interactIVe
Accident avoidance by active intervention for Intelligent Vehicles

Deliverable D7.4 | Test and evaluation plans

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SEVENTH FRAMEWORK PROGRAMME

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Table of contents

Figures

Tables

Executive summary

interactIVe introduces safety systems that autonomously brake and steer. The driver is continuously supported by interactIVe assistance systems which warn the driver in potentially dangerous situations. The systems do not only react to driving situations, but are also able to actively intervene in order to protect occupants and vulnerable road users. Seven demonstrator vehicles – six passenger cars of different vehicle classes and one truck - are being built up within this project to develop, test, and evaluate the next generation of safety systems.

The purpose of this deliverable is to present the test and validation plans for the specific functions and outline the assessment of the test procedures which includes studying the feasibility of conducting test scenarios, setting up and running tests and obtaining data on the indicators. It also includes a methodology for safety impact assessment and an overview of the tools and equipment that will be used during the process. The tests will reveal how the functions work according to function description, requirements and also how the functions are accepted and received from a user perspective by accepting or rejecting the proposed hypotheses and obtained answers for research questions on the definition of relevant aspects to develop Advanced Driver Assistance Systems (ADAS).

In order to evaluate the developed ADAS, an evaluation framework is required. Therefore, a subproject called “Evaluation and Legal Aspects” is part of the interactIVe project which main objective is to provide this framework and give support to the vertical subprojects in their evaluation work.

The evaluation of the interactIVe functions has been divided in three main categories:

- *Technical Assessment* to evaluate the performance of the developed functions and collect information and data for safety impact assessment.
- *User-Related Assessment* to assess the functions from the user perspective, and also to provide further input to the safety impact assessment.
- *Impact Assessment* to estimate how and how much the functions influence traffic safety.

The three vertical subprojects SECONDS, INCA and EMIC together involve 11 different functions with a wide range of target areas. The developed ADAS comprise the following systems;

- SP4 “SECONDS” dealing with functions, which support the driver continuously in the driving process. These functions should not only support the driver in dangerous situations, but help the driver to avoid them.
- SP5 “INCA” dealing with functions, which combine longitudinal and lateral control of the vehicle in order to prevent imminent accidents. The INCA functions’ focus is not only on the collision avoidance in rear-end conflicts, but also in other types of conflicts, like blind-spot or run-off the road conflicts.
- SP6 “EMIC” deals with critical pre-crash applications, where collision mitigation can be realised at a reasonable cost.

It needs to be pointed out that this deliverable provides a plan for testing and evaluation of the interactIVe functions for an “ideal” situation based on currently available information. The “ideal” situation means that the demonstrator vehicles are fully equipped with the planned systems and they are ready and available for testing under the necessary conditions. There may be deviations from this “ideal” situation; then adaptation of the test plan will be necessary. Deviations are not only to be expected from the technical side, but also the available resources may be an issue.

Test and assessment objectives

The main objective of the evaluation is to assess how well the different interactIVe functions perform to fulfil their objectives as specified by their target scenarios. Hence, the functions are evaluated from a development point-of-view and not from a consumer point-of-view.

The general procedure of the PReVAL project identified following steps for the evaluation of ADAS and will be used during the technical evaluation process:

- *Step 0: System and function description*
  - This step was taken in WP7.3 and is reported in D7.1.
- *Step 1: Expected impact and hypotheses*
  - Here, the evaluations are split up into (i) technical, (ii) user-related and (iii) safety impact assessment. This step was executed in WP7.4 and is reported in deliverable D7.2.
- *Step 2: Test scenario definition*
  - This step has been taken into account in the deliverable D7.2 and is updated in this deliverable.
- *Step 3: Evaluation method selection*
  - The final evaluation method is featured in this deliverable
- *Step 4: Measurement plan*
  - The measurement plan is reported in this deliverable.
- *Step 5: Test execution and analysis*
  - This step will be described in deliverable D7.5.

Test tools

To conduct the technical and user-related assessment the following equipment is required, in addition to the demonstrator vehicles:

- test tracks,
- data logging devices and reference measurements,
- in case of avoidance and/or mitigation: target objects,
- reference measurements, e.g. for position,
- driving simulators for the user-related assessment when testing on a test track or public road is either not possible or too dangerous.

Challenges for the evaluation in interactIVe

The SP7 partners have identified some challenges that are specific for the assessment in interactIVe. The challenges deal with the type of tests to be carried out, with the maturity and uniformity of the ADAS functions under testing, and bundling of functions. These challenges influence results that can be obtained from the technical, user related and impact assessments. Therefore, these challenges are addressed separately from the actual assessment plans. Specifically, the following challenges are addressed in turn:

- Maturity of functions,
- Long term effects on driver interaction,
- Bundling of functions,
- Uniformity of functions and systems,
- Complexity of functions,
- Resource limitations.

Technical assessment plans

The methodology for the technical testing is straightforward after the choice of the appropriate test scenarios. For interactIVe, the nature of the applications requires full hardware testing, e.g. using the demonstrator vehicles. The testing will be mainly performed on test tracks, but some of them must run in normal traffic and some tests can be performed in laboratory surrounding. The challenge for interactIVe is to comprise all test results so that:

- a conclusion on the functional performance of a function can be drawn,
- the results can be used for the safety impact assessment.

In order to synchronize the tests, the test results have to be reported in a specific standardised form. It is proposed to group the test results by test scenario (per demonstrator vehicle):

1. Test scenario: Rear-end collisions,
2. Test scenario: Head on collisions,
3. Test scenario: Lane change collisions,
4. Test scenario: Cross traffic collisions,
5. Test scenario: Collisions with vulnerable road users,
6. Test scenario: Unintended lane departure accidents,
7. Test scenario: Excessive speed accidents,
8. Test scenario: Traffic rule violations,
9. Test scenario: Verification tests,
10. Test scenario: Test on public road.

For each test scenario a summary table need to be filled in (to ease a quick glance over the test results and later grouping of the overall function performance). An example is given in section 4.1.2.

Outline of the experiments

The objective of the technical assessment in interactIVe is to draw conclusions from the technical performance of the interactIVe functions. Therefore, it is necessary to study the function's behaviour in different situations by means of the indicators. The performance indicators are calculated based on the different measurements and should answer to the hypotheses defined.

One issue for the tests in the technical assessment is the testing effort, which results from the high number of use cases. Overall, there are nine different categories of use cases covered by interactIVe functions:

- Rear-end collisions,
- Head-on collisions,
- Blind-spot collisions,
- Cross traffic collisions,
- Collisions with vulnerable road users,
- Unintended lane departure accidents,
- Excessive speed accidents and
- Traffic rule violations.

A reasonable approach to decrease the number of tests is to prioritise the test cases in primary and secondary test cases.

- Primary test cases are test cases, which test the main functionality of the function. For these test cases, different parameter configurations are tested. These tests are mandatory.
- Secondary test cases are test cases, which test side aspects of the function. Therefore a less extensive testing is conducted, which means that only a few parameter configurations will be tested. The secondary test cases will be carried out depending on the available resources and time.

User-related assessment plans

The user-related assessment will use the Code of Practices defined in RESPONSE3 and PReVAL within the PReVENT project as support tools adapted to the specific needs of the interactIVe systems and functions

The final user-related assessments will illuminate drivers' correct reactions to the developed functions by mainly using naïve subjects in simulated driving situations, in an instrumented vehicle on test track or in real traffic. All tests will be followed by questionnaires or interviews that also will give information of the test drivers' opinions on the functions in question. Using naïve subjects means that the test drivers have equal experience and prior knowledge of the system as a later customer will have.

Outline of the studies

The user-related tests will be performed on public roads, on test tracks with an equipped demonstrator vehicle or in simulator studies at different sites depending on the function under testing. The test cases are chosen to test mainly the driver's reaction to a given function and how the function is accepted and used. The tests are like the technical tests, divided in primary and secondary tests, where the secondary test cases will be a complement to the primary ones and will only be conducted depending on time and resources. Outline of the studies will follow the code of practice for Design and Evaluation of ADAS on how to conducting tests with subjects.

SECONDS – Field trials, both in real traffic and on test track

INCA – Simulator

EMIC – Simulator

Safety impact assessment plans

The safety impact assessment method is described on two levels, generally and as a specific application to interactIVe. The reason for setting up a general method not specifically tailored for interactIVe is that it will then be useful also for other applications. This is in line with the spirit of the method used in eIMPACT and PReVAL, which the InteractIVe method is based on.

Safety mechanisms

This concerns methods that identify factors contributing to a crash, and then employ direct or indirect methods to estimate the effect of an ITS on these factors. Simple approaches may consider factors such as exposure and severity, see e.g. [JOK72], or target population and effectiveness, as mentioned above. A more detailed subdivision of safety impacts of ITS is given by the so-called nine safety mechanisms [DRA98]. These mechanisms are:

1. Direct in-car modification of the driving task,
2. Direct influence by roadside applications,
3. Indirect modification of user behaviour,
4. Indirect modification of non-user behaviour,
5. Modification of interaction between users and non-users,
6. Modification of road user exposure,
7. Modification of modal choice,
8. Modification of route choice,
9. Modification of accident consequences.

The first five address accident probability and to some extent severity too. The next three address exposure and the final one addresses severity related to post-crash modifications (i.e. timeliness of the emergency service response). The boundaries between the mechanisms are not sharply defined, and some safety aspects can be listed under several headings. For example, an application that mitigates crashes could have its effects listed under mechanism 1 or 9. However, this is not problematic, because the purpose of this structure is not so much to define precisely the categories of safety effects, but rather to help the researcher to be complete in listing all potential effects.

Main challenges for the evaluation process

Technical assessment

Regarding the technical assessment plans the main challenge will be to conduct all tests. The number of test is quite high due to the high number of use cases. Therefore the test cases have been prioritised. Other challenges will be to keep consistency between the test site environments, definition of driver reaction and access to the different test sites. According to the time plan, the testing will take place during wintertime and there will be limitations due to snow and low temperature at least in Sweden.

User-related assessment

Except for the fact that interactIVe will not be able to test the long term effects on driver behaviour, the user related assessment plans also faces future challenges. In general the main issues will be the definition of parameters since the testing will be performed in different environments. This leads to an importance of consistency between the test sites.

Another issue for the user-related tests is the testing effort. The tests have to be limited to a certain number of test persons and also the test itself has to be limited (e.g. test route). Therefore, the test persons should preferably have to drive the same route twice in order to be able to compare the driver behaviour with and without the function. Due to the limited time and the limited availability of the demonstrator vehicles and simulators, it will be not possible to do the tests with a large number of test persons or on a long test route.

The SECONDS functions will be active continuously, supporting the driver in “normal” driving not only in a situation with risk for imminent collision. Hence, the SECONDS functions can be tested with “naive” drivers on public roads in real traffic. However, for some of the demonstrator vehicles certain regulations affect the testing, e.g. a demonstrator vehicle can only be driven by employees of the company which will limit the selection of test persons. In another case a special driving license, issued by the car manufacturer, is needed to drive the demonstrator vehicle. In this case, it is not possible to carry out test drives on public roads with “naive” drivers.

The INCA and EMIC functions address emergency situations and will basically be carried out in simulators. Here, it will be difficult to design the scenarios and trick the test driver in the specific situations without revealing the outcome of the event. It will also be challenging to implement the functions for correct behaviour in the simulator environment.

Safety impact assessment

The advantages of this method are that it is transparent in the sense that it documents clearly what the breakdown of safety effects is, it covers all possible safety effects - both intended and unintended effects, it has relatively little data needs and does not require excessive amounts of resources. The disadvantages of the method are that for most mechanisms it will be hard to obtain solid results, hence the method heavily relies on secondary sources, expert judgment and the use of (low, high) ranges. Besides, treating all situations can be a tedious task and validation is difficult.

The impact assessment will determine risk modifiers for nine mechanisms, which classify the impact on the traffic in different categories. One challenge for the impact assessment is the relation between the impact zone and the injury risk, which must be considered for the CMS function. The relation between the change of the velocity during the impact and the injury risk is well reported in different documents. Furthermore, the issues for the other assessment (e.g. long term effects) will also be a problem for the impact assessment.

In general, matching between the test results for SECONDS, INCA and EMIC could lead to problems, since the uniformity of functions and systems in the different demonstrators are different. It needs to be decided on how to handle this, when analysing the test results from the technical and user-related assessment to be able to make a conclusion on the functional performance so the result can be used for the safety impact assessment. For all tests that have any interaction with another vehicles, it must also be ensured that the situation could be tested without damaging the demonstrator vehicles or even people.

1 Introduction

This deliverable is part of work package 7.5 (WP75) and provides a test and evaluation framework for the assessment of the interactIVe applications with respect to technical performance, human factors and safety. Also test scenarios, evaluation methods, and test procedures as well as tools for evaluation are provided.

The objective of InteractIVe is to develop new integrated Advanced Driver Assistance Systems (ADASs) and active safety systems in order to promote safer and more efficient driving. In order to evaluate these systems, an assessment framework is required. This document describes the whole evaluation process for the three assessments (technical, user-related and safety impact), which are conducted for the interactIVe functions. The results of the previous deliverables D7.1 "*Requirements for the evaluation",* and D7.2 "*Specifications for the evaluation"* as well as the feedback, from all necessary partners involved in the development and evaluation process, on these deliverables are considered.

The evaluation framework is built on the results and experiences from previous European projects, e.g. PReVAL, eIMPACT and ASSESS. The practices chosen from those projects will ensure solid evaluation results, and proper decision-making regarding the implementation and further development of active safety systems.

The developed ADAS comprise the following systems; SECONDS, INCA and EMIC. Each system consists of two or more functions:

- SECONDS, dealing with continuous driving support in order to avoid dangerous situation at an early stage.
- INCA combining longitudinal and lateral control of the vehicle preventing possible accidents.
- EMIC, focusing on critical pre-crash applications where collision mitigation can be realised at reasonable cost.

Seven different demonstrator vehicles will be developed with different sets of functions of SECONDS, INCA or EMIC. Some vehicles will even combine functions of different systems. Testing and the analysis of results will start in September 2012 and the final event of interactIVe will take place in June 2013. In Figure 1.1 the overall time plan of SP7 is presented.

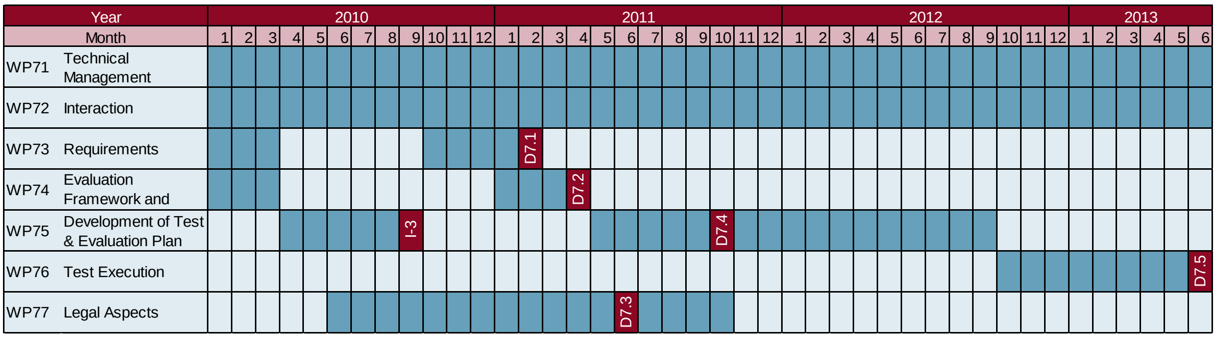


Figure 1.1: Overall time plan of the interactIVe SP7.

1.1 Document structure

This document deals with the evaluation framework which will be used to evaluate the interactIVe systems. A short presentation of the different chapters is given below.

First chapter gives an introduction of the interactIVe project and a general presentation of the objective and the scope of the deliverable. It also gives the background of interactIVe with a description of previous research projects on European and national level within the development field of improving traffic safety and ADAS systems. It also presents the project drivers, the vision and objectives of the interactIVe project and the organization outline.

Chapter 2 presents the approach and scope for the test and assessment objectives.

Chapter 3 provides the definition of the test plans and the test and assessment methodology. Also the different demonstrator vehicles and functions under tests are described.

In chapter 4, 5 and 6 the technical-, user-related-, and impact assessment plans are given.

The annexes include the specific assessment plans for each demonstrator, the Research Questions (RQs) and hypotheses, test scenarios, test facilities and finally a signal list of the tests.

1.2 Background, interactIVe

Due to 34 500 road fatalities and 1 500 000 injured persons on European roads in 2009 the European Commission has announced the objective to half the number of road traffic fatalities up to 2020 [NN11].

In order to reach this objective several different research projects related to traffic safety have been carried out on European and national level. These projects started in the late 1980s as part of the DRIVE programme that was generated by the PROMETHEUS initiative within EUREKA outside the European Commission. The DRIVE programme identified the potential improvements in road safety and reduction of congestion on the European road network. Research continued in the 3rd framework programme (1992-94) with the Transport Telematics strand of the Programme “Telematics in Area of General Interest”. In the 4th framework programme (1994-98) transport telematics activities covered research and demonstration in all modes of transport.

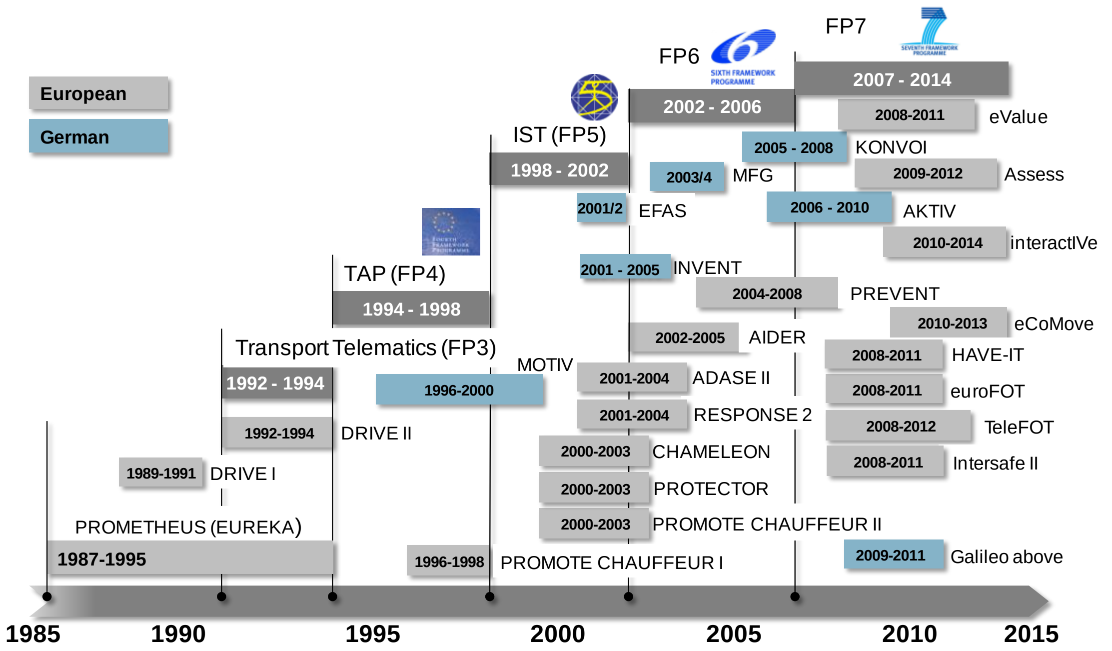


Figure 1.2: Overview on relevant ADAS research projects on EU and national (Germany) level [ZLO11].

In the 6th framework programme (2002-2006) the PReVENT project, which is one of the most important research project with respect to ADAS, was conducted. Within this integrated project, applications with different functions in the fields of longitudinal and lateral control, intersection safety, and collision mitigation were developed and demonstrated.

The work started in the previous framework programmes is being continued today in the 7th framework programme by a variety of projects (e.g. INTERSAFE 2, HAVE-IT or interactIVe). An overview on the most relevant projects of the 7th framework programme as well as on former research projects on EU and national level is given in Figure 1.2.

1.2.1 Project drivers

In its first white book regarding the European road traffic "European transport policy for 2010: time to decide" the European Commission introduce to ambitious goal to halve the number of road fatalities by the year 2010:

"In the battle for road safety, the European Union needs to set itself an ambitious goal to reduce the number of people killed between 2000 and 2010" [NN01].

The initial point for the reduction of the road fatalities was 40 000 deaths (EU-15) on European roads in 2001. In the recent years great effort has been made in order to improve traffic safety. Although advancement has been made in the reduction of accidents, in 2009 still 34 500 people (25 100 EU-15) were killed on European roads (Figure 1.3). Against this background the European commission has reinforced the goal of reducing road deaths in their second white book “Schedule to reach an integrative European traffic – up to a competitive and gently resource handling traffic system”:

“By 2050, move close to zero fatalities in road transport. In line with this goal, the EU aims at halving road casualties by 2020. Make sure that the EU is a world leader in safety and security of transport in all modes of transport” [NN11].

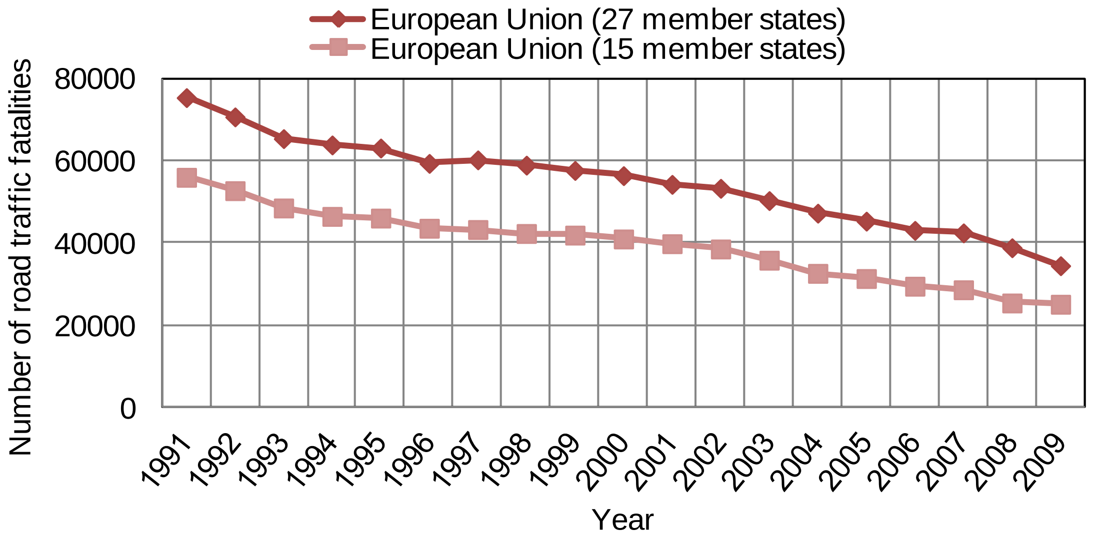


Figure 1.3: Number of road traffic fatalities [NN11b].

1.2.2 interactIVe vision and objectives

The interactIVe project is a European research project, which is co-funded by the European Commission DG Information Society and Media in the Seventh Framework programme "Information and Communications Technologies (ICT) for Safety and Energy Efficiency in Mobility". interactIVe is also supported by EUCAR (European Council for Automotive R&D), which coordinates high-level research activities with the participation of all European OEMs.

The interactIVe consortium comprises of 29 partners from ten European countries. The partners consist of original equipment manufacturers (OEMs), suppliers, research institutes and small and medium-sized enterprises.

The main vision behind the endeavour of the interactIVe project is to have an accident-free traffic. An important role on the way towards this objective is played by active safety systems. Therefore, interactIVe aims to extend the dispersion of active safety systems with overall aim to bring active safety systems in all vehicles.

On the way towards this objective different challenges need to be overcome. For example, the functions need to operate independent of obstacles. Furthermore, the functions must be applicable to different vehicle types (cars and trucks). And finally the costs of such functions need to be reduced in order to reach a high market penetration in order to reach a significant effect of these functions.

Therefore the focus of interactIVe is on different topics related to the development of active safety systems:

1. Extend the range of possible scenarios and the usability of ADAS by multiple integrated functions and active interventions.
2. Improve decision strategies for active safety systems and driver-vehicle-interaction.
3. Develop solutions for collision mitigation that are able to improve the market potential towards low segments.
4. Create an innovative model and platform for enhancing the perception of the driving situation.
5. Further encourage the application of standard methodologies for the evaluation of ADAS

The developed ADAS functions, which focus on different aspects in order to prevent accidents, will be integrated in seven demonstrator vehicles.

1.3 interactIVe organization and outline

interactIVe is divided in three horizontal subprojects (HSP) and three vertical subprojects (VSP). It is important to point out that each VSP focuses on a different field of ADAS functions. The VSP, which aim to develop the active safety application, are:

- SP4 “SECONDS” dealing with functions, which support the driver continuously in the driving process. These functions should not only support the driver in dangerous situations, but help to keep the driver away from them.
- SP5 “INCA” dealing with functions, which combine longitudinal and lateral control of the vehicle in order to prevent imminent accidents. The INCA functions focus is not only on the collision avoidance in rear-end conflicts, but also in other types of conflicts, like blind-spot or run-off the road conflicts.
- SP6 “EMIC” deals with critical pre-crash applications, where collision mitigation can be realised at a reasonable cost.

These three VSPs are supported by the three horizontal subprojects dealing with technical or methodological aspects shared by all VSPs.

- SP2 “Perception” will advance the multi-sensor approaches and focus on sensor data fusion processes. Furthermore, a common perception framework for multiple safety applications will be developed in this subproject.
- SP3 “IWI Strategies” defines the requirements for information, warning and intervention strategies (IWI) for the developed applications based on its use cases. Furthermore, SP3 develops an iterative design, prototyping, and user testing of IWI strategies based on the initial requirements.
- SP7 “Evaluation and legal aspects” provides a test and evaluation framework for the assessment of all interactIVe applications with respect to technical performance and human factors. The results of the technical and user-related assessment will be used to determine the possible impact of the interactIVe functions on road traffic safety. Besides this, the corresponding legal aspects of the interactIVe applications will be analysed.

The structure of the project is also in Figure 1.4 below.

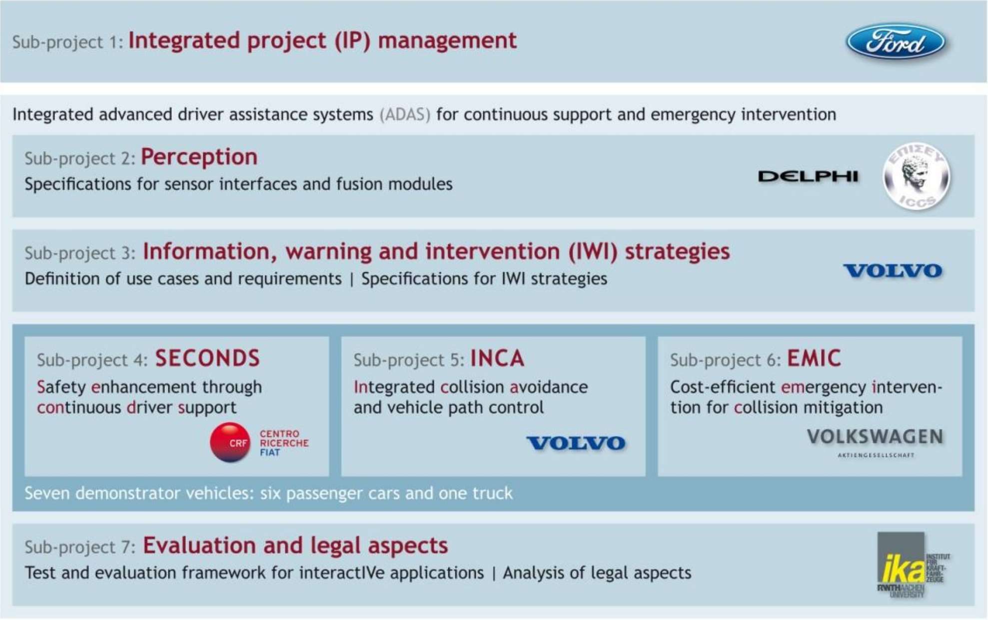


Figure 1.4: Subprojects of the interactIVe project.

Besides the six presented subprojects there is also the SP1 "Management" subproject, which includes the coordination of the other subprojects, links to external activities, dissemination and the general administration.

2 Test and assessment objectives

The first ideas of the development process for the evaluation framework was presented in the internal report I-3 “Draft evaluation plan“ which describes the first approaches and plans of SP7 for the technical, user-related and safety-impact assessment. The basis for the described evaluation methodology was mainly from a literature review of other European research projects, e.g. PReVENT, eIMPACT and ASSESS. The internal report has also been the fundament for the discussion with the VSPs on the evaluation methodology.

The second step of SP7 was to start with the definition of the evaluation framework. This step has been conducted in D7.1 “Requirements for the evaluation framework”. It includes the function descriptions and research questions, which concern the evaluation of the interactIVe functions.

D7.2 “Specifications for the evaluation framework” has been the third step of the development process for the evaluation plan. The objective was to describe how the interactIVe functions will be evaluated through defining hypotheses derived from the research questions. The hypotheses are either verified or falsified by means of indicators, which also have been defined in the deliverable.

A continuous and close contact between the VSPs and SP7 has been essential in order to adjust the testing process and is needed for the final evaluation of the functions. Therefore the feedback of the VSPs on the internal report as well as on the research questions and hypotheses has been closely considered during the whole process.

An overview of the structure of the project is given Figure 2.1.

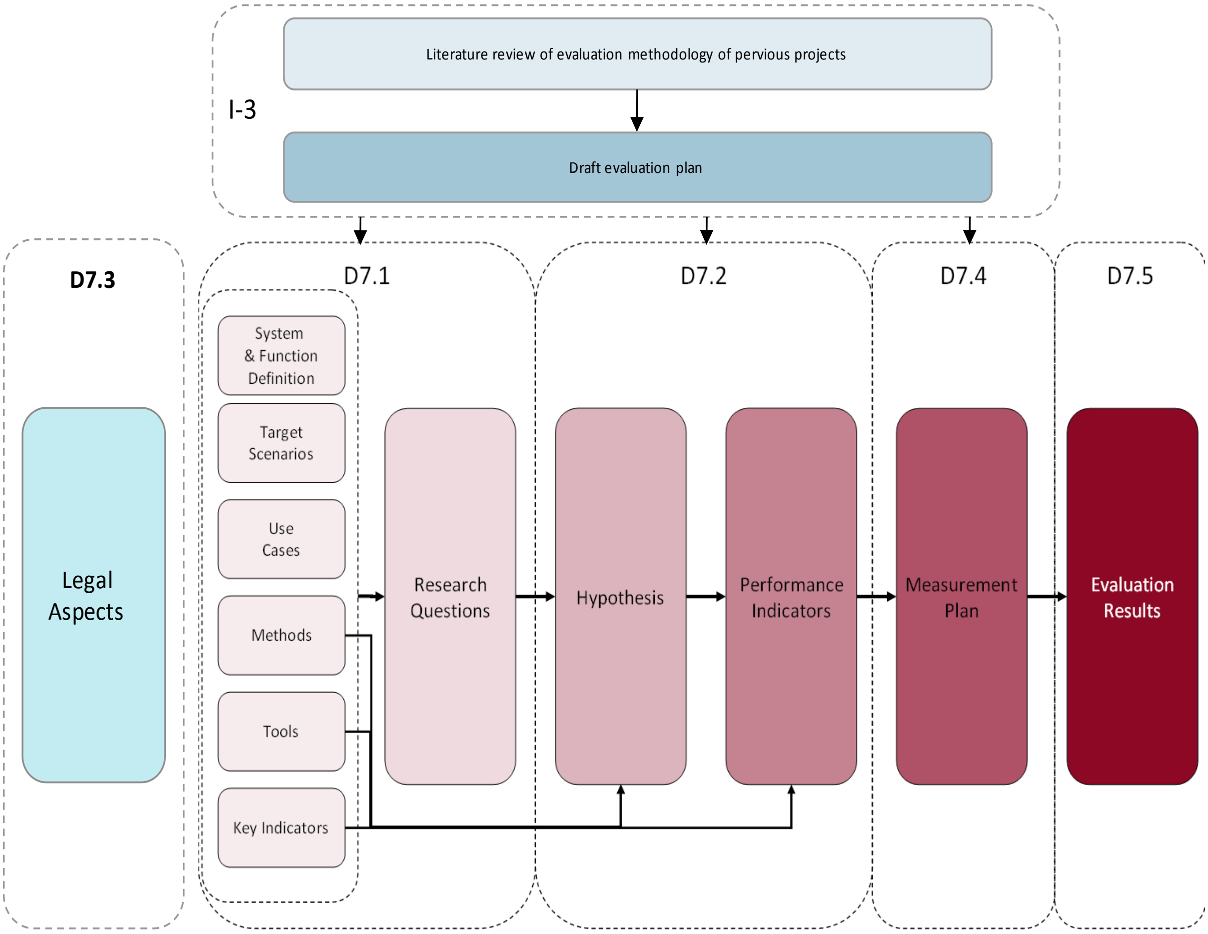


Figure 2.1: Overview of the structure of SP7.

The purpose of the tests is to analyse the interactIVe functions from a technical-, user-related and safety impact point of view. The three assessments are all related to the final situational control. Figure 2.2 shows the relations between the different evaluations, as described by the PReVENT project [SCH08]. The technical performance of the function is the major contributor to the control of the driving situation. When the driver is in the loop, the driving performance is also affected by the usability and user acceptance of the function. The safety impact assessment builds on the results of the technical and human factors evaluation.

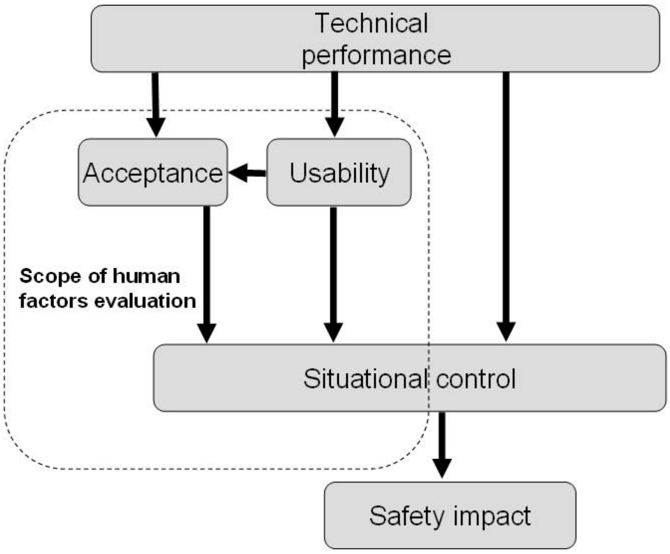


Figure 2.2: Description of the relations between the different evaluations [SCH08].

2.1 General approach & scope

WP75 focuses on the development of a common evaluation framework for technical, user-related, and impact assessment of interactIVe applications. SP7 has selected the methodology of PReVAL project [SCH08], which will ensure solid evaluation assessment methods. One of the main objectives of PReVAL was to define a framework for estimating the safety impact of active safety systems, which were developed in the PReVENT integrated project. Both technical performance and human factors were taken into account.

Assessment is always carried out against certain requirements or goals for technical assessment or against a reference for impact assessment. Depending on the development stage, testing is different. The process of system development and testing is best described in the V-model, which is used more and more in automotive system development (Figure 2.3).

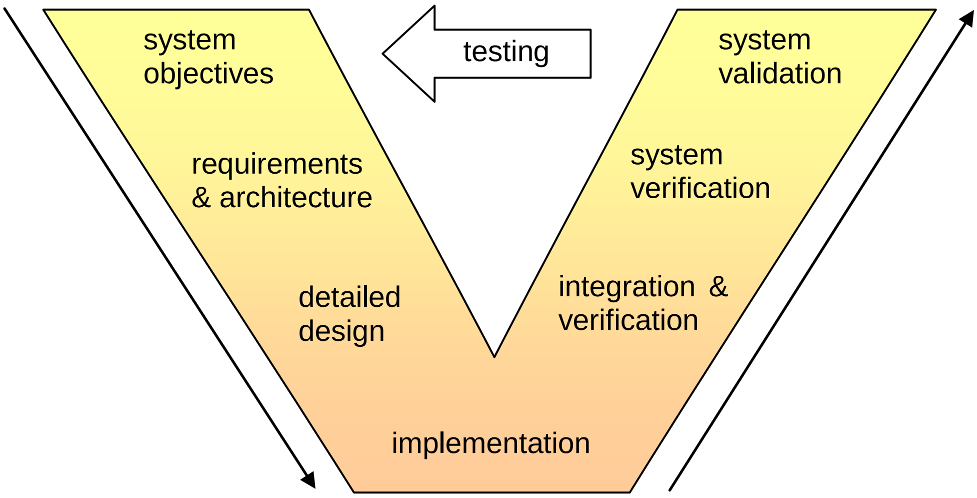


Figure 2.3: Generic V-model for system design and testing.

For the evaluation of the interactIVe functions in the system validation phase of Figure 2.3 the PReVAL evaluation method will be used. It provides a thorough framework containing technical, user-related and safety impact evaluation (Figure 2.4)[1].

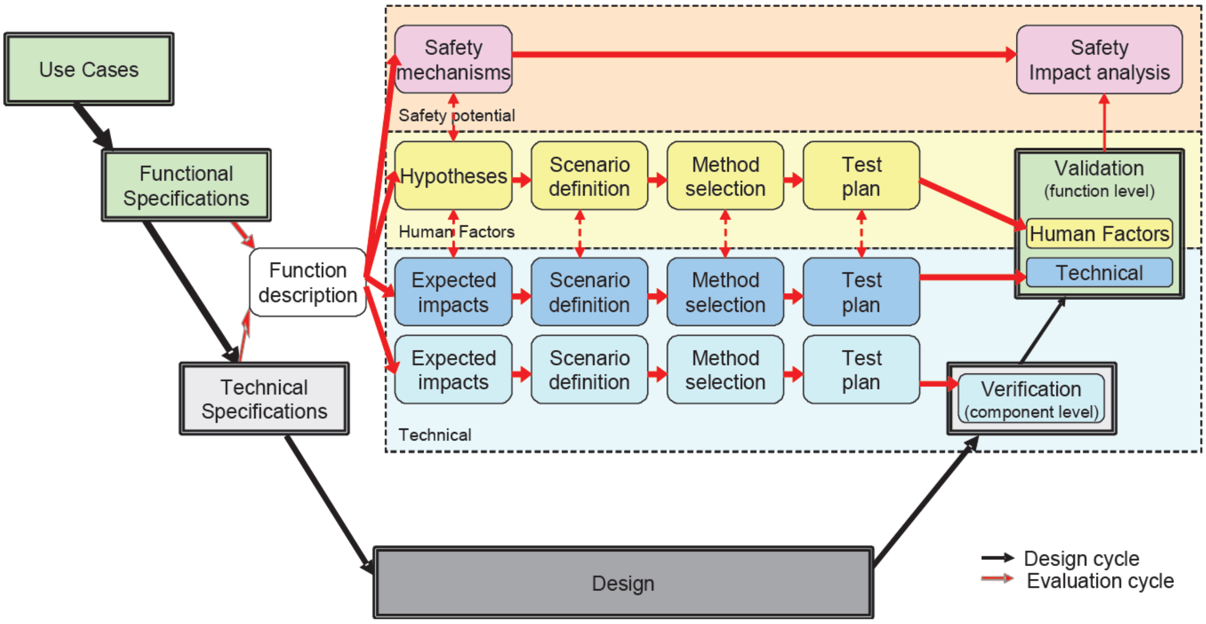


Figure 2.4: PReVAL evaluation framework [SCH08].

A challenge faced in the evaluation is how to carry out the assessments and evaluations given all the different functions and vehicles. It has been decided that mainly the functions of the different systems are evaluated and, if time and budget allow, some specific combinations of functions will be assessed. Hence there will be no 'SECONDS'-, 'INCA'- or 'EMIC evaluation' as such.

[1] Legal aspects are considered separately, and described in D7.3.

The main objective of the evaluation is to assess how well the different interactIVe functions perform to fulfil their objectives as specified by their target scenarios. Hence, the functions are evaluated from a development point-of-view and not from a consumer point-of-view (cf. EuroNCAP) taking the current state of development of the functions into account. Consumer evaluation may be too general for the specific system as they aim to test a multiple of similar systems in the same way to be able to still compare the systems. Nevertheless, projects aiming at providing methods to assess from a consumer or regulations point of view (like e.g. ASSESS [BAR10]) may provide useful insights to the evaluation framework and will be taken into consideration along with other projects (see Internal Report I-3 – Draft Evaluation Plan).

The general procedure of the PReVAL project identified following steps for the evaluation of ADAS:

Step 0: System and function description

In this step information is gathered on what the system is supposed to do and how it should work:

- general information,
- functionality and use cases,
- targeted accidents limitations and
- subsystems.

This step was taken in WP7.3 and is reported in D7.1.

Step 1: Expected impact and hypotheses

Here, the evaluations are split up into (i) technical, (ii) user-related and (iii) safety impact assessment. However, since the safety impact assessment requires input from user-related and technical evaluation and since user-related assessment requires input from technical evaluation, the hypotheses generation should be harmonized. In this way overlapping work can be kept to a minimum.

A first step in defining the hypotheses was taken in D7.1 by defining the research questions. From these the hypotheses are derived in this deliverable.

Once the hypotheses are formulated, the indicators for establishing the impact or testing the hypotheses can be derived. This needs to be carried out for each function. In the end, there are common hypotheses or common indicators for several functions, but this certainly is not the case for all functions. Especially, but not exclusively, for technical evaluation the indicators are directly measured in the vehicle or derived from the measurements.

This step was executed in WP7.4 and reported in deliverable D7.2.

Step 2: Test scenario definition

In this step the test scenarios for the evaluations are defined. Indeed, these scenarios must be defined in such a manner that they are relevant for evaluating the hypotheses. A foundation is formed by the work reported in D1.5 [MÄK10], the use cases and target scenarios, but also other projects may offer relevant scenarios, like e.g. the ASSESS scenarios [BAR10].

The role of test scenarios in evaluation differs for each type of evaluation. Test scenarios are directly applicable to the technical tests and to some extent to the user related tests. They are only to a certain extent directly applicable in the safety assessment. The safety impact, which is related to direct impact on driver behaviour, such as speed or time headways, braking behaviour, lane keeping, lane change, etc., can be determined with the help of test scenarios. Indirect effects, such as interactions between users and non-users or exposure, can (usually) not be directly measured from the test scenarios. Nonetheless, test scenario definitions should try to take indirect effects into account as much as possible.

Moreover, this step has been taken into account in the deliverable D7.2 and is updated in this deliverable.

Step 3: Evaluation method selection

With the hypotheses, indicators and scenarios available, the most appropriate evaluation method must be determined. Testing can be done through full simulation, software-in-the-loop simulation, hardware-in-the-loop simulation and real world trials on test tracks or on public roads, either by professional drivers or (potential) users. The choice depends on many factors. The most important ones are:

- required outcome (e.g. opinion of a driver on the acceptance of the system or the amount of reduced speed at impact, determining false alarm rate, etc.),
- safety of a scenario,
- required number of vehicles for a scenario,
- availability of suitable targets (dummy vehicles),
- availability of simulators,
- time and budget constraints and
- legal aspects (e.g. the vehicle is not certified to drive on public roads) and company constraints (e.g. only professional test drivers are allowed to drive the demonstrator vehicle).

