Testing and Evaluation Methods for ICT-based Safety Systems

Collaborative Project

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Executive Summary

This report sums up the activities performed during the complete duration of the project from January 2008 until December 2010. Following the motivation for testing and evaluation of active safety functions, the technical development within the project is described. This includes the derivation of relevant traffic scenarios, a collection of potential test approaches as well as the proposed testing protocols and a collection of experiences made during the application of the protocols.

Besides the results of the project, open issues and weaknesses in connection with future research need are discussed herein. Furthermore, links to existing initiatives and projects in the same domain are described.

An important part is also the documentation of a critical debate about the results of the project that was held during the final demonstration event. Representatives of all relevant stakeholders including the automotive industry, governing and legislative institutions as well as research and academia discussed and commented the achievements, thus giving important input for future research and other initiatives.

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Version Chart

Version	Date	Comment
0.1	22.10.2010	First draft version to be extended by WP leaders
0.2	02.11.2010	Second draft including WP summaries
0.3	10.11.2010	Third draft with additions on deliverables
0.4	12.11.2010	Draft version as initially submitted to the EC
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1.0	21.02.2011	Final version

Authors

The following participants contributed to this deliverable:

Name	Company	Chapters
Micha Lesemann, Adrian Zlocki	IKA	all
Lucía Isasi	TECNALIA	3.1
Andrés Aparicio	IDIADA	3.2
Jan Jacobson, Henrik Eriksson	SP	all
Fredrik Bruzelius	VTI	3.4
Lars Nordström	VTEC	all

Coordinator

Dipl.-Ing. Micha Lesemann
Institut für Kraftfahrzeuge - RWTH Aachen University
Steinbachstraße 7, 52074 Aachen, Germany

Phone: +49-241-8027535
Fax: +49-241-8022147
E-Mail: lesemann@ika.rwth-aachen.de

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1 Introduction

Over the last years, active safety systems have been massively implemented into new vehicle generations, offering a high potential in decreasing road accidents. While testing and rating of the passive safety of vehicles are based on established and accepted methods and programmes, no such are available for active safety of cars or trucks today. Thus it is difficult to assess the performance of such systems for industry, legislation and further stakeholders. In particular, the customer cannot judge about the active safety of different vehicles based on easy-to-understand ratings as they are offered by different new car assessment programmes (NCAPs), see Figure 1. This leads to a relatively low awareness of active safety systems and hinders a high market penetration.

The main focus of the European research project "Testing and Evaluation Methods for ICT-based Safety Systems (eVALUE)" was to define objective methods for the assessment of vehicle active safety. The methods are based on relevant traffic scenarios that, according to investigated statistics and databases, represent the majority of accidents, where active safety systems can come into effect.

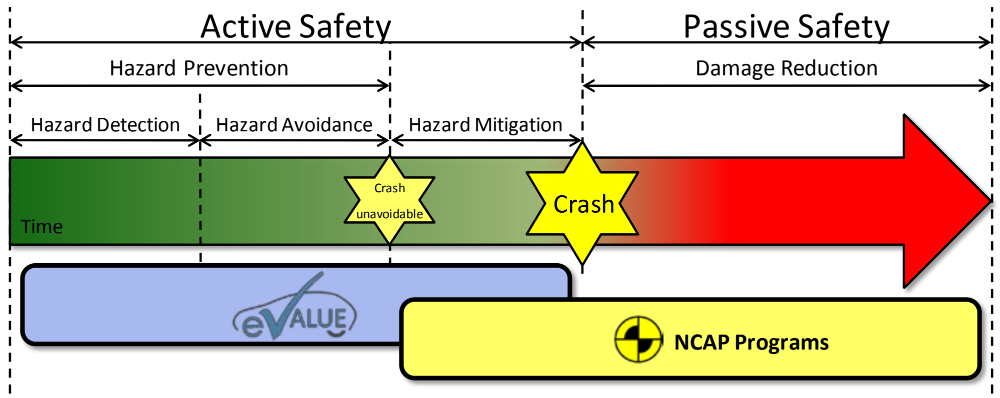


Figure 1 – Timeline of active and passive safety

The test methods investigated and defined by the eVALUE project are compiled in protocols for both inspection of the subject vehicle as well as physical testing of it. They give a baseline for the assessment of the active safety performance of a vehicle. However, the eVALUE consortium has only defined the test methods while the thresholds for the specific values have not been specified. This remains the competence of every institution adopting the test methods and actually applying them in order to assess different vehicles.

While some procedures are soon ready for implementation, some others require additional work that was out of scope for the project. In the end, the results which can be generated by applying these (enhanced) methods will increase the public awareness for active safety systems and foster the development within the industry.

2 Motivation, Objectives, Scope and Approach

Whereas the motivation for increased safety in general and related performance assessment in particular is obvious, objectives, scope and approach have been discussed and decided in the beginning of the project like described in the following.

2.1 Motivation

Modern society strongly depends on mobility, and the need for transport of both people and goods is expected to grow further in the future. Cleaner, safer and more efficient transport systems are needed. Mobility and especially road transport cause major societal problems: accidents, pollution and congestions. More than 40,000 lives are lost every year due to road accidents in the European Union only, and the costs are estimated to be about 2 % of its GDP [1].

The European Commission and its member states have made major efforts to improve traffic safety, and the results can be seen in a decreasing number of fatalities in many European countries [2]. Nowadays, new ways must be found to reduce the number of fatalities and injuries even further. The public awareness of the large impact that active safety systems would have on road safety must be raised. It must be easy for the customer to understand the benefits of safety systems, which are based on Information and Communication Technologies (ICT).

The average car buyer cannot assess the performance of active safety systems in vehicles, nor their impact on traffic safety. Today, there are no publicly accepted test methods and no established ways to communicate the test results. The situation is quite different for passive safety systems, where test programs such as Euro NCAP have established impact test methods and ways to explain the test results in different levels of detail. While the car buyers may compare star ratings for passive safety between different cars, the professional safety engineer may compare measurement data from the tests.

To change this situation and make the customer as well as all other involved stakeholders aware of the performance of different vehicles by means of active safety was the motivation for the eVALUE project and the involved organisations, see Figure 2.

