netherlands Organisation for Applied Scientific Research
TV	Test Vehicle
USDOT	United States Department of Transportation
vFSS	Working group on Advanced Forward-Looking Safety Systems
VRU	Vulnerable Road Users