Once the evaluation method has been chosen, the identification of suitable and available tools follows naturally.

The final evaluation method is featured in this deliverable.

Step 4: Measurement plan

In this step the actual measurements and evaluations are specified. This involves defining the signals to be logged, the experimental design of the test including the number of tests and subjects, and other details which are required to acquire statistically significant results in order to test the hypotheses and carry out the impact assessment.

The measurement plan is reported in this deliverable.

Step 5: Test execution and analysis

This final step consists of conducting the tests and analysing the results. The challenge in this project is the coordination of the tests as the VSPs are responsible for the testing and recording of the data (supported by SP7, as agreed at the workshop in November 2010), but the analysis and assessment will be done by SP7.

This step will be described in deliverable D7.5.

3 Test and assessment methodology

3.1 General description of the functions under test

This subchapter describes the functions that are being developed in interactIVe. It is structured with regard to the three vertical subprojects (SECONDS, INCA and EMIC). For each system the different functions are described separately.

The functions' descriptions are based upon the information given in the interactIVe deliverables D1.5 [MÄK10] and D1.6 [LYT11] and describe the current status at the time this deliverable is being written. Therefore, the final functions may differ from the described functions in this deliverable.

The developed functions will be integrated in the seven demonstrator vehicles. An overview on the functions and the demonstrator vehicles, in which the functions are integrated, is given in the Table 3.1 below:

Table 3.1: interactIVe demonstrator vehicles and functions.

interactIVe functions	Demonstrator vehicle						
	BMW	CRF	Conti-nental	FFA	VCC	VTEC	VW
SECONDS							
Continuous Support		X		X	X		
Curve Speed Control				X			
enhanced Dynamic Pass Predictor	X						
Safe Cruise					X		
INCA							
Lane Change Collision Avoidance				X	X		
Oncoming Vehicle Collision Avoidance/Mitigation						X	
Rear End Collision Avoidance				X		X	
Side Impact Avoidance				X		X	
Run-off Road Prevention				X	X	X	
EMIC							
Emergency Steer Assist			X				
Collision Mitigation System							X

3.1.1 SECONDS

The SECONDS functions should support the driver continuously in the driving process in order to avoid dangerous situation in advance. Besides this, they should also support the driver in critical situations.

The subproject “SECONDS” includes the following four functions:

- Continuous Support [CS],
- Curve Speed Control [CSC],
- Enhanced Dynamic Pass Predictor [eDPP] and
- Safe Cruise [SC].

3.1.1.1 Continuous Support

The Continuous Support (CS) function supports the driver continuously while driving by means of different HMI channels in order to prevent the driver from running into dangerous situations. By means of the CS function rear-end, blind spot, road/lane departure and excessive speed accidents as well as traffic rule violations should be prevented. Furthermore, the function assists the driver in dangerous situations. The support of the CS function consists mainly of information and warnings. But depending on the demonstrator vehicle, in which the function is installed, the function can also intervene in the driving behaviour of the vehicle.

In order to support the driver through the driving process the function continuously evaluates the status of the host vehicle as well as the surrounding traffic base on the information of the on-board sensors. The reaction of the CS function is common for the different use cases. After the CS function has detected an imminent hazard, the function issues a warning to the driver in order (re)direct the driver’s attention to the situation. The warning status can increase continuously depending on the situation and the degree of a hazard. The detailed warning strategy will be developed in collaboration SP3 ‘IWI Strategies - Information, Warning & Intervention Strategies’. If the driver does not react to the imminent hazard, the function will also - depending on the demonstrator vehicle - intervene in the dynamic behaviour of the vehicle.

3.1.1.2 Curve Speed Control

The Curve Speed Control (CSC) function informs or warns the driver when approaching a curve with an unsafe speed. Negotiating a curve with a too high speed increases the risk of losing control or to collide with oncoming vehicle in an adjacent lane.

The safe speed for an upcoming curve is calculated by means of the digital map data and the information provided by the onboard camera sensor. The safe speed for the curve is compared to the driven speed. Based on this it is decided, whether the CSC has to warn the driver or intervene.

After the function has detected the excessive speed for the upcoming curve, the function issues a warning first. If adaptive cruise control (ACC) is active, the CSC function will autonomously adjust the set speed of the ACC before the curve to the safe speed.

3.1.1.3 enhanced Dynamic Pass Predictor

The enhanced Dynamic Pass Predictor (eDPP) function determines whether the driver of the host vehicle wants to overtake the lead vehicle, and whether the available overtaking path is sufficient for the planned overtaking manoeuvre. Therefore the function calculates the needed overtaking path. This calculated overtaking path is compared to the available overtaking path in front of the vehicle, which is determined based on the information of the different onboard sensors (radar and camera), Vehicle-to-Vehicle (V2V) communication and the digital map. If the available overtaking path is shorter than the calculated overtaking path, the function will inform the driver depending on the situation that overtaking is not recommended.

3.1.1.4 Safe Cruise

The Safe Cruise (SC) function enables autonomous vehicle following at a safe distance on rural roads and motorways. Besides observation of the environment and surrounding traffic by the function, the SC function needs to monitor the driver in order to ensure that the driver is not engaged in excessive secondary tasks while the SC is active.

If the SC function is activated, the vehicle will follow the current lane automatically. The driving speed is set to the current speed limit, which is detected by the function or – if no speed limit is available - to the set speed in order to make sure a safe speed is kept. If there is another vehicle in front of the host-vehicle, the function will adjust the distance between the vehicles to the driver’s preferred headway.

3.1.2 INCA

The vertical subproject “INCA” includes the following five functions to avoid accidents:

- Lane Change Collision Avoidance [LCCA],
- Oncoming Vehicle Collision Avoidance/Mitigation [OVCA],
- Rear-End Collision Avoidance [RECA],
- Run-Off Road Prevention [RORP],
- Run-Off Road Prevention (curve) [RORP (curve)] and
- Side Impact Avoidance [SIA].

3.1.2.1 Lane Change Collision Avoidance

The Lane Change Collision Avoidance (LCCA) function should prevent collisions in the event of intended or unintended lane changes. The function covers not only lane change situations with oncoming vehicles, but also with vehicles approaching from behind.

In order to avoid a collision the function can intervene by means of the steering or braking system of the vehicle – depending on the situation. But first the driver is warned e.g. by a haptic device. If the driver does not react to the warning, the function intervenes by means of braking and steering.

The function should also support the driver in lane changes while overtaking. In this case two situations have to be distinguished: The starting point of the situation is that the host vehicle drives on a rural road and has recently started an overtaking manoeuvre. But there is an oncoming vehicle, and due to this the manoeuvre has to be aborted.

- In the first situation the initial lane, in which the function wants to steers back into to avoid the imminent collision, is blocked by another vehicle. In this situation the function inhibits the gas pedal and initiates an autonomous braking. At the same time a visual warning (e.g. red LEDs) is issued to the driver of the host vehicle. If a sufficient gap in the target lane is detected, the function performs a lateral intervention in order to steer the host vehicle to the target lane and disarm the situation.

- In the second situation the initial lane is not blocked by another vehicle. In this case the lateral intervention is conducted directly.

3.1.2.2 Oncoming Vehicle Collision Avoidance/Mitigation

The Oncoming Vehicle Collision Avoidance/Mitigation (OVCA) function is intended for situations, in which another vehicle is approaching the host vehicle in the same lane. The objective of the function is to warn both drivers and – if it is necessary – to apply the brakes of the host vehicle in order to give the oncoming vehicle more time to change lane back to the original lane. The second objective of the braking is to reduce the impact speed in case that the collision cannot be avoided.

The main challenge related to the function is the correct detection of an oncoming vehicle, since there is not much time left to the collision due to the high relative velocity between both vehicles. Hence it must be decided fast, whether the situation is critical or not. Furthermore, it must be detected in which lane the oncoming vehicle is approaching, since the function should only react to vehicles in the same lane as the host vehicle. Therefore the different sensor information is used in order to evaluate the hazard of the situation. Before the function intervenes in the driving behaviour of the host vehicle, the driver of the host vehicle as well as the driver of the oncoming vehicle will be warned. Therefore the host vehicle can use e.g. the headlights (flashing) or, if available, V2V communication.

3.1.2.3 Rear-End Collision Avoidance

The Rear-End Collision Avoidance (RECA) function prevents rear end accidents by autonomous braking and steering intervention. During normal driving the function determines continuously the risk of a collision and possible evasive trajectories based on the onboard sensor information. Therefore the position and motion of the host vehicle in relation to the lane markings and other detected objects (stationary and moving and including VRU) are calculated. Especially information on the driving direction of the adjacent lanes is important, because it must be prevented that the host vehicle evades in an oncoming traffic lane, even if it is empty.

If an imminent collision is detected the RECA function will first warn the driver. If the driver does not react to the warning, the function will intervene by applying either the braking or steering actuator depending on the situation. The natural approach to a rear end conflict is to brake in order to reduce the vehicle velocity. If the function detects during the braking manoeuvre that the manoeuvre will not be sufficient, the function can additionally try to avoid the collision by steering (if there is sufficiently wide shoulder to the right and no other obstacles). The functions checks, if the requirements are fulfilled and performs an automatic steering manoeuvre towards the shoulder.

The steering intervention without braking is chosen for situations with a very high relative velocity. Therefore the RECA function checks first, whether a steering avoidance manoeuvre is possible (e.g. is there no traffic approaching from behind in the adjacent lane?). After the steering manoeuvre is completed, steering control is handed over back to the driver.

3.1.2.4 Run-Off Road Prevention

The Run-Off the Road Prevention (RORP) function prevents run-off road accidents by autonomous steering intervention on straight roads. In order to prevent run-off the road accidents the RORP function must identify the road border edge and the position of the vehicle on the road.

Based on the sensor data, the function determines the hazard potential of the situation and whether a warning should be issued or whether the function should intervene. If an unintended veering towards the road border is detected by the RORP, the function will issue first a warning (e.g. steering wheel feedback and/or directional sound) to the driver in order to redirect the driver’s attention to the situation. If the driver does not respond to the warning in time, the RORP function will initiate an autonomous steering manoeuvre back to the road.

3.1.2.5 Run-Off Road Prevention (curve)

The Run-Off the Road Prevention (curve) (RORP curve) function in curve informs respectively warns the driver when there is an upcoming sharp curve and the vehicle speed is too high. Hence the function should prevent a road departure in a curve in advance.

For the calculation of a safe speed beside to the information of the curve, also the information of the truck needs to be considered (e.g. position of the centre of gravity). Based on the sensor information the function determines an appropriate reaction to the current situation. If the host vehicle approaches a sharp bend at an excessive speed, the function will first inform the driver on the curve. If the driver does not react to this information, a warning will be issued as a second step. If the driver still does not respond to the warning, the RORP function will inhibit the accelerator pedal and performs a smooth braking in order to reduce the speed.

3.1.2.6 Side Impact Avoidance

The objective of the Side Impact Avoidance (SIA) function is to avoid so called "blind-spot accidents". Blind-spot accidents occur in situations, in which the driver of the host vehicle wants to perform a lane change, but another vehicle is in the blind spot or approaching rapidly from behind in an adjacent lane.

The countermeasures to avoid the imminent accident are calculated based on the hazard potential of the situation, which is detected by different onboard sensors. First, the function warns the driver. If the driver does not react to this warning, the function will intervene in the lateral dynamic behaviour. There are two types of interventions:

1. preventing that any part of the vehicle leaves the host lane,
2. steering back when a part of the vehicle has already left the host lane (major part still in the host lane).

3.1.3 EMIC

The vertical subproject EMIC intends to develop low cost mitigation avoidance functions for accidents, consisting of two functions:

- Collision Mitigation System [CMS],
- Emergency Steer Assist [ESA].

3.1.3.1 Collision Mitigation System

The Collision Mitigation System (CMS) function should mitigate the consequences of an imminent accident by intervention in the driving behaviour of the vehicle by means of braking and/or steering. The objective of the braking manoeuvre is to reduce impact speed. The objective of a steering intervention is to optimize the point of impact and the impact orientation in order to reduce the consequences of the accident.

Due to the two available mitigation strategies it is essential to choose the best mitigation strategy depending on the situation at hand. Based on the sensor information, the function determines whether a collision is imminent and - in case of an unavoidable collision - the probable point of impact and possible alternative impact points. For these points, an assessment is made regarding the resulting passenger injuries. Based on these calculations, the intervention strategy is chosen and the braking and steering actuators are applied. Besides the intervention by braking or steering, the function also warns the driver by an acoustical, a visual and a haptic warning.

The warning and intervention strategy of the function depends not only on the criticality of the situation, but also on the driver reaction. Thereby depending on the driver reaction the function will react differently. If the driver react strongly after the warning, starts to steer or press the accelerator pedal, the function will not intervene respectively the intervention will be stopped.

3.1.3.2 Emergency Steer Assist

The Emergency Steer Assist (ESA) supports the driver in dangerous situations, in which the driver tries to avoid an imminent collision by steering. In order to support the driver in dangerous situations the function observes the surrounding environment. If an imminent collision is detected first a warning is issued. If the driver starts a steering manoeuvre to avoid the collision, the function will adjust the available chassis systems - in this case mainly Electric Power Steering (EPS) - to stabilize the vehicle and to support the driver by making a safe and stable steering manoeuvre.

It is important to point out that the function does not help to avoid the accident. The function only supports the driver, if he/she reacts with a too weak or too strong steering manoeuvre.

3.2 Limitations of the functions

Important aspects for the evaluation tests to be considered are given limitations to the functions, especially with respect to the environmental conditions. This means that the functions are not able to work under all situations. There are different types of limitations, which could be relevant for the interactIVe functions. The most relevant limitations are listed below:

- Weather conditions (the function might not work in adverse weather conditions),
- Road type (the function might only work on certain road type, like extra urban roads) and
- Speed range (the speed range, in which the functions operate, might be limited in order to prevent misuse or to avoid misdetections).

Due to the fact that the interactIVe functions are still under development, it is not possible to describe the relevant limitations for each function in detail. Anyhow, for the tests the limitations of the functions must be considered in order to prevent a non-functioning in given test situations. If this is the case, the affected test case must be adapted for this function.

3.3 Demonstrator vehicles

As mentioned in previous section, there are seven demonstrator vehicles that together will contain the full interactIVe functionality. The demonstrator vehicles, which are shown in Table 3.2, will be used not only for demonstration purposes but also for the development, data collection and verification. A more detailed description of the vehicles is found in D1.7 and D1.6.

Table 3.2: interactIVe demonstrator vehicles

Demonstrator Vehicle	Picture	Car model	Integrated functions
BMW		BMW 535i	SECONDS • enhanced Dynamic Pass Predictor
CRF		Lancia Delta	SECONDS • Continuous Support
FFA		Ford Focus	SECONDS • Continuous Support • Curve Speed Control INCA • Lane Change Collision Avoidance • Rear End Collision Avoidance • Side Impact Avoidance • Run-off Road Prevention
VCC		Volvo S60	SECONDS • Continuous Support • Safe Cruise INCA • Lane Change Collision Avoidance • Run-off Road Prevention
VTEC		Volvo Truck FH-480 6*2	INCA • Oncoming Vehicle Collision Avoidance/Mitigation • Rear End Collision Avoidance • Side Impact Avoidance • Run-off Road Prevention
VW		VW Golf GTI VI	EMIC • Collision Mitigation System
CONTIT		VW Passat B7	EMIC • Emergency Steer Assist

3.4 Use cases

The key role of the use cases is to provide a fairly general description of the intended functionality of the envisioned systems as a basis for the more detailed specification of functional requirements.

Deliverable D1.5 presents the overall process of the work with requirements definition and was a starting phase for interactIVe. It begins with a description of hazardous traffic situations to be addressed and goes all the way from target scenarios through use cases to the definition of functional requirements with different levels of hierarchy. A total number of 207 requirements for the applications were defined. They served as an input for following work in the architecture and specifications definition, and consequently to the actual development work.

The target scenarios thus define the problems to be addressed in interactIVe but not the solutions. The use cases definition starts from the flow of events based on the target scenarios and describes how the intended function by means of interaction with the driver and/or direct intervention with vehicle control, prevents/mitigates the undesired outcome defined by the target scenario. Since interactIVe focuses on safety functions, the great majority of the target scenarios have been derived from road accident data. This involved both high-level statistics (frequency and injury distributions) on the general targeted accident types as well as more detailed descriptions, based on in-depth accident analysis, on the flow of events (including driver- and vehicle kinematic states) leading to the accident.

The general idea behind the methodology for the requirements specification was to start from the key problems to be addressed by the interactIVe functions, that is, the *target scenarios*. The term “target scenario” refers to the “problem scenario” that a function is intended to address. In most cases, this relates to road accidents although target scenarios may also describe other undesired outcomes such as, for example, traffic rule violations. The target scenario thus describes a flow of events leading to an undesired outcome which may be prevented, or mitigated, by the envisioned interactIVe function.

Based on these target scenarios, complemented by an assessment of major user needs, a number of *use cases* were developed: these define, in general terms, how the problems are tackled by the intended applications. In the last step, the use cases then served as the basis for defining the *functional requirements*.

The use cases definition starts from the flow of events characterising a target scenario (and the associated problem) and describes how the intended function, by means of interaction with the driver and/or direct interventions, can prevent or mitigate any undesired outcome. The key role of the use cases is thus to provide a fairly general description of the intended functionality of the envisioned systems, with a time sequence of events, as a basis for the more detailed specification of the functional requirements.

The use case-based methodology is today a standard practice in industrial system development and various models for defining use cases exist. However, these models are generally not optimal for use with active safety systems. In particular, there is usually no explicit link between use cases and the target accidents that they address. Thus, one unique contribution of the interactIVe project was the development of new models for target scenario- and use case definition with similar scenario representations. Accordingly, the use cases could be based directly on the target scenarios in a relatively straightforward manner.

3.5 Definition of research questions and hypotheses (and parameters)

In the deliverable D7.1, assessment has been divided in three different categories: technical assessment, user-related assessment and, impact assessment as it is pointed in Figure 3.1.

Moreover, the hypotheses, which are based on the research questions of D7.1, have been defined in the deliverable D7.2. These hypotheses were set up in two categories per assessment category (technical, user related and impact):

- General
- System / function specific (SECONDS, INCA, and EMIC).

The research questions were the first step of the evaluation and provide information on what is evaluated in the technical, user-related and impact assessment. Based on the research questions, the hypotheses were defined.

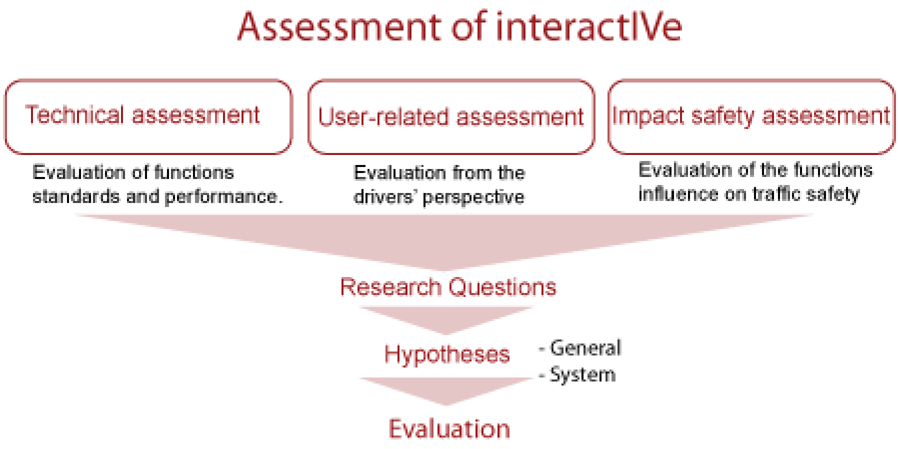


Figure 3.1: Assessment of interactIVe

This section gives an overview of the different types of research questions. The tables with all the detailed information on the research questions, hypotheses and indicators can be found in Annex C.

3.5.1 Significance level for testing of hypotheses

In hypothesis testing, the probability that the difference between the results of an experiment and the null hypothesis is coincidental is compared to the chosen significance level. If the probability is less than or equal to the significance level, the null hypothesis is rejected and the difference is said to be statistically significant. Thus, the probability that the null hypothesis is falsely rejected (that is, the null hypothesis is actually true, but is still rejected) is less than or equal to the significance level.

The level of significance is the criterion used for rejecting the null hypothesis. Traditionally, either the 0.05 level (also called the 5% level) or the 0.01 level (also called the 1% level) have been used in traffic related research. The lower the significance level, the more the observed mean value must differ from the null hypothesis to be significant. The 1% level is more conservative than the 5% level [NAV08].

The probability of the difference depends on the number of observations and the variance (standard deviation) of the mean of the observed values. Hence, to use a conservative significance level, a large number of observations (besides low variance in the data) is necessary.

For a given significance value, one has to design a test such that the probability of falsely rejecting the null hypothesis is guaranteed to be lower than this value. This is of course always possible by erring on the side of acceptance. However, this increases the risk of false acceptance of the null hypothesis that is, accepting the null hypothesis while it is actually not true. The inverse of this, that is, the probability that the null hypothesis is correctly rejected, is called the power of the test.

In hypothesis testing one desired a low significance level and a high power. However, these requirements are contradictory – indeed, a test that guarantees a low significance level has to accept the null hypothesis for many outcomes, but then the power is low, and vice versa. The source of this problem is that in the above setup there is only one hypothesis, namely the null hypothesis. A way around this issue is to test the null hypothesis against an alternative hypothesis which is not its complement. In this case the power is the probability that the alternative is correctly accepted.

A typical case is where the hypothesis is that the average value of some observed variable is (less than or) equal to some given value A, and the alternative is that it is greater than some given value B, where B > A. In this case, a typical test compares the observed average against some well-chosen value between A and B. A high power and low level of significance can then be achieved if

- The difference between A and B is large, relative to the standard deviation in the outcomes.
- The number of observations is sufficiently high.

However, the latter can be hard to fulfil for the high number of functions and use cases in interactIVe. Therefore, this raises a challenge for the evaluation in interactIVe. Chapter 3.8.7 describes the way in which SP7 deals with this issue in interactIVe.

3.5.2 Technical research questions

The technical research questions are divided in the following four categories: full function performance, perception, safety logic and technical user-related. The general hypotheses are relevant for all interactIVe functions and therefore they should be tested for all functions.

1. Full function performance

In the first category “full function performance” research questions and hypotheses are presented, which investigate the overall function behaviour. (E.g. How do different environmental conditions affect the function’s availability and performance?).

The functions designed in the interactIVe project are prototypes, and they may not work under all environmental conditions. The different technologies have restrictions regarding the environmental conditions (amount of light needed to function, range dependency upon rain, fog or snow). Starting from knowledge on the sensor’s limitations, the availability of the function under different environmental conditions can be determined.

The environmental conditions include the following:

- Weather (rain, snow, fog etc.),
- Road type,
- Lighting conditions,
- Road condition (dry, wet, black ice, ice, snow, oil),
- Gradient of the track and
- GPS signal availability (urban canyons, tunnels).

One example of hypothesis related with the RQ mentioned before is the next: Hyp_T_gen_perf_01: “The function’s availability is determined by the sensors’ availability and the indicators needed are missed alarm rates, false alarm rates and rate function “on” per environmental condition”. Research questions, hypothesis and indicators about this category can be found in Annex C.1.1.

Specific hypotheses for SECONDS are shown in Annex C.1.5. (CS), C.1.8 (CSC), C.1.11 (SC), for INCA in Annex C.1.13 (General), C.1.14 (RECA), C.1.18 (LCCA), Annex C.1.22 for EMIC and Annex C.1.24 for EMIC (CMS).

2. Perception

In this category of research questions and hypotheses performance related to perception components is investigated. (E.g. Is the relevant target detected by function during the test?) The hypotheses and indicators are related to perception in the sense that for the tests the relevant information is provided to the function's logic. One example of hypothesis is Hyp_T_gen_perc_01: "Information on the relevant target(s) is provided to the function's logic (during the test)" and the indicators to test it are: missed detections, number of false positive detections, number of false negative detections, rate of correct detection and time target visible and in sensor coverage area until first detection.

3. Safety logic

The research questions and then the hypotheses regarding the safety logic deal with the safety strategy of the function and decisions, made by the function (See Annex C.1.3). E.g. RQ_T_Gen_Safe_01 (In what way is the function expected to improve traffic safety?) was formulated in this category. An example of hypothesis proposed for the last research question is Hyp_T_Gen_safe_01: "The function reduces the impact speed" and it would be tested with the indicator impact speed. The results of these hypotheses and indicators can directly be used in the impact assessment.

4. Technical user-related

The objective of these questions and its hypotheses is not to investigate the driver's behaviour, but deal with the system's role in driving and the identification of the driver status and actions by the function. (E.g. is there after a warning, enough time left for an intervention by driver?)Complete list of these research question, hypothesis and indicators could be found in Annex C.1.4.

The hypotheses and indicators are technical but also user-related. These hypotheses and indicators are mainly focusing on the timing aspect of the warning. Next to that, it is studied, if the user can always override the function, which is important from a liability perspective and with respect to the controllability.

3.5.3 User-related research questions

At first, general Research Questions (RQs) are provided with relevance to all systems. Afterwards, an individual approach to the VSPs is taken.

The concept of situational control is central for the formulation of research questions and hypotheses regarding interactIVe systems. Situational control basically means whether the joint driver-vehicle system (JDVS) has enough control in a given situation to prevent a collision [LJU10]. Since this concept covers both the driver and the technical system, situational control can be quantified through technical, objective measures such as time headway and curve entrance speed. In the user-related domain, usability, behavioural effects and driver's acceptance of the system are of key importance [SCH08]. As such, it is important to investigate both how the driver and system react to and interact in critical situations, but also how the driver perceive and understand the system's operating principles. It might be the case that the driver has an insufficient understanding of the system's functionalities or operating conditions and overly trust that the system will resolve a specific situation. In this case, the driver has an erroneous perception of being within his/her safety zone (perceives that the situation is safe/controllable although it isn't), which obviously may be devastating and lead to a failure of adapting to the situation. In a similar way, since the system exerts a greater degree of control (both braking and steering) than current state-of-the-art ADAS, it will be important to investigate drivers' understanding and attitude towards such enhanced control. If the driver does not accept the enhanced control over the situation, this may result in unintended/unwanted behaviour and possibly that the system is switched off.

Therefore, common research questions and hypotheses were identified related to driver behaviour, trust and acceptance and system usage are the ones in the following.

Driver behaviour

A general Research Question (RQ) was proposed to assess how the system in question affects driver behaviour in the different defined scenarios. This RQ may include both intended effects and unintended effects but should target at finding out whether the driver carries out the actions properly as predicted in use cases and whether the system provides useful support when the driver is no longer able to handle the situation. In other words, this RQ aims at assessing the usability of the system, which is a key factor in terms of situational control. According to ISO 9241-11, measurement of usability (in general) should cover the assessment of:

- Effectiveness (the ability of users to complete tasks using the system, and the quality of the output of those tasks),
- Efficiency (the level of resource consumed in performing tasks) and
- Satisfaction (users' subjective reactions to using the system).

Effectiveness translated to the domain of ADAS technologies would mean how well the driver responds to warnings, in terms of reaction time and the correctness of the actions, and in general, how well the joint-vehicle-driver-system manages to avoid accidents or reduce accident severity.

The efficiency dimension of this RQ is translated as the level of resource, or the mental effort needed to handle the vehicle in the test scenarios. This may be done by using scales such as the RTLX (Raw Task Load Index, [BYE, 89]), RSME (Rating Scale Mental Effort, [ZIJ93]) or the Subjective Workload Assessment Technique (SWAT [REI81]). It is expected that the INCA and SECONDS systems will reduce workload compared to driving without the system. There is a risk however, that in situations where the driver has to monitor the system for possible limitations in its performance and for malfunctioning, mental effort will actually increase [DEW99].

Regarding satisfaction, it is obviously important that the driver has a positive attitude towards the system. This issue will be brought up in further RQs.

The "Driver Behaviour" category comprises a range of driver responses to the different scenarios, for which the functions have been designed for, but also the general behaviour is addressed. The hypotheses are formulated as null-hypotheses. An example of hypothesis in this category is the following: Hyp_U_Gen_Beh_01 Driving speed does not differ when driving with the function compared to driver without the function. This hypothesis will be tested to answer the next RQ: RQ_U_Gen_Beh_02 "Is there any difference in speed behaviour when driving with the system/function on compared to driving without the system?". And the indicators that will be taken into account to evaluate it are: speed profile, spot speed at selected sections and speed variance.

Trust and acceptance

Trust is a particularly important factor influencing the effectiveness of different strategies [DON09]. If drivers do not trust the system, this may lead to low system acceptance and disuse. Higher levels of trust, however, do not necessarily lead to greater acceptability of technology [SIE00] and it is also likely that over-reliance on the system can lead to a failure to monitor the system's behaviour properly and understand its limitations [LEE04]. This effect is sometimes also called complacency (see e.g. [DEW99]).

For safety impact evaluation purposes, one should also evaluate the willingness to pay and endorse.

System usage

The utilisation of interactIVe systems by the drivers must be safe, while assuring its effectiveness through its usage. For evaluating the system usage, the RQs are summarized in Annex C.2.3. One of this RQ is, e.g., RQ_U_Gen_Use_01: "Does the driver use the system as was intended?", the respective hypothesis: "The driver uses the function as it was intended", and it can be assessed by the number of times the driver uses/reacts to the function as intended.

3.5.4 Safety impact research questions

The main objective of the safety impact assessment is to evaluate in which way and how much the different functions influence traffic safety.

In order to determine the impact of the interactIVe functions on traffic safety, the accident frequency in the relevant use cases, and the output from technical assessment on technical performance of the functions and the output from user related tests on driver behaviour when driving with the function (such as, speed, distance keeping, lane keeping, reaction time etc.) will be used. Apart from the impact on traffic safety, which is determined for all systems, the impact of the SECONDS functions on fuel efficiency also needs to be studied.

This is done by analysing how the ADAS affects the nine safety mechanisms (addressing crash risk, risk of fatality/ injury, and exposure). These nine safety mechanisms are [DRA98] are described in chapter 6.2.

First the focus is on the direct effects. The main research questions and hypotheses related to this mechanism deal with the question: Does the function improve traffic safety?

There are two ways to improve traffic safety:

1. To avoid an accident and
2. To mitigate the consequences of an accident.

Both effects are also investigated by means of hypotheses. Besides to this research questions and hypotheses there are additional hypotheses which cover other aspects (e.g. under which condition does the function work?).

The first and most important hypotheses for all interactIVe functions are derived from the main objective to improve traffic safety. For all functions this hypothesis determines, whether they improve traffic safety.

Safety relevant hypotheses, tested in the technical assessment and user-related assessment are important for the safety impact assessment. Hence the safety impact assessment will use – when necessary and possible – the results from the other assessments.

General RQs, hypotheses and indicators for Safety Impact assessment are presented in Annex C.3.1. For example, in this table, RQ_U_GEN_01 "Does the function improve the traffic safety?" is presented. This will be tested through the hypothesis Hyp_I_Gen_01:"The function improves the traffic safety" through the indicators number of accidents and reduction of the accident severity.

The tables with all the detailed information on the research questions, hypotheses and indicators can be found in Annex C.

3.6 Definition of the test plan

For the assessment it is necessary to carry out various tests to get the needed data for the evaluation of the functions. But it would not be sufficient to test the function only in different scenarios, because this would only provide a clear picture on the function behaviour for one parameter configuration. In fact, the function must also be tested for different parameter configurations (e.g. velocities) in order to analyse for example how the function behaves over its speed range.

Before the test parameters are discussed, first the different terms related to the testing should defined.

- Test scenario:
    - group of test cases, which are related to the same type of critical situation,
    - comparable to “category of use case” or “category of target scenario”,
    - there are according to the interactIVe use cases 9 different test scenarios.
- Test case:
    - a general description of a tested situation,
    - one test case includes different tests, for which the relevant parameters are varied,
    - comparable to “use case” or “target scenario”.
- Test:
    - detailed description of a tested situation,
    - the description includes a detailed definition of the relevant parameters,
    - each test is repeated several times for statistical reliability.

The following Figure 3.2 shows the relation between the test scenarios, test cases and tests.

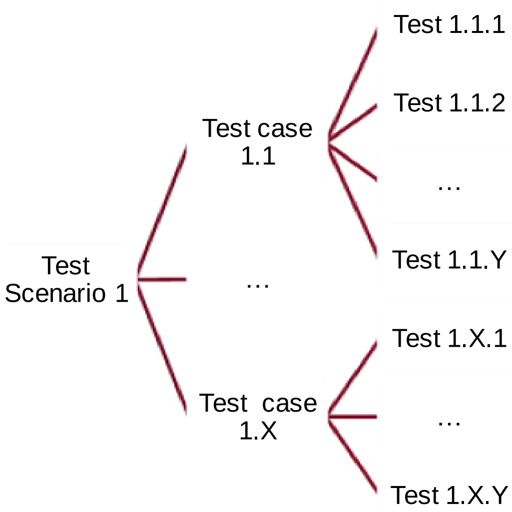


Figure 3.2: Relation between the test scenarios, test cases and tests

The conducted tests in interactIVe have two aims: the tests should assess the function’s performance (respectively technical performance and user-related interaction), and they should provide information for the impact assessment. Both objectives have to be considered for the definition of the test parameters.

Furthermore, for the definition of the test parameters, a distinction must be made between parameters, which are related to the involved vehicles (e.g. velocity, distance), and the parameters related to test environment (e.g. number of lanes, curvature). Both kinds of parameters can influence the function behaviour and have therefore to be taken into account. For example a function might not react with an evasive manoeuvre if there is only one lane in the driving direction.

First the environmental test parameters are discussed. The environmental test parameters are mainly affected by the road type, at which the function should work. Therefore, main environmental test parameters are:

- number of lanes in driving direction (1, 2, 3); total number of lanes,

- lane driven in (right, middle, left),
- road delineation (straight, different radius),
- lane markings (solid, dashed, solid dash) and
- traffic signs (e.g. speed limits).

In order to give the function the possibility to conduct an evasive manoeuvre into another lane, in general, the tests should be conducted on a road with two lanes in the driving direction. The exceptional case is that it is tested, whether the function considers correctly the environmental conditions and suppresses the lateral evasive manoeuvre on a road with one lane in the driving direction.

The driven lane is obviously related to the number of lanes. If there is only one lane foreseen in the test case, the lane driven in needs not to be specified. On a road with two lanes in the driving direction it can be analysed, whether the function behaviour differs depending on the driven lane. A scenario, where the host vehicle drives in the middle lane is only possible on a road with three or more lanes. But the maximum number of lanes, which is required in interactIVe tests, is three. This test is for example interesting for rear-end conflict in order to answer the question to which side the function prefers to evade. But for the three-lane scenario, the parameters driving in the left or in the right lane don't need to be considered, because they are already covered by the two-lane scenario (it is assumed that the function will not perform a lane change over two lanes).

The road delineation (e.g. road curvature) must also be considered as an environmental test parameter for two reasons. The obvious reason is that the road radius must be varied for the tests of the functions, which should ensure a safe speed in an upcoming curve in order to prevent a road departure due to a too high velocity. But also in other test scenarios the road delineation can influence the function behaviour. One reason is that the perception of the objects might differ in a curve compared to a straight road. The second reason is that in an evasive manoeuvre the requirements for the actuators can be higher, because in addition to the steering torque, which is required for continuing the driven course, the steering torque for the evasive manoeuvre must be applied.

The type of the lane markings can be relevant for the functions, which are related to lateral conflicts. These are functions intended to prevent blind-spot or run-off road conflicts. In this case the function must be able to detect the lane-, respectively road edge independent of its forms. A bad detection of the lane or road edge can result in a limitation of the situations, in which the function can prevent accidents. This information is especially relevant for the impact assessment.

Traffic signs are especially relevant for the interactIVe functions, which should avoid an exceeding of the given speed limit. Therefore, the function's behaviour depends on the speed limit as well as correct interpretation of the traffic signs must be tested. But also in other tests traffic signs are need. Traffic signs are needed for example for the tests of the functions intended to prevent accidents in overtaking manoeuvres.

Besides these general parameters, there are also some additional parameters, which are only relevant for a certain test case (e.g. gradient of road). These parameters are not discussed in detail at this point.

After the environmental parameters, the vehicle related test parameters are discussed. For choosing the vehicle related test parameters, it is necessary to answer the question, what is the intention of the test cases. One objective of the technical assessment is to provide data for the safety impact assessment. Therefore, a straightforward approach is to analyse accident statics, like national accident statics, GIDAS, OTS, STRADA or STATS 19, in order to identify the most relevant accident types und the typical parameters (e.g. velocity). These parameters can be used afterwards to set up the test cases. The approach has been followed by different EU projects like ASSESS or INTERSAFE 2. interactIVe considers the results of these projects for the development of the tests.

A specific vehicle related test parameter is the load of the vehicle. This parameter is only relevant for the test with trucks involved, because the lateral driving behaviour of the truck is strongly influenced by the vehicle load. Therefore, the vehicle load must be considered by the function for the trajectory planning for the evasive manoeuvre. For passenger cars the influence of the vehicle load is smaller compared to the truck. Hence, for passenger cars this parameter is not considered.

The provision of data for the impact assessment is only one goal of the tests. The tests should also give the possibility to assess the performance of the functions. To meet this requirement at least for some test cases, a variation in the test parameters is required. In order to determine the relevant parameters, there are at least three different approaches, which can be used:

- Function specifications (including the target scenarios and use cases),
- Theoretic considerations regarding the functions' behaviour and
- Simulations.

Due to the fact the intervention and warning strategies will depend on the results of SP3, the function implementation is not finalized at the time of writing of this document. Therefore, the functions' specifications can only provide limited information. However, the function specifications can give some hints for the test parameters, especially for the speed range, for which the functions are designed.

Also simulations, as reported in the interactIVe deliverable D5.1 [NOZ11], and theoretical considerations regarding the intervention behaviour of the functions must be used to determine the relevant test parameters. Both approaches might help to identify for example the speed range interesting for testing. A typical example is to identify in rear-end conflicts if the function reacts by a braking manoeuvre or by an evasive manoeuvre.

In order to explain the selection of the vehicle related test parameters in a more detailed way, the test case 1.1 “approaching stationary target” is chosen as an example. In this scenario the host vehicle is approaching a stationary target. The approach velocities for the host vehicle are 50 km/h, 60 km/h, 70 km/h, 80 km/h and 100 km/h. Furthermore, for at least one velocity the functional behaviour in this situation is also tested for different road configurations (number of lanes, driven lane and road radius). This velocity will be defined based on the test results.

The general velocities of 50 km/h and 80 km/h have been chosen according to the test scenario of the ASSESS project, which determined the velocities based on accident data of different accident databases [BAR10]. The other velocities (60 km/h, 70 km/h and 100 km/h) have been selected according to theoretical considerations in order to analyse, at which velocity the function might react by braking or by swerving.

In principle, the velocity, for which it is more effective to do an evasive manoeuvre than to brake, can be calculated based on assumptions. The calculated velocity depends on these assumptions for the maximum possible accelerations and on the chosen evasive manoeuvre.

In the following paragraphs, for a passenger car the needed distance for braking is compared to the distance for an evasive manoeuvre for different velocities. For the following calculation it is assumed that the maximum lateral acceleration is 6 m/s², the maximum longitudinal acceleration is 9.81 m/s² and a lateral movement of 3 m is needed to avoid the accident. The distance needed for the braking manoeuvre can be calculated by means of the following equation:

$$dx_{Braking} = \frac{v^2}{2a_x}$$ Eq. 3-1

For the estimation of the distance for a lateral evasive manoeuvre, a simple approach[2] is chosen, which is described by a circular trajectory [ECK11], see Figure 3.3.

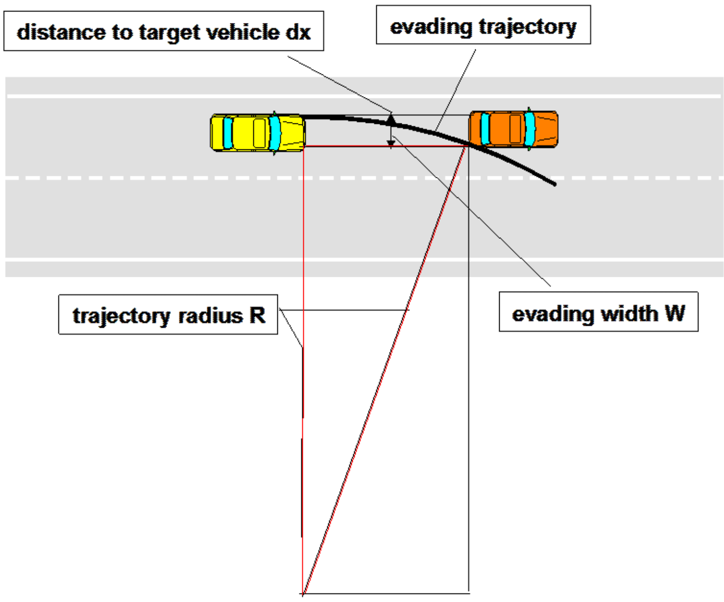


Figure 3.3: Principle sketch of a collision avoidance manoeuvre with a circular evading trajectory.

The minimal distance for an evading manoeuvre results from the estimation of the radius of the evading trajectory considering the lateral dynamic:

$$R = \frac{v^2}{a_{lateral,max}}$$ Eq. 3-2

with:

R:	Radius of the evading trajectory [m]
v:	own velocity [m/s]
$a_{lateral,max}$:	maximal possible lateral acceleration [m/s²]

The Pythagoras from the triangle between the vehicle and the centre can be expressed as:

$$(R - W)^2 + dx^2 = R^2$$ Eq. 3-3

$$\Rightarrow dx = \sqrt{R^2 - (R - W)^2} = \sqrt{2R \cdot W - W^2}$$

Combining the equations Eq. 3-2 and Eq. 3-3 results the minimal distance, at which an evading manoeuvre is still possible.

$$dx_{min,avoidance} = \sqrt{2\frac{v^2}{a_{lateral,max}} \cdot W - W^2}$$ Eq. 3-1

[2] This approach does not consider the counter steer manoeuvre, nor does it account for any dynamics of the vehicle and/or driver. Therefore it must be seen as lower limit for an evasive manoeuvre.

The following Figure 3.4 compares both distances calculated for different velocities and the given conditions. The conclusion of the diagram is that for avoiding an accident, steering is more effective than braking for velocities over 69.48 km/h. It must be noted that the calculations are theoretical, so no dynamics or driver delays are taken into account.