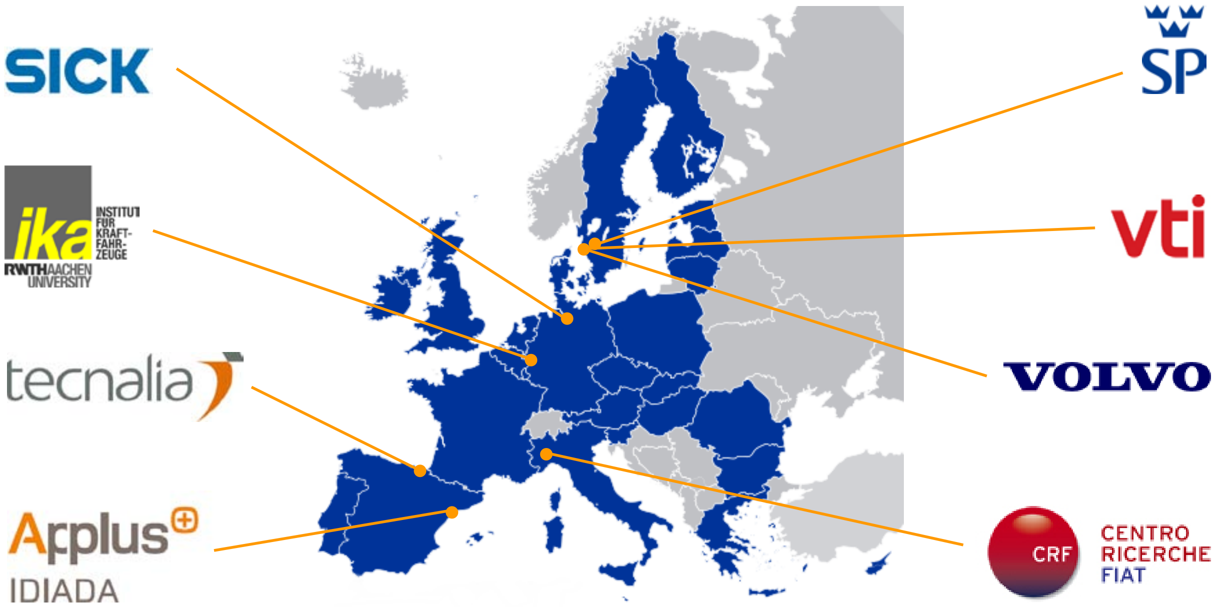


Figure 2 – Names and origins of involved project partners

2.2 Objectives and Scope

Performance test results presented to the public will help to promote the use of active systems. This has e.g. also been underlined by the eSafetyForum working group on Research and Technological Development in their "Recommendations on forthcoming research and development" [3]. Additionally, the behaviour of equipped over not equipped cars (in case the safety function can be deactivated) shall make clear to the non-expert how much safety improves by active safety functionality.

By this means, also the research and development of new safety systems is encouraged. Accordingly, the long-term goal was and must be to agree on testing protocols that will be used by all involved stakeholders. This has already proven to be an effective way in terms of promoting passive safety [4].

However, the project did not perform any activities which would have led to a direct standardisation of the methods developed. Furthermore, there were no pass or fail criteria defined for the different performance values. The clear focus was on objective and repeatable methods while rating remains to the potential users of these methods or methods based on the ones developed by the eVALUE project.

It must also be underlined that certain limitations apply to the scope of the project given by the limited time and resources that were available (see also chapter 6.1). Figure 3 highlights the scope of the project in the context of safety performance analysis, which is based on real life accidents. The derivation of scenarios that represent dangerous traffic situations and the development of test methods based on those scenarios were within scope of the eVALUE project, while performance rating and subsequently an estimation of the safety impact could not be covered. This safety impact would in the end have an effect on the accidents, thus closing the circle.

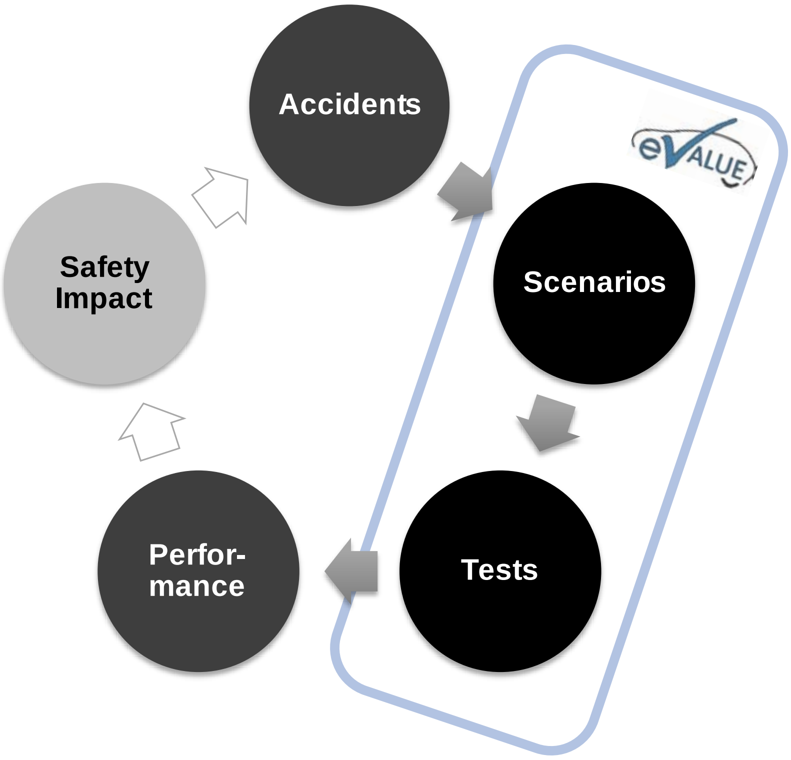


Figure 3 – Scope of the eVALUE project in the context of safety performance analysis

With limited background by means of accidentology (compare chapter 6.1), a practical approach was chosen by the project partners.

2.3 Approach

In 2007, the ASTE study [5] investigated the feasibility of performance testing for active safety systems. In addition, needed methods and principles for verification and validation of those systems were investigated. Therefore, three different approaches were considered.

The system approach is based on the capabilities of specific systems and mapped to traffic scenarios. Performance of the different systems with similar functions is then assessed.

The scenario approach is directly based on traffic scenarios. The vehicle is tested as a black-box and its overall performance in those scenarios is determined. As a third option, a document-based approach was discussed. This could complement physical testing and might be particularly valuable for HMI evaluation.

According to the conclusions of the study, vehicle active safety shall be tested following the scenario-based approach. It was further stated that performance testing of active safety systems is technically and economically feasible and that a consensus between different stakeholders will be possible. The importance of communicating test results in a very simple way was underlined.

The eVALUE project was a direct follow-up of this study. Most partners of ASTE are also involved the eVALUE project. Figure 4 gives an overview of the eVALUE approach for the development of the testing and evaluation methods. Based on accident statistics, relevant scenarios have been derived that represent the majority of accidents in which active safety systems could possibly mitigate the outcome. A vehicle will be assessed by applying the methods. Those shall be recognisable also by the end customer as critical situations that can happen during normal driving. One example is approaching suddenly congesting traffic or a similar, non-moving obstacle. The benefit of active safety systems (e.g. by automatic braking in this case) will thus be even more clear.

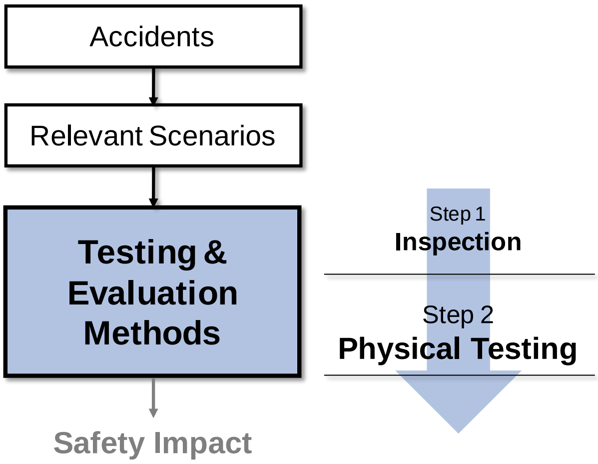


Figure 4 – Scientific approach for active safety assessment development

3 Technical Development

Following the described approach, the technical development of eVALUE project was executed in a serial way with a corresponding division in work packages. After the definition of the concept to be followed, the different testing strategies with respect to laboratory testing, physical testing and simulation as well as reviews by means of inspections were analysed. In the following step, the actual transition of the different test procedures into testing and inspections protocols was carried out. This was strongly linked to extensive physical testing, since the application of the protocols led to valuable experiences and allowed improvement of the testing protocols to their final form.