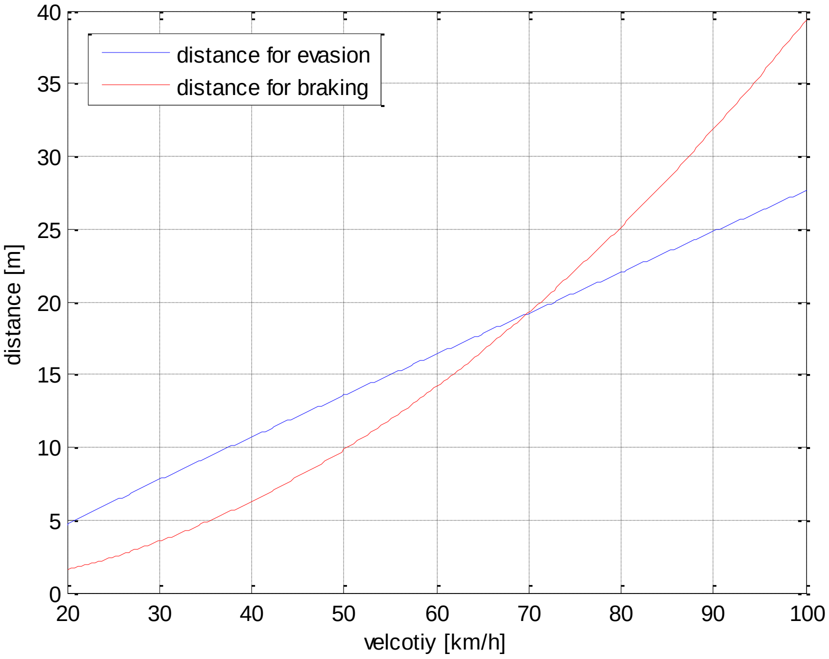


Figure 3.4: Distances for collision avoidance through evading and braking dependent on the vehicle velocity.

Of course, this value is only valid for the given conditions and assumptions. Therefore, the same calculations are also made for different maximum accelerations. It is assumed that the maximum acceleration, which is reached in a longitudinal braking manoeuvre, is equal or higher than the acceleration reached in swerving. The results are given in the following Table 3.3.

Table 3.3: Velocity, for which it becomes more effective to swerve than to brake, for different maximum accelerations

		Maximum lateral acceleration [m/s^2]						
		3	4	5	6	7	8	9.81
Maximum longitudinal acceleration [m/s^2]	3	29.16						
	4	39.96	33.84					
	5	50.04	42.84	37.8				
	6	60.48	51.84	46.08	41.4			
	7	70.56	60.84	54	48.96	45		
	8	81	69.84	62.28	56.52	51.84	47.88	
	9.81	99.36	86.04	76.68	69.48	64.08	59.76	53.28

The velocities, which are covered by the speed range of the test parameters, are marked in grey. It can be considered that most of the cases are covered by the selected parameters. Especially, if it is taken into account that the tests are conducted in dry conditions, where it can be assumed that higher longitudinal acceleration will be reached.

3.7 Test tools

To conduct the technical and user-related assessment the following equipment is required, in addition to the demonstrator vehicles:

- test tracks,
- data logging devices and reference measurements,
- in case of avoidance and/or mitigation: target objects,
- reference measurements for e.g. position,
- driving simulators for the user-related assessment when testing on a test track or public road is either not possible or too dangerous.

This section summarizes the availability of this equipment at the VSP partners in interactIVe[3].

Table 3.4 summarises the available test tracks, with possible limitations. Test tracks are needed for almost all functions to be tested. They offer the possibility to test more dangerous situations, like pre-crash and crash situations or high speed manoeuvring, which cannot be tested on public roads.

Table 3.4: Available test tracks for the interactIVe assessments.

Partner	Test track location	Test track availability
BMW	not required for eDPP	Test will be conducted on public roads.
	Hällered (80 km from Gothenburg, SWE)	Joined test with VCC demonstrator for V2V related applications.
CONTIT	Frankfurt (GE)	only available for ESA testing permission required for filming the tests limited size, some tests may not be done here
CRF	Orbassano (IT)	also available for other demonstrator testing permission required for filming
	Lommel (BE)	Test for curve speed warning depending on available resources
FFA	Lommel (BE)	also available for other demonstrator testing a Lommel driver's licence required vehicle must be proven to be safe permission required for filming and video material will be checked afterwards
	ika test track in Aachen (GE)	No digital map data is available.

[3] Note that the test facilities of the SP7 partners were reported in detailed in internal report I-3

	ika test track in Aldenhoven (GE)	Test track is available.
VCC	Hällered (80 km from Gothenburg, SWE)	also available for other demonstrator testing Hällered driver's licence required filming not permitted
VTEC	Hällered (80 km from Gothenburg, SWE)	also available for other demonstrator testing Hällered driver's licence required (filming not permitted)
	Autoliv's test track near Vårgårda (SWE)	The truck weight and size impose additional requirements on both the test track and the target objects
VW	Wolfsburg (GE)	only available for CMS testing permission required for filming

Besides a test track, also objects are needed that represent other traffic, but can be crashed into without damaging the demonstrator vehicle or its driver. Table 3.5 gives an overview of the available targets of the demonstrator partners in interactIVe. At the moment there are different open issues, especially with respect to the moving targets. This will be clarified until the tests.

Table 3.5: Available target objects for the interactIVe assessments.

Partner	Static targets	Moving targets
BMW	not required for eDPP	Real vehicle in front of the host vehicle
CONTIT	balloon car, crashable up to 70 km/h[1]	-
CRF	stationary vehicle object (balloon car) in the course of obtaining a pedestrian object	ika target (under construction) BASt cart for testing of Automatic Emergency Braking Real vehicle
FFA	balloon car and foam cubes	ika target (under construction) BASt cart for testing of Automatic Emergency Braking Real vehicle
VCC	available, but can only be used on VCC test track	4 balloon cars, 2 of which are on rail and 2 are free moving. One has a maximum speed of 90 km/h and one can be crashed up to 50 km/h speed difference

VTEC	vehicle and pedestrian objects	vehicle object for longitudinal scenarios
VW	static foam cubes crashable up to 90 km/h balloon car	in the course of obtaining one (car)

1 This speed can indeed be used with the target, however, the target can only be used for a limited amount of times at this speed and also the test vehicle may suffer damages.

From this table it becomes clear that there are little or no movable targets available now. There are, however, many developments in this field at the moment. So will the EU-project ASSESS develop a movable crash object (see www.assess-project.eu under newsletter no. 4). Moreover, some interactIVe partners are in the course of acquiring or (co)developing such targets.

Another way of testing apart from full system testing on public roads or test tracks is testing in laboratory environments with hardware in the loop (HIL) and software in the loop (SIL) setups. Only few partners use HIL/SIL to test the functions. CRF does some testing in a simulator and FFA performs HIL/SIL tests. VeHIL testing will be done for the VW demonstrator. VeHIL also has a SIL setup with a surroundings generator, a steering wheel and pedals to mimic driving with the real software. FFA has expressed interest in testing in VeHIL.

For the user-related assessment, testing in a driving simulator may be the best solution, especially when collision mitigation and collision avoidance functions are involved. Table 3.6 summarises the availability of simulators at the demonstration partners. It should be noted that some effort may be needed to get a certain function running in a specific simulator.

Table 3.6: Information on available driving simulators for the interactIVe assessment.

Partner	Driving Simulator details
BMW	not required for eDPP
CONTIT	Does not have a full driving simulator, but are working on a ‘desktop simulator’ consisting of a screen and a steering wheel.
CRF	6 DOF motion base simulator for CRF developments
FFA	not available
VCC	not available
VTEC	fixed base simulator with a 135° field of view VTIs simulator with moving platform (under discussion)
VW	fixed based simulator

Finally, for the reconstruction of the testing situations, additional reference sensors may be needed. Precise GPS and video data may help out here. Table 3.7 gives the available equipment for reference measuring.

Table 3.7: Available reference measurement equipment for the interactIVe assessment.

Partner	Available reference measurement equipment
BMW	normal GPS (accuracy of a normal GPS system should be enough for the normal test; for the joint test with VCC demonstrator GPS system with a higher accuracy is needed)
CONTIT	RTK-GPS
CRF	Vector CANgps or D-GPS form Novatel
FFA	a position reference system is available (RT3000 GPS)
VCC	a position reference system is available an eye tracker is available but its logging is still unclear
VTEC	RTK-GPS
VW	RTK-GPS

3.8 Challenges for the evaluation in interactIVe

The SP7 partners have identified some challenges that are specific for the assessment in interactIVe. The challenges deal with the type of tests to be carried out, with the maturity and uniformity of the ADAS functions under testing, and bundling of functions. These challenges influence results that can be obtained from the technical, user related and impact assessments. Therefore, these challenges are addressed separately from the actual assessment plans. Specifically, the following challenges are addressed in turn:

- Maturity of functions,
- Long term effects on driver interaction,
- Bundling of functions,
- Uniformity of functions and systems,
- Complexity of functions,
- Resource limitations.
- Level of significance for hypotheses testing

The sections below describe how these challenges will be addressed. It is clear that this project will not completely solve all these issues, and indeed, some of them cannot be solved within the scope of interactIVe. In those cases, it will be mentioned, how the project will cope with that challenge.

3.8.1 Maturity of functions

The functions and systems under testing are in various stages of development. This has consequences for the type of tests that will be performed, namely:

- **False activation and missed activation rates**: These rates influence the user interaction with the function and the impact of the function, because they influence the ability of the function to react to specific events, as well as the level of acceptance and trust in the function of the user. For functions that are not fully developed, no information will be available on false activation and missed activation rates[4]. Indeed, in the development stage false activations and missed activations are used as incentives to improve the function, rather than as an evaluation of the function. Therefore, assumptions will have to be made on these rates for the fully developed functions.

- **Function availability in bad weather:** It is difficult to determine under which conditions the functions will and will not work. Sometimes a function is explicitly disabled under given conditions, for example in a given speed range. This does not need to be tested. But it may also be that a function is unavailable because it does not work well, for example when visibility is poor. If this is not tested, the information when a function works or does not work will be obtained from the function's sensor specifications.

3.8.2 Long term effects on driver behaviour

The user-related and safety assessment both depend on the interaction of the driver with the function. This poses the following challenges:

- **Test conditions**: This project will perform tests under controlled conditions, such as laboratory tests, driving simulator experiments and experiments on closed test tracks. The SECONDS system will also be tested on public roads with naive subjects. This poses a challenge to the proper assessment of the user interaction with the function. Indeed, a user who is aware of the artificial test conditions may behave differently compared to natural circumstances. For example, the behaviour may be more risk seeking if risks are not perceived as real, or a user may try to show socially acceptable behaviour because he knows he is being observed. Thus, the challenge is to elicit reactions from the driver that are as natural as possible so that the test results would represent reality.

  The point of view from the user-related side is that naive subjects (someone, who never used the function before) need to be informed on the function before. The driver may know that the function exists but has never experienced it. Therefore, the drivers should be informed that the tests will be active, but concerning INCA tests for example the driver will not be informed what the function will do. The reason for this is that otherwise the driver would wait for such situations, in which the function may intervene and then he / she will be more prepared.

- **Long term effects**: User interactions with new technology typically change over time. At first, the driver has to explore the function and learn how to interact with it. Moreover, in the long run behaviour patterns may change, for example if users learn to rely on the system to handle certain tasks. User behaviour can be divided into transient, short term effects and stable, long term effects. From the safety perspective, long term effects are the most interesting because they will by large determine the safety impact of the function. However, the tests performed in interactIVe will not be able to measure long term effects directly, because users will not be exposed to the systems for longer periods

[4] For warning systems these rates are often called false alarm and missed alarm rates. Here we use the term activation instead of alarm, to stress the fact that it also applies to intervening functions.

3.8.3 Bundling of functions

The assessment in interactIVe is first performed on the function level. This means that all tests address a single function. Based on that, the systems SECONDS, INCA, EMIC[5], each consisting of a bundle of functions, will be assessed to the extent possible. This poses the following challenges for the assessment:

- **Separation of functions**: Each single function needs to be addressed separately by the tests, so that its effects can be determined in isolation. This means that other functions need to be turned off during the test, or – in case the functions cannot be turned individually off - it needs to be ensured in some other way that they do not interfere, and the function which is active should be logged.
- **Separation of systems:** The FFA and VCC demonstrators contain more than one system. As a consequence of the separate testing of each function, the systems are separated tested automatically. This means that this challenge is solved by default.
- **Combination of functions in systems**: In order to assess a system, the results of the functions comprising the system need to be combined. There are several ways to address this challenge. One way is to test the combinations as well. This is a scientifically sound approach, but it requires a huge effort. Another way is to methodologically combine the results of the individual functions' assessments. This approach was selected in interactIVe. For the safety assessment this is addressed in section 7.6.

3.8.4 Uniformity of functions and systems

This proposes the following challenges for the assessment of functions and systems:

- **Uniformity of functions**: Functions with the same name in different demonstrator vehicles do not always have the same functionality. For example, the Continuous Support (CS) function in the CRF demonstrator addresses collisions with pedestrians, while the CS function in the FFA and VCC demonstrators does not.
- **Uniformity of systems**: A system does not always comprise the same set of functions in the different demonstrators. For example, the SECONDS system contains the eDPP function in the BMW demonstrator but not in other demonstrators.

3.8.5 Complexity of functions

One of the functions in interactIVe is CMS (Collision Mitigation System) aiming at collision mitigation by active steering. This function reduces the consequences of an accident by optimizing the impact point by means of the impact orientation. This poses a specific challenge for the safety impact assessment:

- **Speed-risk relation**: The safety impact relies on established relations between collision speed and injury risk. These relations are obtained from literature and they have usually been derived by an analysis of highly aggregated accident data. The relations typically distinguish impact areas such as frontal, side, rear, but not more detailed distinctions than that are made. This means that they do not distinguish between the optimized impact point of CMS and the non-optimized impact point without CMS. It is still under discussion in the SP7 team how this challenge will be

[5] Note that the EMIC functions are assessed separately in different demonstrator vehicles

tackled. One possible approach is to use simulations. A decision on the final approach to address the problem will be taken later.

3.8.6 Resource limitations

The project has to stay within time and budget constraints. This poses the following challenges for the assessment of functions and systems:

- **Number of use cases**: One challenge for the assessments in interactIVe is the high number of use cases for the developed functions. There have been 47 use cases defined in interactIVe deliverable D1.5 [MÄK10]. If all use cases are analysed in detail, this will end up in a high number of test cases. Since resources are limited, a detailed testing of all test cases is impossible.

  There are two approaches to reduce the testing effort. The first approach is to reduce the number of tested parameters for each test case. But on the other hand a reduction of the test parameters means that there is less information available for the assessments. The other approach is to focus only on certain test cases. But this could mean that some functionalities of the developed function are not evaluated during the assessment.

  Hence, for interactIVe a combination of both approaches is chosen. The test cases are divided into primary and secondary test cases. In the primary test cases the main functionality of the function is analysed. Whereas the secondary test cases are used to test and evaluate secondary functionalities. Therefore, in the primary tests, tests with different parameter configurations are conducted. For the secondary test cases only a minimum set of parameters are tested. Furthermore, the secondary tests will only be conducted depending on the available resources.

- **Testing season**: A second challenge for the testing is the seasons, at which the tests are planned to be conducted. According to the interactIVe time plan, the tests will be conducted in autumn or in winter. In order to prevent a reduction of the function performance due to the environmental conditions, the test conditions must be defined so that testing in adverse conditions is avoided. However, since the weather cannot be influenced, there might be some periods where testing is not possible. Therefore, the testing might take more time during autumn and winter than testing in summer time.

3.8.7 Level of significance for hypotheses testing

The high amount of use cases of the interactIVe functions is an issue for the testing of the hypotheses. A correct testing of the hypotheses requires enough data samples in order to prove that the calculated results are statically significant and not the result of a random error. Therefore, the relevant questions for the technical and user-related assessment in interactIVe are:

- Which level of significance is SP7 using for the testing of the hypotheses?
- How many tests are required in order to reach the aimed level of significance?

A conservative approach is to aim for a significance level of 1% (compare to chapter 3.5.1). Ideally SP7 would aim for this level of significance.

However, it needs to be taken into account that the interactIVe project is a research project, testing newly developed systems. Hence, there might be stronger variation in the results of the functions than for a market ready system. Therefore it might not be possible to reach this strict level of significance. Considering this issue, SP7 has decided to aim for the hypotheses testing for at least a significance level of 5%. If the significance level is not reached, the reasons will be discussed.

An open question is the required number of test data in order to reach the significance level. This cannot be answered by just considering the level of significance. As already stated the required amount of data samples depends also on the measured effects as well as the variation in the observed effects. The following paragraph describes how the different assessments deal with this issue.

For the technical assessment it is difficult to comment before the tests, how much test data is required in order to reach the chosen level of significance, because the variation in the test data, which depends on the function behaviour, the measurement equipment as well as the accuracy of the test repetition, is not known beforehand. The natural approach to overcome this issue is to repeat the tests often enough to ensure that the level of significance is fulfilled. Due to the limited resources of interactIVe this is not possible for all test cases. Hence, prioritization of the test cases is necessary. A prioritization in primary and secondary test cases has already been done for safety impact assessment. For some demonstrator vehicles the number of tests is still too high. A further prioritization is necessary in order to conduct the tests in the available time frame.

The data of the technical tests should not only be used for the technical evaluation, but also as input data for the safety impact assessment. Therefore, information on the function behaviour is needed from all relevant use cases. Hence, a compromise is necessary as this requires to take different test cases into account and a prioritization on a low number of test cases with high repetition is in contrast to this demand.

The compromise for this test dilemma is to check, by means of a pre-test, which variation in the test data can be expected. Based on the results of the pre-test the number of necessary observations can be roughly estimated. This puts a lower bound on the required number of tests per test case (see Figure 3.2 above for an explanation of this terminology), while limitations on the project resources put an upper bound. This is resolved by increasing the number of the test repetitions per test to the required number only for the most important scenario of a function. For this scenario the testing of the hypotheses will be conducted in detail. For the other scenarios the number of test repetitions will be limited to three per test in order to ensure that input data for the safety impact assessment is available. Of course, for these scenarios the hypotheses cannot be tested on test case level. A test of the hypotheses on test scenario level should still be possible. Even if the required level of significance is not reached, and thus in a strict sense the outcome is not significant, the outcome will still be reported and used in the safety assessment.

Also for the user-related assessment the limited resources in interactive need to be taken into account. For the user-related assessment two types of experiments are foreseen (simulator studies and small field tests). The number of test person in these studies is relatively low, but the number of observed events is expected to be satisfactory. Based on the experience in previous projects, it is likely that the foreseen level of significance can be reached with this number of test persons.

The safety impact assessment is different from the technical and user-related assessment, because it is not based directly on the test data. For example in the safety impact assessment a forecast of the accident data for the year 2030 is conducted. This forecast relies on assumptions and data with uncertainties that are difficult to quantify. Other uncertainties concern the relation between the number of critical situations on the one hand, and the number of accidents, injuries and fatalities on the other hand. Hence there is the question how relevant the level of significance can be for the hypothesis testing in the safety impact assessment, and whether stating a level of significance for partial results would not be counterproductive by suggesting an uncorroborated level of confidence in the overall outcomes. Therefore in the safety impact assessment the focus will be more on tendencies than on showing significance.

4 Technical assessment plans

This chapter describes the plans for the technical assessment. In the first section the methodology for evaluation is outlined. Section 4.2 discusses the testing itself, which is, though challenging, quite straightforward. However, coming to conclusions from the individual tests requires a strategy for the presentation of the results. Here, the approach of Safespot is taken and adapted to the needs of interactIVe. Section 4.3 describes, whether testing in different test environments may have an effect on the test results. Conformity between the test results should be assured. Finally, section 4.4, discusses the details: the parameters to be used in the different tests.

4.1 Methodology

The methodology for the technical testing is straightforward after the choice of the appropriate test scenarios. For interactIVe, the nature of the applications requires full hardware testing, e.g. using the demonstrator vehicles. The testing will be mainly performed on test tracks, but some of them must run in normal traffic and some tests can be performed in laboratory surrounding (VeHIL). The challenge for interactIVe is to comprise all test results so that:

- a conclusion on the functional performance of a function can be drawn,
- the results can be used for the safety impact assessment.

To this end the approach used for the results reporting in Safespot [FAK11] is adapted to the needs of interactIVe.

The method prescribes that the results should be reported using the hypotheses as defined in the previous deliverable D7.2. These hypotheses were derived from the research questions of D7.1[6].

4.1.1 Standardised results reporting

Firstly, the test results have to be reported in a specific standardised form. It is proposed to group the test results by test scenario (per demonstrator vehicle):

1. Test scenario: Rear-end collisions,
2. Test scenario: Head on collisions,
3. Test scenario: Lane change collisions,
4. Test scenario: Cross traffic collisions
5. Test scenario: Collisions with vulnerable road users,
6. Test scenario: Unintended lane departure accidents,
7. Test scenario: Excessive speed accidents,
8. Test scenario: Traffic rule violations,
9. Test scenario: Verification tests,
10. Test scenario: Test on public road.

[6] Note that the hypotheses were updated after publishing D7.2 and compiling the feedback of the interactIVe partners on the hypotheses. The revised hypotheses can be found in Annex B

These reports will make the basis for the conclusions from the performance of the functions and the input for the safety impact assessment.

The following general structure of the test reports is required:

1. Introduction:
   - Give a short description of the application, test site and test scenario.
2. Method:
   - Aim of the experiment / Hypothesis / measured indicators,
   - Test site description,
   - Test case descriptions (including photos or sketches and reference to test cases),
   - Technical Setup (SW/HW/Cars/RSU/…),
   - Setting: Weather, Temperature, Driver etc.,
   - Description of the procedure followed during the test (e.g. report exemplary test trail),
   - Participants / Drivers profile,
   - Applied tools to obtain the results,
   - Data processing or statistical analysis methods applied.
3. Results:
   - Report the results in tables and bar-diagrams, preferably by means of the identified indicators,
   - Report only relevant findings, but report all outcomes that will influence your conclusions.

5. Interpretation of results:
   - Interpretation of results (reliability of results / how did [technical] problems [might have] influenced the results),
   - Summarize the results that are in your opinion relevant and reliable.

6. Discussion / Conclusion:
   - Which hypotheses are addressed in the test and what are the conclusions that can be drawn with respect to these hypotheses.

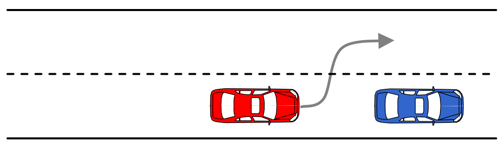
7. References:
   - Give reference to documents used in your report.

8. Annexes
   - Photos + Videos,
   - Time plots of most important signals / indicators,
   - Tables,
   - Statistical calculations,
   - Test checklists.

4.1.2 Results summary table

For each test scenario the following summary table need to be filled in (to ease a quick glance over the test results and later grouping of the overall function performance). An example is given below Table 4.1Table 3.7 (the results are freely invented examples and do not represent technical results). The table summarises the results against the most important hypotheses for that test and function. More elaborations can be added in the respective chapter of the test report.

Table 4.1: Summary of the (invented) 10 results against the most important hypotheses for test and function

Function	ESA (Emergency Steer Assist)	**Driving environment** ○ **Urban** ○ **Rural** ● **Motorway**	**Testing environment** ○ **Simulation** ○ **Simulator** ○ **Test track (closed road)** ● **Test site (public road)**
Test scenario	Rear end collision		
Tests performed	test case 1.1: 30 tests test case 1.2: 90 tests test case 1.4: 30 tests test case 1.7: 60 tests		
Goal	Prevention of potential crash of both vehicles through a supported evasive manoeuvre.		

Evaluation results		> 75%	75% - 50%	50% - 25%	< 25 %	**Comment:**
Hyp_T_gen_perf_03: Using maximum (possible) acceleration.						Lateral acceleration was evaluated only as this makes more sense for ESA.
Hyp_T_gen_perf_05: No false negative activations						0 false negative activations (note that the driver activates manoeuvre)
Hyp_T_gen_perf_06: No false positive activations						0 false positive activations (note the that driver activates manoeuvre)
Hyp_T_gen_perc_01: Information on the relevant target(s) is provided to the function's logic (during the test).						Since function was working as expected this was not further evaluated.
Hyp_T_gen_perc_02: Information on the relevant target is provided in time to assure that the function can react as intended.						Since function was working as expected this was not further evaluated.
Hyp_T_gen_safe_02: The function improves traffic safety by avoiding an accident in a target scenario.						70% of the accidents are avoided. Most difficult are the scenarios with the braking target vehicle.
Hyp_T_gen_safe_05: The function supports in all tested scenarios, in which a support is required.						In all situations requiring a support, a support was given.

Hyp_T_gen_safe_07: The function behaves in the same way in similar situations.						Only two conditions tested: warm sunny weather and light rain.
Hyp_T_gen_TecU_01: The driver has enough time to react and avoid the accident, when the warning is issued.						Not specifically tested for, the warning was recorded in each test and evaluation afterwards confirmed that the warning would have been in time to avoid the collision through braking only.
Hyp_T_gen_TecU_04: The function can always be overridden by the driver.						Not especially tested for.
Hyp_T_EMI_gen_01: The function always recognizes the avoiding steering action of the driver (in the scenarios).						Since an expected support was always given, this hypothesis is automatically fulfilled. Note that it was not tested what the minimal driver input should be for support.
Hyp_T_EMI_gen_02: Too weak or too strong reaction of the driver is recognized.						Support is always appropriate (collision avoided), hence the reactions of the driver are recognized well.
Hyp_T_EMI_gen_03: After supporting the driver through the evasive manoeuvre the situation was correctly perceived to be safe enough to stop the driver support / intervention.						No special vehicle behaviour was observed after avoiding a collision.

Technical Challenges
First the optimal evasive manoeuvre was considered. Then the tests for the too weak and too strong driver reaction were driven. For the high speed test cases the original distance at which the driver should start the evasive manoeuvre had to be increased as the situation was considered too challenging with respect to safety. Sometimes it was difficult to exactly reproduce a test case. Especially the braking target vehicle was challenging.
Conclusion
Successful evaluation of the 'rear end collision' test scenarios. Note that the severity of the manoeuvre very much depends on the distance from where the driver is allowed to start the evasive manoeuvre. Here it was chosen such that braking would not have avoided the collision. The repeatability (tested through 5 repetitions) is good; the system acted the same in each test.

The colouring coding for the evaluation results of the hypotheses is as follows:

- dark blue: 75% of the tests or more confirm the hypothesis,
- blue 50 – 75% of the tests confirm the hypothesis,
- light blue/grey: 25 – 50% of the tests confirm the hypothesis,
- light blue: less than 25% of the tests confirm the hypothesis,
- grey: no evaluation possible, please state reason in comments column.

For the technical assessment, the majority of the hypotheses are formulated in a positive way, i.e. a dark blue marked cell reflects good behaviour of the function. However, some hypotheses are defined in a negative way. In this case the light-blue represents a good behaviour.

Under ‘Technical Challenges’ both involved challenges on the function and on the testing of the function (e.g. testing equipment) should be reported.

4.1.3 Synthesising the test results

To be able to draw conclusions on the test results for a specific function the results of all test scenarios of this function are taken and comprised to a single conclusion. Here the results summary table should help to get a fast collection of the results. This should result in a similar summary table but then for the performance of the specific function.

Finally the performance results per function are taken to be able to conclude on the results per system (SECONDS, INCA and EMIC).

4.2 Outline of the experiments

The objective of the technical assessment in interactIVe is to draw conclusions from the technical performance of the interactIVe function. Therefore, it is necessary to study the function’s behaviour in different situations by means of the indicators. The performance indicators are calculated based on the different measurements and should answer to the hypotheses defined.

One issue for the tests in the technical assessment is the testing effort, which results from the high number of use cases. Overall, there are nine different categories of use cases covered by interactIVe functions:

- Rear-end collisions,
- Head-on collisions,
- Blind-spot collisions,
- Cross traffic collisions,
- Collisions with vulnerable road users,
- Unintended lane departure accidents,
- Excessive speed accidents and
- Traffic rule violations.

A side aspect, which is only relevant for the SECONDS functions, is the evaluation of the fuel efficiency. Due to the fact that the interactIVe functions are mainly intended to improve traffic safety and due to the already high test effort, there will be no special tests on the fuel consumption conducted. The needed data for the analysis of the functions' effect on fuel consumption will be stored during the test drives for the user-related assessment on public roads.

In order to reduce the testing effort, the number of tests needs to be reduced. But the number of tests cannot be reduced arbitrarily, because it must still be ensured that the needed data for the technical assessment as well as for the impact assessment are available. Hence, a compromise between the testing effort and the provision of the needed data must be found.

A reasonable approach is to prioritise the test cases in primary and secondary test cases.

- Primary test cases are test cases, which test the main functionality of the function. For these test cases, different parameter configurations are tested. These tests are mandatory.
- Secondary test cases are test cases, which test side aspects of the function. Therefore a less extensive testing is conducted, which means that only a few parameter configurations will be tested. The secondary test cases will be carried out depending on the available resources and time.

A detailed description of the test cases can be found in Annex D.

4.3 Consistency between test site environments

The tests for the technical assessment will be conducted on different test tracks and test routes. The test tracks are chosen for each demonstrator vehicle separately according the availably of the demonstrator vehicle and test tracks.

In order to ensure the integrity of the data requirements regarding the consistency between the different test sites and the used test tools are needed. These requirements are needed, because otherwise it could happen that the function's performance is decreased, which will have a negative effect on the test results.

The demonstrator vehicle as well as the sensors used by the interactIVe functions can be affected by the environmental conditions, especially by the weather conditions. Therefore it is especially important to describe the weather conditions under which tests can be conducted:

- The tests should be conducted in daylight (no back light / no dazzle due to sun light) and constant lighting conditions.
- The tests should be conducted on a dry track with a track temperature higher than 0°C (a track temperature higher than 4°C is preferred) in order to avoid that the dynamic performance of the vehicle is reduced.
- Tests on an icy test track are prohibited.
- Tests in light rain without spray and ponding on the track are also permitted if the demonstrator vehicle can withstand it as well.

Another aspect, which is important for performance of the function, is the used target objects. It is important that the target object can be detected by the used sensors. Therefore the signature of the target should be comparable to signature of the real object. Depending on used sensor there are different requirements. If for example only a radar sensor is used, it might be enough to use a corner reflector instead of car. On the other hand if camera sensor is used, different attributes are important with respect to the target object, e.g. roof or tyres.

Regarding the target objects it must be considered that due to limited resources not all target objects can be used in all tests. This could also mean that some tests have to be conducted with targets, which may not so well be detected by the sensors as real vehicles.

4.4 Experiment parameters

In this chapter the relevant experiment parameters are discussed. The experiment parameters cover most aspects, which could have an influence on the results and must be considered for this reason.

Hence, the test parameters and the used tools for the tests, which have an influence on the test results, are also covered by the experiment parameters. For the selection of the test parameters, please see section 3.5, and for the used tools, see section 3.7. This section focuses on the experiment parameters, which have not been discussed up to now.

First, the parameters related to the test design are discussed. The experiment parameters with respect to the environment and especially weather conditions have been discussed in the previous chapter. It is important that the tests are not conducted in weather conditions that influence the function or the sensor performance in a negative way.

In order to minimize the adulterating of the test results by outlier at least five correct test runs are need for each test (in exceptional cases only three test will be conducted). “Correct test runs” mean that there should be no disturbance of the tests by e.g. bad weather or failures in the data logging equipment.

As shown in Table 3.1 for some demonstrator vehicles there are more than one function integrated. For some demonstrator vehicles there may be at least two functions, which address the same use case category. For the tests interferences between the functions must be avoided. Hence the tests have to be done for each function separately. This means that one function must be switched off, if possible, while the other function is tested.

In technical assessments the developed function and not the driver should be assessed. Consequently, tests should be as far as possible independent of the driver. This means that the driver reactions must be defined before the tests. Therefore, it is not important, who drives the vehicle as long as the driver is able to perform the required manoeuvres accurately. The required driver reaction for each test case is defined in the test case description. In general, the driver should perform a prescribed manoeuvre (e.g. lane change, steer vehicle to run off the road) and react in a test case only when the highest warning or intervention level is reached by the function. Hence, it should be possible to test the complete functionality of the function. Depending on the test case and the used target object, also different driver reactions may be required in order to prevent any damage. This has to be discussed for each test separately between the VSPs and SP7.

There are also some experiment parameters, which do not influence the tests directly, but that are important for the evaluation. These parameters are related to the data storage as well as to the indicators needed for the evaluation.

The VSPs are responsible for the data logging. Hence different logging tools can be used by them, e.g. ADTF or CANape. From SP7 side there is no requirement to use a special data logging tool. Instead SP7 has specified the signals, which have to be logged, and the format, and the data format, in which the data should be converted for the evaluation. The data should be converted and stored in a MATLAB-file, because MATLAB will be used for the evaluation.

Besides the vehicle data, also video data should be logged. By means of video data it should be possible to check dafter the test runs, what has happened during the test. This is especially important if the vehicle data do not provide a clear picture. The camera should be mounted in the vehicle and look forward. As video format any standard windows video format (.avi, .wmv, and .mpeg) can be used. The resolution should be equal or higher than 640 x 480. And the video should be synchronized with the vehicle data or contain a global timestamp. This time stamp and the information on the related frame should be also stored in the MATLAB-file.

A list of the signals, which should be logged during the tests, can be found in Annex E.

4.4.1 Analysis

The data provided by the functions performance will be analysed by means of the verification or falsification of the hypotheses defined. To test the hypotheses different indicators have be defined. The indicators defined should provide the opportunity to analyse the hypotheses by comparing them to a reference (e.g. no system use or a threshold). An overview of the most relevant indicators is given in the Annex B.

There are two types of research questions and hypotheses, please see chapter 3.5. There are function-specific research questions and hypotheses as well as general research questions and hypotheses. They will be analysed for all functions and in all test scenarios. But due to the different nature of the test scenarios (e.g. rear-end conflict vs. traffic rule violations), it will not be possible to use the same analysis tools for each scenario in order to analyse the research questions and hypotheses. Hence the used tools have to be adjusted according to each test scenario. The approach for the analysis tool is discussed in this section.

For the analysis of the function in the technical assessment, the focus is on the whole function. This means that there will be no special assessment of given subcomponents of the function (e.g. perception platform).

The technical assessment will be based on the logged data of the test drives. For the evaluation, MATLAB based tools will be developed and used. These tools will be developed by SP7. The evaluation tools provide the possibility to analyse the function performance in the different test scenarios and test cases. This means that the tools should be able to calculate the different indicators for the different scenarios.

The coordinate system used for the technical assessment is shown in Figure 4.1 below. It has been defined in accordance to ISO 8855 and the definition in interactIVe deliverable D1.7.

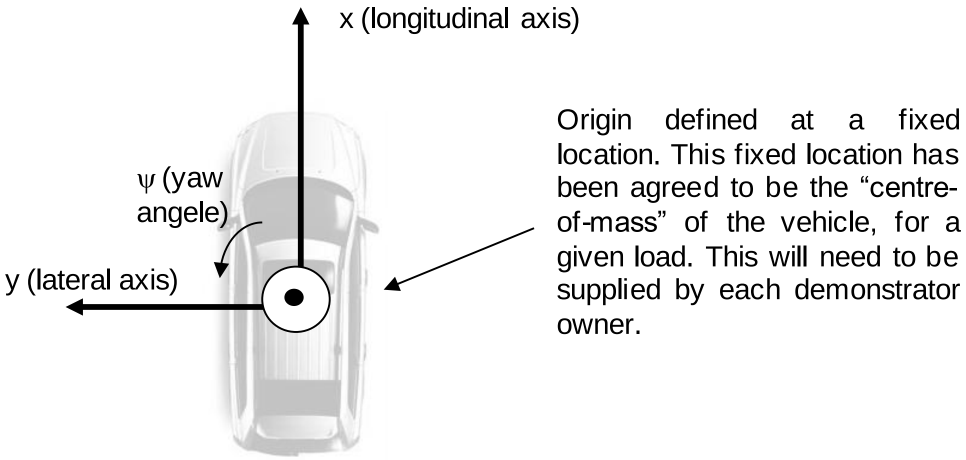


Figure 4.1: Vehicle coordinate system [SHA11]

Further measurement conventions for the technical assessment are:

- Heading angle 0 north, 90 east, 180 south, 270 west.

In order to analyse the performance of the developed functions, it needs to be investigated how the function and how strongly the function reacts to imminent danger of a collision (e.g. point of time of warning, achieved deceleration in a scenario, TTC at intervention).Depending on the test scenario the focus for the evaluation will be on different aspects.

For most scenarios (e.g. rear-end conflicts, head on conflicts) the position of the demonstrator vehicle in relation to target object must be available. It is proposed to measure the position of both objects by means of the reference measurement system in UTM-coordinates (<UTM-Zone> U <Easting> <Northing>). Based on the measured position of both objects ($N_{Host\ Vehicle}$, N_{Target}, $E_{Host\ Vehicle}$, E_{Target}) and course angle of the vehicle (ψ = 90° - Heading angle) the relative distance can be calculated in the vehicle coordinate systems (see Figure 4.2)

$$\Delta N = N_{Host\ Vehicle} - N_{Target}$$

$$\Delta E = E_{Host\ Vehicle} - E_{Target}$$

$$d = \sqrt{\Delta N^2 + \Delta E^2} \quad \beta = \left|\tan\frac{\Delta N}{\Delta E}\right| \quad \text{for } -180° < \tan x < 180°$$

$$\alpha = (\beta + \psi \cdot \text{sign}(\Delta N)) \cdot \text{sign}(\Delta N) = \left(\left|\tan\frac{\Delta N}{\Delta E}\right| + \psi \cdot \text{sign}(\Delta N)\right) \cdot \text{sign}(\Delta N) \text{ for } \Delta E \geq 0$$

$$\alpha = (180° - \beta + \psi \cdot \text{sign}(\Delta N)) \cdot \text{sign}(\Delta E) = \left(180° - \left|\tan\frac{\Delta N}{\Delta E}\right| + \psi \cdot \text{sign}(\Delta N)\right) \cdot \text{sign}(\Delta N) \text{ for } \Delta E < 0$$

$$\Delta x = d \cdot \cos\alpha$$

$$\Delta y = d \cdot \sin\alpha$$

The measured distance can be used in order to determine when the function warns or intervenes, respectively.

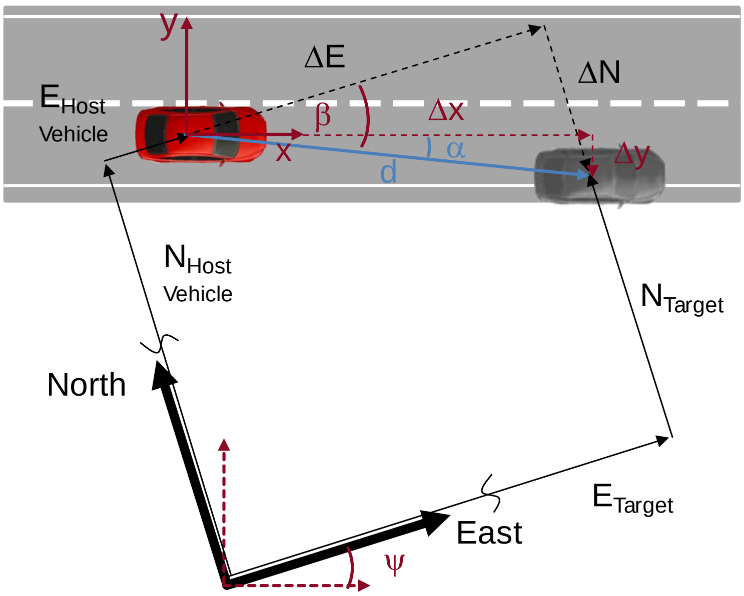


Figure 4.2: Measured distance for a GPS-based reference measurement system

More information on the analysis for the other scenarios can be found in the Annex B.

Furthermore, independently of the test scenario it needs to be reported, whether the function behaves in all test cases of the scenario correctly or whether false activation (warning or intervention) were observed (Hyp_T_gen_perf_05 and Hyp_T_gen_perf_06). A distinction has to be made between false negative activations (the function does not warn or intervene although it would be necessary) and false positive activations (the functions warns or intervenes although not intervention respectively warning is necessary). The false activations are identified by comparing the measured function reaction with the specified function reaction, which describes how the function should react in the given scenario. This description can be found in the test plans in Annex A. Obviously the time point, when the function initiates an intervention or warning, needs also to be considered for the evaluation on false positive and false negative activation.

An approach for a more detailed analysis is to use the stored ground-truth data as the input for the function instead of the sensor data. This analysis cannot be done online and needs to be conducted offline.

In addition, in certain scenarios it is evaluated, whether the driver is able to override the function (Hyp_T_gen_TecU_04). Therefore the function status is analysed after the function has issued a warning or starts to intervene in the dynamic behaviour and the driver has started a reaction in a manner that he/she wants to override the function (e.g. kick down of accelerator pedal). If the function is overrideable, the intervention or warning status of the function should change to a lower level. It is not the task of the technical assessment to evaluate, whether the chosen threshold for overrideability of the function is appropriate. It is only investigated, whether the function can be overridden. For longitudinal intervention the overrideabiltiy of the function is analysed in the test case 1.1 and for lateral intervention in the test case 6.1.

4.4.2 Tests for technical assessment

The following tables provide an overview of conducted test scenarios for each interactIVe function. Furthermore if prioritises the conducted tests for each function. A detailed test plan for each demonstrator vehicle can be found in Annex A. The test cases are described in Annex D.

Table 4.2: Tests for rear-end collisions"-scenario.

ID	Test case	CRF	FFA		VCC		VTEC	VW	CONTIT
		CS	CS	RECA	CS	SC	RECA	CMS	ESA
1.1	Approaching stationary target	P	P	P	P	-	P	P	P
1.2	Approaching parking target	P	P	P	P	P	P	P	P
1.3	Approaching end of traffic jam	S	S	S	S	S	S	S	-
1.4	Approaching slower vehicle	P	P	P	P	P	P	P	P
1.5	Approaching slower vehicle, left lane blocked by other vehicle	S	S	S	S	S	S	S	-
1.6	Braking front vehicle	P	P	P	P	P	P	P	P

Table 4.3: Tests for "head-on collisions"-scenario.

ID	Test case	BMW	VCC	VTEC	VW
		eDPP	LCCA	OVCA	CMS
2.1	Oncoming vehicle while overtaking	P	-	P	P
2.3	Oncoming vehicle (traffic) while overtaking	-	-	S	S
2.4	Intended lane change with oncoming traffic	P	S	S	P
2.5	Conflict with oncoming vehicle while left turn	-	-	-	P
2.7	Upcoming curve	P	-	-	-
2.8	Upcoming intersection	P	-	-	-

2.9	Upcoming hill	P	-	-	-
2.10	Overtaking prohibition	S	-	-	S

Table 4.4: Tests for “lane change collisions”-scenario.

ID	Test case	CRF	FFA			VCC		VTEC
		CS	CS	LCCA	SIA	CS	LCCA	SIA
3.1	Vehicle in left blind spot	P	P	P	P	P	P	S
3.2	Vehicle in right blind spot	S	S	S	S	S	S	P
3.3	Fast approaching vehicle	P	P	P	P	P	P	P
3.4	Vehicle in blind spot 1 with lead vehicle	S	S	S	S	-	-	-

Table 4.5: Tests for “cross traffic collisions”-scenario.