3.1 Concept Definition

The first step[1] classified the ICT-based safety systems considered under eVALUE scope into three clusters: longitudinal, lateral and yaw/stability, based on the driving path of the subject vehicle. Derived from market availability and penetration rate, the project has focused the research work on the following eight preventive or mitigation safety systems, classified by clusters:

- **Cluster 1 (longitudinal)**
  Adaptive Cruise Control (ACC), Forward Collision Warning (FCW) and Collision Mitigation by Braking (CMbB)

- **Cluster 2 (lateral)**
  Blind Spot Detection (BSD), Lane Departure Warning (LDW) and Lane Keeping Assistance (LKA)

- **Cluster 3 (stability)**
  Antilock Brake System (ABS) and Electronic Stability Control (ESC)

Subsequently, concepts for different possibilities of testing and evaluating were defined for the eight primary safety systems[2]. The types of test taken into account in the eVALUE methodology have been split into inspection, laboratory testing and physical vehicle testing:

- **Inspection**
  The main objective of the inspection scenario approach is to verify, if the vehicle is able to cope with unexpected events and suddenly occurring critical situations. These traffic conditions, compiled by clusters, are distributed in the different scenarios considered on the physical vehicle testing (detailed below)

- **Laboratory testing**
  Tests that are driven on a static environment such as a laboratory or a workshop, in

[1] "State of the Art", eVALUE project deliverable D1.1
[2] "Concepts Definition", eVALUE project deliverable D1.2

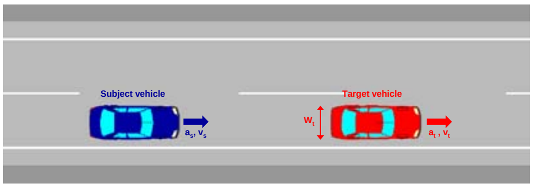
order to identify and determine the concepts, requirements, specifications and limitations of the safety systems and subsystems in the subject vehicle.

- **Physical testing**
  The purpose of this type of test is to assess the complete vehicle's performance rather than testing one particular ICT-based safety system under different scenarios, i.e. specific real driving situations, which are relevant regarding the functionality of the considered safety systems.

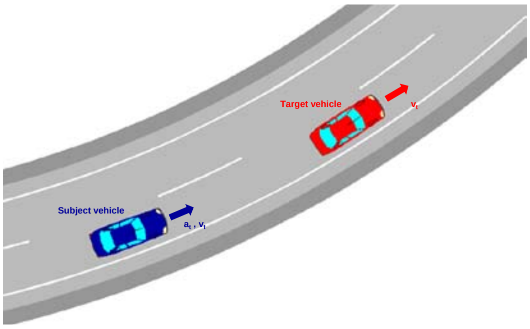
The derivation of relevant scenarios from accident statistics directly has already turned out to be a challenge. No reliable accident databases are available that are capable of delivering a comprehensive analysis of accident circumstances for the whole of Europe. While some European projects such as TRACE have been working on ideas for the harmonisation of accident statistics, waiting for them being available is not acceptable. Thus the partners have defined relevant scenarios based on information that is available today. This includes standards for testing of certain systems, results from other projects and the expertise of the involved institutions.

The following scenarios classified by clusters were selected to be considered under eValue scope:

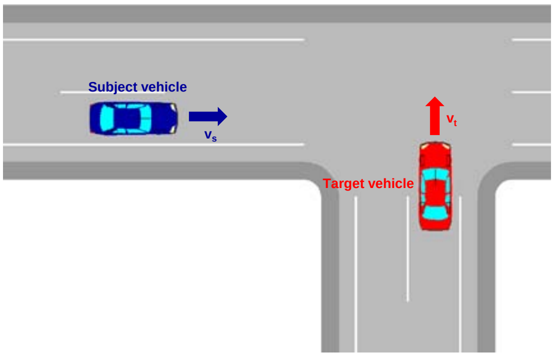
- **Cluster 1**
  For active safety functions aiming at longitudinal control, three different scenarios have been chosen. They represent a straight road, a curved road and a target, which is transversally moving in the way of the subject vehicle.



Regarding the straight road, the objective of the chosen scenario is to validate that the subject vehicle can detect and handle (warn, support, and/or intervene) a target vehicle in the same lane.

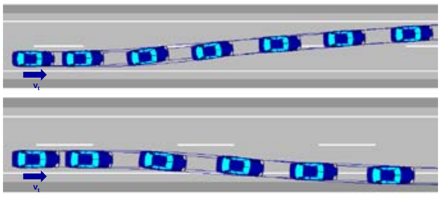


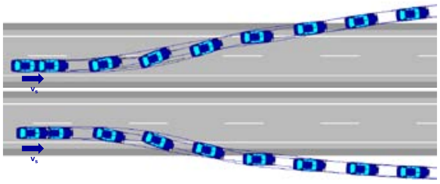
The same objective applies for the scenario for a curved road, i.e. validate that the subject vehicle can detect and handle (warn, support, and/or intervene) a target vehicle in the same lane on a curved road.



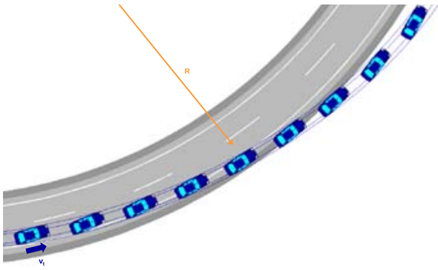
The objective of the third scenario is to validate that the subject vehicle can detect and handle (warn, support, and/or intervene) a target (e.g. other vehicle, pedestrians …) which moves lateral to the subject vehicle.

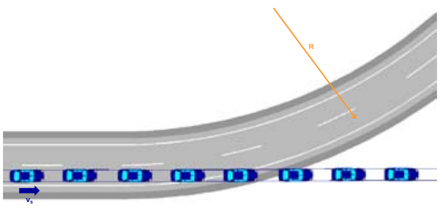
- **Cluster 2**
  Scenarios addressing systems which are providing lateral assistance. For straight as well as curved roads, a differentiation is made regarding lane and road departure.



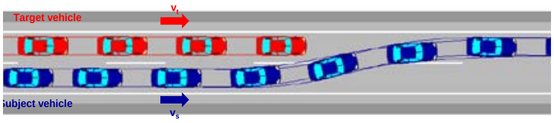


Meant to validate the subject vehicle capability to avoid involuntary (left/right) lane departure driving on a straight road. As a form of extension of the first scenario, the second is meant to validate the subject vehicle capability to avoid involuntary road departure driving on a straight road.





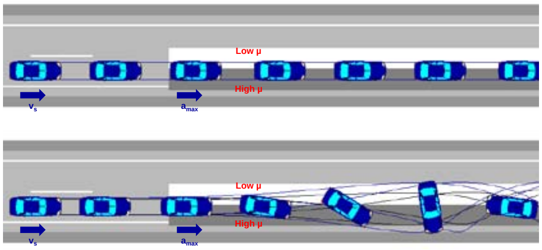
These scenarios regard lane or road departure while the subject vehicle is driving in a curve or just before a curve. Once more, the capability to avoid the involuntary lane or road departure is the main objective on this scenario.



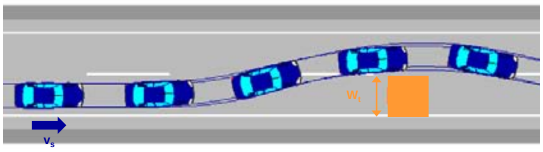
It addresses lane change collisions which are well-known in multi-lane traffic both at low and high speed. This scenario validates the capability of the subject vehicle to avoid a lateral collision when changing lane on a straight road and encountering an approaching target vehicle.