ID	Test case	VCC	VW	CONTIT
		CS	CMS	
4.1	Crossing traffic stand still 1	P	-	-
4.2	Crossing traffic (stand still) 2	S	-	-
4.3	Crossing traffic (moving) 1	P	P	-
4.4	Crossing traffic (moving) 2	S	-	-
4.5	Crossing traffic (moving) 3	S	-	-
4.6	Parking 1	-	-	-
4.8	Parking 3: Unparking vehicle	-	-	P

Table 4.6: Tests for “collisions with vulnerable road users”-scenario.

ID	Test case	CRF	CONTIT
		CS	CMS
5.1	Standstill pedestrian	P	P
5.2	Moving pedestrian (crossing)	P	P
5.3	Stopped pedestrian	S	P
5.4	Moving pedestrian (oncoming)	S	-
5.5	Moving animal	S	-
5.6	Stopped animal	S	-

Table 4.7: Tests for “unintended lane departure-accidents”-scenario.

ID	Test case	CRF	FFA		VCC			VTEC		VW
		CS	CS	RORP	CS	LCCA	RORP	RORP	OVCA	CMS
6.1	Unintended lane / road departure (right)	P	P	P	P	-	P	P	-	-
6.2	Unintended lane / road departure to obstacle (right)	-	-	-	-	-	-	-	-	P
6.3	Unintended lane / road departure (left)	S	S	S	S	-	S	S	-	-

6.4	Unintended lane departure with oncoming traffic (left)	-	-	-	S	P	-	-	P	P
6.5	Unintended lane departure + opponent vehicle	-	-		-	S	-	-	-	-
6.6	Barrier	S	-	S	-	-	-	S	-	S
6.8	Lane departure in curve	S	-	P	S	-		P	-	-

Table 4.8: Tests for “excessive speed accidents”-scenario.

ID	Test case	CRF	FFA	VCC
		CS	CSC	CS
7.1	Speed curve	P	P	P
7.2	Approaching zone, which required a lower speed (e.g. speed bump)	S	-	-

Table 4.9: Tests for “traffic rule violations”-scenario.

ID	Test case	CRF	VCC	
		CS	CS	SC
8.1	Approaching speed limit	P	P	P
8.2	Approaching series of speed limits	P	S	S
8.3	Approaching dynamic speed limit	S	S	S
8.4	Approaching covered speed limit	S	S	S
8.5	Approaching similar speed limit signs	S	S	S
8.6	Approaching speed limit (country)	S	S	S
8.7	Exit speed limit	P	P	P
10.1	Test on public road (including different scenarios / conducted instead of test case of the “traffic rule violations”)	P	P	P

4.4.3 Limitations for the technical tests

The main issue for the test in the technical assessment is the high number of use cases for the interactIVe functions, which result in a high number of test cases. A high number of test cases will result unavoidably in a huge effort for the testing. Therefore one requirement for the test plans is to limit the testing effort to a reasonable level. The chosen approach is to prioritize the test cases (see chapter 4.2).

Besides the testing effort, there are also other limitations to the technical tests, which need to be considered in the test plan. Most of the tests for the technical assessment will be conducted on a test track. Hence first the limitations with respect to the testing on a test track are discussed.

For all tests, which are related to a conflict with another vehicle, it must be ensured that the situation can be tested without the danger of damaging the demonstrator vehicle or even people. Therefore, instead of real vehicles often target objects like e.g. balloon cars are used. The target objects can only be used, if there is no difference regarding the detection by the sensor. Besides the detection the crash forgiveness of the target velocity must also be considered. The crash forgiveness of the target object depends on the type of the target and on the relative velocity. Hence, it must be checked before the tests, if it is feasible to conduct the tests with the proposed relative velocity of the test case without damage. One way to check is to build up the tests starting with the lower speeds and take a decision on increasing the speed on the results of last test.

Furthermore moving target objects must be used in different test cases. The number of available moving target on the interactIVe partners' site is limited. This means that at least for some demonstrator vehicles other approaches have to be used. One approach - especially for the SECONDS function, which does not intervene in the driving behaviour of the vehicle in scenarios with low relative velocities - is to use real vehicles in spite of the higher danger of damaging a demonstrator vehicle. In order to prevent any damage additional safety actions have to be discussed and to be taken. This could mean that in these cases deviations are made from the test case description (e.g. by reducing the vehicle velocity in the test).

Also the available test tracks can limit the evaluation tests. For example the Curve Speed Control function, which should be analysed for different curve radii and curve angles, can be only tested on the available curves on the test track.

Tests for some functions require digital map data. This means that for some test tracks, for which these data are not available, the tests cannot be conducted, except if digital map data is generated before the actual testing period.

In addition to the tests on test tracks also tests on public roads will be conducted for the technical assessment of the SECONDS functions. Especially for the function, which should prevent speed limit violations or should inform on a road section, where overtaking is not recommended, tests on public roads are a reasonable approach. For these tests the given law must be obeyed during the test. This limits obviously the testing parameter and must be taken into account for the test planning (e.g. approaching speed for a curve). Additional safety measures must also be discussed for tests on public roads.

For the tests on the fuel consumption on public roads the surrounding traffic is an issue, which cannot be controlled during the tests on public roads. It can be tried to minimize the effects by starting the test drives at the same time of day. But nevertheless it cannot be ensured that there will be the same traffic condition in both test runs. If there are major differences in traffic conditions of the two trips for a given test driver, the test drive will be excluded from the analysis. It is likely that the effect of the function on the fuel efficiency is not constant and that there is variation in the effect for different parts of the test drive. In order to consider also this, it is necessary to analyse the fuel consumption also for given road sections (e.g. approaching the speed limit).

The last limitations for the tests are the weather conditions. These will not only affect the tests for the technical assessment but also the outdoor tests for the user-related assessment. Depending on the demonstrator planning, tests may be planned during the late autumn respectively winter. This might limit the tests due to weather conditions, which can be expected for this season. An icy track or bad weather can reduce the function's performance. Therefore, the minimum test conditions have been specified in order to ensure that the performance of the function is not negatively affected.

5 User-related assessment plans

In this chapter, the methods and tools to assess the interactIVe systems from the user perspective are presented. This includes a list of key performance indicators, the outline of the studies for the different SP's, consistency between the test sites and the limitations of the user-related assessment plans.

The aim of the user related assessment is to evaluate the systems effect on driver behaviour, reactions to and acceptance of warnings and interventions. Depending on the possibilities to observe, control the scenario and ensure the safety of the driver, the tests will be performed in real traffic on test sites or in simulated traffic conditions.

The most important key issues in the user-related domain are driver reactions/behaviour, usability and driver's acceptance of the system. These issues include both the efficiency, which the driver and system react to and interact in normal and in critical situations, as well as how the driver perceives, understands, accepts and trusts the system's operating principles. An appropriate degree of usability and acceptance is crucial since, for example an insufficient understanding of the system's functionalities or operating conditions may lead to over trust (that the system will resolve a specific situation when in fact it does not). Driver acceptance and trust for the greater degree of control (both braking and steering) exerted by the interactIVe systems is of importance to avoid unintended/unwanted behaviour or even that the system is switched off.

Driver behaviour and function usage should be observed by objective methods and should, as much as possible be free from subjective analysis when evaluating system performance. The following three aspects associated with objective testing are of importance [FERYY]:

- Defining metrics for measuring performance,
- Conducting tests under controlled conditions,
- Measuring conditions and performance variables using an independent measurement system.

5.1 Methodology

It needs to be pointed out that today there is no established methodology for fast evaluation of ADAS and especially not with multiple functions integrated. The most reliable method of evaluation safety systems and supporting functions is Field Operational Tests (FOT), which investigates driver's interaction with the functions during natural driving conditions for a longer period of time. The method is time-consuming and will not be relevant for interactIVe due to the lack of time and resources. The user-related assessment will therefore use the Code of Practices defined in RESPONSE3 and PReVAL within the PReVENT project as a support tool adapted to the specific needs of the interactIVe systems and functions.

The user-related assessments will illuminate drivers' reactions to the developed functions by mainly using naïve subjects in relevant driving situations, in an instrumented vehicle in real traffic or in a driving simulator. All tests will be followed by questionnaires or interviews that also will give information of the test drivers' opinions on the functions in question. Using naïve subjects means that the test drivers have equal experience and prior knowledge of the system as a later customer will have.

Small-scale field-trial with instrumented vehicles

These studies, involve observing drivers while they are using the system in a naturalistic way and comparing their behaviour when driving without the system. The field trial may be carried out unobtrusively, with – for the driver – hidden instruments in the vehicle, which will let the test driver drive alone during the test. Another alternative, giving the possibility of acquiring more behavioural data, is the in-car observation method. Then, the observations are carried out by two observers, riding along in the car with the driver. For the SECONDS functions, a small-scale field-trial (one instrumented car with relatively few test drivers, 20-30 and with two observers in the car) will be used. This means that the driver will run the tests in real traffic conditions. See more details about the method in 5.2.1.

Driving Simulator study

A driving simulator study is suitable for the assessment of the INCA and EMIC systems as they are designed for supporting the driver in critical conditions. In a driving simulator these systems can be tested safely and under controlled conditions. Driver behaviour is studied with a number of test subjects when driving with the INCA and EMIC functions in various traffic situations. The main challenge will be to implement the functions in the simulators and make them comparable with the demonstrators. See more details about the method in 5.2.2.

The description of available simulators is presented in Annex A.

Questionnaires

All participants in the field-trials and the simulator studies will be answering questionnaires. The questions will be tailored to the function under testing and will be answered individually by each test driver. The questionnaires may be administered by the investigator or may be self-administered. See more details about the method in Annex A.

The questionnaires for each test are to be found in Annex F.

Structured Interviews

Structured Interviews may in some cases be added to the questionnaire-questions to get more developed subjective opinions of the functions. See more details about the method in Annex A.

5.2 Outline of the studies

The user-related tests will be performed on public roads, on test tracks with an equipped demonstrator vehicle or in simulator studies at different sites depending on the function under testing. The test cases are chosen to test mainly the driver's reaction to a given function and how the function is accepted and used. The tests are divided in primary and secondary tests, where the secondary test cases will be a complement to the primary ones. The secondary test cases will only be conducted depending on time and resources. Outline of the studies will follow the code of practice for Design and Evaluation of ADAS on how to conducting tests with subjects.

Relevant test scenarios for user-related evaluation are derived directly from the use cases. For full description of the test scenarios (see Annex D).

5.2.1 SECONDS field trials

The order of driving will be balanced as far as possible (the so-called ABBA-design) and the number of participants will be 20–25 drivers. The users just have to drive normally, but specific situations can be provoked.

The instrumented vehicles will be highly equipped with logging devices and sensors for accurate measurements.

The test route should consist of varying driving conditions, divided into smaller parts with the same characteristics categorized into different road types. It should take approximately 30–45 minutes to drive. The drivers are supposed to drive normally while they are participating in the study, so the data will show how drivers use the system and how their behaviour is changed by the system in question.

As scenarios cannot be created in real traffic, the in-car observers' task during the field-trials is to monitor driver behaviour continually and register observation variables in the test scenarios. Also, logged data will be analysed from these scenarios. The relevant scenarios for the SECOND functions are:

- Rear-end interaction with other vehicles,
- Overtaking situations,
- Interaction with other vehicles during lane change,
- Interaction with crossing traffic,
- Interaction with pedestrian or animal on the road,
- Unintended lane departure,
- Hazardously high speed in curve and
- Exceeding speed limit.

5.2.2 INCA simulator studies

Since the INCA functions only will intervene during emergency- or critical situations, most of the evaluation will be performed with simulator. The studies will be similar for car and truck functions but depending on availability and time the simulated vehicles cabin will be switched to car and truck cabins. The participants will drive a simulated test route twice. The order of driving will be balanced in such a way that every other subject drives first with the system switched off and then with the system switched on. By doing this, the effects of biasing variables, such as getting used to the test route or to the observers and the test situation cannot be eliminated, but such effects can be spread evenly across the situations.

Specific tasks will be given during the test drive to mask the purpose of the experiment, to create surprise effects and to provoke the target scenarios:

1) Navigation task (route guidance messages),
2) Message typing distraction tasks which require the participants to look away from the road (both “dummy” tasks during which nothing happens and “real” distraction task during which the simulator is provoked into the target scenarios).

The relevant scenarios for the INCA function are:

- Rear-end collisions (RECA),
- Oncoming vehicle in own lane (OVCA),
- Oncoming vehicle in own lane (OVCA),
- Vehicle in left blind spot (SIA),
- Vehicle in right blind spot (LCCA),
- Unintended road departure (RORP),
- Unintended lane departure + opponent vehicle (SIA),
- Unintended lane departure + oncoming opponent vehicle (LCCA) and
- Road departure in curve (RORP).

5.2.3 EMIC simulator studies

The following scenarios were selected for carrying out the simulator experiments for EMIC and ESA. The test scenarios for the user-related evaluation are derived directly from the use cases found in Annex D. During the trials in simulator environment the in-car observers' task is to monitor driver behaviour continually and register observation variables in these test scenarios. Also, logged data will be analysed from these scenarios. Before beginning the test scenarios drivers will drive a training to get used with the fact of driving in the simulator.

- Rear-end collision;
    - Approaching stationary target (1.1),
    - Approaching parking target (1.2),
    - Approaching end of traffic jam (1.3),
    - Approaching slower vehicle (1.4),
    - Braking front vehicle (1.7),
- Cross traffic collisions;
    - Parking 3: unparking vehicle and steer assist (4.8),
- Collisions with vulnerable road users,
    - Standstill pedestrian (5.1),
    - Moving pedestrian (crossing) (5.2).
    - Stopped pedestrian (5.3).

5.3 Consistency between test site environments

Since many of the tests need to be conducted in driving simulators for safety reasons, additional questions administered after these tests will aim at measuring simulator fidelity. It will probably be impossible to ensure that all simulators involved in the test plans have the same degree of fidelity, but it has to be ensured that they all meet some basic criteria. Such criteria can be based on objective measures such as field-of-view and frequency response of audio system and delay times in the vision and motion systems (which are used for standardization of flight simulators for example). However, SP7 primarily aims at gathering information about the perceptual side of simulator fidelity which involves ratings of e.g.

- Self-motion perception and control,
- Visual, auditory, haptic and kinaesthetic realism,
- Manoeuvring realism and
- Sense of "being there" (presence).

5.4 Test/experiment parameters

The parameters that describe and are relevant for all the user-related experiments are presented in this sub-chapter.

Blocking

The conditions influencing the data collection should be as far as possible controlled and homogeneous. A series of test done in the same conditions is called a "block". A block of tests refers to more or less the same conditions (of weather conditions for example).

Statistical relevance

The number of tests performed should be related to the expected level of statistical confidence. Completeness: concentrating the resources on most important aspects is better than spreading efforts with the consequence of a low statistical significance. Sample size is therefore adapted depending on experiment design, resources and time.

Bias

No disturbance of the validation process: no bias except accidental ones introduced in the measurement plan.

Sample composition (age, gender, experience)

In RESPONSE3, practical testing revealed that a number of 20 valid data sets per scenario can supply a basic indication of validity. For some of the simulated tests (INCA) the number of participants will be up to 48 subjects, where a half of them make a baseline group. The number of participants has been used in other large studies and will also keep a safe distance to the minimum of valid data sets that needs to pass the criteria. In simulator studies for example, motion sickness and risk of simulator error could occur which could fail the test. If the test person already has been exposed for the scenario he/she will be consumed as a subject.

The field trials for SECONDS and INCA will use the recommendations from RESPONSE3 and the test persons should, as far as possible be divided equal of male and female drivers, evenly distributed throughout the 29-59 age range. The participants should also hold a valid driving license. The minimum criteria for driving experience and driving exposure is set to at least three years of licensure and a minimum of 7,000 annual driving miles for car drivers and 30,000 annual miles for truck drivers.

Observation variables

Objective performance data are usually preferred for experiments. In addition, they are required for design evaluations whenever the evaluation criteria are objective. Unfortunately, however, objective measurements are frequently more difficult to carry out, and the process of collecting objective data is usually more time-consuming and costly. In contrast, subjective data may be obtained easily, quickly, and inexpensively. The subjective measurement technique also provides the only direct means for the assessment of user opinion and preferences. [CUS91]

The sources of objective data that are frequently used in user trials can be divided into three categories: [MCL95]

1. direct objective measurements of the user,
2. directly recorded data resulting from users' actions, registered by the investigator or by some remote means, such as video or automatic event recording,
3. data measured directly from the product on the completion of or during the trial.

Objective variables:

Speed profile

- spot speed at selected sections,
- speed variance during test drive,
- Number of conflicts,
- Alarm length, (seconds),
- Driver reaction time (sec),
- Time distance (sec) to the vehicle ahead,
- Standard deviation of side position in the lane,
- number of correct lane changes and
- number of correct interactions.

Trust and acceptance

- N of looks in rear mirror.
- use of turning indicator.
- use of gearbox.

System usage

- N of uses different from what designers intended,
- Types of uses different from what designers intended.

The typical methods used in subjective measurement are: [SIN95]

- ranking methods,
- rating methods,
- questionnaire methods
- interviews
- checklists.

However, subjective data and preference data must be interpreted with caution. Cushman and Rosenberg (1991) [CUS91] suggested that the following points should be considered when evaluating subjective data:

- If the subjects in experiments and tests do not fit the user profile compiled during the planning phase, their opinions and preferences may not accurately reflect those of the intended users of the product. Conclusions based on data obtained from inappropriate subjects may not be valid.
- Attitude measures and self-reports may be distorted by biasing factors, such as the ”halo effect”, acquiescence, and cognitive dissonance [RUB84, CUS91]
- Subjects' preferences are affected by events in the recent past.

Cushman and Rosenberg (1991) [CUS91] recommended collection of both objective and subjective data during experiments and tests whenever feasible. Collecting subjective data will add little to the cost of the study, but may provide significant insights not obtainable by objective methods. In addition, subjective data may be particularly useful if objective measurements fail to detect any differences between conditions. This study also emphasised the need for both subjective and objective data to support or complement each other in the evaluation.

Subjective variables

- Subjective workload,
- Experienced effects of the system,
- Usefulness and satisfaction of the system,
- Perceived benefits of the system,
- Usability and
- Willingness to have and pay.

Experimental design

The tests will be performed with a within subject design where half of the subjects will be exposed for treatment during the first driving session, and the other half during the second driving session.

Questionnaires

The questionnaires addressing both objective and subjective information and will be answered after each test drive.

5.4.1 Logistics

The responsible partners for the user-related test are CTAG, Lund and VTEC and their task is to support the VSPs during the test. This support task can, like the technical related tests, be divided into different subtasks:

- Definition of a test and evaluation framework for each application with respect to safety and human factors.
- Development of test scenarios, experiment design, and evaluation methods.
- Provision of tools for evaluation like equipment, test catalogues, questionnaires or software and support for testing.
- Definition of test and evaluation criteria.

The tests will be conducted by the VSP and they are also responsible (except for the driving simulator studies. See below) to provide the demonstrator vehicles and the transportation of them. Needed test tools like measurement equipment, simulators and recruitment of test subjects will be provided by the VSPs and SP7 together. After the tests the stored data should be transmitted to SP7 for evaluation process. It is important that all VSPs do security backup before transmission to eliminate the risk of loss of data.

The driving simulator studies for the EMIC user-related assessment will be carried out by CTAG, using the CTAG Driving Simulator and their data acquisition tools with the VSP support for the integration of the application in the driving simulator.

Regarding the test planning, there are several different aspects that will influence time and completion:

- availability of demonstrator vehicles, simulators and test track,
- availability of test tools,
- availability of test persons,
- number of tests.

5.4.2 Analysis

The aim of the analysis of logged data is to study the interaction between the driver and the system, focusing both on general results and driver behaviour after an alarm occurs. In the first case, the focus of analysis is on how the system affects average driving style, and in the second case the focus is on the influence of the system on manoeuvres made during and after critical situations. The logged parameters are to be studied with help of the ANOVA statistical method, in order to test statistical significance of differences between mean values of observed variables. A first session of overall analysis is to explore indicators concerning all the parameters regarding driving performance.

The driving simulator and test cars should be equipped with logging facilities. The logged variables are listed in Annex E.

The analysis of the logged data should start with preliminary processing. All collected data is to be processed to debug the logged files, and convert them into formats manageable by statistic software used in the following steps, in order to convert the system time unit into a standard time unit.

5.4.3 Limitations for the user-related tests

For the user-related tests a distinction must be made between the tests for the SECONDS functions and the tests for the functions of the other VSPs, because the SECONDS functions will be active continuously, not only in a situation with risk for imminent collision. The SECONDS functions support the driver during the whole driving process; hence these functions are possible to be tested with “normal” drivers on public roads in real traffic.

However, there are at least for some of the demonstrator vehicles, regulations affecting the testing. For example, one demonstrator vehicle can only be driven by employees of the company. This limits the selection of test persons, especially with respect to the age groups, because it is will not be possible to find employees older than 65 years in the company. In another case a special driving license, issued by the car manufacturer, is needed to drive the demonstrator vehicle. In this case, it is not possible to carry out test drives on public roads with “normal” drivers.

For the INCA and EMIC functions the user-related tests will be conducted in a driving simulator, because it would be dangerous to test these functions on public roads. For the CMS function, e.g. tests on public roads are not possible, because either the test persons would never experience the function or the test drive would end up in a crash. Therefore, the only safe approach is to carry out the tests in a driving simulator or on a test track. However, there are limitations for the tests in a driving simulator, too. First, a driving simulator must be available and the function must be implemented in the simulator. Furthermore, it must be ensured that the results of the tests can be transferred to the real world. One issue for these tests can be the lateral dynamic behaviour of the simulator. This depends also on the simulator used for the tests. A static simulator for example will not provide the driver with a realistic feedback during the evasive manoeuvres. For a moving simulator the feedback to the driver will be better, but there might still be some limitations for high dynamic manoeuvres.

An additional limitation for the user-related tests is the testing effort. The tests have to be limited to a certain number of test persons and also the test itself has to be limited (e.g. test route). Therefore the test persons should preferably have to drive the same route twice in order to compare the driver behaviour with and without the function. Due to the limited time and the limited availability of the demonstrator vehicles (at least for the user-related tests in SECONDS) it will be not possible to do the tests with a large number of test persons or on a long test route.

Long term user behaviour poses a problem for interactIVe, because measurements in the type of tests performed in interactIVe address by their nature the short-term effects. The problem is well known but there are not enough resources to study the long term effects within the scope of InteractIVe project.

6 Safety impact assessment plans

This chapter explains the safety impact assessment method. The method will be used to assess the safety impacts of the interactIVe functions. But the method will be set up such that it is usable in a more general context. The description will make the basis for an assessment tool that will be used in interactIVe. But the developed tool will not be limited to the purpose of impact assessment in interactIVe. It will be developed in way that it can also be applied for other functions, which are not developed in interactIVe.

In this section the focus is on direct safety impacts, here fatalities and injuries. Indirect impacts are reductions in congestion due to fewer accidents. The method for this is relatively straightforward (see e.g. [WIL08]), and is not discussed here.

For the analysis of the fuel efficiency, which is a side aspect of the developed SECONDS functions, please see section 4.4.1.

The chapter starts with introductory sections 6.1 on the scope of the method. The main part of the chapter makes a description of the assessment method in section 6.2. Background information is provided in section annex B.

6.1 Scope of the safety impact assessment method

The safety impact assessment method is described on two levels, generally and as a specific application to interactIVe. The reason for setting up a general method not specifically tailored for interactIVe is that it will then be useful also for other applications. This is in line with the spirit of the method used in eIMPACT and PReVAL, which the InteractIVe method is based on.

The two levels are to be distinguished for two reasons. On the one hand, the general method may be more encompassing than strictly needed for interactIVe, for example if a specific aspect of the method is not needed by any of the interactIVe applications. On the other hand, the application of the method to interactIVe may involve an adaptation of the generic method to handle practical specifics.

In order to distinguish between the general method and its application in interactIVe, the subsections of section 6.2 describing the assessment method are subdivided into parts called “General method” and “Application to interactIVe”, where applicable and necessary (where no distinction is made, the text applies to both).

This chapter is intended to be a complete description of how the safety impacts are to be obtained, and therefore not all the described steps are carried out as part of the safety impact assessment. Some are part of the technical assessment, user related assessment or other parts of interactIVe.

The safety impacts will be determined first for the individual functions[7]. Therefore the same assessment method will be used for all applications. The impacts of the systems SECONDS, INCA, EMIC will be assessed based on that to the extent it is possible. This is explained in more detail in section 7.6. The different versions of a function in different demonstrators are

[7] The term “function” is used for an individual function, like eDPP. The term “system” is used for the function combinations SECONDS, INCA, EMIC. The term “application” is used for either a function or a combination of functions.

considered the same[8], but perhaps the differences will be accounted for by providing a range.

The safety impacts will be determined in terms of number of saved fatalities and severe injuries, both per driven km and for deployment scenarios that specify a region, a target year and penetration rate of the application under assessment. Section 6.2.3 explains which scenarios will be considered. Table 6.1 shows an overview of Abbreviated Injury Scale (AIS) and Maximum Abbreviated Injury Scale MAIS levels and the corresponding survival probabilities.

Table 6.1: Distribution of the AIS-Codes in the National Trauma Database (NTDB) and in the German In Depth Accident Study (GIDAS) database (Abbreviated Injury Scale, (AIS), maximum AIS-value (MAIS)) [HAA10]

AIS-98-Code	Severity	National Trauma Database [%] (AIS)	GIDAS [%] (AIS)	GIDAS [%] (MAIS)
0	Not injured	100.0	100.0	100.0
1	Minor	99.3	99.8	99.8
2	Moderate	99.2	99.5	99.3
3	Serious	96.5	98.1	93.8
4	Severe	85.4	80.0	77.4
5	Critical	60.4	64.3	37.4
6	Maximum	21.0	8.0	0.9

6.2 interactIVe safety assessment method

This section describes the assessment method that will be used in interactIVe. Based on the literature review (please see Annex B), a variant on the safety mechanism approach, which has been used in eIMPACT and PREVAL project [WIL08; SCH08], will be used, because it best fits the requirements and limitations of the project. The main reasons are that it covers all possible safety effects, is transparent, has relatively little data needs, and does not require excessive amount of resources.

This concerns methods that identify factors contributing to a crash, and then employ direct or indirect methods to estimate the effect of an ITS on these factors. Simple approaches may consider factors such as exposure and severity, see e.g. [JOK72], or target population and effectiveness, as mentioned above. A more detailed subdivision of safety impacts of ITS is given by the so-called nine safety mechanisms [DRA98]. These mechanisms are

1. Direct in-car modification of the driving task,
2. Direct influence by roadside applications,
3. Indirect modification of user behaviour,
4. Indirect modification of non-user behaviour,
5. Modification of interaction between users and non-users,
6. Modification of road user exposure,

[8] At the moment it is unkown to what extent the functions with the same name in the different demonstrators will really be the same. For example CS (continuous support) seems to be different in the different vehicles.

7. Modification of modal choice,
8. Modification of route choice,
9. Modification of accident consequences.

The first five address accident probability and to some extent severity too, the next three address exposure and the final one addresses severity related to post-crash modifications (i.e. timeliness of the emergency service response). The boundaries between the mechanisms are not sharply defined, and some safety aspects can be listed under several headings. For example, an application that mitigates crashes could have its effects listed under mechanism 1 or 9. However, this is not really problematic, because the purpose of this structure is not so much to define precisely the categories of safety effects, but rather to help the researcher to be complete in listing all potential effects.

The following *collision scenario variables* (CSV's) are represented in European accident statistics:

1. vehicle type host (passenger car/goods vehicles),
2. vehicle type target (passenger car/goods vehicles),
3. collision type (9 categories, defined in the accident statistics):
    a. collision on the road with pedestrian,
    b. collision on the road with all other obstacles,
    c. collision besides the road with pedestrian or obstacle or other single vehicle accidents,
    d. frontal collision,
    e. side-by-side collision,
    f. angle collision,
    g. rear collision,
    h. other accidents with two vehicles,
    i. all other collisions.

The type of target vehicle is important because it will impact both the detection rate and the severity of the consequences of a collision.

The following situational variables (SV's) are represented in European accident statistics:

4. road type (motorway/rural/urban),
5. weather conditions (normal/bad),
6. lighting conditions (light/dark),
7. location (intersection/not intersection).

This means there are in total 3*2*2*2=24 situations and 28 collision configurations[9], for 24*28=672 possible scenarios. Some of these may be unlikely or impossible (e.g. frontal collision on a motorway), but the total number remains large.

In the discussion below, first the notions of safety costs and safety modification factors are presented in section 6.2.1. Section 6.2.2 describes how the safety mechanism approach is adapted and improved for use in interactIVe. Section 6.2.3 discusses the functionality and deployment scenarios of the ITS to be assessed. Subsequently, sections 6.2.1 – 6.2.8 discuss the safety mechanisms one by one.

6.2.1 Safety cost and safety modification factor

The level of safety of car occupants is a function of probability for car occupants to be involved in accident (per kilometre), accident severity (in terms of fatalities and injuries of car

[9] This number is slightly less than 2*2*9=36 because in single-vehicle collisions there is no choice of target vehicle. There are 5 collision types with 2 vehicles and 4 types with 1 vehicle, leading to 2*2*5 + 2*1*4 = 28 collision configurations.

occupants), and exposure (number of kilometres driven). Sometimes this is stated as: *safety cost = probability * severity * exposure*. This is a little too simple, as there can be many severity levels, each with their own probability. So a more precise formula is:

$$\textit{safety cost} = \sum_s prob(severity = s) \ * \textit{exposure},$$

where the sum ranges over all severity levels and *prob*(*severity*=*s*) is the probability per km of an accident with severity *s*. Furthermore, exposure can be split by situation that are distinguished by situational variables such as lighting or road type, and it is more accurate to do so because the accident probabilities generally depend on these situational variables. Hence an even more precise formula is:

$$\textit{safety cost} = \sum_{s,r} (prob(severity = s, situation = r) \ * \textit{exposure}(\textit{situation} = r)),$$

where the sum ranges over all severity levels and all situations, *prob*(*severity*=*s, situation* = *r*) is the probability per km of an accident with severity *s*, in situation *r* and *exposure*(*situation* = *r*) is the number of kilometres driven in situation *r*.

An ITS application can impact safety by modifying any of these factors, that is,

- By changing the probability attached to some severity level and situation, or
- By changing the exposure to some situation.

Note that other effects like “lowering the severity” or “changing routes from rural roads to motorways” can always be phrased in terms of (combinations of) these two.

The safety impact of an ITS can be characterized by a safety modification factor *SMF*, defined by *SMF* = *SC*(*1*)/*SC*(*0*), where *SC*(*p*) is the safety cost when a fraction *p* of all vehicles is equipped with the ITS. The safety modification factor measures how traffic safety changes when all vehicles are equipped with the ITS, compared to the reference where no vehicle is equipped. A safety modification factor smaller than 1 means that the ITS improves safety, equal to 1 means that it does not impact safety and larger than 1 means that it decreases safety.

A related notion is that of a crash reduction factor (CRF), which is equal to 1-SMF and measures how much safety increases (positive values) or decreases (negative values) with the ITS, relative to the current situation.

6.2.2 Safety mechanisms

General method

The safety impact assessment in interactIVe will generally follow the same path as in eIMPACT and PReVAL, that is, it will use the nine mechanisms to determine the safety impacts, taking the scenarios into consideration.

The following refinements of the method will be considered:

- **Detailed accident types**
  State of the art: eIMPACT and PReVAL consider only the main accident types listed above.
  Desired improvement: The accident types listed above are main accident categories and can be subdivided into subcategories that provide more detail on the specific manoeuvres or collision points. See e.g. [REE08; cited in MCC10] for the GDV classification of accident types.
  There are two relevant detailed accident classifications for interactIVe. The first classification is the GDV classification. This classification has been introduced by the German insurance company association (Gesamtverband der Deutschen Versicherungswirtschaft e.V.). This classification is used in various accident

databases or projects, e.g. GIDAS database or SafetyNet. The second accident classification is used for the French in-depth accident databases of the Laboratoire d'Accidentologie et de Biomécanique (LAB) and Institut national de recherche sur les transports et leur sécurité (INRETS). This classification is further used in the European Truck Accident Causation (ETAC) study, which deals with truck accidents in Europe.
In interactIVe, the use cases of the functions have been defined based on accident data. For this purpose the GIDAS database (for passenger cars) and the ETAC database (for trucks) have been used. Both classifications aim to describe the accident situation respectively the conflict which caused the accident. However, the detail level of the classification is different. Hence the accident types of both classifications must be linked.
The refined method is able to handle these subcategories. This means that more CSV's will be added to the list of section 6.2.

- **Contributing factors**
  State of the art: There is no clear methodology for obtaining the safety modification factors for the nine mechanisms. In eIMPACT and PReVAL these factors were formed by expert judgment of available literature and data. Desired improvement:
  The refined method will examine contributing factors to the mechanisms and in this way takes the method one step further.

- **Scaling up**
  State of the art: The effect of the ITS if all vehicles are equipped is given by a safety modification factor *SMF*. If only a fraction p of the vehicle fleet is equipped, then the effect is scaled linearly and set to $p * SMF$.
  Desired improvement: This is not entirely correct when interaction effects are considered. Indeed, interaction effects between two equipped vehicles scale as p^2 while interaction effects between one equipped and one unequipped vehicle scale as $p (1-p)$. The refinement will consider a suitable method for scaling up.

As a concrete result, the safety impact assessment will develop a software tool that implements this method. It should allow researchers to employ the refined nine mechanisms method for safety impact assessment. The researchers will need to provide safety modification factors. The software tool performs all the necessary calculations. The tool has some standard statistics, and allows the user to provide alternative data. The tool enables a hierarchical approach, where the user can provide modification factors on a level of detail of his choosing. For example, he fills in either a single high level factor or several contributing factors. Or he fills in one global factor that is valid for a large set of scenarios and then modifies it per scenario or subset of scenarios where desired. Implementation details of the tool are to be decided.

An option to be considered is augmenting this quantitative approach with a qualitative record of the findings and assumptions like the fact sheets used in eIMPACT and PReVAL. These fact sheets contain a functional description and qualitative/quantitative effects for each mechanism as found in literature or by expert opinion. This part of the product can simply be the template for the functional description and can be used to record background information and the reasoning or references behind user inputs in the tool. It will be used only for background information on the calculations and estimates, and not for the actual calculations/estimates, but may provide helpful background information and a memory aid for the user.

Globally, the method functions as follows. First, a reference scenario R is chosen by fixing CSV's and SV's. For the reference scenario, risk modifiers $r_1, \ldots, r_9$ are determined for the nine mechanisms and for a desired level of severity, for example fatalities. The Safety Modification Factor for this scenario is then defined by

$$SMF_{R,fat} = \prod_{i=1}^{9} r_i, \qquad \text{Eq. 6-1}$$

and the Crash Reduction Factor is $CRF_{R,\ fat}$ = $1\text{-}SMF_{R,\ fat}$. From an accident prognosis, one retrieves the projected number of fatalities $F_{R,wo}$ for this scenario without the ITS present. Then the estimated number of fatalities saved by the ITS at 100% penetration rate is $CRF_{R,\ fat} * F_{R,wo}$ for this scenario, and the number of remaining fatalities $F_{R,w}$ is given by $F_{R,w} = (1\text{-}CRF_{R,\ fat}) * F_{R,wo}$. Similar calculations can be made for other injury severity levels, for example some MAIS level. The risk modifiers r_1, …, r_9 have to be determined for each injury severity level.

For other scenarios, the crash reduction factor can be obtained by means of two methods:

1. By providing modification factors for each CSV and SV, as described in section 6.2. Let the number of CSV's and SV's be n in total, and let n_j, $j = 1, \ldots, n$ be the number of values of the j^{th} variable. Let $m_{j,k} \geq 0$ be the modification factor of the k^{th} value of the j^{th} variable, compared to the reference scenario. Then the Crash Reduction Factor $CRF_{S,\ fat}$ for a scenario S defined by the CSV and SV values $k_1, \ldots, k_n$ is given by

$$CRF_{S,fat} = \prod_{j=1}^{n} m_{j,k_j} CRF_{R,fat}, \qquad \text{Eq. 6-2}$$

   The modification factors are always positive. A modification factor less than 1 means that the ITS is less effective in the scenarios corresponding to this modification factor than in the reference scenario. A factor equal to 0 means that the ITS is not effective in the corresponding scenarios. A factor equal to 1 means that the ITS is equally effective in the corresponding scenarios as in the reference scenario. A factor greater than 1 means that the ITS is more effective in the corresponding scenarios than in the reference scenario.

2. By calculating the *CRF* directly for another scenario, in the same way as it was done for the reference scenario.

As mentioned in section 6.2, the first method has the advantage of requiring fairly little effort, but the disadvantage that it assumes that all the CSV's and SV's modify $CRF_{R,\ fat}$ independently. The second method allows more detail approach but requires much more effort. A good compromise approach is to use the first method by default, and allow the user to overrule the calculated *CRF* for user-selected scenarios using the second method. This is the approach that the assessment method and tool will support.

Application to interactIVe

An overview of the method and the links to the technical and user-related assessments is shown in Figure 6.1.

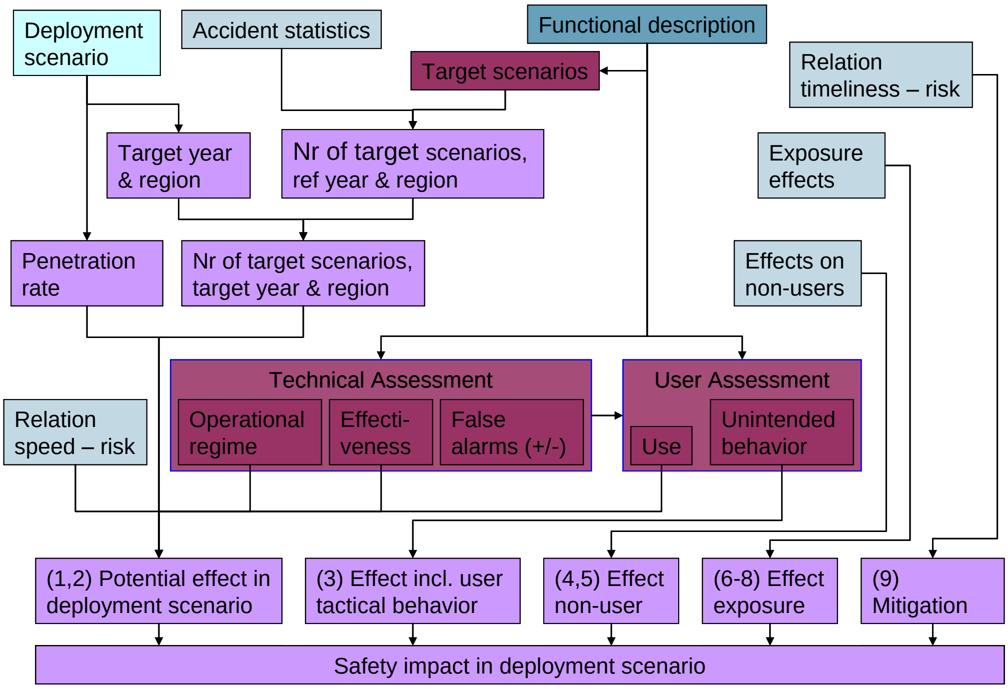


Figure 6.1: Overview of the safety assessment method.

For the legend see Figure 6.2. The numbers in brackets refer to the safety mechanisms. The user related aspects refer to long term effects (because the safety impact of short term effects is negligible).

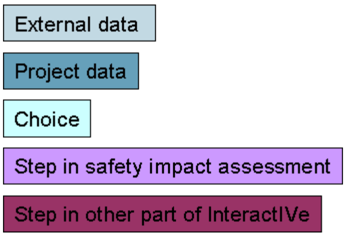


Figure 6.2: Legend of Figure 6.1

For practical and budgetary reasons, the amount of testing in InteractIVe will be limited. This means that although a full methodology will be described and will be implemented in the tool, not everything mentioned in the methodology will actually be tested for every function. Default choices or expert judgment will be used to cover for missing data. In particular, the influence of the CSV's is to be derived from the functional specification and partially from testing. The same is true for the SV's, except for location, for which no tests are foreseen. Furthermore, there are probably no tests regarding false alarms.

6.2.3 Functionality of the ITS and the deployment scenario

General method

The functioning of the ITS and the deployment scenario determine which safety modification factors need to be provided in the subsequent steps, which external data is needed and which penetration rate to use. For example, if the ITS cannot be turned off by the driver, then this limits the possibilities for user behaviour.

The following needs to be answered for the deployment scenario:

- What is the target year and region? This determines the accident statistics to be used. Typically they are scaled to adjust to a future year. Of course, accident statistics may not be available for every region.
- What is the penetration rate of the ITS? This scales the safety effect as explained above. For in-vehicle ITS (or ITS components), the penetration rate is the fraction of the total distance driven with the ITS on board. For roadside ITS, the penetration rate is the fraction of the total distance driven with the ITS on the road side.
  - A deployment scenario typically provides a roadmap or the market penetration rate of ITS applications. The market penetration rate is the number of equipped vehicles that will be sold per year and the number of aftermarket units that will be sold per year (if the ITS can be installed aftermarket). Examples of roadmaps can be found for example in [LES09; EHM04]. An example of estimated market penetration rates can be found in [WIL08].
  - The penetration rate can be related to the market penetration rate. The eIMPACT project has provided a calculation method that relates the penetration rate, the fleet penetration rate and the market penetration rate [WIL08]. The fleet penetration rate is the fraction of equipped vehicles and is different from the penetration rate because newer vehicles travel more kilometres and are more likely to be equipped than older ones.
- Is the ITS stand-alone or cooperative? This determines how the effect is scaled with penetration rate.

The following needs to be answered based on the functional specification of the ITS:

- Activation: Can the user turn the ITS on and off?
- Interaction: Is the ITS advisory, warning, intervening and / or controlling? More than one can be answered positively.

Based on the answers, there are the following possible configurations. Warning and advisory are considered similar for this purpose, and so are intervening and controlling:

Table 6.2: Possible functional configurations regarding activation and interaction.

Nr	On/off switch	Advisory/Warning	Intervening/Controlling
1	Y	Y	Y
2	Y	Y	N
3	Y	N	Y
4	Y	N	N
5	N	Y	Y
6	N	Y	N
7	N	N	Y
8	N	N	N

- If On/Off switch = Y, then factors are needed for on/off switching behaviour,
- If Advisory/Warning = Y, then factors are needed for reaction to advice/warning,
- The cases 4 and 8 where the ITS is not Advisory/Warning and not Intervening/Controlling seem impossible or at least unlikely,
- It is of course possible that an ITS is both Advisory/Warning and Intervening/Controlling (cases 1 and 5),
- The case 6 of an Advisory/Warning application that cannot be switched off seems unlikely.

Application to interactIVe

The deployment scenarios are chosen, based on the expectations of the VSPs and the expertise of the safety assessment team, see [MÄK10].

The following choices are made:

- The base year is 2030, because it is estimated that it will take this much time to reach significant penetration rates.
- The deployment rates are 0% (reference), 100% (maximum potential effect) and one or two realistic values in between, either a mean value or a high and a low value. These values will be determined based on an estimate on the market penetration of the application and projected figures on the composition of the vehicle fleet and the relation between vehicle mileage and age.
- At least the eDPP functions will use V2V communication, functions CS and eDPP use V2I communication, and all others are stand alone.
- The choice of the region will depend on the availability of accident data and other statistics; the aim is to cover the EU-27 or most of it.

In interactIVe, almost all functions warn before they intervene. But the SC is continuously intervening. Therefore it is not likely to warn the driver always before intervening.

Table 6.3: Activation and interaction configuration per function

Function	On/off switch	Advisory/Warning	Intervening/Controlling
CS	Y	Y	Y / N (depending on the function mode)
CSC	Y	Y	Y / N (depending on the function mode)
eDPP	Y	Y	N
SC	Y	Y / N (?)	Y
LCCA	Y	Y	Y
OVCA	Y	Y	Y
RECA	Y	Y	Y
RORP	Y	Y	Y
SIA	Y	Y	Y
CMS	N	Y	Y
ESA	N (always active)	Y	Y (only after reaction of the driver)

During the interactIVe experiments, the applications are in general switched on (except baseline experiments for the user-related assessment). On/off switching therefore will be tested with questionnaires to some extent. Another option is to use data on usage from a field operational test like euroFOT, depending on how comparable the applications are.

Reaction time, time spent in the hazardous situation and the user reaction to warnings will be measured in the user related assessment.

6.2.4 Direct effects

General method

This concerns mechanisms 1 and 2:

1. Direct in-car modification of the driving task;
2. Direct influence by roadside applications.

The direct effects are usually defined as the intended effects of the ITS, which typically is the maximum effect that the ITS can have. Thus, while realistic limits to the application performance and driver behaviour are taken into account, this does not account for undesired effects on driver behaviour. Direct effects are usually positive[10], i.e. they reduce safety costs.

Direct effects are obtained in target scenarios, which are the scenarios where the application is designed to work. The scenarios are defined in terms of the CSV's and SV's (such as lighting, road type) listed above in section 6.2, and optionally more variables that further specify accident types and circumstances. Accident statistics and prognosis will provide the incidence of the target scenarios in the chosen region and year (see section 6.2).

For each target scenario, the following aspects of application performance and driving behaviour are included in the direct effects:

- Operational regime: How often the ITS works (e.g. what fraction of circumstances, what speeds, time headways etc). This needs to be linked to the incidence of these circumstances in accident statistics, which requires representative in-depth accident data.
- Performance: The intended effect of the ITS in the cases where it is functioning, in terms of accidents prevented, or in case an accident is not prevented, mitigation of accident consequences, in terms of saved fatalities and (severe) injuries. The direct effects estimation assumes the driving behaviour as intended by the designer (and relevant for the application), taking into account reasonable physical limitations (e.g. thresholds on reaction time), driver state (affection etc) and realistic assumptions on activation status and settings of the application. See annex B for a more detailed discussion on mitigation.
- False and missed alarms: How often the ITS issues a warning when it should not, and how often it does not when it should. Missed alarms influence the performance of the ITS, while false alarms will influence its indirect effects on the user, that is, safety mechanism 3.

These aspects are usually determined in a technical and user-related assessment of the application. FOT data can also be used.

Mechanisms 1 and 2 need external data in the form of relations between collision speed change and risk for all accident types, as detailed in annex B. It provides the potential (maximum) effect of the ITS for the selected deployment scenario in terms of a risk modifier, assuming intended behaviour.

The process flow for obtaining the direct effects is sketched in Figure 6.3. First, target scenarios are obtained from the function definition by expert judgment. The target scenarios are accident scenarios defined in such a way that they can be linked to accidents in an (usually in-depth) accident database. In this way, one obtains on the one hand the relative

[10] A negative value could occur for certain scenarios, for example if a car with a collision warning system brakes hard and then is hit from behind. This effect has been reported for ABS [EVN96]. A safety system with an overall negative direct effect is of course very unlikely to be put on the market.

frequency of the target scenario[11] and, on the other hand, typical initial conditions of the accident scenario, describing the vehicle speeds, positions and orientations and the circumstances of the accident. These can be matched with the test conditions applied in a technical assessment to find the changes caused by the ITS application in the collision speed and impact zone. These changes can be translated into changes in safety, in terms of fatalities and injuries, via the risk curves mentioned below.

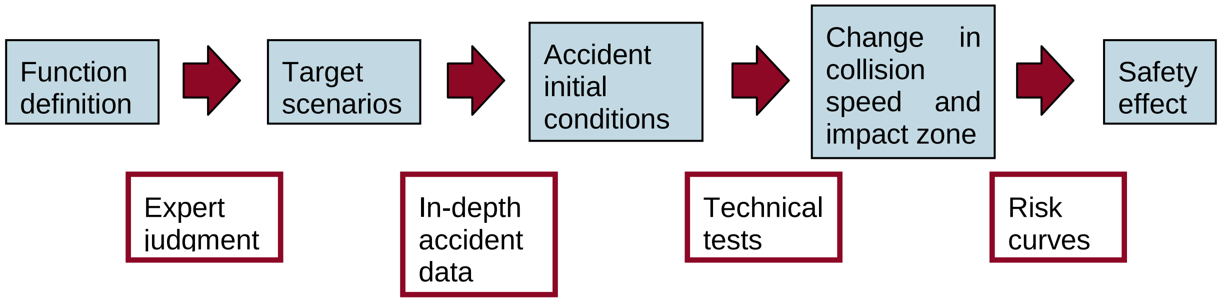


Figure 6.3: Process flow of direct effects.

Application to interactIVe

All ITS in interactIVe are vehicle based, so mechanism 2 is irrelevant for this project and its modifier will be set to 1. The target scenarios for interactIVe are defined in [MÄK10].

In interactIVe the performance will be analyzed in the technical assessment but the operational regime will probably be specified but not verified. False and missed alarms can maybe not be analysed accordingly, because they play a less important role in the development process of a research project. The user related assessment will have to provide inputs on the driver state and on realistic assumptions on activation status and settings of the application.

A limited selection of situations will be tested, because the testing requires many resources. Table 6.4 shows a first attempt at defining (rough) target scenarios for all functions. Please note that the accident types do not match 1-1 with the types listed above, so some work needs to be done. This table is based on [MÄK10; LYT11; SHA11].

The method will be worked out in more detail in a later stage.

Table 6.4: Target accident types for the functions in interactIVe.

Scenario	CS	CSC	eDPP	SC	OVCA	LCCA	RECA	RORP	SIA	CMS	ESA
Rear-end collisions:	x			x			x			x	x
Head on collisions:			x		x	(x**)				x	
Lane change collisions	x					x			x		
Cross traffic collisions	(x***)									x*	
Collisions with vulnerable road users	x										x
Unintended lane departure accidents	x							x		x	
Excessive speed accidents	x	x									
Traffic rule violations	x			x							

(*: only for low speed; **: No detection of oncoming vehicles; ***: only visualisation)

[11] When an in-depth accident database is used, this may require some further assumptions on the representativeness of this database.

6.2.5 Indirect effects on user

General method

This concerns mechanism 3:

3. Indirect modification of user behaviour.

Indirect effects on the user are changes in the (tactical/operational) driving behaviour of the user that are not intended by the application. This concerns all tactical/operational effects on the user's driving behaviour that are not covered under direct effects. A prime example is risk compensation (e.g. by increasing secondary tasks). Indirect effects are usually negative (i.e. they reduce the benefit of the application).

There is often a difference between short-term and long-term effects, because drivers need time to learn to use the application, they need time to discover its possibilities and limitations, and because novelty effects wear off. Short term effects usually disappear after a few weeks. For traffic safety therefore, only long-term effects are relevant. This means that for the behavioural aspects presented below, the interest is always in their long term values. This means that tests also have to address long term effects, which may pose a problem for many types of experiments.

The following aspects of user behaviour have been identified based on earlier research work, e.g. in projects AIDE, eIMPACT, PReVAL and euroFOT:

- Distraction
- Workload
- Usage (on / off)
- Misuse
- Driving style
- Settings of the ITS
- Situational awareness
- Event detection
- Loss of skills
- Mode error
- Acceptance, trust, understanding and experience with function

A more detailed description of different user behaviour aspects can be found in the Annex B

Some of the aspects listed above can be quantified, whereas others are more subtle and sometimes quite difficult to measure. Moreover, these aspects are not all independent on one another. For example, one can imagine correlations between *Distraction*, *Workload* and *Event detection*. (E.g. a distracted driver will not detect events very well; a low workload may lead to distraction.). Furthermore, these notions are on different levels of abstraction and scope. For example, *Usage* is a very specific and concrete notion, whereas *Situational awareness* is a much more abstract notion of large scope that encompasses some other aspects such as *Distraction* and *Event detection*.

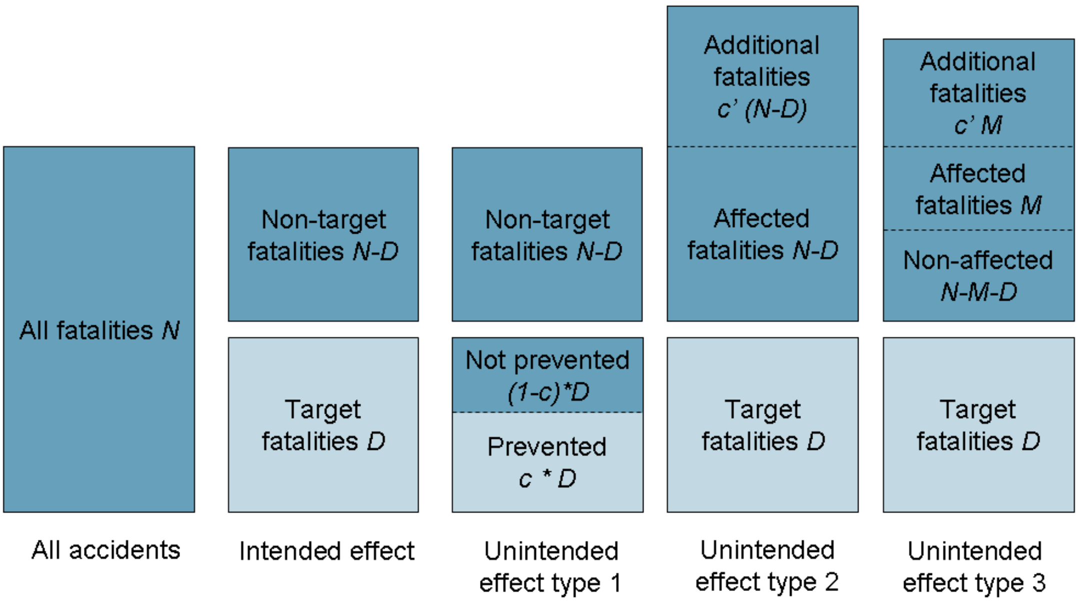
In other words, it can become quite complicated to visualize and take into account for the mutual influences of all the aspects, and any analysis probably has to focus on just a few. To the best of our knowledge, there is no conceptual model that provides a complete (or even partial) picture of the relations between the listed aspects

A final observation in this section is that some behavioural changes will affect only the target scenarios of the ITS, some will affect the whole drive, and some are in between. This has consequences for the way the effect should be accounted for (see also Figure 6.4):

1. Impact only on target scenarios: For example, acceptance effects may influence this way. The behavioural change acts as a reduction on the effectiveness of the ITS as determined by mechanism 1 & 2. That is, if mechanism 1& 2 reduce the number of fatalities N by an amount D to $N – D$, then the effect of mechanism 3 is to decrease

this reduction to $c*D$ for some $0 \le c \le 1$, and the number of fatalities with the ITS is $N – c*D$. In this case, the effect of the ITS remains positive (i.e., the number of fatalities with the ITS is lower than without the ITS).

2. Impact on the whole drive: For example, risk compensation may function this way. The behavioural change acts as a general increase or decrease in risk on all remaining fatalities. That is, the ITS still saves the *D* targeted fatalities but also has a positive or negative effect on the remaining *N-D* ones. With the same notation as above, the number of fatalities becomes $(1+c') * (N – D)$ for some percentage-wise risk change c'. If $c' > 0$ then the risk increases due to the unintended effect; if $c' < 0$ then it decreases. The overall effect of the ITS amounts to a change of $N – (1+c') * (N – D) = D – c' * (N – D)$ in the number of fatalities, which is positive if $c' \le 0$, and may be positive or negative if $c' > 0$.
3. Impact in between of both pervious impacts: For example, for limited forms of risk compensation may work this way (e.g. behavioural change only in certain situations). The behavioural change acts as an increase in risk applied to part of the fatalities denoted by *M* where $0 \le M \le N – D$, and the number of fatalities with the ITS becomes $N – D + c' * M$ for some percentage-wise risk change *c'*. If $c' > 0$ then the risk increases due to the unintended effect; if $c' < 0$ then it decreases. The overall effect of the ITS amounts to a change of $D – c' * M$ in the number of fatalities, which is positive if $c' \le 0$, and may be positive or negative if $c' > 0$.



# fatalities	$N-D$	$N-c*D$	$(1+c')*(N-D)$	$N-D + c'*M$
# saved	D	$c * D$	D	D
total	N	N	$N + c'*(N-D)$	$N + c'*M$

Figure 6.4: Example for the influence of the intended effect and three types of unintended effects on road fatalities:

(1) a reduction of the intended effect; (2) an increase or decrease in the number of non-targeted accidents; (3) the same for a part of the non-targeted accidents. For types (2) and (3) an increase is shown. The table shows the number of remaining fatalities, the number of saved fatalities and the sum of these two. The sum can be higher than N in case the application induces new risks, for example by risk compensation.

Application to interactIVe

Safety mechanism 3 (Indirect modification of user behaviour) is difficult to assess, because many aspects of user behaviour are not well known, not easily quantified or measured or even defined, and it is often hard to determine what impact they have on safety. There are no known models for this kind of assessment. The fact that user behaviour needs to be determined for the long term poses a particular problem, as already stressed out in chapter 5.4.3. It is proposed that earlier results on similar or related systems are used where possible to correct for this discrepancy.

However, this is an important mechanism that needs to be taken into account, because user behaviour can have a major impact on the safety effect of an application and may be very different from the intended behaviour covered under the direct effects.

Therefore, in interactIVe user related tests will first conducted, see which aspects of user behaviour are significantly impacted by the applications, and from there decide how to assess this mechanism.

Certain aspects of user behaviour will be measured in interactIVe, such as the reaction time, the time spent in a high risk situation, and the driver reaction to warnings. Other aspects will not be measured, like the number of false or missed alarms and the usage (the latter is covered to a limited extent by questionnaires, but in the objective tests the application is always on). Yet other aspects may not be relevant for the safety assessment in interactIVe. For example, “mode error” is more relevant for HMI design (SP3) than for safety assessment.

Aspects that seem to be important, well defined and measurable are *Distraction*, *Workload*, and *Usage*, so it will be considered to focus on those in interactIVe, with the remark that *Distraction* will be hard to measure in interactIVe due to limitations of the tests.

6.2.6 Effects on non-users

General method

This concerns mechanisms 4 and 5:

4. Indirect modification of non-user behaviour;
5. Modification of interaction between users and non-users.

Effects on non-users can arise in various ways:

- Limitations, for example non-users adopt the same speed as users (mechanism 4). This can have a positive or negative effect on safety (e.g. positive for a speed limiter that restricts speeds below the speed limit; negative for a Cooperative Adaptive Cruise Control (CACC) that maintains extremely short headways).
- Forcing, for example non-users are forced to maintain the same speed as users because they cannot overtake (mechanism 4). This will usually be a positive effect.
- Interaction effects in case of cooperative systems, for example users rely more on cooperative systems to interact with other road users, to the detriment of non-equipped users, in particular vulnerable road users (mechanism 5). This will usually be a negative effect.

Some of these may be obtained by means of simulation or simple traffic models.

Application to interactIVe

In the eIMPACT and PReVAL studies these effects were found to be typically very small. Hence it can be assumed that the interactIVe applications (being similar to the eIMPACT and PReVAL ones) will probably also show small effects. Furthermore, it will probably be difficult to measure these mechanisms in Interactive. However, there are also cases where the effect is quite significant. For example, traffic simulation of a mandatory ISA system in the UK showed that the bulk of the benefits of ISA will be realised when 60% of vehicles are fitted with the system [CAR00].

Hence it is proposed that it is checked whether for the interactIVe applications these effects are so small that they can be ignored, and it is proposed that the tool only provides rudimentary support. A sensible approach is to not expand this into contributing factors, but rather model the three factors listed above in a simple way, e.g. as shown in Figure 6.5.

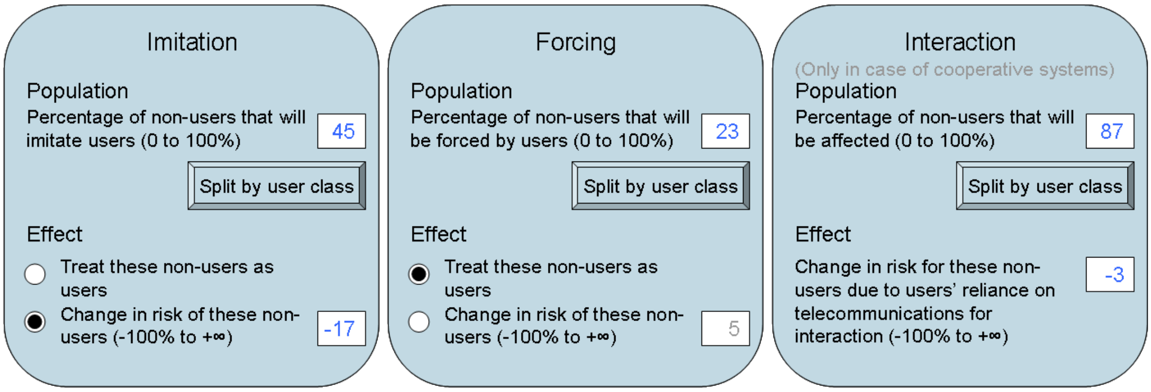


Figure 6.5: Illustration of possible models for the effects on the non-user.

The diagrams show which data the user of the tool has to supply for the imitation, forcing and interaction effects.

For each of the three factors, the user of the tool has to supply the percentage *p* of non-users that will be affected, and the size *r* of the risk change for these affected non-users. If the fraction of equipped users is *q* and their average risk is *SC(0)*, then the overall risk change due to one of the three factors is given by *(1-q)*p*r*SC(0)*, which may be positive or negative, depending on the sign of *r*. For imitation and forcing, the risk change can be set equal to the (intended + unintended) risk change for the users, in case the imitation or forcing is perfect and the affected non-users cannot be distinguished from the users. In this case no specific risk change needs to be supplied. It does not make sense to have such an option for the interaction factor, because it aims at negative side effects.

A more elaborate version would split this by road user class (e.g. car driver, truck driver, pedestrian, cyclist, and motor cyclist) and ask for affected proportions and effect sizes for each class separately – that is, the input screens above would be supplied for each road user class. Similarly, one can imagine a further subdivision by accident type. The analysis in interactIVe will not include accident type for simplicity.

6.2.7 Exposure effects

General method

This concerns mechanisms 6, 7 and 8:

6. Modification of road user exposure;
7. Modification of modal choice;
8. Modification of route choice.

Exposure effects include:

- Changes in the number or length of trips due to the application (mechanism 6). This can for example happen for travel information applications or applications that change the comfort in car driving.
- Changes in the mode of travel between car and other modes (mechanism 7), for example, under influence of applications that change the comfort in driving.
- Changes in the route of car trips (mechanism 8), e.g. caused by applications that modify the attractiveness of certain road types.

This type of effect is typically obtained from naturalistic field data or from questionnaires.

Application to interactIVe

In the eIMPACT and PReVAL studies these effects were found to be typically very small, hence it can be assumed that the interactIVe applications (being similar to the eIMPACT and PReVAL ones) will probably also show small effects. Furthermore, it will probably be difficult to measure these mechanisms in Interactive.

Hence it is proposed that these effects are ignored in interactIVe and that the tool only provides rudimentary support. A sensible approach is to not expand this into contributing factors, but rather model these factors in a simple way, e.g. as shown in Figure 6.6.

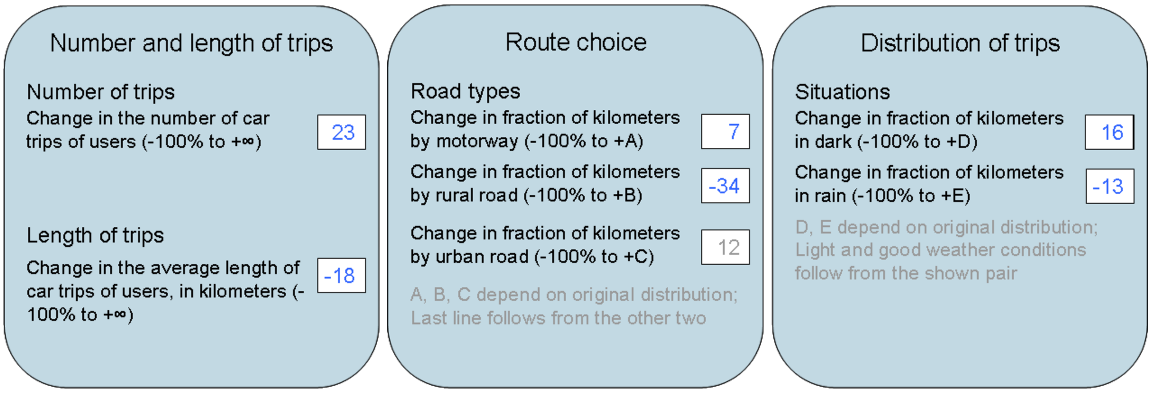


Figure 6.6: Illustration of possible models for the exposure effects (on the user).

The diagrams show which data the user of the tool has to supply.

If the number of car trips changes by a percentage "*a*" and the average length by a percentage "*b*" and the fraction of equipped users is *q*, then the total distance covered by car changes by a factor $q * ((1+a) * (1+b) - 1) = q * (a*b + a + b)$. This combines mechanisms 6 and 7.

Mechanism 8 addresses changes in the distribution of car kilometres over different road types, and we also include the distribution over other situations here. Mechanism 8 does not modify the total distance driven, only the distribution over situations. The relevant situational variables are *road type*, *lighting conditions* and *weather conditions*. The variables *host vehicle type*, *target vehicle type* and *location* do not seem to be relevant because it is not likely that an ITS will change them, and therefore they are not included. The situational variables are considered independent. If for example the changes in the fraction of kilometres driven on motorways, in dark and in rain are *c*, *d*, *e*, respectively, then the fraction of kilometres driven on motorways in the dark in rain changes by a factor $(1+c)*(1+d)*(1+e)-1$.

The factors for the different values of any single situational variable are dependent: for example, let a fraction *s* of all kilometres be driven in dark, and a fraction of *1-s* in light. If the change in the fraction of kilometres driven in dark and light is equal to *e* and *f*, respectively, then the relation $s*e + (1-s)*f = 0$ needs to hold because all fractions need to add up to 1. Similar relations hold for the other situational variables.

It is assumed that the ITS application is only available for a single road user class and hence splitting by road user classes is not needed. Subdivision by accident type is not needed because exposure cannot depend on accident type.

6.2.8 Effects on post-accident consequence modification

General method

This concerns mechanism 9:

9. Modification of accident consequences.

This mechanism covers the effect of the ITS on timeliness of emergency services. This mechanism has a need for statistics on the relation between the timeliness of the emergency services and the severity of the accident consequences, see e.g. [EVA99] for research in this area.

This mechanism is important for ITS like eCall that specifically address the timeliness of emergency services. Note that the effect of the ITS on mitigation via changing the collision speed change is already covered in mechanism 1 & 2.

Application to interactIVe

The applications in interactIVe will not have an effect on the timeliness, and hence this effect does not need to be assessed in interactIVe. In general, estimates on the effect of the ITS on the timeliness of emergency services have to be provided by the technical assessment, where appropriate.

Further background information on different topics of the impact assessment (e.g. description of the used accident databases, as well as a description of the relation between collision speed change or the impact zone and injury risk) are provided in Annex B.

7 Conclusions

The three vertical subprojects SECONDS, INCA and EMIC together involve 11 different functions with a wide range of target areas. Some of the functions are intended to be supportive for normal driving, some intervenes in emergency situations in order to avoid the imminent collision and some functions aims to mitigate the accidents consequences.

This deliverable describes how these functions will be assessed with respect to their technical performance, their interaction with the user and their impact on the traffic safety in Europe. Basis for the assessments are the research questions and hypotheses defined in the previous deliverable D7.1 and D7.2. Both have been updated in this deliverable based on the feedback of the VSP. Due to the role of the different subprojects a close cooperation between SP7 (defines evaluation framework and evaluate the function) and the VSPs (develop functions and conduct the defined test) is essential.

The three different assessments are described in general with respect to

- outline of the experiments
- consistency between test site environments
- experiment parameters
- logistics
- analysis
- Limitations for tests

The general information is used afterwards to define individual test plans for each demonstrator vehicle.

Technical assessment

Regarding the technical assessment already in D7.2 the hypotheses for the functions and almost 70 test cases were defined. Towards D7.4 the hypotheses were updated and the test cases were elaborated with relevant parameter settings. Latter results in very many tests even considering that some have been defined as secondary tests. Hence the biggest challenge for the technical evaluation will be the amount of tests to be done and involving reporting and wrapping these towards a final conclusion. For the reporting a standard test report is defined including a summary table that should help in wrapping up the individual test result to overall results.

Other challenges for the technical assessment turn out to be the availability of certain target objects, especially moving ones. Moreover, it is to be expected that many of the testing will be done in winter times, which may impair consistency between the tests or even testing itself. It stands without reason that safety is considered first for all tests. This may mean that some tests are build-up e.g. in speed to ensure that the function has the desired effects at high speeds.

Finally the analysis of the data to be able to verify or falsify the hypotheses is discussed in this deliverable.

User-related assessment

Except for the fact that interactIVe not will be able to test the long term effects on driver behaviour, the user related assessment plans also faces future challenges. In general the main issues will be the definition of parameters since the testing will be performed in different environments. This leads to an importance of consistency between the test sites.

Another issue for the user-related tests is the testing effort. The tests have to be limited to a certain number of test persons and also the tests itself have to be limited (e.g. test route). Therefore, the test persons should preferably have to drive the same route twice in order to be to able compare the driver behaviour with and without the function. Due to the limited time and the limited availability of the demonstrator vehicles and simulators it will be not possible to do the tests with a large number of test persons or on a long test route.

The SECONDS functions will be active continuously, supporting the driver in "normal" driving not only in a situation with risk for imminent collision. Hence, the SECONDS functions can be tested with "naive" drivers on public roads in real traffic. However, for some of the demonstrator vehicles certain regulations affect the testing, e.g. a demonstrator vehicle can only be driven by employees of the company which will limit the selection of test persons. In another case a special driving license, issued by the car manufacturer, is needed to drive the demonstrator vehicle. In this case, it is not possible to carry out test drives on public roads with "naive" drivers.

The INCA and EMIC functions address emergency situations and will basically be carried out in simulators. Here, it will be difficult to design the scenarios and trick the test driver in the specific situations without revealing the outcome of the event. But it will also be challenging to implement the functions for correct behaviour in the simulator environment. SP3 has performed simulator studies during the development of INCA with good results. SP7 will learn from their studies during the evaluation process and also try to re-use some of the road environments and traffic scenarios.

When analysing the results of the INCA and EMIC functions, it must be taken into account that the tests are not conducted during real traffic conditions. Since the scenarios they address only occur in emergency situations, which are more or less impossible to reconstruct, the drivers actions cannot be totally established. Driving in a simulator environment cannot replace real driving and real emergency situations. In this project though, this will be the best solution for this evaluation study and will be the safest way to get information of user reaction and acceptance of the functions.

Safety impact assessment

For the impact assessment the used methodology, which bases on the method used in eIMPACT and PReVAL, has been described, as this method fits best the requirements and limitations of interactIVe. The method is based on the idea to determine risk modifiers for nine mechanisms, which classify the impact of an ITS on the traffic in different categories. The nine safety mechanisms are quite helpful in the sense not to lose the orientation during the impact assessment.

Due to the high number of different functions, for which the impact assessment should be conducted, and the resulting high number of risk modifiers, which need to be calculated, the only reasonable approach is to use impact assessment tool. Therefore the interactIVe partners, who are involved in the impact assessment, are going to develop such a tool. Since the nine safety mechanism approach could be used for all ITS functions and not only for the interactIVe function, it would not make sense to limit the tool to purpose of the interactIVe safety impact assessment. Hence the tool will be implemented in a modular and expandable way in order to ensure that it can also be used for other function and in other assessments.

But the more difficult question for the impact assessment is how to calculate the risk modifiers. This question must be answered for each safety mechanism separately considering the given limitations of the interactIVe project.

There are some safety mechanisms, which will not be affected by the interactIVe function (e.g. "direct influence by roadside applications" and "modification of accident consequences") therefore they can be ignored for the impact assessment in interactIVe.

For the safety mechanism related to the exposure effects it has been decided based on the results in previous project (eIMPACT and PReVAL) that these factors can be ignored, because their effects on the interactIVe function will be quite low. The same decision has been made for the safety mechanism related to the effects on non-user. For all these mechanisms the impact assessment tool will therefore only provide rudimentary support.

The two mechanisms, which are most relevant and on which is concentrate in interactIVe, are the mechanisms “Direct in-car modification of the driving task” and “Indirect modification of user behaviour”. The modification for the first mechanism will be calculated by means of accident data, which is a limiting factor. If the safety impact of the functions is calculated on EU 27 level, which is the goal in interactIVe, this would require detail accident data for each country. Such data are not available. Detailed accident data are only available for some countries or even regions of countries. Hence the results must be scaled up on EU level. This scaling up process is associated with some uncertainties. This must be taken into account for the results of the impact assessment.

For mechanism “Indirect modification of user behaviour” it will be difficult to determine the change in the user behaviour within in the short testing period of interactIVe. The reason for this is that user behaviour, which effect the safety impact of the function, like risk compensation, occurs after a certain time period. And these effects cannot be analysed by means of the short period testing. The interactIVe tests can only provide data regarding the acceptance and user-behaviour in the beginning of a usage of the functions. Although it might be possible to assume a certain user behaviours base on the experience with other function, but a verified statements to the longer term user behaviour will not be possible. This would require a different type of tests, e.g. field operation tests. Therefore he results of mechanism will also be limited.

Regarding the target scenario is has been decided to have three different scenarios. There will be a baseline scenario without the functions and an optimum scenario with a penetration rate of 100%, which should identify the optimum impact, which the function could have. In the third scenario a realistic penetration will be assumed. The target year will be 2030. The target year has been chosen, because it seems not realistic that functions, which are developed in a research project, could reach a significant market penetration within 10 years. Therefore the target year 2020, which has been chosen in different other EU projects, has not been an option for interactIVe. The disadvantage of the chosen target year is that a forecast of nearly 20 years must be made, which raises uncertainly with respect to the accident data. But this disadvantage must be expected, if the impact should be calculated for realistic market penetration.

Next step

In the next step of WP75, SP7 will focus on the development of the test tools (e.g. data conversion tool, training of observers, development of assessment tools, impact assessment tool) needed for the evaluation tests. SP7 will also support the conducting of the VSP’s tests and experiments at the different sites.

The results from the three evaluation areas need to be combined since they in some way, more or less, are linked to each other. The technical performance may be major for the function to work but when interactions with a driver take place, the driving performance is affected by the usability and user acceptance of the function and the safety impact assessment builds on the results of both technical- and user-related evaluation.

Keep also in mind that the evaluation from SP7 will be on prototypes. The maturity of the functions could therefore influence the test results so the coming results are not final and there need to be more tests before market introduction.

After the evaluation framework has been applied to the VSPs, results from this application will be used to improve the evaluation framework.

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Abbreviations

Abbreviation	Description
ABS	Antilock Brake System
ACC	Adaptive Cruise Control
ADAS	Advanced Driver Assistance System
AIS	Abbreviated Injury Scale
AV	Approaching Vehicle
C2C	Car to Car
CAN	Controlled Area Network
CDC	Collision Deformation Classification
CDS	Crashworthiness Data System
CMS	Collision Mitigation System
CRF	Crash Reduction Factor
CS	Continuous Support
CSC	Curve Speed Control
CSV	Collision Scenario Variable
CV	Crossing Vehicle
eDDP	enhanced Dynamic Pass Predictor
EC	European Commission
EEG	ElectroEncephaloGram
EMIC	EMergency Intervention for Collision mitigation
ESA	Emergency Steer Assist
ESC/ESP	Electronic Stability Control / Electronic Stability Program
EU	European Union
FARS	Fatal Accident Reporting System
FEV	Fatal Equivalent Value
FOT	Field Operational Test
GIDAS	German In-depth Accident Study
GSR	Galvanic Skin Response
HMI	Human Machine Interface / Interaction
HV	Host Vehicle
INCA	INtegrated Collision Avoidance and vehicle path control
ITS	Intelligent Transportation System
IWI	Information, Warning and Intervention
JDVS	Joint driver vehicle system
LCCA	Lane Change Collision Avoidance
LKS	Lane Keeping System

Abbreviation	Description
LV	Lead Vehicle
MAIS	Maximum Abbreviated Injury Scale
NASS	National Accident Sampling System
NEFZ	Neuer Europäischer Fahrzyklus (New European Driving Cycle)
NHTSA	National Highway Traffic Safety Administration
OEM	Original Equipment Manufacturer
OV	Opponent Vehicle
OVCA	Oncoming Vehicle Collision Avoidance/Mitigation
PI	Performance Indicator
RECA	Rear End Collision Avoidance
RORP	Run-off Road Prevention
RQ	Research Question
RT	Reaction Time
SAM	Self Assessment Manikin
SC	Safe Cruise
SECONDS	Safety Enhancement through CONtinuous Driver Support
SIA	Side Impact Avoidance
SP	Subproject
SMF	Safety Modification Factor
SUS	System Usability Scale
SV	Situational Variable
TET	Time Exposed Time to collision
THW	Time Headway
TLC	Time to Line Crossing
TTC	Time To Collision
UA	Unattended Animal
UC	Use Case
VRU	Vulnerable Road User
VSP	Vertical Subproject

Glossary

Glossary	Description
Aspect	A specific action that is part of a function and / or a system and that is common for different functions / systems. E.g., “automatic steer”.
Component	A device or a set of devices necessary for the implementation of an aspect, function or system. E.g., “perception component”, “logic component”
Function	A task, action, or activity that must be accomplished to achieve a desired outcome. E.g., “lane keeping”
System	A collection of components organized to accomplish a specific function or set of functions. E.g., “EMIC”
Target scenario	The general purpose of the target scenarios in interactIVe is to define the *problem* - in terms of an undesired outcome - that the envisioned interactIVe functions are to address
Test case	Tested situation, which contains different tests with different initial parameters.
Test scenario	Scenario where a certain aspect, function or system is tested. A test scenario consists of different test cases.
Use case	*Use cases* which define *how the problem will be solved*, that is, how the function is intended to prevent the targeted accidents or mitigate their consequences

Annex A1: VCC Demonstrator assessment plans

Confidential information

Annex A2: FFA Demonstrator assessment plans

Confidential information

Annex A3: BMW Demonstrator assessment plans

Confidential information

Annex A4: CRF Demonstrator assessment plans

Confidential information

Annex A5: VTEC Demonstrator assessment plans

Confidential information

Annex A6: VW Demonstrator assessment plans

Confidential information

Annex A7: CONTI Demonstrator assessment plans

Confidential information

Annex B: Background information for the Deliverable D7.4

1. Technical assessment

1.1 Background information on the logistics for the technical assessment

In this section the logistics aspects for the tests in the technical assessment are described. The responsible partners for the technical assessment on SP7 site are ika, TNO and VTT. An overview on the demonstrator vehicles and the responsible partners is given Figure B.1.

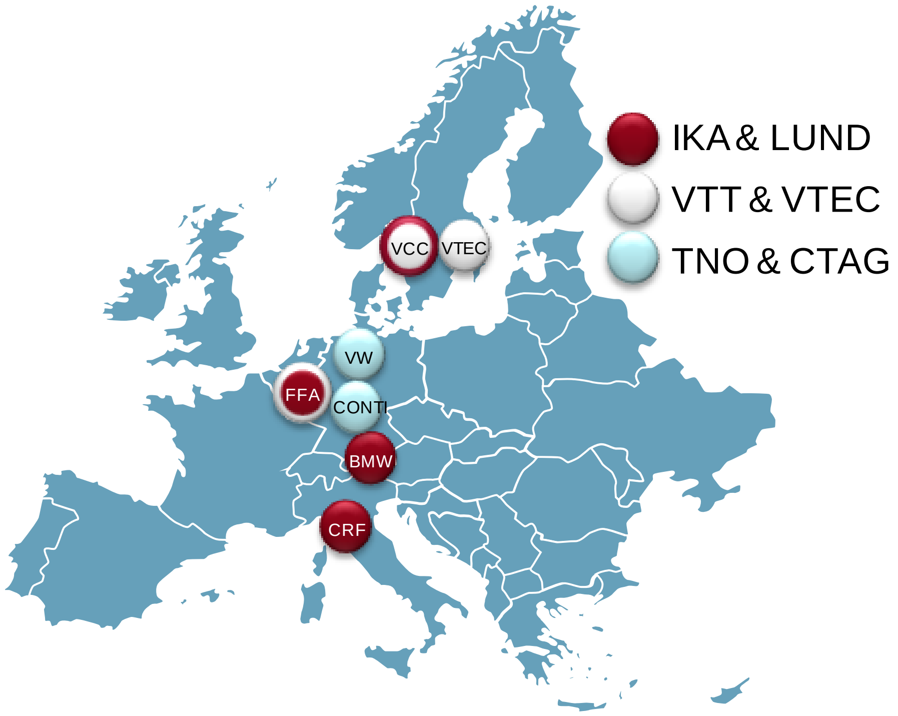


Figure B.1: Demonstrator vehicles and responsible SP7 partners

According to the description of work the task of SP7 is to support the VSP during the final tests. This support task can be divided into different subtasks:

- Definition of a test and evaluation framework for each application with respect to technical performance and human factors,
- Development of test scenarios, procedures, and evaluation methods,
- Provision of tools for evaluation like equipment, test catalogues, questionnaires or software and support for testing and
- Definition of test and evaluation criteria.

The tests will be conducted by respective VSPs. For the tests different test sites on VSP and SP7 side are available, which are presented in Table 3.4. The test sites have been chosen according to the tests to be conducted and the available test tools (target object, digital map data). Another important aspect for the selection of the test sites are the available resources. A long transport to a test track is not only expensive but also time consuming and should be avoided. Hence most of tests are conducted close to the VSP facility.

There is one additional test, in which a joined testing of two demonstrator vehicles is required. This is the joint test with the BMW and the VCC demonstrator, which is conducted on the Volvo test track in Hällered. In this test the Vehicle-2-Vehcile (V2V) applications are tested. BMW and VCC will use the same V2V technology. And due to the fact that for a test of V2V at least two vehicles are needed, a joint test with both vehicles seems to be the most reasonable approach for testing these applications.

The demonstrator vehicles are provided by the VSPs, who are also responsible for the transport of the vehicle. Because for most of the demonstrator vehicles there are regulations regarding the driver, the VSP will also provide a test driver, who drives the demonstrator vehicle in tests. The driver has to perform the manoeuvres accurately to guarantee the repeatability of the results.

The needed tools for the testing will be provided by SP7 and the VSP. The question, which test tools are need for which test and who provides the needed test tools, will be discussed for each demonstrator vehicle bilaterally between SP7 and the related VSP partner. Independently from these discussions SP7 will provide the tools to evaluate the tests results and determine performance indicators.

After the tests the stored data will be transmitted to SP7 for the evaluation. In principle there are two ways:

1. The data is stored on hard disk and this hard disk is handed over to SP7,
2. The data are transmitted via internet (for this approach safety measures must be taken in order to prevent unauthorized access to the data).

Independently from the chosen approach for the data transport a security backup should be made just after the tests or even better directly during the tests in order to prevent a loss of data.

In addition to the place and the test tools, also the time plan for the tests must be considered. The time-line for the testing and evaluation work packages in interactIVe is shown in

The first VSP, which will start with the testing, will be EMIC. But it must be taken into account that the testing period for EMIC includes also the tests, which are related to the development of the functions. Hence the tests that are relevant for evaluation will be conducted later. For the other two VSPs the testing will start in the end of the summer 2012 respectively in the autumn of 2012. Hence, it is clear that at least some of the tests have to be conducted during the winter. This could raise different problems for the testing and must therefore be considered for the detailed test planning for the demonstrator vehicles.

Table B.1: Time line of testing work packages in interactIVe

SP	WP	Task	2012												2013					
			1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6
SECONDS	WP46	Test & Evaluation																		
INCA	WP56	Test & Evaluation																		
EMIC	WP66	Test & Evaluation																		
SP7	WP76	Test execution																		

The tests for the evaluation can be conducted either sequentially or simultaneously. The final decision, in which way the tests will be conducted, will be taken at later stage, because different aspects must be considered for the test planning:

- Availability of the demonstrator vehicle,
- Availability of the test tools (test tools, measurement equipment, etc.),
- Availability of test persons, test drivers and (if needed for the tests) SP7 partners,
- Number of tests and
- Weather conditions.

In order to find the optimum solutions for the tests, the time plan is continuously discussed with the VSP.

In the following the current planning for the evaluation tests in the SECONDS is presented. The first tested demonstrator vehicle will be the BMW demonstrator. The reason for this is that from today's point of view the BMW demonstrator vehicle will be the first vehicle ready for the evaluation tests. Afterwards the order of the tests is affected by the geographic position of the VSP in order to minimize problems due to the weather conditions. It must be considered that the average monthly temperature in Sweden is negative during the months December-March. Therefore the planning of tests during this period should be avoided. This means that, for SECONDS, after the BMW demonstrator first the VCC demonstrator then the FFA demonstrator and finally the CRF demonstrator is tested.

2. Relevant indicators for the technical assessment

Below the relevant indicators for the technical assessment are listed:

Table B.2: Indicators for the technical assessment of the interactIVe functions

Indicator	Description of the indicators
Brake pressure / force (Extra applied)	Brake pressure or force (depending on which signal is available for the demonstrator vehicle) applied by the driver or by the function
CAR (Correct Activation Rate)	Rate of correct activation (including warning and interventions) in the tests. Calculated based on the number of test runs.
Difference of detected and current speed limit (mean / max)	Difference of detected and current speed limit.
min/mean/max Distance to target object (longitudinal) at certain points (e.g. first detection/alarm/intervention)	Distance between host vehicle and target objects in longitudinal direction.
min/mean/max Distance to target object (lateral) at certain points (e.g. first detection/alarm/intervention)	Distance between host vehicle and target objects in lateral direction. Determined at different time points, which are interesting (e.g. first detection / alarm / intervention)
Driver braking reaction after alarm	Brake pressure applied by the driver after alarm
Driver reaction after alarm	Change in steering angle and brake pedal position applied by the driver after alarm
Driver steering reaction after alarm	Steering angle applied by the driver after alarm
Duration of intervention	Time between start and end of the intervention of the function (change in the intervention status of the function)
FAR (False Activation Rate)	Rate of false activations (including warning and interventions) in the tests. False activations are activations, which are not necessary due to the lack of danger. Calculated based on the number of test runs
Function intervention status	Intervention status of the function (0: no intervention; >=1: intervention).
Function on/off status (per braking pedal / steering wheel position or velocity)	Status of the function depending on different condition (e.g. brake pedal position, steering wheel position). The indicator is needed to check the overrideability of the function.