- **Cluster 3**

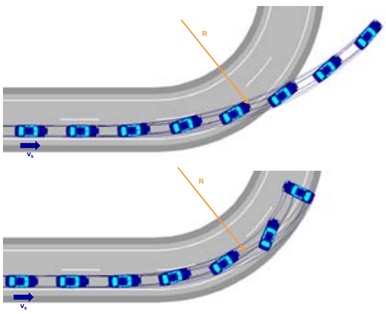
  Yaw and stability assistance are given by systems which have been collected in the third cluster. Here, some manoeuvres are already established in testing.



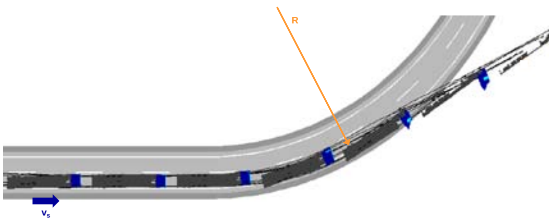
Emergency braking on a µ-split, i.e. surfaces with different friction coefficients. Evaluate the subject vehicle capability to stop in a reasonable space keeping the desired driving direction while braking on asymmetric surface.



Evaluate the subject vehicle capability to avoid the loss of control in case of a sudden obstacle avoidance manoeuvre, followed by a come back to the original lane in order to avoid the collision with an incoming vehicle.



Evaluate the subject vehicle capability to avoid a loss of control as well as a lane/road departure in the case of approaching a curve too fast.



Roll stability: evaluate the subject vehicle capability to avoid a loss of stability which may result in a rollover event while negotiating a long curve, such as highway entrance or exit ramps.

All scenarios do not only consider passenger cars but generally also apply for trucks and busses.

3.2 Testing Strategies

After the scenario specification, the objective inside eVALUE was to provide specific test procedures for each safety system and integrate them into general procedures for global performance assessments and evaluations. For this reason, there were provided many test procedures that partly overlapped and needed to be integrated in the following work packages.

In other words, the specific objective with testing strategies was the definition, development and analysis of test and evaluation procedures for all different properties/features of the systems selected as the focus of the eVALUE project.

Two objectives can be identified:

- the assignment of testing procedures to ICT-based safety systems
- definition and detailed development of testing and evaluation procedures for each feature of the domain of ICT-based safety systems

The definition of a testing matrix[3] formed the basis for the work that was done for testing strategies. The main achievement was the testing matrix that related all proposed tests procedures to scenarios, systems and types of tests.

The specification list[4] compiled the final results achieved within testing strategies and completed the remaining objective. Initial requirements for the test procedures were drafted:

- Cover all safety categories
- High repeatability of the manoeuvre
- Driver independent
- Clear metric available for safety assessment
- Accurate results
- Reasonable test and evaluation effort
- Neutral for different vehicle categories
- As neutral as possible for different weather and track condition
- Motivate OEM for new system introduction and improvement
- Accident representative
- Promote the use of the available safety features

One of the major achievements shown is the definition of the safety indicators. For each of the three clusters (longitudinal domain, lateral domain, stability domain), a selection of variables able to show the performance of a vehicle under specific condition has been done.

[3] "Testing Matrix Definition", eVALUE project deliverable D2.1
[4] "Specification List", eVALUE project deliverable D2.2

SAFETY INDICATOR / CLUSTER	CLUSTER 1	CLUSTER 2	CLUSTER 3
Collision speed	X	X	X
Driver's acceptance and usability	X	X	X
Headway time	X		
Time Line Crossing		X	
Path deviation		X	X
Target detection, dimension and classification	X	X	
Function output type and relevance	X	X	X
Driver's intention	X	X	X
Braking distance			X
Vehicle's control			X

Figure 5 – Initial safety indicators

These safety indicators aimed to be the basis of the test procedures, which were defined accordingly.

3.3 Test Development

The development of tests has been done using mainly physical testing. The results of the physical tests at the test tracks have been documented in test reports[5] where updates to the testing protocols[6] have been proposed. After the updates, the testing protocols have been re-evaluated on the test track. This iterative process is depicted below.

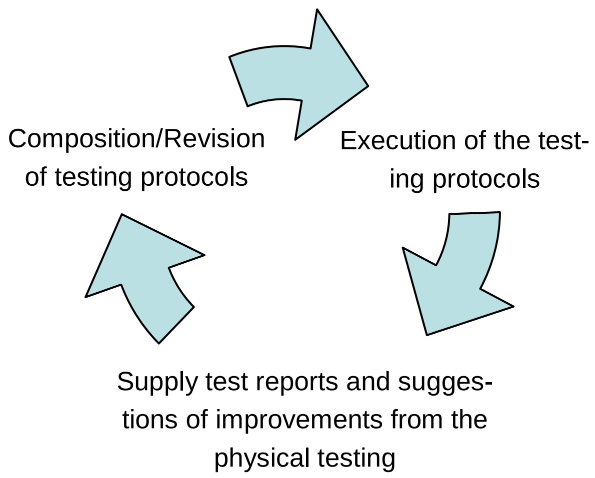


Figure 6 – The interaction between the physical testing at the test tracks and the composition of the testing protocols.

[5] "Test Report", eVALUE project deliverable D4.2
[6] "Final Testing Protocols", eVALUE project deliverable D3.2

The three clusters “longitudinal”, “lateral”, and “stability” were the basis for the work with the testing protocols. The scenarios proposed for each cluster have been covered in testing protocols.

The results of the tests are presented as safety performance indicators. These indicators shall reflect a real impact on road safety and should not be confused with test conditions or measured values. They are intended to give the essential information of how well the ICT-based safety function performs in a given scenario. An example of a safety performance indicator is collision speed used in the longitudinal testing protocols. The aim of the testing protocols is to introduce a small number of indicators usable for evaluation. However, the intention is not to give specific values for “good” or “bad”.

Development tests have been performed with wide ranges of scopes depending on the maturity of the testing protocols. Some scenarios adopted existing manoeuvres while some were developed from scratch. Development testing that has been conducted can be divided into two main groups:

- **Manoeuvre test type**, where the execution procedure and parameters of the test is the topic of investigation. Examples of tests have been tests to determine suitable speeds for which the manoeuvre should be performed etc.

- **Safety performance indicator test type**, where the objective has been to determine the performance index. Example of tests in this class is tests performed with two different subject vehicles to enable a comparison of the indicator.

For the more mature scenarios and later in the project, validation was one of the main objectives of the tests. Validation type of tests that have been performed can be divided into two main categories:

- **Comparative tests**, i.e. tests that compare the results from different types of vehicles, test tracks, environmental conditions etc. to determine robustness as well as assessment capabilities.

- **Repetitive tests**, i.e. test that are performed using e.g. the same type of vehicle on different test tracks to determine how repeatable the tests are.

Two testing protocols have been established for the longitudinal domain: “Avoidance of rear-end collision” and “Avoidance of collision with transversally moving target”. Both testing protocols are proposed as open loop tests, i.e. tests without considering the natural response and feedback from the driver.

A closed loop test (i.e. a test based on the interaction with the environment) has been selected for one of the testing protocols in the stability domain: “Emergency braking on µ-split”. The same testing protocol is also implemented as an open loop test. The other two testing protocols in the stability domain are: “Obstacle avoidance” and “Highway exit”.

Two testing protocols have been developed for the lateral domain; “Avoidance of lane departure” and “Avoidance of lane change collision”. These are both open loop tests.

Inspection protocols are presented for “Definition of the subject vehicle” and “Environmental conditions”. These two inspections are used as a preparation for testing, see Figure 7. The inspection protocols on “HMI” and “Functional Safety” are applied as a check that the aspects of HMI and functional safety are satisfactorily covered in the design of the subject vehicle.