Indicator	Description of the indicators
Function alarm status	Alarm status of the function (0: no alarm; >=1: alarm)
Impact orientation	Orientation of the host vehicle relative to the hit objected at the time point of collision
Impact speed	Relative velocity of the host vehicle at the time point of collision
Lateral acceleration (max.)	Lateral acceleration of the host vehicle (measured during a manoeuvre with respect to maximum, minimum and mean value)[12]
Lateral acceleration required to avoid collision at given points	Lateral acceleration, which is required to prevent a collision calculated at different time points.
Longitudinal acceleration (max.)	Longitudinal acceleration of the host vehicle (measured during a manoeuvre with respect to maximum, minimum and mean value)
Longitudinal acceleration required to avoid collision at given points	Longitudinal acceleration, which is required to prevent a collision by braking calculated at different time points.[13]
MAR (Missed Activation Rate)	Rate of missed activations (including warning and interventions) in the tests. Missed activations are activations are situations, in which the function should become active, but the function is not activated. Calculated based on the number of test runs.
Number of false activation	Number of false activations

[12] Lateral acceleration required to avoid collision at certain points (a circular evasive trajectory is assumed; W = lateral distance for the evasive manoeuvre; $v_{rel} = v_{OV} - v_{HV}$; no longitudinal deceleration of the host vehicle → v_{HV} = const is assumed)

$a_y = \frac{2\,v^2\,W}{dx^2 + W}$ with $dx = v_{HV}\,\frac{dx_0}{v_{HV} - v_{OV}}$,if the front vehicle is not decelerating a_{OV} =0 and

$dx = v_{HV}\left(\frac{v_{rel}}{a_{OV}} +/- \sqrt{\left(\frac{v_{rel}}{a_{OV}}\right)^2 - \frac{2\,dx_0}{a_{OV}}}\right)$ if the front vehicle is decelerating a_{OV} <0

[13] Longitudinal acceleration required to avoid collision at certain points (HV: Host vehicle, OV: other vehicle, dx0 = relative longitudinal distance between both vehicles):

$$a_{x\,required} = a_{OV} - \frac{(v_{HV} - v_{OV})^2}{2\ dx_0}$$

If the lead vehicle stops before the host vehicle reach the minimum distance to the lead vehicle $t_{stop} = \frac{v_{OV}}{a_{OV}} < t_{deceleration} = \frac{v_{HV} - v_{OV}}{a_{OV} - a_{x\,required}}$, then the required longitudinal acceleration

$$a_{x\,required} = \frac{{v_{HV}}^2}{2\,dx_{EndOV}} = \frac{{v_{HV}}^2}{2\,(dx_0 + v_{OV}t_{stop} + \frac{1}{2}a_{OV}t_{stop})}$$

Indicator	Description of the indicators
Number of missed activation	Number of missed activations
Rate function "on" per status	Rate function is “on” during the test (measured based on the time or the travelled distance)
Rate of correct detections	Rate of correct detections in a test. (Can also be calculated on test case or scenario level)
Rate of false detections	Rate of false detections in a test. (Can also be calculated on test case or scenario level)
Rate of missed detections	Rate of missing detections in a test. (Can also be calculated on test case or scenario level)
Speed reduction (max/mean/min)	Speed reduction achieved during the manoeuvre
Steering torque (Extra applied)	Steering torque applied by the function during one test
Steering wheel angle (during intervention)	Steering wheel angle during an intervention of the function (calculated with respect to the maximum value)
THW at given points	Time headway measured at certain points of interest (e.g. first detection)
Time between alarm and intervention	Time between the first warning is issued and the initiation of the intervention
Time distance at first detection (min/mean/max))	Distance to the relevant objected divided by the velocity of the host vehicle (calculated with respect of the maximum, minimum and mean value)
Time target visible and in sensor coverage area until first detection	Duration between the time point the target object is visible and the time point, at which the target object is the first time correctly detected.
TLC at given points	Time-to-Lane-Crossing (measure at different time points)
TTC at given points	Time-To-Collision (measure at different time points)
Vehicle position at given points	Position of the vehicle at certain points of interest (e.g. first detection)
Vehicle speed at given points	Velocity of the host vehicle at different point (e.g. beginning of speed limit, measured with respect to the maximum, minimum and mean value)

3. Further information analysis of the interactIVe scenarios

For the analysis not only the distance between two vehicles need to be taken into account as described in chapter 4.4.1. For the test scenarios related to lateral conflicts (blind spot conflict or unintended road / lane departure), the position of the vehicle in the lane plays a important role, because as long as the vehicle keeps its lane there is no danger to collide with a vehicle in the blind spot respectively in the adjacent lane. Hence, it must be measured when the vehicle leaves the lane. A lane departure takes place if one part of the vehicle crosses the lane boundary (see Figure B.2).

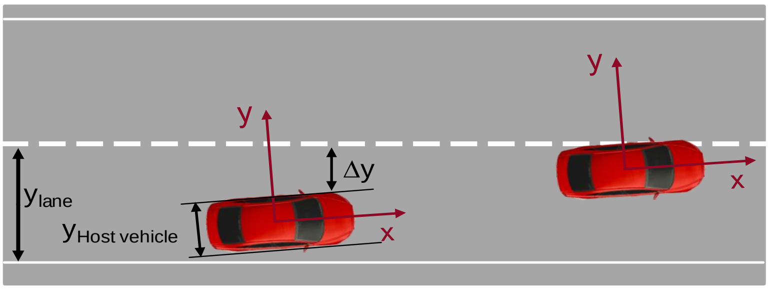


Figure B.2: Measured distance to the lane boundary (left) and time point of lane departure (right)

In order to be able to calculate the position of the vehicle in the lane, the on board sensor information as well as - if the accuracy of the system is high enough - the reference measurement system is used. When the reference measurement system is used, the GPS-position of the lane must be measured before the test. In the test itself only the position of the vehicles is measured. Afterwards both results are combined and in due consideration of the vehicle dimensions the lateral distance to the lane is calculated.

For different test scenarios the distance to the stationary environmental objects must be calculated. In this case the position of the object must be determined by means of a reference measurement system before the test. During the test the movement of the vehicle is stored similar to the lateral conflict tests. After the test both data are combined in order to determine the distance between the vehicle and the stationary object.

An example of a stationary object is an upcoming curve. In this scenario it is necessary to analyse, when the function informs/warns the driver due to an upcoming curve. This is analyzed by means of the distance to the entrance of the curve, which is the reference point for the test, see Figure B.3.

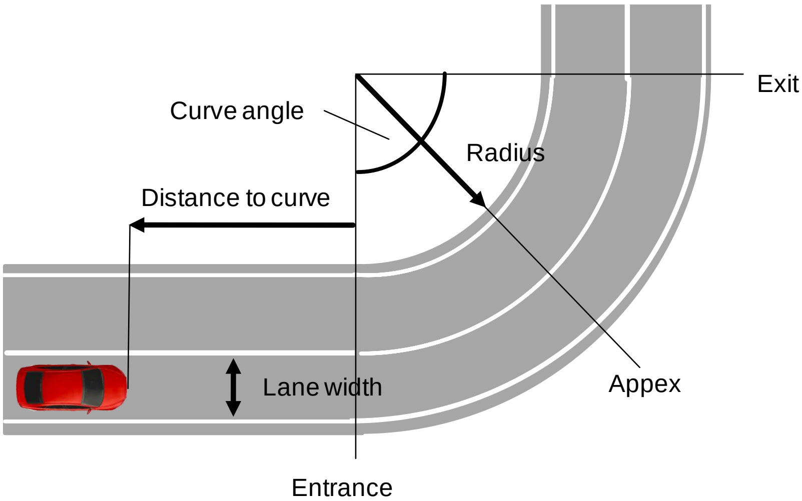


Figure B.3: Relevant parameters for the curve warning.

For the determination, whether the warning of the function has been appropriate or not, the geometry of the curve (radius, angle, lane width) must be considered. An indicator to decide, whether a warning is appropriate, is the lateral acceleration measured during the curve negotiation. The measured accelerations will be compared to lateral accelerations during normal driving and can be handled by the driver, like e.g. the safety limit of a normal driver in a passenger car for curve driving shown Figure B.4. It must also be taken into account that the maximum lateral acceleration is not only influenced by the geometry of the curve but also by the driver and his driving skills. For trucks the maximum lateral acceleration also depends on the load of the vehicle respectively the position of the centre of gravity.

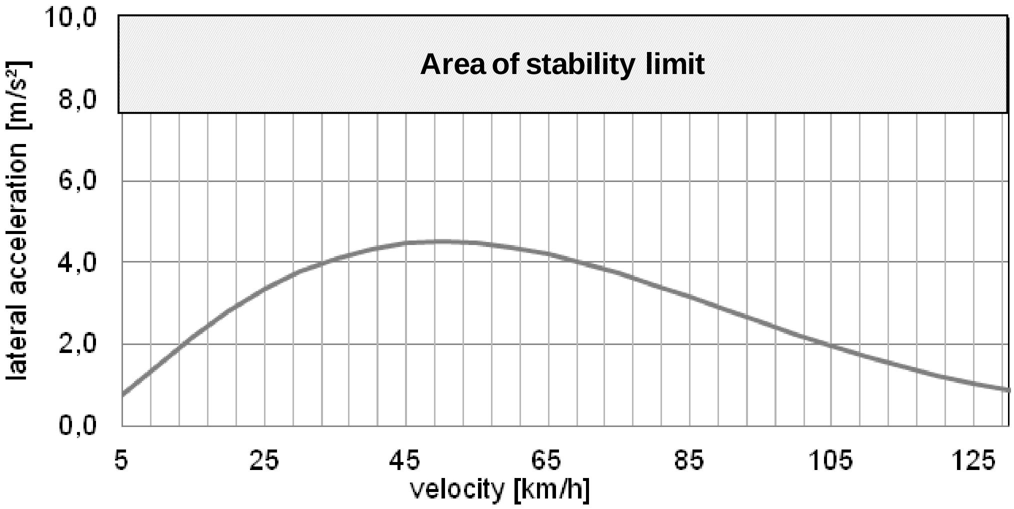


Figure B.4: Safety limit of a normal driver for curve driving (passenger car) [SCH85]

Another side aspect for the SECONDS functions, which will be evaluated at least for some functions, is, whether the fuel consumption is effected by the functions. It needs to be pointed out that this is not the main focus of the functions. Hence, the technical assessment focuses on the safety related performance of the functions. Measurements for the fuel consumption evaluation are performed during the user-related assessment, through comparison of test drives with and without using the function. Therefore, the average fuel consumption is analysed over the whole trip. This requires that both trips are conducted under the same conditions.

4. User-related assessment

The user-related assessments, to study drivers' reactions to the developed functions, can be made by using naïve subjects in relevant driving situations, in an instrumented vehicle in real traffic or in a driving simulator. The tests drives are followed by questionnaires or interviews that also will give information of the test drivers' opinions on the functions in question. Using naïve subjects means that the test drivers have equal experience and prior knowledge of the system as a later customer will have.

Small-scale field-trial with instrumented vehicles

Field-trials with instrumented vehicles involve observing drivers while they are using the system in a naturalistic way and comparing their behaviour when driving without the system. The field trial may be carried out unobtrusively, with – for the driver – hidden instruments in the vehicle, which will let the test driver drive alone during the test. Another alternative, giving the possibility of acquiring more behavioural data, is the in-car observation method. Then, the observations are carried out by two observers, riding along in the car with the driver.

Advantages:	An observational field-trial is based on real driving and should have a higher degree of ecological validity than driving simulator studies.
Disadvantages:	A disadvantage is the lack of control and a possibility to repeat and fully control the scenarios tested. The observer being present may have an effect on driver behaviour.

Driving Simulator study

A driving simulator study is an experimental study, and it is carried out with predefined scenarios. In this way, the exact conditions in which the system needs to be tested can be generated. On the other hand, an important precondition is that the driver behaviour is as natural as possible, which should be ensured by using a simulated environment as close to reality as possible. Driver behaviour is studied when driving with the new in-vehicle technology in various traffic situations and road- and weather conditions. The aim of the driving simulator studies is to get insight in the driver behaviour under different circumstances while using the studied of system.

A driving simulator study is suitable for the development and user-related testing phases of new ADAS (INCA, EMIC) systems, since they can be tested safely and under controlled conditions. Since the traffic situation can be controlled totally, systems can be tested under specific circumstances with no risk of injuries to the test persons.

Advantages: When high control and repeatability is of importance, a driving simulator has clear advantages over field observation studies. A driving simulator is also useful when the driver has to be put into a potentially dangerous situation. Safety effects can be derived from surrogate safety parameters, such as proportion of critical time-to-collisions, speed differences, short headways or strong decelerations. Specific and rare hazards can be tested by predefining these situations in the driving simulator scenarios.

Disadvantages: The ecological validity of the results obtained from a driving simulator depends on the fidelity of the simulator. Therefore, a moving platform is preferred.

Questionnaires

To asses opinions and attitudes of a population quantitatively, a questionnaire is an appropriate tool.

Advantages: The main advantages of questionnaires are that you can collect lots of information in a short time, relatively low cost and without the need of special material and sophisticated technology [MAR10]. The possibility to have very large samples makes it easier to obtain statistically significant results. Moreover, they have the advantage to be easy to administrate and they can be used both for simulator and real world studies.

Disadvantages: Despite their obvious advantages, questionnaires are vulnerable to socially desirable response tendencies as it was pointed by Lajunen & Summala (2003) [LAJ03]. A too large number of questions might influence the respondents' willingness to answer or also the reliability of their answers. The answer is much dependent on how the question is formulated.

Structured Interviews

During a conversation, the interviewer asks questions prepared in advance and preferably framed in a questionnaire to obtain information from the user. This method implies a good previous preparation of the interview (questionnaire, procedures etc.) and the interviewer needs to have cleared the objectives of the study and should have a good knowledge of the procedures to be followed during the interview. This method may in some cases be added to the questionnaire-questions to get more developed subjective opinions of the functions.

Advantages: The benefit of structured interviews is that it allows time for reflection and the possibility to ask supplementary questions e.g. “What do you mean by that?” “Could you please explain more?”

Disadvantages: This will provide a subjective judging and depends on the person doing the interviews, which can be different and therefore have different ways to pose the questions.

Focus Group study

A Focus Group is a qualitative method in which a group of people are asked about their opinions and attitude towards a product, service, concept, advertisement, idea, or packaging. After a test drive, the test persons gather in groups of 8-10, discuss their experiences under the guidance of an experienced leader of focus group discussions. The discussion during the session is recorded by video. Using focus groups to evaluate a system is a very efficient way to get user feedback and gauge initial reactions to a design. Focus Groups are also good at discovering how the system being tested differs from the user's current expectations. This method will however not be used within the user-related assessment plans as it looks like up to this day.

Advantages: Focus groups, as a qualitative method, have several fundamental strengths. First, it is useful for exploration and discovery. They are usually used to learn about different topics. Moreover, focus groups create a process of sharing and comparing among the participants, they generate their own interpretations of the topics that came up in their discussions [KRU98].

Disadvantages: Focus groups are susceptible to provide information at an individual level, and this information is not representative of other groups.

5. Impact assessment

5.1 Literature review on safety impact assessment method

This section presents a literature review on safety impact assessment methods. The review is non-exhaustive because

- a number of assessments follow similar course, and so it is not necessary to look at all of them,
- numerous assessments are not compatible with the needs and means of interactIVe, e.g. when it comes to data requirements, and
- the resources in interactIVe are limited and a full scale literature review is not deemed to be the best way to spend them.

Several sources have identified classified types of assessment methods.

The TRACE project [PAP08; KAR07; PAG07] has identified methods for ex-ante (a priori) and ex-post (a posteriori) evaluation. Similar distinctions are made by Joksch and Wuerdemann [JOK72] and Busch [BUS05]. Putting all sources together, the following methods can be distinguished for an ex-ante evaluation of active safety systems:

- Safety mechanisms: this entails an estimation of the target population of the ITS and an expert evaluation of its effectiveness in preventing or mitigating accidents.
- Accident reconstruction: this is based on case study-approach, where accident scenarios are simulated with and without the ITS present, and the outcomes are compared. The scenarios are retrieved from an in-depth accident database. The analysis is either automated, and then it can cover all relevant accidents, or it is done manually, and then it is restricted to selected cases only. Then the analysis, however, is carried out in more detail.

- Black box statistical analysis: TRACE considers a method based on artificial neural networks that assesses safety-based on information about the relevance and influence of the ITS on accident characteristics.

Ex-post evaluation is based on accident data with and without the ITS. Two problems recognized by [BUS05] are that sufficient data becomes available only a long time after the introduction of the ITS, and that it is difficult to properly take into account the applications that prevent accidents (since they no longer appear in the data). Furthermore, [BUS05] distinguishes assessment methods for passive and active safety systems, and for each case a subdivision is made into methods based on controlled tests, simulations and accident data. For active safety systems, controlled tests typically evaluate minimum requirements e.g. on brake operation or lighting. Simulations require a driver model; one approach is to use driving simulators but this usually leads to small sample sizes.

The In-Safety project [DIJ05] has created an overview of models, tools and guidelines for road safety assessment. It mentions several assessment methods; among them:

- Accident data,
- Crash prediction models that express road safety by the number of crashes per kilometre, taking into account the road type and other explanatory variables such as the width of the carriageway,
- Methods based on analysing conflicts and near-crashes, or surrogate safety measures such as Time to Collision,
- Various kinds of risk analysis and
- Microscopic and macroscopic simulation tools.

The use of FOT-data to assess safety is not explicitly mentioned by these sources, but it is a frequently used approach.

The methodology presented here will consider only ex-ante evaluation of safety impacts, and the literature review will be restricted to that. The review will discuss the following methods:

- Safety mechanisms,
- Accident reconstruction and
- FOT data analysis.

5.2 Safety mechanisms

This concerns methods that identify factors contributing to a crash, and then employ direct or indirect methods to estimate the effect of an ITS on these factors. Simple approaches may consider factors such as exposure and severity, see e.g. [JOK72], or target population and effectiveness, as mentioned above. A more detailed subdivision of safety impacts of ITS is given by the so-called nine safety mechanisms [DRA98]. These mechanisms are

1. Direct in-car modification of the driving task,
2. Direct influence by roadside applications,
3. Indirect modification of user behaviour,
4. Indirect modification of non-user behaviour,
5. Modification of interaction between users and non-users,
6. Modification of road user exposure,
7. Modification of modal choice,
8. Modification of route choice,
9. Modification of accident consequences.

The first five address accident probability and to some extent severity too, the next three address exposure and the final one addresses severity related to post-crash modifications (i.e. timeliness of the emergency service response). The boundaries between the mechanisms are not sharply defined, and some safety aspects can be listed under several headings. For example, an application that mitigates crashes could have its effects listed under mechanism 1 or 9. However, this is not really problematic, because the purpose of this structure is not so much to define precisely the categories of safety effects, but rather to help the researcher to be complete in listing all potential effects.

The following *collision scenario variables* (CSV's) are represented in European accident statistics:

8. vehicle type host (passenger car/goods vehicles),
9. vehicle type target (passenger car/goods vehicles),
10. collision type (9 categories, defined in the accident statistics):
    j. collision on the road with pedestrian,
    k. collision on the road with all other obstacles,
    l. collision besides the road with pedestrian or obstacle or other single vehicle accidents,
    m. frontal collision,
    n. side-by-side collision,
    o. angle collision,
    p. rear collision,
    q. other accidents with two vehicles,
    r. all other collisions.

The type of target vehicle is important because it will impact both the detection rate and the severity of the consequences of a collision.

The following situational variables (SV's) are represented in European accident statistics:

11. road type (motorway/rural/urban),
12. weather conditions (normal/bad),
13. lighting conditions (light/dark),
14. location (intersection/not intersection).

This means there are in total 3*2*2*2=24 situations and 28 collision configurations[14], for 24*28=672 possible scenarios. Some of these may be unlikely or impossible (e.g. frontal collision on a motorway), but the total number remains large.

These mechanisms were used in eIMPACT and in PReVAL [WIL08; SCH08]. For a given ITS, safety modification factors were determined for each of the 9 mechanisms and an overall safety modification factor for the ITS was defined as the product of these 9 factors. Optionally, this calculation is done for each scenario separately, with scenario dependent safety modification factors. The overall safety modification factor is computed as the weighted average of these scenario dependent factors, where the weights are the frequencies of the scenario in accident statistics. Thus the weights can be determined if these frequencies can be retrieved from the accident database used.

This approach needs 672 (scenarios) * 9 (mechanisms) = 6 048 safety modification factors, which can be a daunting task to determine. Therefore, eIMPACT made the simplifying assumption that each CSV and SV influences the safety impact independently of all others. Hence, its influence can be represented by a modifier for each value of the CSV or SV and each mechanism, and the number of parameters to determine reduces to 9 safety modification factors for one "special" scenario (called the reference scenario), and 15 * 9 = 135 modifiers to cover all other scenarios, for a single function. Some further reduction may

[14] This number is slightly less than 2*2*9=36 because in single-vehicle collisions there is no choice of target vehicle. There are 5 collision types with 2 vehicles and 4 types with 1 vehicle, leading to 2*2*5 + 2*1*4 = 28 collision configurations.

be possible, for example by taking the same modifiers for all mechanisms for all scenarios except the special one, which will reduce the number to 9 + 15 = 24 modifiers per function.

The assumption of independence has not been validated. External validation checks the assumption against data and is only possible with sufficient accident statistics with and without the application. Such data is rare (ESC is one of those rare examples), and often numerous circumstances have changed over the (long) deployment period of the application, which makes such data hard to interpret. Internal validation checks whether the assumption is justified by proven cause-effect relations, and also seems hard to accomplish. Face validation is the weakest form of validation and checks whether the assumption is reasonable in the light of general expectations on the model. While generally speaking it seems reasonable to assume that the CSV's and SV's modify risk independently, one can also easily imagine a function for which it is not true – for example, night vision (not present in interactIVe) may be very effective in the dark on rural roads, but hardly have any effects at all on other road types or when it is light. Thus, the assumption is hard to justify and is mostly made to ease the calculations.

Advantages of this method are:

- It is all encompassing,
- It has limited data needs,
- It covers both intended and unintended effects,
- It requires relatively little effort,
- It is transparent in the sense that it documents clearly what the breakdown of safety effects is.

Disadvantages of this method are:

- For most mechanisms it will be hard to obtain solid results, hence the method heavily relies on secondary sources, expert judgment and the use of (low, high) ranges,
- Treating all situations can be a tedious task,
- Validation is difficult.

5.3 Accident reconstruction

This approach reconstructs accidents based on the data logged in an in-depth accident database and then assesses what would have happened if a particular ITS had been present. The method has been used in [KAR07; BUS05] and consists of a few steps:

1. Reconstruction of the pre-crash phase based on accident data for each accident under consideration. The accident data is obtained from an in-depth accident database which typically contains data from the moment of the accident or later, but no data on the pre-crash phase. To assess the effectiveness of ITS, typically the pre-crash phase is important, and hence this phase is reconstructed until some starting time point a few seconds before the accident, based on the available data and using physical models of the movement of the vehicles. Data is obtained for accidents, where the ITS has not been not present. So, this reconstruction can be seen as a reference case.
2. Construction of a hypothetical alternative evolution in the presence of the ITS. This evolution originates from the situation at the starting time, but may follow another path than the reference case due to the actions of the ITS. This construction requires a model of the functioning of the ITS and its influence on the driver behaviour. It leads to a difference in the physical parameters of the accident (e.g. the collision speed change) between the alternative and the reference.
3. Transformation of the change in physical parameters to a change in physiological parameters, e.g. fatality risk. This yields the safety impact of the ITS on the accident under investigation.

4. Scaling up of the safety impact to the target population, e.g. the national level. This step has to account for deployment scenarios as well as the representativeness of the in-depth accident database.

Advantages of this method are:

- It will provide a highly detailed analysis of the safety effect of the ITS on real world accidents.
- Its case by case approach allows further inspection into the mechanisms by which an ITS prevents or mitigates crashes.

Disadvantages of this method are:

- The analysis requires access to detailed accident data, which may not exist or may be non-representative,
- The reconstruction may be sensitive to model assumptions or inaccuracies in the data. In particular, assumptions need to be made regarding driver behaviour,
- The method analyses only the effect on accidents that have occurred, which is not the full effect of the ITS on driving behaviour. Some ITS may induce the driver to take more risks than he would have done without it. This is called risk compensation and it is neglected completely by this method,
- The analysis requires significant effort, as each accident from the database is treated individually,
- It requires specialized software tools,
- Validation is difficult.

5.4 Black box statistical analysis

The neutral network based evaluation called “The black box” statistical analysis has been used in the TRACE project. By means of this approach the potential effects with respect to reduction of accident consequences in given accident configurations should be calculated.

By means of a neutral network a link between the input parameters (e.g. collision type, weather condition) and the output (severity level) is determined. Besides to the input and output layer, there is the hidden layer (Figure B.5). This hidden layer consists of different neurons nodes, which contain the information on the affects of input parameters on the output parameters. In order to determine this information, how strong the relation between the input and output is, the neutral network is trained with a dataset (in TRACE 70% of the recorded accident has been used). Afterwards, the rest of the data are used in order to test and validate neural network [KAR07].

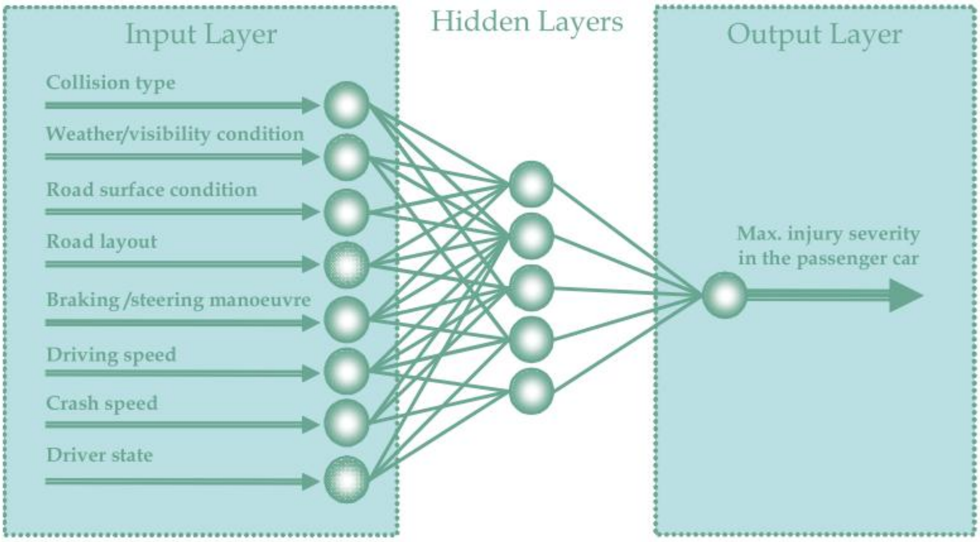


Figure B.5: Neural network architecture used in TRACE [PAP08]

The approach is divided in the following eight basic steps:

1. Acquire knowledge for the safety functions of passenger cars to be evaluated,
2. Selection of the modelling parameters (parameters that affect the safety impact of the function),
3. Accident data collection according to the selected parameters,
4. Design neutral network architecture for predicting the severity level of different accident configurations based on the available data,
5. Define the relevance of safety function to accident configurations,
6. Estimate the influence of a safety function on different accident parameters,
7. Using the neutral network calculate the effectiveness of the safety function on the level of severity,
8. Estimate the effectiveness of the studied safety function based on the calculation of the injury severity mitigation (in percentage) [PAP08].

Advantages of this method are:

- Depending on the chosen parameters it needs only limited data needs.
- The same neural network can be used for different function. Hence if the neural network is once created, the methodology is straightforward.
-

Disadvantages of this method are:

- Due to the "black box" approach it very difficult (for persons not involved in the impact assessment) to comprehend the calculated effects.
- The effect on the function on the chosen parameter is estimated. These estimation has huge impact on the calculate safety impact. But there is no validation, whether the estimations are correct.
- Depending on the chosen parameters detailed accident parameters could be needed.
- The approach focus mainly on the intended effects. The unintended effects respectively the effects on other road users are not considered.

This hidden layer consists of different neurons nodes, which contain the information on the impacts of input parameters on the output parameter.

5.5 FOT data analysis

This approach uses FOT data to assess safety. The size of a FOT is too small to record significant numbers of (serious) accidents. Hence assessment methods use data on near accidents or risky events and translate that data into an estimate on safety.

One approach is the Event Based Approach, followed for example in [DIN06; SAY10]; it identifies events that are thought to be crash related, and then compares the frequency of these with and without the ITS. These events are thought to be potential precursors of a crash, but they occur much more often than crashes and can be identified from the FOT data. If one assumes that the ratio of the frequency of crashes is the same as the ratio of the frequency of these crash related events, then the safety impact of the ITS can be deduced.

An improved version developed by NHTSA considers a more general relation between crash related events and crashes [NAJ00; NAJ03; NAJ06; BAT07]. This allows for example for the assessment of ITS mitigating crashes without avoiding them.

The method assumes that it is possible to determine the incidence of crash related events in crash situations from an accident database. The method calculates the number of avoided crashes N_a as follows:

$$N_a = N_{wo}(C) * \sum_i P_{wo}(S_i \mid C) * \left(1 - \frac{P_w(C \mid S_i)}{P_{wo}(C \mid S_i)} \frac{P_w(S_i)}{P_{wo}(S_i)}\right).$$ Eq. B-1

Here the event of a crash is denoted by *C*, and $N_{wo}(C)$ is the number of applicable crashes without the application, which is obtained from an accident database. The crash related events are denoted by S_i. The probability $P_{wo}(S_i|C)$ is the fraction of crashes preceded by event S_i and has to be obtained from the accident database. The ratio $P_w(S_i) / P_{wo}(S_i)$ is called the exposure ratio and is the frequency with which events occur with the system ("w") compared to without ("wo"). This can be measured from the FOT, using CAN and video data. The ratio $P_w(C|S_i) / P_{wo}(C|S_i)$ is called the prevention ratio and measures the ability of the system to prevent crashes after a crash related event has occurred, relative to the case without the ITS. This ratio is determined using simulation of simple traffic scenarios.

The relation between the number of avoided crashes and the corresponding reduction in fatalities is obtained by estimating the severity of each conflict type, possibly depending on a further subdivision, for example by the impact speed of the crash.

Tarko [TAR11] has developed a similar method that calculates safety benefits in terms of avoided crashes using extreme value theory. It is based on measured data regarding conflicts of various types and on the assumption that the probability distribution of conflict severity is a Pareto distribution, including crashes as the most severe conflicts. By matching this distribution to the data one obtains the estimated number of crashes as a function of the measured number of conflicts of varying severity.

This method, therefore, produces an estimate of the number of expected crashes without use of an accident database, and in an absolute setting, that is, not as a comparison between "with" and "without" cases. It is event based although severity is taken into account, and it relies on the assumption that the severity parameter is Pareto distributed.

In the euroFOT project, detailed data is collected on the everyday driving of hundreds of normal drivers, with and without ITS. Two methods will be used for assessing the safety impacts [FAB11]. The first method is the Event Based Approach, which is mostly applicable to applications that warn for dangerous situations.

The second method, Aggregated Based Approach, applies to applications that impact driving continuously in time, such as Adaptive Cruise Control. This method is a refinement of the NHTSA approach that associates a risk to every recorded data point of a trip, based on collected data on the state of the driver, the vehicle and its surroundings [NOO11]. This removes the arbitrary distinction between risky and non-risky situations and replaces it by a smooth risk scale. The risk calculation itself is done with a simulation of simple traffic scenarios, while the exposure is calculated directly from the FOT data. Comparison of these risks between the cases with and without the ITS leads to an estimate of the safety impact of the ITS.

Advantages of this method are:

- It is based on data measured under natural conditions,
- It can capture both intended and unintended effects. In this sense it is not biased towards a certain assumption on the effect of the ITS, if the crash related events are setup correctly,
- It provides a statistically valid assessment if the FOT is set up correctly, that is, if drivers, traffic situations, etc are representative,

Disadvantages of this method are:

- It relies on the assumption that there is a relation between crashes and crash related events,
- It requires FOT data,
- Validation is hard.

6. User behaviour aspects relevant for the safety impact assessment

The following aspects of user behaviour have been identified relevant for the safety impact assessment based on earlier research work, e.g. in projects AIDE, eIMPACT, PReVAL and euroFOT:

- **Distraction**
  Distraction means that the driver is not focusing on the driving task, but on other tasks. It is defined as "the diversion of attention away from activities critical for safe driving, toward a competing activity" [REG08], and is measured as the number of times per km that the driver takes his eyes off the road for at least two seconds consecutively. Distractions of short duration are not significantly dangerous, but distractions longer than 2 seconds are known to increase risk significantly. A two seconds threshold for observing driver distraction is recommended; hence drivers rarely glance away from the roadway for more than two seconds [LAN04]. This concerns distraction by the ITS, and distraction by other (secondary) tasks. Data from an observational study, the "100 car study" in the United States suggests that driving while drowsy was a contributing factor for 22 to 24 percent of the crashes and near-crashes and secondary-task distraction contributed to over 22 percent of all crashes and near-crashes [KLA06].

- **Workload**
  This refers to the strain being put on the driver's resources by the driving task. The driver has to accomplish certain driving tasks and has a certain capacity for doing so. Workload has been defined by Senders as "a measure of the 'effort' expended by a human operator while performing a task, independently of the performance of the task itself" [SEN70]. Knowles defined workload as the answers to the two following questions: "How much attention is required?" and "How well will the operator be able to perform additional tasks?" [KNO63]. As driving consists of many overlapping tasks, each requiring a certain portion of the driver's attention, Knowles' definition seems to be appropriate for the driving environment.
  The driver's capacity for doing work is not constant over time and is influenced by driver state (fatigue, drunkenness, etc). It may also vary from driver to driver. A driver will adapt the tasks he is doing based on his available capacity; essentially, the tasks cannot exceed the capacity[15]. So, if the driver has too many tasks, he will drop some or not do them fully. If he has too few, he may take on other (secondary) tasks. Both these situations create additional risk, as sketched qualitatively in Figure B.6. It shows that as the workload increases, the performance decreases. It also shows that the performance decreases when the workload drops below a certain threshold. This can be explained by the fact that when the driver has very little to do, he tends to lose attention and become less vigilant. One can hypothesize that accident risk is a decreasing function of performance, that is, accident risk increases as the performance decreases. With this assumed relation, Figure B.6 (right) shows the qualitative relation between workload and accident risk.

- **Usage (on / off)**
  This can be measured as the fraction of time that the application is activated by the user. This directly influences the effectiveness of the application (it can only help when it is active).

[15] This is not an exact science: for a short while a driver may exceed his capacity ("fighting fatigue"), that is, he apparently has a bit of reserve. But this cannot last for long.

- **Misuse**
  This refers to the use of the application by the driver for unintended purposes. For example, if the driver drives all the time in the left lane on the motorway to avoid „too-short distance“-warnings. Such unexpected misuse can be observed by observers in the car.

- **Driving style**
  This can be measured in terms of speed (average and standard deviation), time headway and the standard deviation of the lateral position in the lane. Driving style may change under the influence of an ITS. The AIDE project has published the relation between these indicators and accident risk. For some indicators, such as speed and time headway, this relation is well researched. For other indicators, like workload, not much evidence is available.

- **Settings of the ITS**
  These will impact driving style (for a warning application) and usage (the driver may use the application more if he can choose settings that he likes).

- **Situational awareness**
  This is the extent to which a driver is aware of the traffic situation and in particular of dangers in a timely fashion. The ITS may impact this both positively (the ITS focuses driver's attention on a danger) and negatively (driver is distracted from a danger by the ITS, or driver does not understand the application, or driver pays less attention to driving due to too much trust in the application – that is, driver thinks the application will address a particular situation, but it doesn't, either intended (application limitation) or unintended (application error)). While situational awareness may have a significant influence on the effectiveness of the ITS, it is quite impossible to measure.

- **Event detection**
  This refers to the timely detection of risky events by the driver. This could possibly be measured by the number of missed events and the reaction time to non-missed events.

- **Loss of skills**
  This means that when an application takes over part of the driving task, then the driver may unlearn this part over time. This can only be measured in a long term study where repeated observations of the same variables are collected over long periods of time.

- **Mode error**
  This means that the driver misjudges the mode that the application is in. E.g. the driver thinks the application is on and will handle a certain situation without his input, but in reality the application is off. Or the driver thinks the application is off, but in reality it is on and intervenes in the driving task in an unexpected way. This is hard to measure by objective means, but can perhaps be discovered via interviews after the drive.

- **Acceptance, trust, understanding and experience with function**
  These measures to what extent the driver accepts the application's warnings or interventions, trusts the application to work correctly, understands the application's warnings or interventions, and knows the application. This type of information can be learned from questionnaires and will influence usage; often it will be easier to measure usage directly.

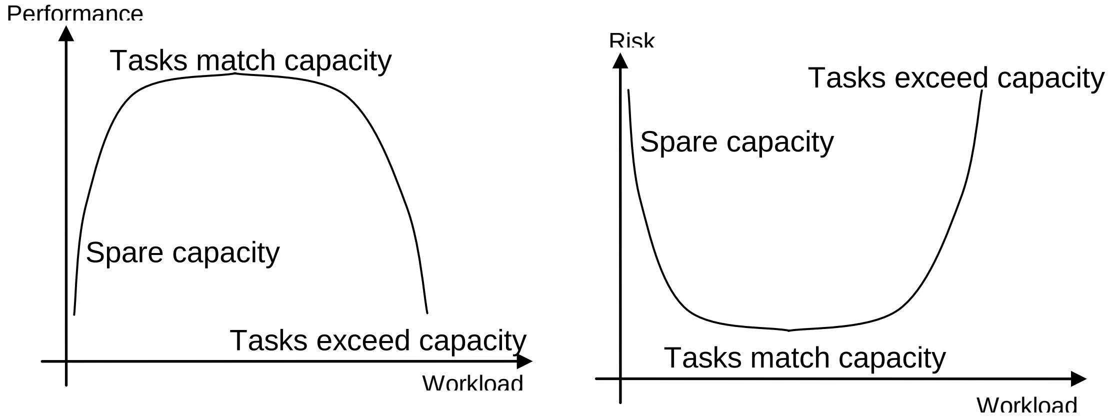


Figure B.6: Conceptual relationship between Workload and Performance (left).

Assuming that Performance is (roughly) the inverse of Accident Risk, the figure on the right shows the inferred conceptual relation between Workload and Accident Risk.

> These aspects may also be influenced by other variables. An important one is the number of false positive and false negative function activations (or alarms). These can be measured as a number of times per kilometre. If no realistic measurements are available, then a requirement on the maximum number of false positive and false negative alarms can be postulated (possibly based on ISO 26262 norm), and this requirement can be used instead of the measured numbers. The frequency of false alarms is expected to have an impact on driving style and usage.

7. Background information for the impact assessment

This section provides background information on accident data and prognosis (7.1), mitigation due to a change in collision speed (7.2), mitigation due to change in impact zone (7.4) and the assessment of combinations of functions based on results for the individual functions (7.6).

7.1 Accident data and prognosis

The existence or non-existence of relevant accident data influences to a large amount the feasibility and results of any safety impact analysis. On the other hand, the safety impact analysis determines the accident data needed. Target scenarios and the resulting CSV and SV determine the variables which have to be included in the analysis. Therefore, the database to be used largely depends on the set of variables indispensable for the impact estimation. In principle, there are three levels of data which can be employed for this project:

- CARE data,
- National accident data,
- National In-depth data.

These data sources vary in terms of range and level of detail. Apart from that the effort and time needed for the exploitation of the different data sources vary considerably.

As a first step, the variables needed for the analysis have to be determined. As a result, the database to be used has to be chosen and the data gathered according to the method necessary for the database used. In the end, the structure of fatalities, injury accidents and other casualties for the latest year of data will emerge.

7.1.1 CARE

The European database and expert group CARE (Community database on Accidents on the Road in Europe) collates the national accident data from different countries across the European Union into one combined database with common variables. This enables road safety problems to be investigated at the European level.

The advantage of the CARE data for this project lies in the fact that data is available easily for all European countries. Nevertheless, there are certain drawbacks to this approach. First of all, data is not available for all years for all countries. Secondly, depending in the variables used, the data quality can be insufficient. Some variables are listed as existent in CARE, but are not available for some of the countries. All in all, the database ought to be the first option, if the desired variables exist in CARE for the desired countries.

7.1.2 National accident data

All European countries host national accident databases which usually include a considerable amount of variables useful for safety impact estimation. In contrast to the CARE database those databases cannot be accessed as easily from other countries. As a result, collecting accident data on a European level based on these databases generate a considerable amount of work – on the side of the institute providing the data as well as on the side of the institute collecting the data. Therefore, if the variables can be extracted from CARE this database will be preferred. Nevertheless, if it proves necessary to draw on the national data, the amount of work can be reduced by using clusters of countries and send a data inquiry to one or two representatives of each cluster. This idea has already proven successful in eIMPACT. Still, this approach requires a considerably higher amount of time and effort, as an estimation of the data structure for the whole cluster based on sound data from the representing countries is needed. The clustering was already done in eIMPACT and can be utilized in this project.

7.1.3 In-depth accident data

In-depth data play a major role within impact assessment studies. The main advantage of in-depth data is that they are much more detailed than, for example, official traffic accident data. Many variables, including pre crash information relevant for accident causation analysis are recorded in in-depth studies, but not in national traffic accident statistics. Due to small sample sizes or imperfect data collection procedures, in-depth traffic accident data are often susceptible to a lack of representativeness with respect to the underlying target population. By adjusting the sample with respect to certain structural variables (e.g. road type and accident outcome severity), i.e. by “weighting” of cases, the accuracy of estimates referring to the true in-depth variables (e.g. collision speed) can be improved.

There are several alternatives to carry out such weighting and expansion procedures, among them adjustment by post stratification methods or hierarchical methods, where a weighting variable is adjusted only within selected categories of another weighting variable in order to avoid problems with empty cells. In doing so, results from in-depth analysis can be generalized to the population of all injury accidents within the study region. Although an extension of the in-depth data to populations outside of the study region is in statistical terms not possible, post stratification methods (like raking) can be applied to generate convincing results.

The variables used for this weighting process must, of course, be available in the official accident data files and should be highly correlated with as many as possible “true” in-depth characteristics.

Several In-depth accident studies exist across Europe, GIDAS in Germany, CCIS and OTS in the UK (stopped in 2009) and LAB Data in France to mention the most prominent ones. For the work in Interactive the GIDAS data base is available.

7.2 Mitigation – relation between collision speed change and injury risk

In case an accident is not prevented by the ADAS, but its consequences are mitigated, the extent of the mitigation needs to be estimated. Often, the mitigation is a consequence of a reduction in collision speed or a change in impact zone. This section addresses the speed change mechanism. The next section will discuss the change in impact zone.