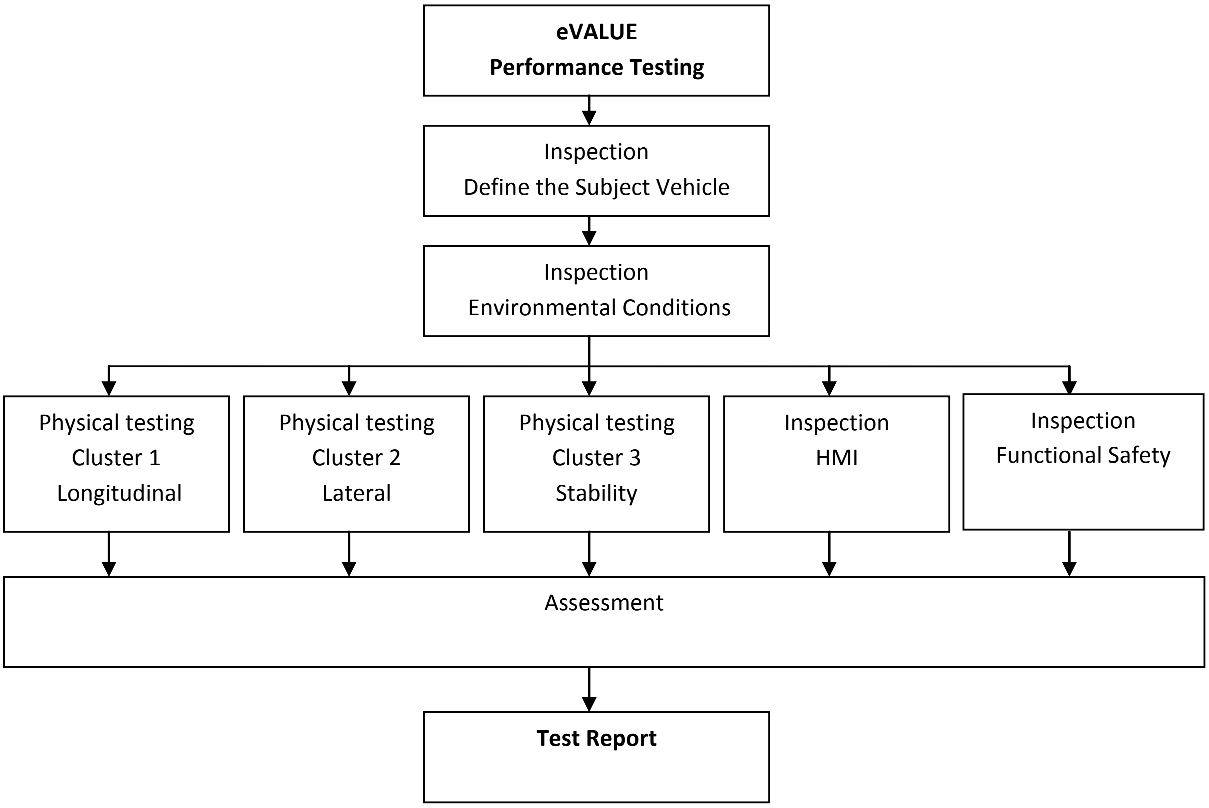


Figure 7 – The eVALUE performance testing process[6]

A number of test cases were selected in each testing protocol. Examples of test cases are different vehicle speeds and decelerations. Each test case shall be performed several times, i.e. trials. Initial work to analyze the required number of test cases and trials is started, but is still an open issue. One requirement that will control the number of test cases is the time and cost requirements. It should be possible to perform the complete eVALUE tests during one week of testing on a test track. Additional time will be needed for preparations, inspections and instrumentation of the subject vehicle. The analysis of the measured data and the reporting of the test will also require additional time. The cost of preparations, testing, analysis and reporting shall be comparable to the cost of NCAP passive safety testing of a vehicle[6].

4 Results

The main results of the project are the protocols for inspection and physical testing of vehicles with respect to their active safety performance in longitudinal, lateral and stability-related functionality. Besides these protocols, to which certain limitations apply before they can be utilised for actual application (see chapter 5), much experiences mainly with respect to physical testing have been gained while applying the draft protocols. This experience is thoroughly documented in deliverable D4.2 that is publicly available. In addition, further reports cover the investigation that led to the chosen approach and relevant scenarios (deliverable D1.2 [10]) while testing approaches that can generally be considered for the intended purpose are collected and analysed in deliverable D2.1 [11].

4.1 The Test Programme in Total

The eVALUE test programme consists of inspection and physical testing protocols. In the following, a brief overview is given, while they are completely defined in deliverable D3.2 [7]. The performance testing process foreseen is described with Figure 7 above.

4.2 Inspection Protocols

By inspection of the subject vehicle, important aspects such as the functionality of the different safety systems on board including any limitations as described in the documentation, the HMI used for warning and information of the driver, environmental conditions applying for the test as well as efforts made by the manufacturer in terms of functional safety are investigated and documented. The inspection protocols define a systematic and comprehensive analysis in order to identify and determine the capability of the vehicle. Most parts of the inspection are done studying the documentation and interviewing the manufacturer, but other parts of the work might be done investigating the vehicle. The inspection protocols are specified in Annex A to deliverable D3.2 [7].

4.3 Physical Testing Protocols

In the core of performance testing as proposed by the eVALUE project stands physical testing of the subject vehicle. The purpose of this type of test is to assess the overall performance of the vehicle rather than testing one particular ICT-based safety system under different scenarios, i.e. specific real driving situations, which are relevant regarding the functionality of the considered safety systems.

In order to do so, a differentiation between longitudinal, lateral and stability-related functionality was followed. It both reflected the different levels of driver support as well as supported the development within different expert groups. It is imaginable that a similar differentiation can be made in a later implemented test programme since it seems understandable also for the customer. This however depends on the organisation to implement the procedures. The testing protocols are specified in Annex B to deliverable D3.2.

5 Discussion

Preliminary and final results of the technical development have been discussed with interested and renowned experts from inside and outside of the consortium at several occasions. This was in line with the very open approach the project partners have decided to follow right from the beginning of the project in order to allow an unhindered exchange with organisations and experts not directly involved in the project.

5.1 External Review

In the summer of 2010, the first complete version of testing protocols developed by the project has been provided to selected experts of ten major automotive OEMs active in Europe. In addition, the draft protocols have been supplied to four major suppliers as well as experienced organisations in the field of (active) safety testing.

5.2 Final Demonstration Event

On 24 and 25 November 2010 a final demonstration event and workshop took place at the IDIADA proving ground in Santa Oliva/Spain. About 50 dedicated experts representing the automotive industry, testing organisations, governing and legislative institutions as well as research organisations and academia were present and intensively discussed the approach and results of the project during those two days.

The event consisted of both theoretical and practical sessions. In the beginning, Francisco Ferreira of the European Commission, ICT for Transport, and Alessandro Coda, Research Coordinator of EUCAR, the European Council for Automotive R&D, put the eVALUE project in the framework and context of current European automotive research.

Afterwards Micha Lesemann, the project coordinator of ika, introduced the project with an overview to all participants. This included the general scope and limitations of the project, the chosen approach and a summary of other related initiatives in the field of active safety testing as well as a first outlook on future research needs that was identified by the project.

As described in the previous chapters, the development of testing methods and protocols was divided in three different clusters for longitudinal, lateral and stability functions. In the related theoretical sessions of the final event, the covered functionalities and current systems as well as identified critical scenarios including their relevance for traffic safety were presented. This was followed by an explanation of the test procedure, the different test cases as well as experiences gained during the validation test sessions within the project. Each theoretical session was followed by a practical session during which examples of the test procedures were given on the IDIADA test track. A plenary discussion of the test protocols proposed by the eVALUE consortium concluded each cluster session.