The effect of an ADAS on collision speed can be given in various ways, for example in absolute terms (collision speed decreases by *x* km/h), in relative terms (collision speed decreases by *x*%) or as a more general function of speed. The literature shows that the relevant parameter is the collision speed change (CSC), defined as the difference between the speeds just before and after the collision, for all collision partners. This measure is found to have no significant disadvantages compared to the more complicated and potentially more accurate measure of occupant impact velocity [GAB06]. Its precise definition may depend on the accident type and is detailed below.

The relation between collision speed change and accident severity needs to be obtained from literature and will depend on the accident type and subtype. Studies that provide this relation typically do so by investigating accident databases. If an accident database records the collision speed change (or measures from which it can be derived) and the accident severity in terms of fatality and injury categories (for example MAIS levels), then in principle a relation between collision speed change and risk can be obtained. Before going into details on some of these studies, the general idea will be first explained and some general remarks about the issues and limitations of this approach will be made.

In order to describe the method, the following stochastic variables and events are introduced:

- *S*: the collision speed change of an accident (given that an accident has taken place),
- *F*: the event that an accident is fatal (given that an accident has taken place),
- *I*: the event that an accident is injurious but not fatal (given that an accident has taken place),
- *N*: the event that an accident is neither injurious nor fatal (given that an accident has taken place).

If desired, the event *I* could be further subdivided into several injury levels I_1, *I,* etc. For simplicity of presentation it will be sticked to one injury class. An accident that includes drivers that are hurt in several levels of severity will for now be classified by the highest level that occurs – but see below for a further remark.

The goal is to obtain the cumulative probability distributions *P(F|S≤s)* and *P(F|S≤s)*. These are the probabilities that an accident with speed at most *s* is fatal or injurious. An accident database however typically contains *P(S≤s|F)* and *P(S≤s|I)*, that is, the probability that a fatal or injurious accident has collision speed change at most *s*. This is not the same, because not all collision speed changes are equally likely. Hence one should be careful not to confuse the two.

The desired distributions are obtained by

$$P(F \mid S \le s) = \frac{P(F, S \le s)}{P(S \le s)} = P(S \le s \mid F)\frac{P(F)}{P(S \le s)}$$
$$P(I \mid S \le s) = \frac{P(I, S \le s)}{P(S \le s)} = P(S \le s \mid I)\frac{P(I)}{P(S \le s)} \qquad \text{Eq. B-2}$$

The probabilities *P(F)* and *P(I)* can be estimated as *P(F)* = the number of fatal accidents divided by the number of reported accidents, and *P(I)* = the number of injurious accidents divided by the number of reported accidents. The probability *P(S≤s)* is obtained by

$$P(S \le s) = P(S \le s \mid F)P(F) + P(S \le s \mid I)P(I) + P(S \le s \mid N)P(N) \qquad \text{Eq. B-3}$$

This uses the fact that any accident falls in precisely one of the event categories F, I or N. In particular, $P(F) + P(I) + P(N) = 1$.

In this way, the desired probability distributions $P(F|S \le s)$ and $P(I|S \le s)$ can be obtained from the data set by estimating $P(F)$, $P(I)$, $P(N)$, $P(S \le s|F)$, $P(S \le s|I)$ and $P(S \le s|N)$, and using equations Eq. B-2 and Eq. B-3. There are however several issues and limitations to this method, which we will now list:

1. The data set in the database needs to be unbiased. This means that ideally it should contain all accidents, regardless of severity. If not, then it may not be possible to use equation Eq. B-3. This is an issue, because non-injurious accidents are often not recorded, and even for fatal and injurious accidents there may be some underreporting; see e.g. [WIL08]. Bias may occur because less severe accidents are simply not reported at all, or because of the interests of the data collectors. The latter is not uncommon for in-depth databases where data collection is expensive and therefore biased towards more severe accidents. For example GIDAS aims to collect injury and fatal accidents only and consequently has an overrepresentation of fatal and severe accidents [ROS09].
   Often the problem comes down to relative underrepresentation of less severe accidents, leading to overestimation of the risk of fatality or severe injury at all collision speed changes. If possible, this problem should be corrected by weighing the data, see e.g. [RIC10].
2. The data in the data set may be restricted, for example by excluding certain groups from data collection, such as older vehicles, certain vehicle types, drunk drivers, unbelted drivers or certain age groups. Sometimes more complicated accident types like multi-vehicle collisions or roll-over accidents are excluded. A perhaps less obvious restriction is that a data set usually applies to a certain population, e.g. a particular country in a particular time period, implying a particular composition of the vehicle fleet, quality of infrastructure, effectiveness of emergency services, etc.
   One should be careful to apply the same restrictions to the use of the collision speed change – risk relation, or compensate in some other way where necessary. Otherwise this may lead to bias.
3. It is quite possible to use one data set for estimating $P(F)$ and $P(I)$ and another one for estimating $P(S \le s|F)$ and $P(S \le s|I)$. Indeed, the first two typically need a representative data set, such as national police records, while the latter two need a more in-depth data set from which the collision speed change can be derived. As long as the two data sets describe the same driver population, differences in sampling can be corrected by applying weights, as in [RIC10].
4. The age of the data is of importance. Older data reflects a time period where vehicles were less safe and hence typically shows higher risks [RIC10]. There may also be differences in traffic rules and driving culture.
5. The age of the vehicle is of importance, for the same reason: older vehicles are generally less safe.
6. The collision speed change has to be determined. In order to find the speed change from the speeds of the vehicles just before the collision, some assumption has to be made on the collision model. The simplest assumption is that the collision is fully non-elastic, that is, after the collision all collision partners move with the same velocity. This assumption is found in the literature, see [NAJ00; RIC10], and is adopted here. An alternative approach using a ‘transformation degree’ can be found in [BUS05]. The difference between the two may be small: [ARB05] finds a difference of less than 5 km/h (or 20%) between the fully non-elastic estimate and reality for side impacts in 49 crash tests.
   The precise definition and formula of the collision speed change depends on the collision type:
   a. For collisions where the ego vehicle experiences a frontal impact, for example in a frontal collision, or as the hitting vehicle in rear end or side collisions: see

Eq. B-4 for illustrations of these collision types and the expression of the after-collision speed vector *w* in terms of the speeds v_1 and v_2 of the two vehicles just before impact, their masses m_1 and m_2 and the angle α between their trajectories.
The collision speed change for the ego vehicle and the other vehicle are, respectively,

$$\left\|\vec{v_1}-\vec{w}\right\| = \frac{m_2}{m_1+m_2}\sqrt{v_1^2+v_2^2-2v_1v_2\cos\alpha}$$

$$\left\|\vec{v_2}-\vec{w}\right\| = \frac{m_1}{m_1+m_2}\sqrt{v_1^2+v_2^2-2v_1v_2\cos\alpha}\,.$$

Eq. B-4

For a rear end collision (α=0) this simplifies to

$$\left\|\vec{v_1}-\vec{w}\right\| = \frac{m_2}{m_1+m_2}\left|v_1-v_2\right|,$$

$$\left\|\vec{v_2}-\vec{w}\right\| = \frac{m_1}{m_1+m_2}\left|v_1-v_2\right|.$$

Eq. B-5

For a frontal collision ($\alpha=\pi$) this simplifies to

$$\left\|\vec{v_1}-\vec{w}\right\| = \frac{m_2}{m_1+m_2}\left|v_1+v_2\right|$$

$$\left\|\vec{v_2}-\vec{w}\right\| = \frac{m_1}{m_1+m_2}\left|v_1+v_2\right|.$$

Eq. B-6

b. For collisions where the ego vehicle experiences a side impact, as the hit vehicle in a side collision: see Eq. B-7 for illustrations of this collision type and the expression of the after-collision speed vector *w* in terms of the speeds v_1 and v_2 of the two vehicles just before impact, their masses m_1 and m_2 and the angle α between their trajectories.
The collision speed changes for both vehicles are given by Eq. B-4. For a straight angle collision ($\alpha=\pi/2$) this simplifies to

$$\left\|\vec{v_1}-\vec{w}\right\| = \frac{m_2}{m_1+m_2}\sqrt{v_1^2+v_2^2}$$

$$\left\|\vec{v_2}-\vec{w}\right\| = \frac{m_1}{m_1+m_2}\sqrt{v_1^2+v_2^2}\,.$$

Eq. B-7

c. For accidents with pedestrians, it is assumed that the persons in the car have zero risk and the collision speed change for the pedestrian equals the speed with which the car hits the pedestrian, ignoring the pedestrian's own speed. See Figure B.9 for an illustration of this collision type and the expression of the after-collision speed vector *w* in terms of the speed v_1 of the vehicle just before impact, and the masses m_1 and m_2 of the vehicle and the pedestrian.
The collision speed change for the pedestrian is given by

$$\left\|\vec{w}\right\| = \frac{m_1 v_1}{m_1+m_2} \approx v_1\,.$$

Eq. B-8

The approximation holds if the mass of the pedestrian is neglected. With the same approximation, the collision speed change for the car is indeed given by $||v_1\text{-}w||=m_2\ v_1\ /\ (m_1+m_2)\ \approx\ 0$, showing that the risk to the car passengers is negligible.

d. Rear impacts have the same formula as frontal impacts.

7. The definitions of fatality and injury categories need to be consistent over all data being used. For example, for fatalities one needs to define a time period after the accident for which death is still considered as caused by the accident. Often this period is 30 days [ROS09]. For injury levels, one often groups several MAIS levels, for example levels 0 and 1 for not injured/very light injuries, levels 2 and 3 for light injuries and levels 4, 5, 6 for severe injuries and fatalities. As Figure B.10 shows, none of the MAIS levels corresponds to fatalities, although sometimes fatalities are defined as MAIS level 6, e.g. in [RIC10], and sometimes as MAIS levels 5 and 6, e.g. in [HAN04].
8. An accident may lead to multiple injuries, in case more than one person is involved. In principle, injuries should be estimated for each person separately, although studies often focus on drivers or vulnerable road users, not on car passengers. At the least, each vehicle involved in an accident needs to be taken into account. For example, in a frontal collision, there are two vehicles experiencing a frontal impact, and both can be assessed, assuming (as the simplest model) independence of the probabilities for the two vehicles.
9. It is preferable if collision speed change – risk relations are presented with confidence intervals. This is particularly true since the amount of data on severe accidents is usually small and hence the confidence interval may be large. For this reason, subdivision of data over different injury levels, age groups etc. should be done with care, as the amount of data in a subgroup is even smaller and hence the confidence interval is likely to get even larger.

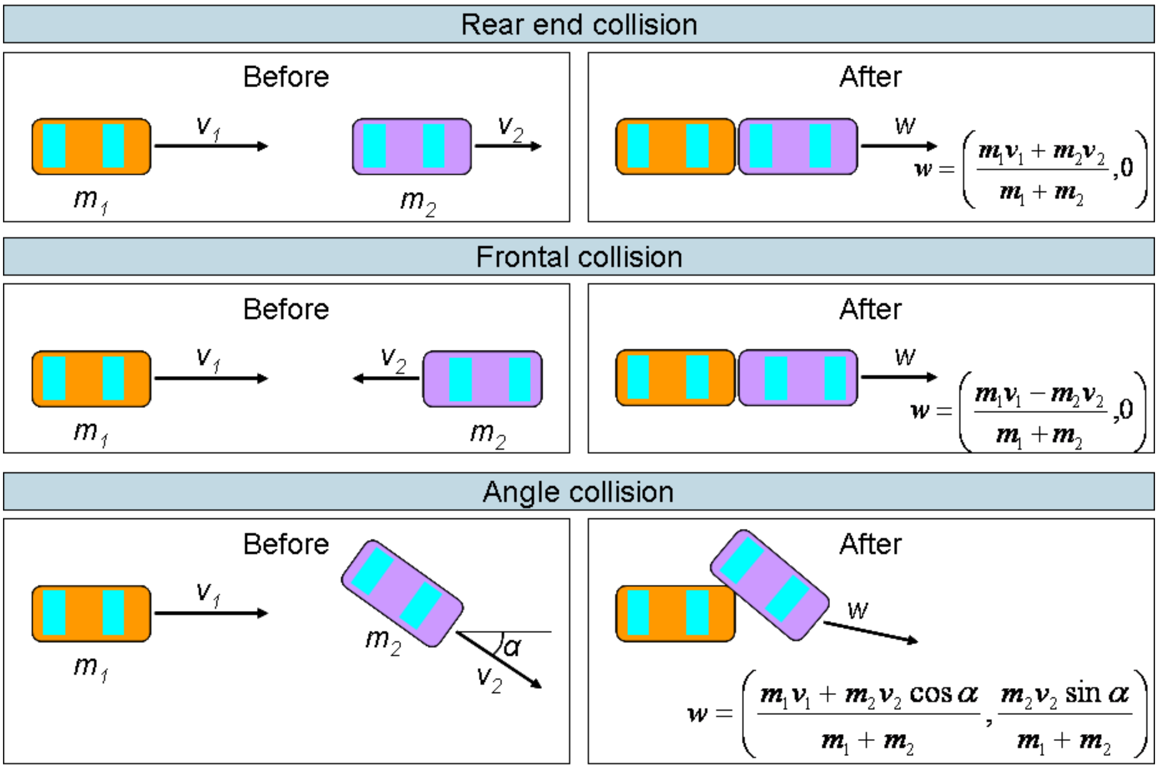


Figure B.7: Collisions where the ego vehicle (orange) experiences a rear-end impact.

The diagrams show the after-collision speed w, expressed in terms of the speeds v1 and v2 of the two vehicles just before impact, their masses m1 and m2 and the angle α between their trajectories. The formulas for rear end collision and frontal collision are special cases of the one for angle collision, with α=0 and α=π, respectively.

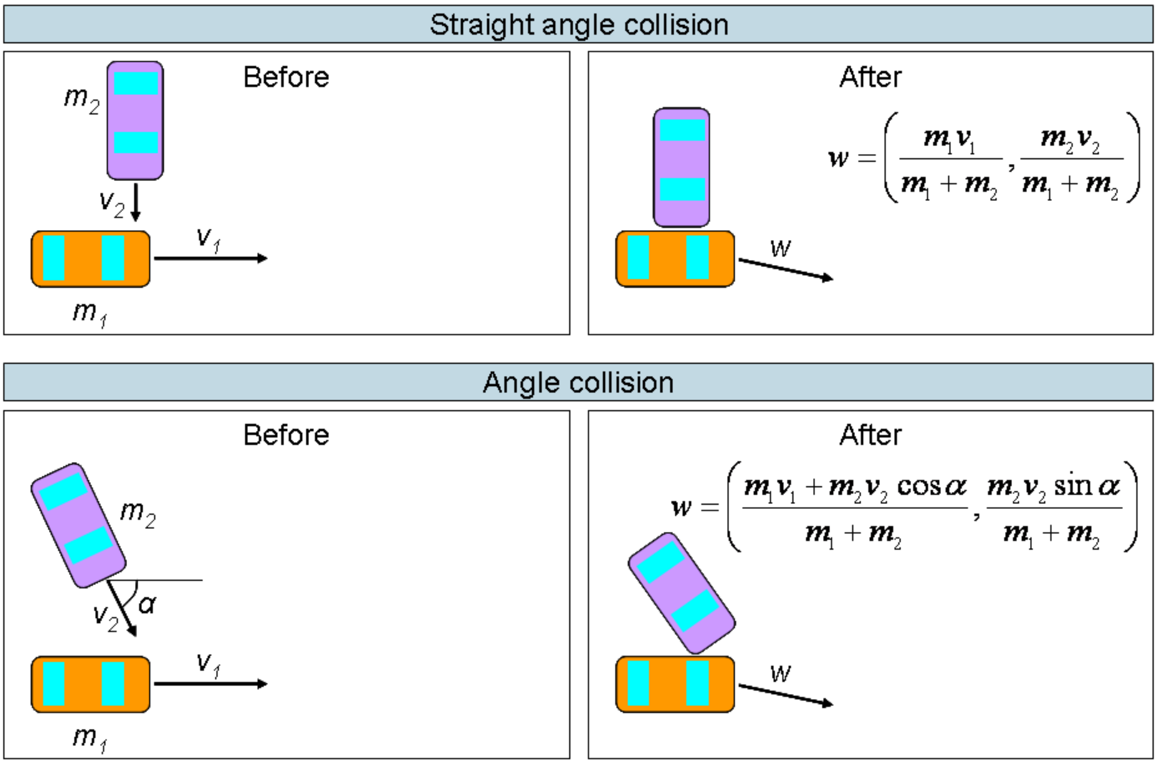


Figure B.8: Collisions where the ego vehicle (orange) experiences a side impact.

The diagrams show the after-collision speed w, expressed in terms of the speeds v1 and v2 of the two vehicles just before impact, their masses m1 and m2 and the angle α between their trajectories. The formula for a straight angle collision is a special case of the one for angle collision, with α=π/2.

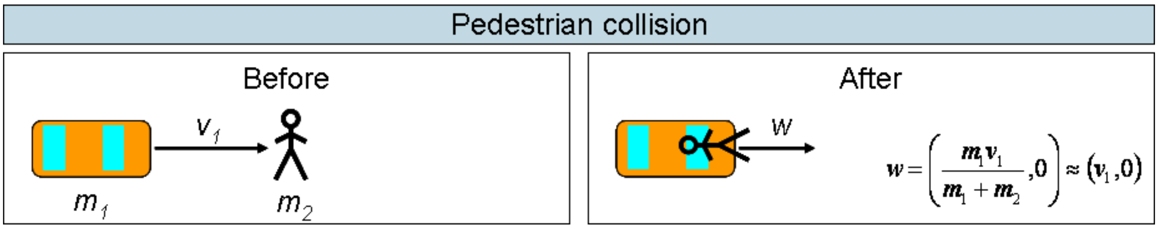


Figure B.9: Collisions where the ego vehicle (orange) hits a pedestrian.

The diagrams show the after-collision speed w, expressed in terms of the speed v1 of the vehicle just before impact, and the masses m1 and m2 of the vehicle and the pedestrian. It is assumed that the speed of the pedestrian is irrelevant. As the mass of the pedestrian is negligible compared to the mass of the vehicle, the after-collision speed of the pedestrian is approximately equal to v1.

7.3 Literature review on probability of accident severities

[ROS09] provide collision speed change – risk relations for pedestrian fatalities based on GIDAS data for the period 1999 – 2007, weighed by national statistics. The relation is given by the probability density

$$f(F \mid S = s) = \frac{1}{1 + \exp(6.9 - 0.090s)} \qquad (1)$$

The impact speed *s* is measured in km/h. See Figure B.10 for a histogram of the data and a graph of this curve. Confidence intervals are taken into account, and the paper describes how this is done. The influence of pedestrian age, gender, height and weight was analyzed. It was found that age and impact speed were the only statistically significant explanatory variables, and a more precise probability distribution is

$$f(F \mid S = s) = \frac{1}{1 + \exp(9.1 - 0.095s - 0.040a)} \quad (2)$$

Here *a* is the pedestrian's age in years, and the formula is valid for ages above 15. Several sensitivity checks are performed, for example by comparing to other studies and by modifying the weights (in order to represent underreporting of less severe accidents in national statistics)

Weighted and non-weighted data are provided for fatalities, but not for injuries or non-injury accidents.

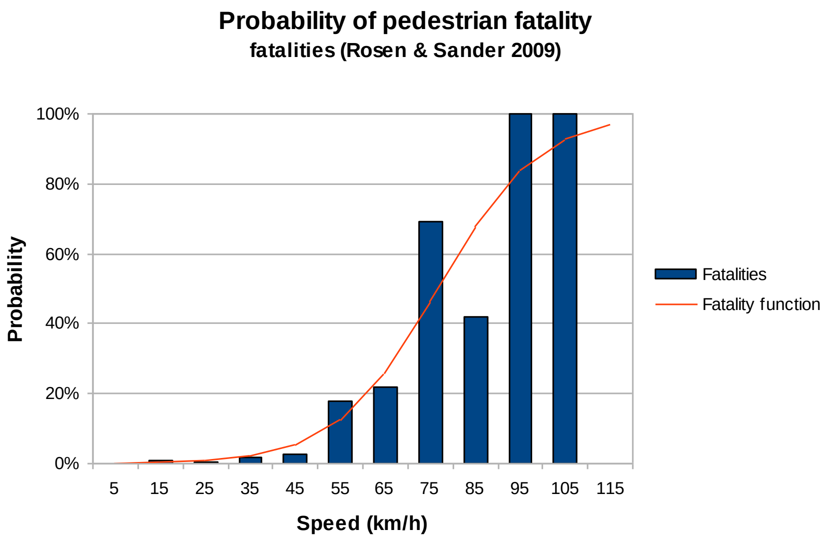


Figure B.10: Probability of pedestrian fatality depending on collision speed change, for the data set of [ROS09].

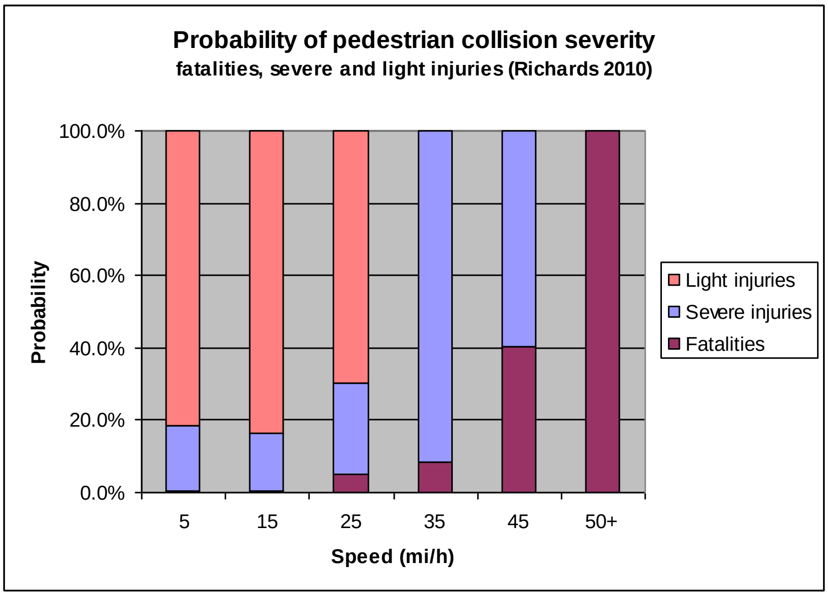
The displayed function is the best logistic regression fit.

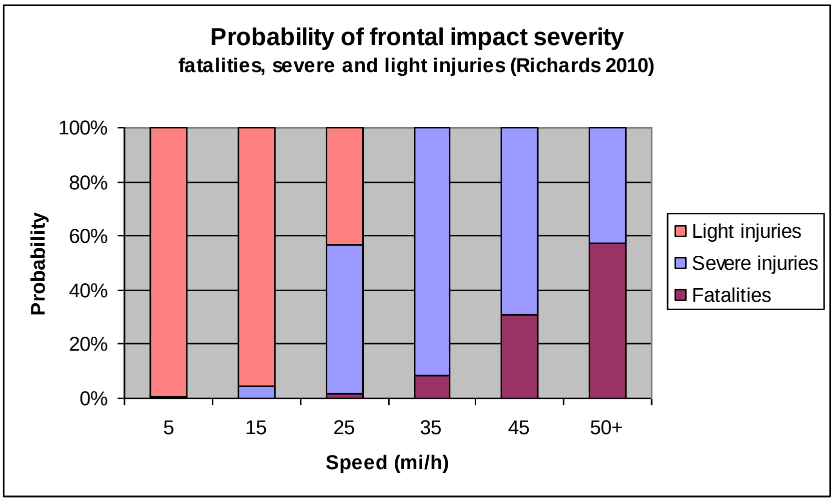
[ROS11] contains an extensive, systematic literature search on collision speed change – risk relations for pedestrian fatalities, citing source from the UK, Switzerland, Germany, USA, China and Korea. Eleven studies are selected as highly relevant. The paper shows graphical and numerical comparisons between the different studies. Of the eleven studies, only two properly account for bias in the sample data, namely [DAV01; ROS09]. Of these, the paper by Davis concerns old data from the 1960s and 1970s.

[RIC10] provides collision speed change – risk relations for pedestrian, frontal impact and side impact fatalities, for several data sets:

- A combination of three current sources of accident data in the UK, namely the On The Spot project (OTS), police fatal files and the Cooperative Crash Injury Study (CCIS), for all three accident types, for varying periods between 1983 and 2010;
- The GIDAS data set of [ROS09], for pedestrian accidents;
- Older data from Ashton and Mackay, collected in Birmingham in the 1970s, for pedestrian accidents. This data was also used by Davis in 2001, with similar results.

The paper shows graphs of the relations for all these data sets and accident types and confidence intervals, but does not present formulas. In all cases the data is weighted by national statistics to account for underreporting. Non-weighted data from the OTS data set is provided for fatalities, severe and slight injuries, for several age classes, see Figure B.11 for a graphical representation. [ROS11] claim that the speeds from the OTS data set may be unreliable, at least for pedestrian accidents.





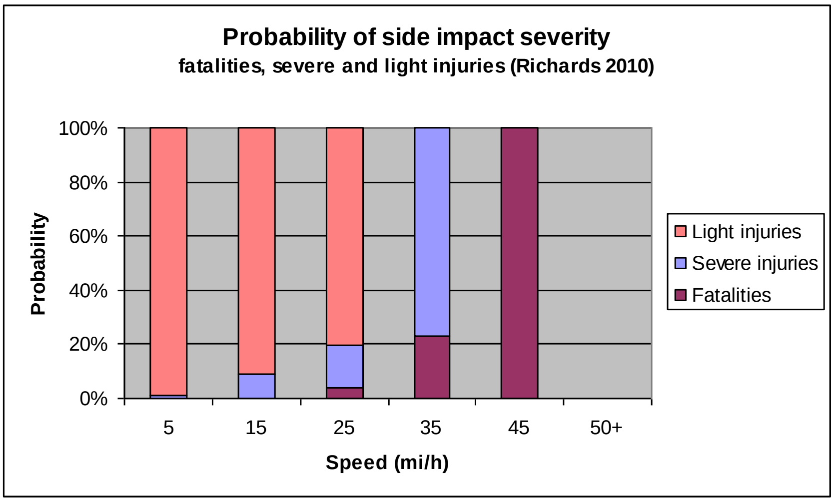


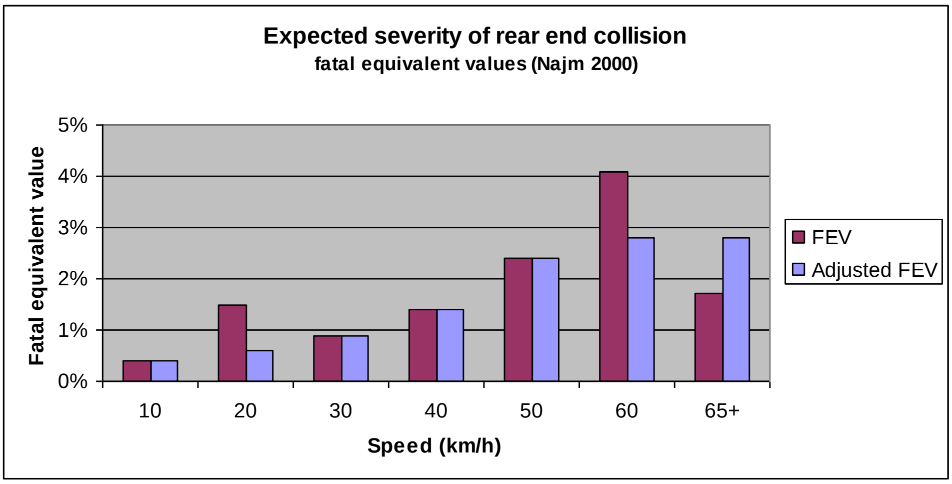
Figure B.11: Probabilities of fatality, severe and light injury depending on collision speed change, for pedestrian accidents, frontal impacts and side impacts, for the OTS/CCIS data set of [RIC10].

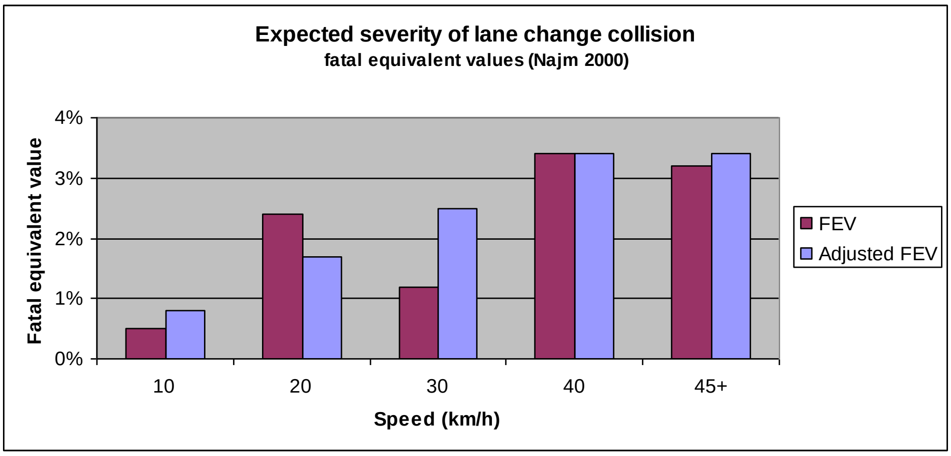
[NAJ00; NAJ03] provides collision speed change – risk relations for rear-end collisions, lane change collisions and single vehicle road departure (SVRD) accidents, using the Crashworthiness Data System (CDS) data set for the years 1994 and 1995. This is a data collection of accidents in the USA that holds in-depth data collected by 24 research teams studying 5000 crashes per year. The data set is claimed to be representative, and weighting is not applied. The data set sometimes seems to suggest that risk decreases as the collision speed change increases, which is probably an anomaly due to the small sample size. It is proposed that the data is adjusted to remove these anomalies.

The collision speed change – risk relations are presented as histograms (both figures and tables) and are based on 455 rear end crashes, 67 lane change crashes and 713 SVRD collisions. They are expressed in terms of a Fatal Equivalent Value (FEV) which is an aggregate of MAIS levels based on economic cost. See for translations of MAIS values to FEV and Table B.3 for a graphical representation of the data and the proposed adjustments.

Table B.3: Fatal equivalent values for each MAIS level, based on the crash economic costs for 1994 (column FEV 1994) and 2000 (column FEV 2000). Sources: [NAJ00; NAJ03].

Fatal Equivalent Values			
MAIS level	**MAIS descr.**	**FEV 1994**	**FEV 2000**
0	Uninjured	0.0014	0.0018
1	Minor	0.0087	0.0096
2	Moderate	0.0417	0.0610
3	Serious	0.1250	0.1698
4	Severe	0.2765	0.3176
5	Critical	0.8483	1.0000
6	Fatal	1.0000	0.8915





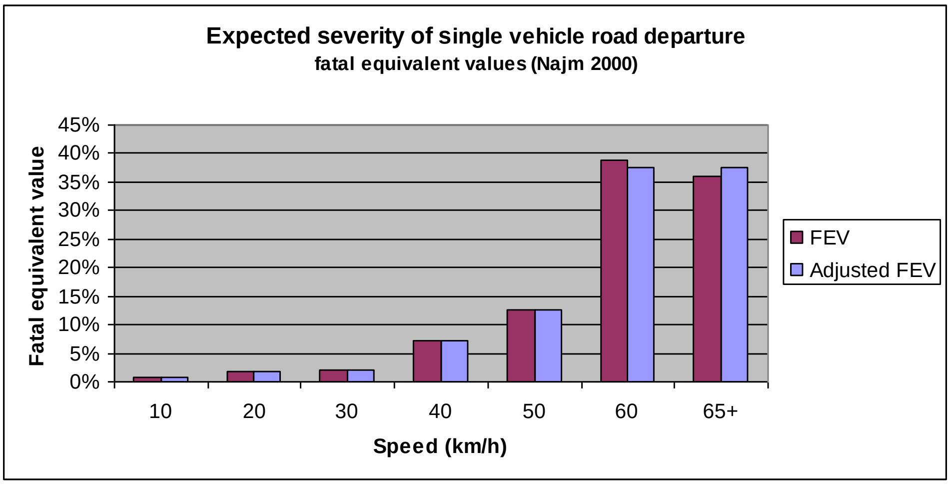


Figure B.12: Fatal equivalent values depending on collision speed change,
for rear end collisions, lane change collisions and road departures, for the data set of [NAJ00].

[HAN04] provides collision speed change – risk relations for pedestrian fatalities and severe injuries based on GIDAS data for the period 1991 – 2003. The paper shows graphs of these relations but does not present formulas or data. The data is not weighted. The graphs are reproduced in Figure B.13.

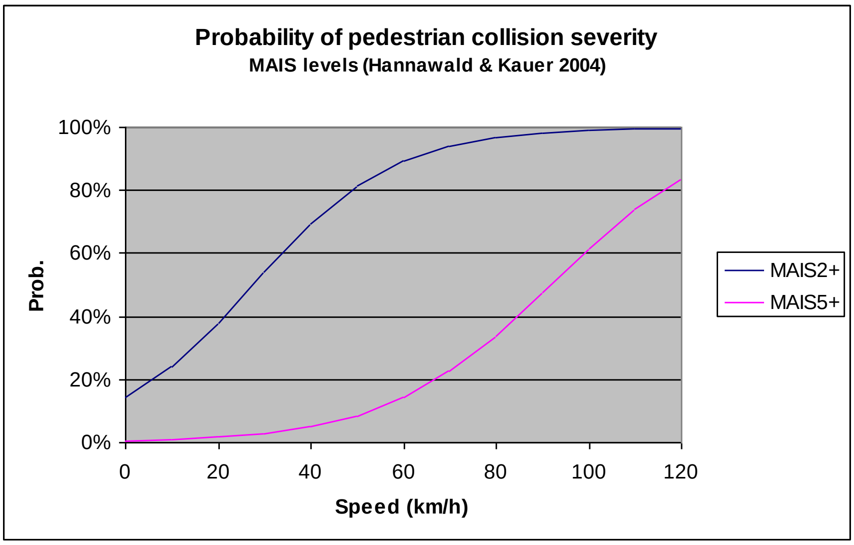


Figure B.13: Probability of MAIS2+ (severe injury) and MAIS5+ (fatality) depending on collision speed, for pedestrian accidents, for the data set of [HAN04].

The parameters of the logistic regression are visually estimated from the graphs shown in the paper.

[GAB06] provides collision speed change – risk relations for severe injuries in frontal impacts, based on Event Data Recorder (EDR) data collected by NHTSA in conjunction with the National Automotive Sampling System/Crashworthiness Data System (NASS/CDS). EDR is only available on General Motors cars and the data is restricted to crashes with injuries. In total 191 cases are considered. No weighting is applied and representativeness of the data is not discussed. Logistic regression is applied to all data and separately for belted and unbelted drivers. The results are shown in graphs and partially in tables, namely only the regression coefficient of the speed, and not the intercept. Both the best fit and confidence intervals are shown. See Figure B.14 for the collision speed change – risk relations found in the paper, where the values of the intercept are visually estimated.

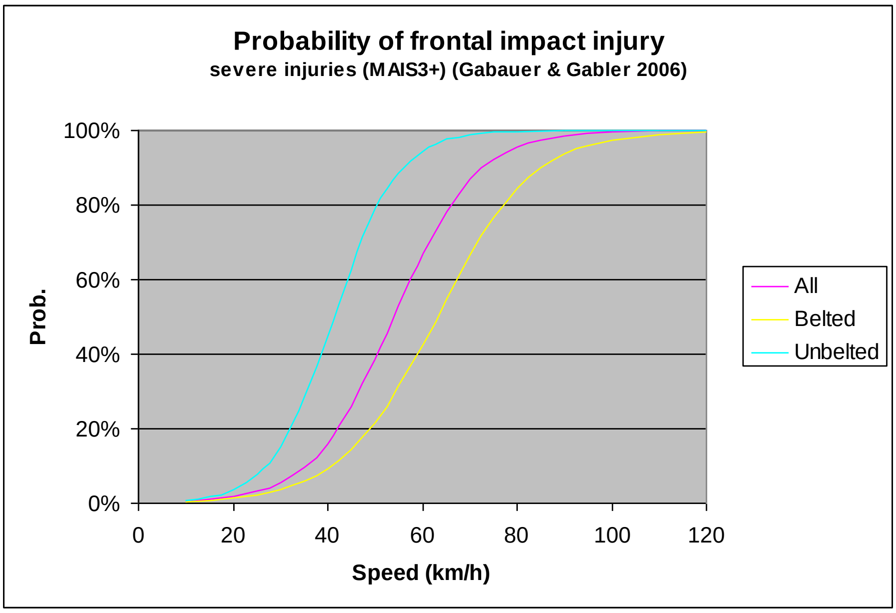


Figure B.14: Probability of severe injury depending on collision speed, for frontal impacts, for the data set of [GAB06].

The values of the intercept of the logistic regression are visually estimated from the graphs shown in the paper; the values of the regression coefficient of the collision speed change are obtained from a table in the paper.

[EVN93] and [EVN94] introduce the notion of a fatality risk ratio *R* for the two vehicles involved in a fatal two car crash, defined to be the probability of driver fatality (or injury) in the *lighter* car, divided by the probability of driver fatality (or injury) in the *heavier* car. Based on Newtonian mechanics and NASS data a relation is obtained between *R* and the mass ratio μ, defined to be the mass of the heavier vehicle divided by the mass of the lighter one. It is found that $R = \mu^k$, with $k \approx 4$ for fatalities and $k \approx 2.5$ for injuries. The relation between speed and fatality is postulated to be $P(\text{driver fatality} \mid \text{accident}) = a\,(\Delta v)^k$ where Δv is the collision speed change in mph and *a* is some parameter. It is claimed that this model fits the data better than a logistic form. It is based on research by Joksch [JOK93] who obtained a similar result, also based on NASS data, finding that $P(\text{driver fatality} \mid \text{accident}) = (\Delta v / b)^k$, for $k \approx 4$, $b \approx 71$ and Δv in mph.

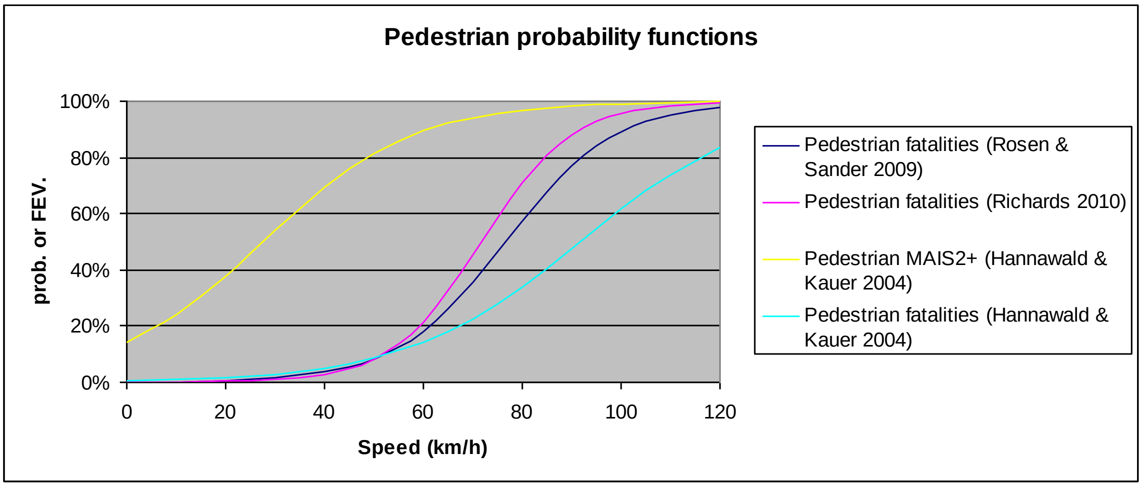
A simple logistic regression has been performed on the data presented in these sources. This regression fits a curve of the form $f(s) = \dfrac{1}{1+\exp(a+bs)}$ to the data, where *s* is the speed and *a* and *b* are the parameters to be fitted (the intercept and the regression coefficient of the speed, respectively). The values for a and b are obtained as follows.

- [ROS09] provides the values of *a* and *b* directly.
- [RIC10] and [NAJ00] (and also [ROS09]) present data on probabilities or FEV for speed bins of 10 km/h or 10 miles/h wide. In those cases, the speed *s* was set to the middle of the bin, and *a* and *b* are estimated by logistic regression.
- [GAB06] provides the value of *b* but not of *a*. Therefore the latter is estimated from the graphs.
- [HAN04] provides no values, only graphs. Therefore both *a* and *b* are estimated from the graphs.

The values of *a* and *b* are shown in Table B.4. The resulting regression curves are shown in Figure B.15.

Table B.4: Estimated values of the regression parameters a and b for the indicated parameter sets.

Data set	***a***	***b***
Pedestrian fatalities (Rosen & Sander 2009)	6.9000	-0.0900
Pedestrian fatalities (Richards 2010)	7.8765	-0.1097
Pedestrian fat. (lower) (Richards 2010)	6.7282	-0.0699
Pedestrian fat. (upper) (Richards 2010)	9.1036	-0.1501
Frontal impact fatalities (Richards 2010)	9.3596	-0.1216
Side impact fatalities (Richards 2010)	9.2863	-0.1456
Rear end collision FEV (Najm 2000)	5.6237	-0.0392
Rear end collision adjusted FEV (Najm 2000)	5.9239	-0.0415
Lane change collision FEV (Najm 2000)	5.4726	-0.0513
Lane change collision adjusted FEV (Najm 2000)	5.1756	-0.0481
SVRD FEV (Najm 2000)	5.8944	-0.0843
SVRD adjusted FEV (Najm 2000)	5.8760	-0.0836
Frontal impact MAIS3+ (Gabauer & Gabler 2006)	6.3930	-0.1184
Frontal impact belted MAIS3+ (Gabauer & Gabler 2006)	6.2405	-0.0991
Frontal impact unbelted MAIS3+ (Gabauer & Gabler 2006)	6.2928	-0.1520
Pedestrian MAIS2+ (Hannawald & Kauer 2004)	1.8025	-0.0655
Pedestrian fatalities (Hannawald & Kauer 2004)	5.2158	-0.0569



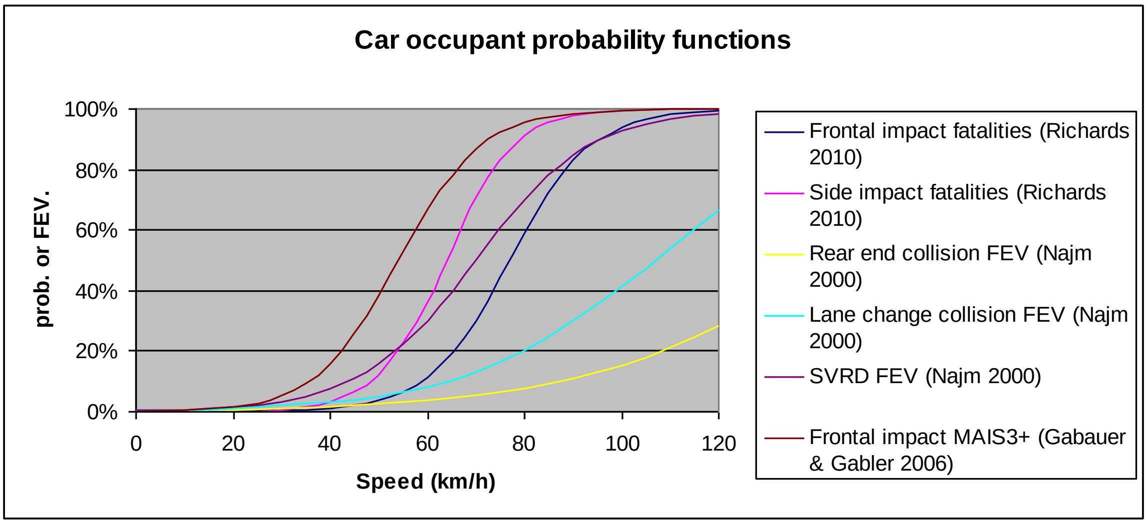


Figure B.15: Probability of fatality or injury, or FEV as a function of collision speed,

This section ends with some comments on the literature regarding the validity, consistency, applicability and the generation of additional curves, and some conclusions.