Longitudinal Functionality

After the presentation of the proposed testing protocols for longitudinal functionality by Håkan

Andersson (VTI) and demonstration on the test track, several aspects were discussed among the workshop attendees. Regarding the chosen scenarios (critical traffic situations) it was concluded that a false positive test should be added in a testing protocol to be implemented in the future. Within the eVALUE protocols, this is addressed by an inspection protocol, which asks for a confirmation by the OEM that false positives have been taken care of during the development process, e.g. by means of a certificate. Some participants proposed that the vehicle OEM should provide a statement that the development took place according to ISO 26262, while others mentioned that this might go along with a minimum requirement definition that would however be up to legislative bodies.

Some participants stated that an overlap unequal 100 % between the subject and the target vehicle should be considered, e.g. 60 or 40 %. The eVALUE experts explained that this was tested, but that a poor performance of the different vehicles/systems was observed. Some other participants added that night conditions might be of even higher importance, however a definition of night conditions could not be found during the discussion.

The number of trials was also subject of some discussions. One proposal was to limit the number of trials (i.e. repetitive test runs under the same conditions) to one. Here it was concluded that one trial could be sufficient for type approval testing, while a statistical approach depending on the test case (i.e. open or closed loop) should be followed when it comes to development or even performance testing.

Further investigation is also required e.g. by means of a driver study in order to identify the optimal time of warning. It was underlined in this regard that it is not the best solution to warn as early (and often) as possible, but rather the right moment to do so should be awarded as best solution.

As an addition to the test setup as it is defined in the eVALUE protocols, more specific requirements were desired for values such as test track length or deceleration values in curves. Therefor it was proposed to reference the UN ECE/GTR regulation fur truck ABS testing.

Furthermore, the brake pedal application was discussed. It was proposed to use the displacement that would be needed to reach e.g. a force of 700 N rather than the force only. In relation to this the speed of brake pedal application should be mentioned. One reference could be given by [14].

As presented during the introduction for the longitudinal functionalities, a light signal trigger was used in order to identify the time of warning. The project partners reported that they had a good confidence and experience with this sensor. In case that the signal carries too much noise, another feasible solution would be dismounting the dash board and using the electrical signal (of e.g. the warming lamp) directly.

In the end of this session, the topic of safety performance indicators and especially a suitable number of them was debated. As an addition to the proposed indicators by the eVALUE project, the remaining distance to the target was mentioned. It was concluded that this topic requires further research, which is directly related to the question of effectiveness.

It was also understood by the present experts that especially regarding the assessment of active safety in the longitudinal direction, several other initiatives have been formed since the start of the eVALUE project. As they mainly are focussing on this domain, they are able to develop more detailed test procedures than eVALUE with its limited time and budget, e.g. by means of a detailed investigation of required target objects. However, they all have in common that they are partly building on and referencing to eVALUE results.

Lateral Functionality

An introduction to the eVALUE testing protocols for lateral functionality was given by Rafael Basso (Volvo Technology). The following discussion addressed several specific issues. This included the common understanding that closed loop testing, i.e. taking the driver reaction into account, would be most desirable. However, since a validated driver model as required input is currently not available, the recommendation of the eVALUE project to use open loop testing can be supported. This is not limited to warning systems and can also be applied to systems giving a steering recommendation, as shown during the eVALUE test sessions in 2010.

The issue of safety performance indicators was also debated in relating with lateral functionality. Here, it was questioned, if the time of warning was a suitable indicator since the lane marking recognition might be of even higher importance. A related indicator could be the percentage of roads on which the function works properly. It was concluded that further investigation is required, while the current development of a regulation for truck LDW within UN ECE should be taken into account.

For lane departure warning there are also ISO standards existing. The eVALUE partners however identified that they are not sufficient for performance testing, but rather for development and potentially regulation testing (minimum standard).

A question was raised, whether a relevance of lateral safety functions for trucks and motorcycles was also given. The attendees agreed that accidentology should give an answer to this while an OEM representative noted that activation speed circumvents detection and mitigation of pedestrian accidents in the lateral direction.

In the end of this session it was concluded that a suitable representation of a standard vehicle target would be desirable for longitudinal <u>and</u> lateral testing.

Stability Functionality

Josep Maria Dalmau of IDIADA introduced the eVALUE testing protocols for stability functionality to the audience. After the physical demonstration on the test track, an intensive debate about the proposal by the eVALUE partners took place. This also due to the fact that stability-related functions such as ABS and ESP are well established in passenger vehicles and accordingly many experiences have been gained in the past.

The eVALUE consortium has taken this into account from the beginning by basing its development on methods such as mu-split braking and obstacle avoidance. These methods have been developed further, for instance with the aim to realise a normalisation regarding different tire/track adherences.

OEM representatives however argued that mu-split testing is not relevant for the customer since it would not be representative for real behaviour on surfaces such as snow or ice. Furthermore, a mu-split test track has turned out to be not sufficient for fine tuning of the vehicle performance. This is directly related to issues of reproducibility and repeatability.

After some discussion it was concluded that a correlation between artificial conditions (allowing repeatable testing) and real life behaviour of the vehicle (as most relevant for the customer) is required. The corresponding protocol proposed by the eVALUE project was thus regarded as suitable for testing minimum requirements, but probably not rating.

Similar to the lateral functionality, also for stability-related testing it was questioned whether an open or closed loop should be followed. It was understood that closed loop testing would be most representative of real life behaviour, but is rather difficult to achieve without a sophisticated driver model. It was noted that a description of the intended driver reaction within the eVALUE closed loop procedure should be described, i.e. the steering input with regard to the trajectory. Also the aspect of the initial yaw rate should not be underestimated, and a vehicle equipped with a corrective steering system might not be testable with the propose method.

The employment of a professional driver for closed loop testing could be a replacement for the application of a driving robot until a driver model is available and implemented in such a robot. Until then, the experts agreed, reaction boundaries should be defined.

The presented obstacle avoidance test might reach human capabilities, even those of professional drivers and even steering robots, commented one OEM representative. He recommended accordingly lower thresholds in order to avoid EPS design to be only depending on (unrealistic) test requirements.

The importance of the yaw rate parameter was further discussed. It was understood that the driver should be able to steer the car in the intended direction again after the first ESC intervention.

Some retention was expressed towards the highway exit manoeuvre as it was newly introduced by the eVALUE project. Especially industry representatives doubted the relevance by means of accidentology. However, the GTR No. 8 “Electronic stability control systems” aims at a similar performance check, while the safety impact remains unclear. Again, a driver study would be needed to clarify the remaining issues.

The eVALUE experts explained that the intention of the highway exit scenario was to represent a real life situation in a better way than the GTR No. 8 or corresponding ISO standards. This added value would have to be further evaluated and validated in the future.

General discussion

Before the general closing discussion, Andrés Aparicio (IDIADA) gave an overview of the status of the ASSESS project while Michael Stanzel (Volkswagen) introduced the vFSS initiative as two of the most advanced initiatives in the field of longitudinal functionality.

Especially the ASSESS project is very active regarding the development of a representative target. The workshop attendees agreed that a good target is highly needed and that commonly used balloon cars might not be enough. It was also noted that a dynamic target is more representative than a static target. Of even higher need could be a suitable pedestrian target, added some participants.

The event was concluded by a summary discussion which was moderated by Pierre Castaing of UTAC. In the beginning, he presented some very recent results concerning frontal impact accident analysis which was done by TRL, BASt and LAB in 2010 and underlined the remaining importance of frontal impact mitigation. He also underlined that different viewpoints of OEMs, rule makers and consumer testing organisations must not be forgotten.

Concerning the efforts needed for a full test programme for active safety it was agreed that the proposal by the eVALUE project to limit the amount to approx. one week plus vehicle preparation and analysis/assessment would be a good target value.

In the plenary discussion, it became obvious that all present experts in general agreed to the need for standardised testing methods and protocols for active safety assessment. The approach chosen by the eVALUE partners was also regarded as valid and applicable. This is also proven by the fact that similar and follow-up activities such as ASSESS, vFSS and others are also following this approach and partly build-up on eVALUE results.

The maturity of the eVALUE testing protocols as well as specific details of the test procedures were intensively discussed among the participants. While the maturity of the stability-related protocols was generally regarded as high, the need for the newly introduced highway exit scenario was questioned by some experts.

Assessment of active safety in the longitudinal direction is current within the scope of several projects and initiatives. The corresponding protocols developed by the eVALUE partners are rather mature, but cannot go in as much detail as dedicated projects are able to deliver it. The present experts however acknowledged the pioneering work that was done by eVALUE and was taken over in the meantime by consortia such as ASSESS and vFSS, which are also striving for a worldwide harmonisation. The protocols for evaluation and assessment of lateral safety are probably the least mature and major efforts need to be invested in the future to enhance them above the level that was developed by the eVALUE team.

5.3 Further Dissemination

With its aim to form the baseline for testing of active safety that is open and free to be used by all interested stakeholder, dissemination has been considered of highest importance for the success and the impact of the project. Accordingly, several activities have been performed. Therefore, the **project website** (www.evalue-project.eu) was the central information point for all interested parties. It has been updated regularly and contains a basic description of the project, the partners list, latest results as well as public presentations and relevant links. It will remain active for at least two more years after closing of the project. Afterwards, a brief description as well as the public deliverables will be available through the website of IKA as coordinator of the project.

The **project newsletter** was sent to more than 200 contacts of relevant persons in the field of active safety who actively subscribed for this service. Several conversations developed from the newsletter, mostly with people asking for more information about the project or having specific questions.

The project has been presented at 21 **conferences and congresses** with high relevance for active safety. This included amongst others the annual ITS World Congress, the bi-annual TRA Conference, the bi-annual FISITA Congress and the also bi-annual ESV Conference. In addition, the project was present at the annual EUCAR Conference where it was considered a EUCAR project as two consortium members are involved in EUCAR.

In total, the presentations attracted around 1,000 persons while the number of receivers of the papers that were submitted with most of the presentations is much higher, but unknown. As agreed by all project partners, one paper per cluster has been submitted for the ESV Conference 2011. This will offer the opportunity to present the full results as well as the final testing protocols to the most relevant group of experts.

While interest of especially industry was relatively low in the first year of the project, this has significantly changed in the second and third year. Both suppliers and OEMs were very interested in the project and the results. These have been intensively discussed during the eleven **workshops** (with the final demonstration event being the twelfth workshop), see chapter 5.2.

The workshops were attended mainly by industry (OEMs and suppliers as well as some research organisations). During the course of the project, it was decided that workshops with public stakeholders, user organisations and press will not be carried out before the final testing protocols are available. The intention was to avoid circulation of premature testing protocols which could be taken as ready for implementation at a stage that would be too early. Accordingly, only technical experts familiar with the topic were involved in the workshops, which led to valuable feedback that was considered and mostly incorporated in the development.

The project was supported by both EUCAR (The European Council for Automotive R&D) and EARPA (European Automotive Research Partners Association). On this account, the project has been presented and discussed during the EUCAR Integrated Safety Program Board meetings, besides the annual EUCAR Conferences.

The EUCAR support meant that an exchange of project results between the different projects was encouraged and the effect of the project on the EUCAR strategy was evaluated. Regarding EARPA, affiliated beneficiaries are IKA, SP, IDIADA and TECNALIA. Presentation and discussion of the project was done at the annual EARPA members meeting 2009. Both for the EUCAR and EARPA support, no financial contribution or influence on the independence of the consortium was given.

6 Open Research Issues

6.1 Weaknesses of the Described Programme

The eVALUE project followed the objective to develop testing and evaluation methods for ICT-based safety systems. However, during the early phase of the project, this objective was shifted towards testing methods that take the full vehicle rather than a specific system into account. Being one of the first projects active in this regard and with this intention, experiences were made that disclosed issues of high relevance for the development of vehicle active safety assessment methods but could not be covered the eVALUE project. The partners then decided to follow a straight forward approach based on data which was available at the time. However, good science requires pointing out those open issues, allowing them to be addressed at a later stage by different initiatives and thus allowing the improvement of the presented results.

6.2 Open Issues

The following open issues are partly or directly related to the above described weaknesses, but could not be addressed by the eVALUE project itself. Nevertheless, the project partners are aware of the fact that only the overcome of these issues will allow the development of a fully scientific test programme for active vehicle safety. Hence they should be addressed by future research activities (see chapter 6.3 below).

Accident statistics
As the most important and required input, detailed statistics that fully cover all accidents on European roads including their outcome, but especially the circumstances under which they occurred as well as all influencing human and technical factors are necessary. These have not been available at the beginning of the project for all European countries, and only with certain limitations for a limited number of countries (see eVALUE deliverable D1.2 [10]). Since definition and agreement on the data to be required and collected, and the collection of a statistically sufficient number of data sets could require a time frame of 10 years and more, a pragmatic approach has been chosen by the project partners. However, since the input is limited, the output must be limited as well. This means in particular that the relevant traffic scenarios that give the baseline for the developed testing protocols cannot cover the real life accidents as they are happening on the roads in Europe, or even worldwide.

Driver model
In contrast to passive safety where the driver does have very limited or even no influence to the course of events, many active safety systems perform with a warning, supportive or intervening functionality. This means that the control over the car remains partly or fully with the driver and thus keeps him in the loop of control. Accordingly, the full performance of the vehicle can only be evaluated if the driver reaction is taken into account. However, since the reaction of each driver is different, it is difficult to be taken into account. Repeatability and comparability of the vehicle performance require furthermore a standardised reaction such as an average driver reaction or similar. As the development of such a validated driver model

(or even more likely a limited number of different driver models such as relaxed, aggressive, cautious or anxious, to name few that seem to be appropriate) requires extensive resources, it was out of scope for this project to perform such a development. Consequently, most of the physical testing protocols are defined as open loop test that do not take into account the driver reaction. To fully evaluate the performance, closed loop protocols shall be applied, taking the reaction into account.

Number of required trials according to statistical discussion

Each test procedure as described in the testing protocols needs to be applied in a statistically or politically sufficient number of trials. "Statistically sufficient" means that repeated tests offer a high level of trust in the performance under a certain procedure, taking into account e.g. the average performance of the vehicle.

"Politically sufficient" refers to the fact that the safety systems that contribute to the active safety of the vehicle shall be able to perform under any circumstances which are not limited by definition as stated towards the customer, e.g. in the documentation of the vehicle. Ensuring functional safety of the safety system, it can be argued that only one trial can be considered as sufficient, as long as the procedures laid out by the protocols are followed.

This issue could not be solved by the consortium, since a much higher number of trials compared to the ones performed within the project would be needed to especially elaborate the statistically sufficient number of trials. The discussion about the approach with only one trial per test came up rather late in the project and should be continued in the discussion within other initiatives and public events.

Target definition

A large number of active safety systems take the interaction with surrounding vehicles into account. Consequently, these vehicles need to be represented in the different test procedures as defined in the eVALUE testing protocols. To be objective and repeatable, these vehicles need to be standardised and suitable to represent real life traffic and, in case of a positive performance, trigger the desired system reaction. However, this project did not have the intention to define specific targets for the different test procedures. Moreover different targets were used as they are utilised today for system development and validation (e.g. an inflatable "balloon car", a pedestrian simulation target etc.). The experience made is covered in the report about the testing activities performed during the project. Besides, some initiatives have lately been started that have a target definition as one of their core objectives (e.g. the ASSESS project). Accordingly, target requirements are part of the testing protocols, while detailed target specifications are not given.

6.3 Future Research Need

In accordance with the above given open issues, the project partners are aware of the fact that future research is needed in order to finalise the testing protocols and allow an application for real assessment purposes. This includes a fully comprehensive European accident database that is freely available for both the development of new and enhanced safety functions on the road towards the vision of halving the number of road fatalities until 2020 [12] as well as for the derivation of the most relevant traffic scenarios with respect to active safety systems and the impact they have on real life safety on our roads.

Furthermore, standardised driver reactions need to be investigated and later-on implemented to into driving robots. This would then allow taking the driver reaction into account and thus fully assess the safety performance of a vehicle. An investigation of statistical effects on performance results and, related to this, an open discussion within the research community whether only one trial per test can be acceptable need to take place as well. This would require a large number of tests at different locations as a test programme cannot only be performed at the same location (cf. the different certified test laboratories for passive safety testing) and under the exact same conditions (e.g. weather due to the required space and testing outdoors).

These research topics are of common interest for all involved stakeholders and can thus be addressed in joint consortia in order to avoid duplication of work and waste of resources. Being of European or even international interest, they would ideally be handled by means of a joint research initiative in the European framework,

6.4 Other Initiatives

Since the start of the project, several other public initiatives started working in the field of active safety testing, though with different objectives and scopes. Below the most relevant initiatives are briefly presented, of which some are also based on results published by the eVALUE project.

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.

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.

vFSS

vFSS is a working group on Advanced Forward-Looking Safety Systems that was initiated mainly by German vehicle manufacturers and research organisations, now 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 will be 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 now actively looking for harmonisation with as many initiatives as possible, e.g. CAMP-CIB and AEB.

Euro NCAP Advanced

Euro NCAP has recently launched 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, will recognize and reward 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 will be evaluated with a pass/fail criteria based on this regulation. In the coming years, a deeper analysis will be defined. This is a first step for giving an independent assessment of active safety systems, which starts with systems already in the market.

The “Beyond NCAP Assessment protocol” is available at the Euro NCAP web page.

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.

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 (Advanced Emergency Braking) 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 to plan basing its test procedures on real crash scenarios taking into account both frequency and severity. Therefore, they will 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 will be developed by the AEB group. They will publish their tests and shared them with other working parties which was done for instance with the vFSS initiative.

ActiveTest

ActiveTest is a Support Action within the Seventh Framework Programme that will start on 1 January 2011 and has the objective to support the dissemination and discussion of among different active safety initiatives and projects such as the ones given above. It will mainly consist of three dedicated workshops each focussing on one of the clusters longitudinal, lateral and stability as defined within the eVALUE project. Moreover, a roadmap for further research in this field will be elaborated during the course of the project (2011-2012).

All persons and organisations interested in the field of active safety testing are invited to make use of the results and experiences made during this project. The project partners are convinced that safety shall always be the top priority in road traffic and is thus to be relevant for all stakeholders regardless of their background and interests.

7 Conclusions

For the performance assessment of automotive active safety systems, no generally accepted standards are available today. Manufacturers of systems, components or vehicles all need to develop their own testing procedures in order to provide both development goals and means to evaluate the system performance. Large R&D efforts are undertaken in parallel by various companies in order to provide the technological background for the development of testing procedures.

Due to this situation of inhomogeneous testing practice throughout the industry, test results acquired in different manufacturer-specific tests cannot be compared by customers and authorities. Furthermore, manufacturers have no means to assess their systems in a generally accepted way.

The eVALUE project now offers explicit testing protocols for vehicle active safety that can found the basis for either implementation or more detailed specification, depending on the level of definition. During the final demonstration event that was attended by representatives from the automotive industry, testing organisations, governing and legislative institutions as well as research organisations and academia, the testing protocols proposed by the eVALUE project have discussed intensively. The scenario based approach taking the full vehicle rather than a specific system into account was generally supported. While the methods for stability-related testing were regarded as mature, testing of longitudinal and lateral safety function requires more research.

This is also necessary in order to reach accepted methods and protocols among all stakeholders fostering the perception and understanding of the active safety performance of a specific vehicle. This additional research has been clearly pointed out by this project, enabling precise follow up actions addressing this research topic of highest interest for all road traffic in Europe on the way to reducing the number of accidents, injuries and fatalities significantly.

In addition, communication with and amongst stakeholders that might be involved in a later standardisation process has been established and will remain in the future, e.g. in the future workshops to be organised by the support action ActiveTest.

8 Acknowledgement

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9 Glossary

ABS	Antilock Brake System
ACC	Adaptive Cruise Control
ACEA	Association des Constructeurs Européens d'Automobiles
ActiveTest	Dissemination of Performance Testing Methods for ICT-based safety Functions in Road Vehicles
AEB	Advanced Emergency Braking
ASSESS	Assessment of Integrated Vehicle Safety Systems for Improved Vehicle Safety
ASTE	Active Safety Test Europe
BASt	Bundesanstalt für Straßenwesen
BMW	Bayerische Motoren Werke AG
BSD	Blind Spot Detection
CAMP	Crash Avoidance Metrics Partnership
CIB	Crash Imminent Braking
CMbB	Collision Mitigation by Braking
CRF	Centro Ricerche Fiat
EARPA	European Automotive Research Partners Association
EPS	Electric Power Steering
ESC	Electronic Stability Control
ESV	Enhanced Safety of Vehicles
EU	European Union
EUCAR	European Council for Automotive R&D
eVALUE	Testing and Evaluation Methods for ICT-based Safety Systems
FCW	Forward Collision Warning
FMVSS	Federal Motor Vehicle Safety Standard
FP7	European Community's Seventh Framework Programme

GDP	Gross Domestic Product
GTR	Global Technical Regulation
HMI	Human Machine Interface
ICT	Information and Communication Technologies
IDIADA	IDIADA Automotive Technology SA
IIHS	Insurance Institute for Highway Safety
IKA	Institut für Kraftfahrzeuge – RWTH Aachen University
ISO	International Organization for Standardization
ITS	Intelligent Transport Systems
LAB	Laboratory of Accidentology, Biomechanics and Human Behaviour
LDW	Lane Departure Warning
LKA	Lane Keeping Assistance
NCAP	New Car Assessment Programme
NHTSA	National Highway Traffic Safety Administration
OEM	Original Equipment Manufacturer
PSA	Peugeot S.A.
R&D	Research and Development
RCAR	Research Council for Automobile Repairs
RWTH	Rheinisch-Westfälische Technische Hochschule Aachen
SARAC	Safety Rating Advisory Committee
SEAT	Sociedad Española de Automóviles de Turismo
SICK	SICK AG
SP	Sveriges Tekniska Forskningsinstitut (formerly: Statens Provningsanstalt)
TECNALIA	Tecnalia Research & Innovation Foundation
TRA	Transport Research Arena

TRACE	Traffic Accident Causation in Europe
TRL	Transport Research Laboratory
UN ECE	United Nations Economic Commission for Europe
USDOT	United States Department of Transportation
UTAC	Union Technique de l'Automobile, du Motocycle et du Cycle
vFSS	Advanced Forward-looking Safety Systems
VTEC	Volvo Technology Corp.
VTI	Statens Väg- och Transportforskningsinstitut
WP	Work Package

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