Validity: This concerns the extent to which the curves can be thought to represent reality.

- The amount of data underlying the curves is often very small, especially the data for the highest collision speed changes. For example, [RIC10] bases his results on about 200 cases for pedestrian accidents, 620 cases for frontal impacts, and about 120 cases for side impacts, often recording 0 or 1 cases for the highest speed categories; [ROS09] uses 490 pedestrian accidents.
- All curves are shown for speeds up to 120 km/h but often the data does not reach that far. In most cases, the bulk of the data only supports the left half of the curve.
- The curves in Figure B.15 are obtained by a regression analysis on the available data, when available. Where no data was available, the curves have been estimated from the graphs. In the regression analysis, the following procedure has been followed:
    - All data is assumed to be accumulated at the middle of a speed bin. There are more complicated methods. For example, [RIC10] evenly distributes the data over a speed bin. This probably does not make a significant difference.
    - Badly defined data is ignored. Badly defined data is: data points where the probability is 0 or 1, because this usually reflects an insufficient number of cases, and the regression method is ill-defined at these points; data points where the speed is given as “larger than X” for some X, because that bin has

no middle. Ignoring badly defined data may have some influence on the outcome, because it removes some data points. It has not been investigated how large this influence is.

- In case of pre-braking systems, the driver's position may shift due to the system before impact, which may influence the speed risk relation. [SCH11] has investigated this with real drivers and crash dummies and found a significant effect on the position.

Consistency: this concerns whether the literature sources provide consistent results.

- Figure B.15 suggests that qualitatively consistency is good. Indeed: more severe injury categories generally have lower probabilities; the two most reliable pedestrian fatality curves are close to one another; rear end collisions have much lower risk than side impacts
- It is important that data from in-depth accident databases is properly weighted, to correct for an overrepresentation of the more severe accidents. Some sources have weighted their data. However, for others it is not clear that weighting has been done, or it is clear that it has not been done.
- There is a difference between collision type and impact zone. E.g. frontal impacts include rear end collisions, frontal collisions, and some single vehicle collisions.
- There is a difference between the notion of MAIS categories and the notion of injury levels. The latter do not necessarily map nicely onto the first. Furthermore, injury levels "severe" or "serious" may not be comparable across data sets due to a difference in definitions between the data sources.
- Differences between curves may be due to different impact categories (fatality, FEV, etc) or collision types (pedestrian, age of pedestrian, side impact, etc). Also, they may be due to exclusion criteria in the data set (e.g. no unbelted drivers, no rollovers, no drunks), improper or lack of weighting, or too small data sets. Finally, they may be due to different time frames of data collection, as newer vehicles tend to provide better protection in accidents.
- Most sources postulate a logistic function for the risk relation, but some claim that a power function fits the data better. Typically the amount of data seems too low, especially at higher speeds, to decide which fit will be best.

Applicability: this concerns the extent to which these results apply to the case of interactIVe.

- All accident types mentioned in section 5.2 are represented, except collisions with obstacles. However, as mentioned under "consistency" above, the curves at not all comparable. Pedestrian accidents and collisions with obstacles are not very relevant for interactIVe because none of the functions specifically address this.
- In each case, the data is from a specific country in Europe or the USA, for a specific time period. This obviously limits the applicability.

Generation of additional risk curves: this concerns the construction of risk curves by the interactIVe project, using data from the literature or other data sources.

- [RIC10] publishes the (aggregated) data underlying the risk curves. This allows to regenerate his risk curves, and also to generate risk curves for severe injuries.
- Another possibility is to use GIDAS data directly to generate risk curves. It has to be decided whether interactIVe has the resources available to do this.
- Some different approaches are to use crash simulations to provide risk curves, or to use a physiological approach where one calculates forces and their effect on the injury level, e.g. as in [SCH11]. A main drawback of the latter is that the relation with accidents is not straightforward and that a detailed knowledge of the vehicle construction may be needed for an accurate analysis.

In conclusion, two ways are identified to obtain speed-risk relations. One is to take them directly from literature. The main advantage is that these are readily available; the main disadvantage is that they are not consistent as remarked above. The other way is to generate new relations based on an in-depth database. GIDAS is available to some of the SP7 members and hence seems a logical choice. The main advantage is that this will provide consistent and up-to-date risk relations; the main disadvantage is that this requires a significant amount of work and specific expertise. It has to be decided which functional form to use, with two candidates represented in the literature: a logistic function and a power function.

7.4 Mitigation – relation between impact zone change and injury risk

The mitigation of the accident consequences by a reduction of velocity achieved by a braking manoeuvre has been discussed in the previous section. But the CMS function, which is integrated in the VW demonstrator, aims to mitigate the accident consequences also by optimizing the impact constellation. An optimization of the impact constellation can be achieved by a change in the impact angle between the involved vehicles or by a change in the location of the impact.

In order to be able to calculate the safety impact of this kind of mitigation the relation between the impact zone and the related change in the injury risk must be known. This means that similar to the curves, which present the probability of certain injuries over the change of the velocity; curves are needed, which provide information on the probability of injuries in dependence of the impact point. But in contrast to the velocity, it does not seem to be reasonable to determine these curves continuously over the whole width or length of the vehicle, because it is difficult to determine the exact point of impact. Instead, different impact zones are defined, for which the probability of injuries is determined.

According to the classification in the Collision Deformation Classification (CDC) used in [BUZ98] and in the classification used in the GIDAS database [NN09] the following classification of different impact zone is proposed for interactIVe (combination of impact zones are not shown):

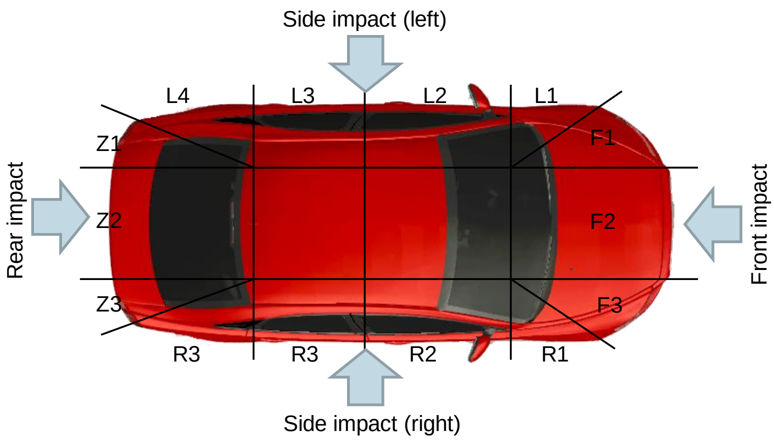


Figure B.16: Proposed classification for impact zones in interactIVe

A detailed specification of the impact zones is given in Table B.5 below:

Table B.5: Detailed specification of the impact zone.

Impact zone	Location
F1	0 – 1/3 of the width of the vehicle (from the left side)
F2	1/3 - 2/3 of the width of the vehicle (from the left side)
F3	0 – 1/3 of the width of the vehicle (from the right side)
F4	F1 + F2
F5	F3 + F2
Z1	0 – 1/3 of the width of the vehicle (from the left side)
Z2	1/3 - 2/3 of the width of the vehicle (from the left side)
Z3	0 – 1/3 of the width of the vehicle (from the right side)
Z4	Z1 + Z2
Z5	Z3 + Z2
L1	From the car front to the A-pillar (left side)
L2	From the A-pillar to the B-pillar (left side)
L3	From the B-pillar to the C-pillar (left side)
L4	From the C-pillar to the end of the car (left side)
R1	From the car front to the A-pillar (right side)
R2	From the A-pillar to the B-pillar (right side)
R3	From the B-pillar to the C-pillar (right side)
R4	From the C-pillar to the end of the car (right side)

Besides, the impact point also other parameters must be considered for determining the injury risk. The injury severity will also depend on the velocity as well as the fact, whether there is a sliding of the vehicle or not after the collision. In order to simplify the following considerations it is assumed that a function either mitigates the accidents by braking or by optimizing the impact point without a change of the vehicle velocity. But in reality both approaches can be combined.

For this reason one approach could be to consider instead of the change of the velocity Δv the Energy Equivalent Speed (EES), because the EES provides information on the relation between the velocity change and plastic deformation, which will indirectly depend on the impact position and the collision opponent. The EES is calculated based on the plastic deformation energy W_{DEF} and provides the equal velocity if a vehicle would crash frontal against a rigid barrier, should be considered.

$$\frac{1}{2} m \, EES^2 = W_{Def} \quad (3)$$

In contrast to the relation between collision speed change and injury risk there are not so much documents available, which deal with the relation between impact zone and injury risk. One example is the document [BUZ98], which studied the front occupant exposure, MAIS2+ and MAIS3+ injury risk, and maximum-injured body regions in frontal off set impacts. The effect of overlap amount has been evaluated based on three data subsets from 9 902 accident-involved Volvo cars with at least 35 000 SEK (= 3 800 €) damage. The results of this analysis are shown in Figure B.17 and Figure B.18.

		Distributed	1/3 overlap		2/3 overlap	
			Near	Far	Near	Far
Front Occupant MAIS2+						
All	EBS	14.9	5.7*	5.0*	12.2*	11.0*
	risk	125	64 (z=8)	46 (z=10.6)	124	85 (z=5)
	inj. prob.	34.5%	14.0%	9.3%	25.5%	16.6%
	#exp	3360	2695	2498	2517	2398
Given an injured co-occupant	EBS	25.9	13.9*	14.6*	19.5*	20.4*
	risk	523	522	417	614 (z=1.6)	440 (z=1.6)
	inj. prob.	54.1%	15.3%		30.6%	
	#exp	237	67	84	114	159
Crash EBS > 20 mph						
	EBS	28.8	30.8	26.4	26.5	25.0*
	risk	275	618 (z=4.2)	357	492 (z=4.3)	333
	inj. prob.	41.9%	9.2%	4.4%	28.4%	16.2%
	#exp	349	34	28	132	111

Figure B.17: Average EBS, MAIS2 + injury probability and risk with off-set configuration,

(1) all front occupants, (2) front occupants, given MAIS2 + injured co-occupant and(3) front occupants with crash EBS > 20 mph [BUZ98]

		Distributed	1/3 overlap		2/3 overlap	
			Near	Far	Near	Far
Front Occupants MAIS3+						
All	EBS	14.9	5.7*	5.0*	12.2*	10.9*
	risk	48	28 (z=4)	15.2 (z=6.3)	49.7	30.4 (z=3.3)
	inj. prob.	33.9%	15.9%	8.1%	26.5%	15.5%
	#exp	3360	2695	2498	2517	2398
Given an injured co-occupant	EBS	27.7	14.4*	15.9*	20.3	22.3
	risk	391	438	263	526	318
	inj. prob.	53.1%	15.6%		31.3%	
	#exp	87	23	38	38	63
EBS > 20 mph						
	EBS	28.8	30.8	26.4	26.5	25.0*
	risk	135	441 (z=4.8)	107	197	162
	inj. prob.	43.1%	13.8%	2.8%	23.9%	16.5%
	#exp.	349	34	28	132	111

Figure B.18: Average EBS, MAIS3 + injury probability and risk with off-set configuration,

(1) all front occupants, (2) front occupants, given MAIS3 + injured co-occupant and(3) front occupants with crash EBS > 20 mph [BUZ98]

Besides to the point of impact, also the position of the occupants can play an important role with respect to the injuries. This effect has been shown in [EVA88]. In this document the relative fatality risk of passenger compared to the driver is calculated for different impact orientation based on the Fatal Accident Reporting System (FARS) data for 1975 through 1985. The results are shown in Figure B.19.

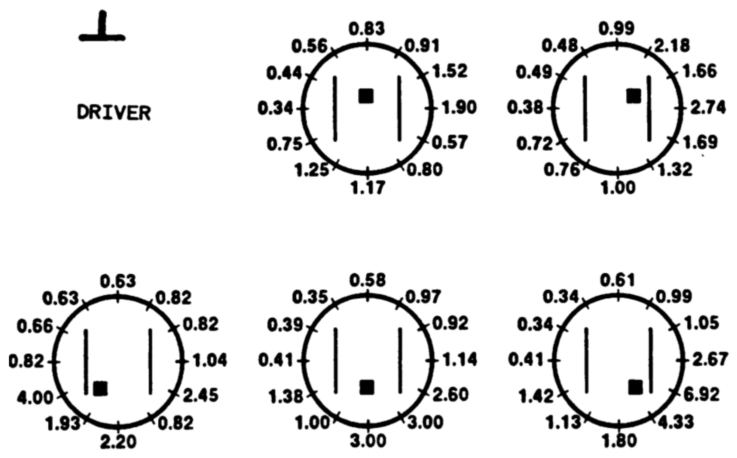


Figure B.19: The relative fatality risk to passengers in different seats as a function of principal impact point [EVA88]

Due to the fact that not many data are available with respect to the relation between impact zone change and injury risk different approaches have to be taken into account. There are three different approaches for determining the impact of an optimization of the impact constellation. These approaches are discussed in the following section.

- Real crash test with dummies

  The first approach is to use data of real crash tests. During the tests the forces on pedestrian dummies can be measured and compared for different offset configuration. By this it should be possible to determine the injury risk for different impact zones. But to be able to do so it is required that crash tests with different overlap configuration have been conducted and that the data are available. Furthermore, there are other parameters, which could influence the results. These parameters must be constant in the tests. This means that for example the car model and the change in the velocity must be the same in the tests, because otherwise a difference in the measure forces on the dummies might be measured due to a variation of the parameters.

Table B.6: Overview on frontal crash test, which analyse injury criteria [APA11].

Accident type	Velocity [km/h]	Overlap	Barrier
ECE-R94	56	40 %	Flexible – 0°
EuroNCAP	64.0	40 %	Flexible – 0°
FMVSS 208	48.0	100 %	Rigid – +/- 30°
	32.0 - 40.0	100 %	Rigid – +/- 30°
	48.0	100 %	Rigid – +/- 30°
	40,0	40 %	Flexible – 0°
	56.0	100	Rigid – 0°

The advantage of this approach is that the tests are conducted under controlled conditions and consider the realistic crash behaviour of the vehicle under test. On the other hand, the test crash tests are very expensive since they cannot be conducted with the available resources in interactIVe. Hence existing data must be used. And for these data it is not likely that many different overlap configurations are tested (see an overview on crash tests in Table B.6). Furthermore in the crash tests often a (deformable) barrier is used instead of a real vehicle. This must also be considered, because in the relevant accident scenarios of the CMS function two vehicles are involved.

- Simulation

The second approach is to use simulation tools in order to determine the relation between impact zone and injury risk. The simulation tools must not only be able to simulate the accident behaviour of the vehicle but also the behaviour of the car occupants in order to determine the resulting injuries and corresponding forces. The forces can be linked afterwards to the injury criteria of the head, neck or thorax in order to calculate the probability of injuries. Different injury criteria are given in [EPP99]. The probability of injuries for the head and the next depending on the related criteria are shown in Figure B.20 and Figure B.21.

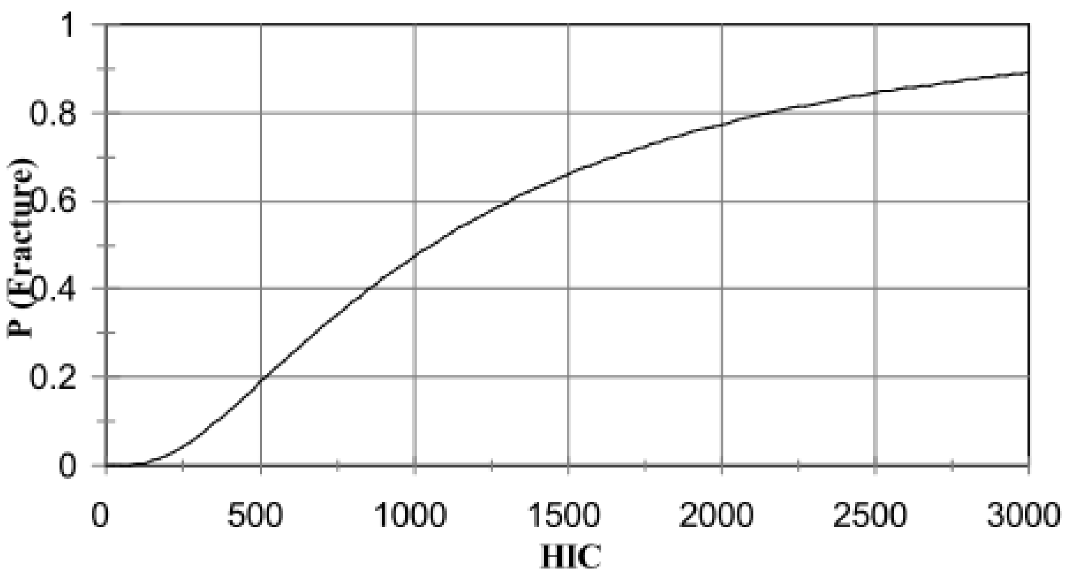


Figure B.20: Injury risk curve for the Head Injury Criterion[16] (HIC) [EPP99]

There are different tools, which can be used for this purpose like e.g. PC-Crash or crash simulation in combination with Madymo. The advantage of this approach is that different impact configuration can be analysed and compared. Disadvantages of this approach could be the transfer of the data to the reality, because no real accidents data are considered. Furthermore assumption with respect to the vehicle type, the

[16] Formula for calculation of the head injury criterion:

$$HIC = \left\{ \left[\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} a(t)\, dt \right]^{2,5} (t_2 - t_1) \right\}_{max}$$

a(t) is acceleration measure in [g] in time frame from t_1 to t_2. t_1 to t_2 represent the interval, for which the HIC attains its maximum value.

stiffness of the car and the inner-car design must be made, because it will not be possible to do the simulation for different vehicles. Especially the inner-car design can affect the injuries of the car occupants strongly. And also the needed resources (purchase as well as the practice and simulation time) for this approach must be considered.

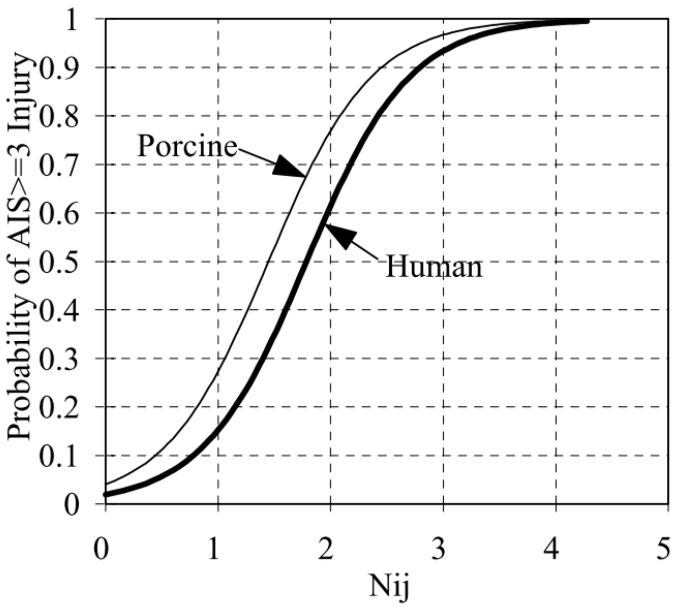


Figure B.21: Injury Risk Curve for Nij Neck Injury Criteria[17] [EPP99]

- In-depth accident database

The third approach is to use data of in-depth accident databases (e.g. GIDAS data). These databases should provide information on the impact conditions (velocity, impact area, etc.) as well as the injury severity of the car occupants. In order to calculate the injury risk depending on the impact zone, the accidents are first classified according to the impact zones, which are shown in Figure B.16. Afterwards the information on related injuries of the accident is used to determine the risk curves.

The advantage of this approach is that it considers real accidents with two vehicles involved. One disadvantage of this approach is that in reality after the first impact a second impact with another vehicle or static objects like e.g. trees can occur. This is especially likely when the overlap between the two vehicles is small and the vehicle is sliding after the first contact. In this case it is maybe not possible to determine, which impact has caused which injury. Another disadvantage of this approach could be that the number of accidents, which is available in the database, is too low to draw statistically valid conclusions.

$$Nij = \frac{F_z}{F_{\text{int}}} + \frac{M_y}{M_{\text{int}}}$$

[17] Formula for calculation of the neck injury criteria

F_z: measured axial load; M_y: measured flexion/extension bending moment; F_{int}: the critical intercept value of load used for normalisation ;M_{int}: critical intercept value for moment used for normalisation

A final decision on the approach for the safety impact assessment has not been taken up to the moment when this deliverable is published. First, the advantages and disadvantages of the three approaches should be investigated. In any case, also the available resources must be considered.

7.5 Road safety forecast for 2030

The compilation of accident data results in a detailed picture of fatalities, injury accidents and other casualties, as it is in the year for which the most actual data exist. However, the project aims at estimating the safety impact of vehicle systems in the future, namely 2030. Unfortunately, up-to-date forecasts for the target years are not available on an EU-27-level. A forecast of accident data is therefore necessary. The general approach of the forecast will be based on the development of the fatality risk by country. Since data on vehicle mileage is not available for all countries, the fatality risk will be based upon population data. A time series analysis will be carried out, using e.g. exponential regression to extrapolate the risk figures for 2030. Then, fatality figures are calculated backwards by using information of population data for the year 2030. At this point of time it is not known if population data for the year 2030 are easily and consistently available. If that is not the case, a separate forecast for population figures will have to be included.

7.6 Impacts of combinations of functions

When assessing a combination of functions, it is more efficient to reuse the results for the individual functions, rather than doing a complete assessment from the start. This poses an issue regarding the correct combination of these results. There are two extreme cases that can be considered:

- Independence: for applications that target different accident scenarios, the effects can be added. However, for applications that have an overlap in the scenarios that they cover, adding the effects may lead to an overestimation of the combination's effect.
- Homogeneity: for applications that target the same accident scenarios, the safety risk modifiers can be multiplied. This assumes that first one application takes away some risk, and then the other application works independently on the remaining cases. This may overestimate the effect if there is an overlap in the functioning of the two applications in the sense that the working of one application is partially annihilated by the other one. For applications that do not completely overlap in the scenarios that they cover, multiplying the modifiers may lead to an underestimation of the combination's effect

In general, a combination of these two will be used. It will be decided later to what extent combinations can be assessed. Table B.7 shows an example how this could work with two applications and two scenarios.

Table B.7: Example of combining two applications (1 and 2) that each target two scenarios (A and B)

Scenarios & incidence	Modifier application 1	Modifier application 2	Modifier per situation	Overall modifier
A: 0.3	0.8	0.9	0.8*0.9=0.72	0.3*0.72+0.2*1.56 =0.528
B: 0.2	1.3	1.2	1.3*1.2=1.56	

Annex C: Updated RQs and Hypotheses

B.1Technical research questions and hypotheses

B.1.1.Technical research questions and hypotheses: Full function performance		General
	HYPOTHESES	**INDICATORS**
RQ_T_Gen_Perf_02: How do different environmental conditions affect the function's availability and performance?	**Hyp_T_gen_perf_01:** The function's availability is determined by the sensors' availability	- missed alarm rates - false alarm rates - rate function "on" per environmental condition
	Hyp_T_gen_perf_02: Different environmental conditions do not affect the function's performance.	- TTC at point in time (alarm, intervention, first detection) - speed reduction (max) - impact speed - driver reaction - missed alarm rates - false alarm rates - information of the function description
	Hyp_T_SEC_CS_Perf_01: The function reacts not earlier, when the road has a side barrier	- TLC (at warning) - TLC (at start of intervention) - (lateral) distance to target object (lane, barrier) at warning - (lateral) distance to target object (lane, barrier) at intervention
	Hyp_I_Gen_08: The function operates on all road types.	- mean function status (per road type)
	Hyp_I_Gen_09: The function works under all weather conditions.	- mean function status(per weather conditions)
	Hyp_I_Gen_10: The function works under all light conditions.	- mean function status (per light conditions)
	Hyp_I_Gen_11: The function works in all traffic conditions.	- mean function status (per traffic conditions)
	Hyp_I_Gen_12: The function works over the whole speed ranges of the vehicle.	- mean function status (per driven speed)

RQ_T_Gen_Perf_03: What are the performance limitations of the function in relation to intervention in longitudinal and in lateral direction?	**Hyp_T_gen_perf_03:** The function uses the maximum (possible) longitudinal acceleration in order to avoid an accident.	- longitudinal acceleration
	Hyp_T_gen_perf_04: The function is able to brake up to stand still autonomously.	- speed reduction (mean, min, max)

B.1.2.Technical research questions and hypotheses: Perception		**General**
	HYPOTHESES	**INDICATORS**
RQ_T_Gen_Perc_01: Is the relevant target detected by the function during the test?	**Hyp_T_gen_perc_01:** Information on the relevant target(s) is provided to the function's logic (during the test).	- missed detections - number of false positive detections - number of false negative detections - rate of correct detection - time target visible and in sensor coverage area until first detection
	Hyp_T_SEC_eDPP_Perc_02: The function detects correctly the passing prohibitions (lane markings as well as traffic signs)	- rate of correct detection (passing prohibitions)
RQ_T_Gen_Perc_03: does the function correctly recognize its target scenarios?	**Hyp_T_gen_perc_02:** Information on the relevant target is provided in time to assure that the function can react as intended.	- TTC (at first detection) - THW (at first detection)
RQ_T_Gen_Perf_04: Are there false negative activations during the tests?	**Hyp_T_gen_perf_05:** There are no false negative activations of the function (during the test).	- number of false negative activations - false negative activation rate
RQ_T_Gen_Perf_05: Are there false positive activations during the test?	**Hyp_T_gen_perf_06:** There are no false positive activations of the function (during the test).	- number of false positive activations - false positive activation rate

B.1.3.Technical research questions and hypotheses: Safety Logic		**General**
	HYPOTHESES	**INDICATORS**

RQ_T_Gen_Safe_01: In what way is the function expected to improve traffic safety?	**Hyp_T_gen_safe_01:** The function reduces the impact speed.	- impact speed
	Hyp_T_gen_safe_02: The function improves traffic safety by avoiding an accident in a target scenario.	- TTC (at start of intervention) - distance to target object (min) - lateral and longitudinal accelerations (max) - duration of intervention - vehicle speed (at the end of the intervention) - vehicle position (at the end of the intervention)
	Hyp_T_gen_safe_03: The function improves the orientation of the car for impact.	- impact orientation
RQ_T_Gen_Safe_02: In which tested scenarios the functions warn the driver?	**Hyp_T_gen_safe_04:** The function warns the driver in all tested scenarios, in which a warning is required.	- function warning status - function intervention status - brake pressure / force (extra applied) - steering torque (extra applied) - TTC (at alarm) - THW (at alarm) - number of false alarms - number of missed alarms - distance to target object – (longitudinal) (at alarm)
RQ_T_Gen_Safe_03: In which tested scenarios the functions intervenes in the driving behaviour?	**Hyp_T_gen_safe_05:** The function intervenes in all tested scenarios, in which an intervention is required.	- function intervention status - duration of intervention - TTC (at start of intervention) - distance to target object – (longitudinal) (at intervention) - THW (at start of intervention) - distance to target object (lane, barrier) – (longitudinal) (at start of intervention) - TLC (at start of intervention) - number of false interventions - number of missed interventions
RQ_T_Gen_Safe_04: Are there tested scenarios, in which the function intervenes without warning?	**Hyp_T_gen_safe_06:** The function never intervenes without first giving a warning to the driver.	- function warning status - function intervention status - brake pressure / force (extra applied)

		- steering torque (extra applied) - driver reaction - time between two actions (warning & intervention)
RQ_T_Gen_Safe_05: Is the function's reaction in a specific situation different under similar conditions?	**Hyp_T_gen_safe_07:** The function behaves in the same way in similar situations.	- function warning status - function intervention status - impact speed - impact orientation
RQ_T_Gen_Safe_06: At which time point does the function warn the driver, prepare the vehicle for an evasive or braking manoeuvre or intervene in the dynamic behaviour of the vehicle?	**Hyp_T_gen_safe_08:** The function prepares (e.g. brake pre---filling) the vehicle for an evasive or braking manoeuvre before the accident (in the scenario).	- TTC (at preparation) - distance to target object – (longitudinal) (at preparation) - distance to target object (lane, barrier) – (longitudinal) (at preparation) - THW (at preparation) - function intervention status - TLC (at preparation)
RQ_T_Gen_Safe_07: At which distance towards the hazard source does the function warn the driver, prepare the vehicle for an evasive or braking manoeuvre or intervene in the dynamic behaviour of the vehicle?	**Hyp_T_gen_safe_09:** The function intervenes before the accident (in the scenario).	- TTC (at start of activation) - Distance to target object - (longitudinal - at start of activation) - THW (at start of activation)

B.1.4.Technical research questions and hypotheses: Technical user-related		General
	HYPOTHESES	**INDICATORS**
RQ_T_Gen_TecU_01: Is there, after a warning, enough time left for an intervention by the driver?	**Hyp_T_gen_TecU_01:** The driver has enough time to react and avoid the accident, when the warning is issued.	- TTC (at alarm) - driver braking reaction (after the alarm) - driver steering reaction (after the alarm)
RQ_T_Gen_TecU_02: What reaction (deceleration or steering wheel velocity) is required from the	**Hyp_T_gen_TecU_02:** The driver has not enough time to react and avoid the accident, when the function starts to intervene in the driving behaviour.	- TTC (at start of intervention) - driver braking reaction (after the alarm) - driver steering reaction (after the alarm)

vehicle/driver in a tested scenario in order to avoid an accident, when a warning is given by the function?	**Hyp_T_gen_TecU_03:** The accident cannot be avoided although a warning is given before the accident.	- longitudinal acceleration (max) - lateral acceleration (max) - longitudinal acceleration required to avoid collision (at time of warning) - lateral acceleration required to avoid collision (at time of warning) - duration of intervention - TTC (at alarm)
	Hyp_T_SEC_Gen_Perf_01: In general it is possible to avoid a imminent accident when a warning is issued	- longitudinal acceleration required to avoid collision (at warning) - lateral acceleration required to avoid collision (at warning) - TTC(at warning)
	Hyp_T_SEC_Gen_Perf_02: In general it is possible to avoid an imminent accident when the function starts to intervene in the driving behaviour.	- longitudinal acceleration required to avoid collision (at start of intervention) - lateral acceleration required to avoid collision at start of intervention) - TTC (at start of intervention)
RQ_T_Gen_TecU_03: Is it possible to override the function?	**Hyp_T_gen_TecU_04:** The function can always be overridden by the driver.	- function on/off - brake pedal angle (during intervention) - steering wheel angle (during intervention) - function "on" per brake pedal angle - function "on" per steering wheel angle

B.1.5.Technical research questions and hypotheses: Full function performance		SECONDS-CONTINUOUS SUPPORT
	HYPOTHESES	**INDICATORS**
RQ_T_SEC_CS_Perf_01: Does the Continuous Support function warn the driver in time, so that he has enough time to react??	**Hyp_T_SEC_Gen_Perf_01:** In general it is possible to avoid a imminent accident when a warning is issued	- longitudinal acceleration required to avoid collision (at warning) - lateral acceleration required to avoid collision (at warning) - TTC(at warning)
RQ_T_SEC_CS_Perf_03: How does the function react, if the vehicle drives in a lane that ends and the driver	**Hyp_T_SEC_CS_Perf_02:** The function will warn the driver, when the lane ends and the driver does not initiate a lane change.	- min TLC - (lateral) distance to target object (end of lane) (at warning)

does not react on this situation?		- (lateral) distance to target object (end of lane) (at intervention)
RQ_T_SEC_CS_Perf_04: How well does the function detect zones, where a reduced speed is required (e.g., speed bumps)?	**Hyp_T_SEC_CS_Perf_03:** The function is able to detect zone, which required a lower speed (e.g. speed bumps).	- rate of correct detections (speed zones)
RQ_I_SEC_10: Does the Continuous Support function increase fuel efficiency?	**Hyp_T_SEC_Gen_Perf_03:** The function reduces fuel consumption	- mean fuel consumption

B.1.6.Technical research questions and hypotheses: Perception		**SECONDS-CONTINUOUS SUPPORT**
	HYPOTHESES	**INDICATORS**
RQ_T_SEC_CS_Perc_01: Does the function react on stationary objects in the tested scenarios (especially vehicles)?	**Hyp_T_SEC_Gen_Perc_01:** The function warns the driver for standing still objects in the vehicle path	- max distance at first detection of object - mean distance at first detection of object - min distance at first detection of object - max time distance at first detection of object - mean time distance at first detection of object - min time distance at first detection of object - Rate of correct detections
	Hyp_T_SEC_SC_Perc_01: The function also detects static objects in the vehicle path.	- max distance at first detection of object - mean distance at first detection of object - min distance at first detection of object - max time distance at first detection of object - mean time distance at first detection of object - min time distance at first detection of object - rate of correct detections

RQ_T_SEC_CS_Perc_05: How well are vulnerable road users detected depending on e.g. size, or movement?	**Hyp_T_SEC_CS_Perc_04**[18]**:** The function detects vulnerable road users independently of their size	- rate correct detection (vulnerable road users) - distance to target object (at first detection)
	Hyp_T_SEC_CS_Perc_05[19]**:** The function detects vulnerable road user moving in all directions	- rate correct detection (vulnerable road users) - distance to target object (at first detection)
RQ_T_SEC_CS_Perc_06: Is the speed limit always detected correctly?	**Hyp_T_SEC_CS_Perc_06:** The function detects the current given speed limit always correctly.	- max difference of detected and current speed limit - mean difference of detected and current speed limit - rate of correct detections (speed limits)
	Hyp_T_SEC_CS_Perc_07[20]**:** The function detects dynamic speed limits correctly.	- rate of correct detections (speed limits)
RQ_T_SEC_CS_Perc_07: Are there limitations of the speed limit detection (e.g. coverage of the sign, lateral position of the traffic sign)?	**Hyp_T_SEC_CS_Perc_08:** The speed limit is detected correctly up to a covering of x (50 %) of the sign.	- rate of correct detections - max distance at first detection of object - mean distance at first detection of object - min distance at first detection of object
	Hyp_T_SEC_CS_Perc_09: The speed limit is detected correctly up to a lateral distance of x (7.5 m) from the outline of the vehicle.	- rate of correct detections - max (lateral and longitudinal) distance at first detection of object - mean (lateral and longitudinal) distance at first detection of object - min (lateral and longitudinal) distance at first detection of object - position of sign with respect to vehicle
	Hyp_T_SEC_CS_Perc_10: The speed limit can distinguish between speed limits and other traffic signs	- Rate of correct detections - max distance at first detection of object

[18] This hypothesis is not relevant for FFA

[19] This hypothesis is not relevant for FFA

[20] This hypotheses is not relevant for CRF, because there is no dynamic speed limit information on CRF demonstrator

	(e.g. height limit, speed limit change in x m).	- mean distance at first detection of object - min distance at first detection of object

B.1.7.Technical research questions and hypotheses: Safety Logic		**SECONDS-CONTINUOUS SUPPORT**
	HYPOTHESES	**INDICATORS**
RQ_T_SEC_CS_Safe_01: Does the function determine the right of way situation correctly?	**Hyp_T_SEC_CS_Safe_01:** The function determines right of way situation correctly.	- rate of correct detections (way of right situations)
RQ_T_SEC_CS_Safe_02: Does the function suggest an appropriate speed for zones, where a reduced speed is requires (e.g. speed bumps)?	**Hyp_T_SEC_CS_Safe_02:** The proposed speed limit of the function will be equal to the actual valid speed limit.	- proposed vehicle speed (at start of speed limit) - mean difference between given and proposed speed - max difference between given and proposed speed

B.1.8.Technical research questions and hypotheses: Full function performance		**SECONDS-CURVE SPEED CONTROL**
	HYPOTHESES	**INDICATORS**
RQ_T_SEC_CSC_Perf_01: Has an intervention of the function a negative influence on the dynamic behaviour of the vehicle?	**Hyp_T_SEC_CSC_Perf_01:** The intervention of the function has no negative influence on the driving behaviour	- Distance to curve (at initiation the intervention) - Time gap to curve (at initiation the intervention) - Speed reduction (mean, max, min) - Yaw rate in the curve (mean, max, min, before / after intervention), - Steering wheel angle - Steering velocity

B.1.9.Technical research questions and hypotheses: Safety Logic	**SECONDS-CURVE SPEED CONTROL**

	HYPOTHESES	INDICATORS
RQ_T_SEC_CSC_Safe_01: Is the proposed speed safe for the negotiating of the curve?	**Hyp_T_SEC_CSC_Safe_01:** The proposed velocity ensures a safe negotiating of the curve.	- proposed vehicle speed (at certain locations) - vehicle speed (at certain locations) - mean max. lateral acceleration - curve radius
RQ_T_SEC_CSC_Safe_02: Does the function choose an appropriate velocity according to the geometry of the upcoming curve?	**Hyp_T_SEC_CSC_Safe_02:** The proposed velocity is adapted appropriate to the geometry of the upcoming curve.	- proposed vehicle speed (at certain locations) - vehicle speed (at certain locations) - mean max. lateral acceleration - curve radius - curve angle

B.1.10.Technical research questions and hypotheses: Perception		**SECONDS-ENHANCED DYNAMIC PASS PREDICTOR**
	HYPOTHESES	INDICATORS
RQ_T_Gen_Perc_01: Is the relevant target detected by the function during the test?	**Hyp_T_SEC_eDPP_Perc_02:** The function detects correctly the passing prohibitions (lane markings as well as traffic signs).	- rate of correct detection (passing prohibitions)
RQ_T_SEC_eDPP_Perc_01: Is the functionality of the eDPP influenced if the oncoming vehicle is not equipped with car---2---car communication?	**Hyp_T_SEC_eDPP_Perc_01:** The function is not impaired when the other vehicles are not equipped with car---2---car communication.	- rate of correct detection

B.1.11.Technical research questions and hypotheses: Full function performance		**SECONDS-SAFE CRUISE**
	HYPOTHESES	INDICATORS

RQ_T_SEC_SC_Perf_01: Can the SC function prevent imminent rear---end collision before the situation becomes critical?	**Hyp_T_SEC_SC_Perf_01:** The function prevents imminent rear---end collision before they become critical	- min TTC - min THW
	Hyp_T_SEC_SC_Perf_02: During driving the TTC does not drop under x (e.g. 1.5 s [VAN93]) when the function is active.	- Time exposed time---to---collision (TET) - min TTC
RQ_T_SEC_SC_Perf_02: Does the SC prevent speeding autonomously?	**Hyp_T_SEC_SC_Perf_03:** The function will ensure the correct speed autonomously (without intervention by the driver).	- duration of speed exceeding - max. difference of detected and current speed limit - mean difference of detected and current speed limit - vehicle speed (at speed limit, before and after speed limit) - distance to speed limit at initiating deceleration - time distance to speed limit at initiating deceleration
RQ_T_SEC_SC_Perf_03: Does the Safe Cruise function increase fuel efficiency?	**Hyp_T_SEC_Gen_Perf_03:** The function reduces fuel consumption	- mean fuel consumption

B.1.12.Technical research questions and hypotheses: Technical user-related		**SECONDS-SAFE CRUISE**
	HYPOTHESES	**INDICATORS**
RQ_T_SEC_SC_TecU_01: Is the function inhibited, if the driver is not focused on the road?	**Hyp_T_SEC_SC_TecU_01:** When the driver is not focusing on the road for a certain time, the function is switched off.	- rate function "on" per status (gazing direction and time)
	Hyp_T_SEC_SC_TecU_02: When the driver takes his/her hands off the steering wheel, the function is switched off.	- rate function "on" per status (position of the hands and time)
RQ_T_SEC_SC_TecU_02: Is the driver warned well in time when the function switches itself off?	**Hyp_T_SEC_SC_TecU_03:** The driver will be warned in time before the function switches itself off.	- time between two events (warning and switch off)

B.1.13.Technical research questions and hypotheses: Full function performance		INCA- General
	HYPOTHESES	**INDICATORS**
RQ_T_INC_Gen_Perf_01: what is the capability and performance to avoid or mitigate collisions in various dangerous traffic scenarios?	**Hyp_T_gen_Perf_07:** The function detects threats and target scenarios according to the specifications	- CAR (Correct Alarm Rate) - FAR (False Alarm Rate) - MAR (Missed Alarm Rate) - function activation in a test scenario
	Hyp_T_gen_safe_01: The function reduces the impact speed.	- impact speed
		-
	Hyp_T_INC_Safe_01: The function selects the appropriate method to avoid collisions or driving---off---road accidents	- function activation in a test scenario - minimum distance to threat during manoeuvre - Max. acceleration during manoeuvre - Max. braking force/steering torque during manoeuvre

B.1.14.Technical research questions and hypotheses: Full function performance		INCA-REAR-END COLLISION AVOIDANCE
	HYPOTHESES	**INDICATORS**
RQ_T_INC_RECA_Perf_01: What's the time of reaction of the function in sudden situations and how does it affect collision avoidance?	**Hyp_T_INC_Perf_04:** The function is able to avoid rear and side collisions according to the specifications	- minimum distance between vehicles during manoeuvre - minimum TTC during manoeuvre
RQ_T_INC_RECA_Perf_02: How does road shape affect impact speeds?	**Hyp_T_INC_Perf_03:** The functionality of the function is not influenced by road curvature	- road curvature - vehicle speed and acceleration - relative longitudinal and lateral speed of host and target vehicle at the start of the manoeuvre - CAR (Correct Alarm Rate), FAR (False Alarm Rate), MAR (Missed Alarm Rate) - minimum TTC during the manoeuvre - vehicle speed at start of manoeuvre

RQ_T_INC_RECA_Perf_03: What's the reduction of impact speed in different event flows?	**Hyp_T_INC_Safe_03:** The intervention avoids or mitigates the collision and does not aggravate it.	- minimum TTC during manoeuvre - impact speed - relative orientation of vehicles at impact - speed reduction (mean)
RQ_T_INC_RECA_Perf_04: Does the outcome of the intervention correspond to the plan at the start of intervention?"	**Hyp_T_gen_Perf_07:** The function detects threats and target scenarios according to the specifications	- CAR (Correct Alarm Rate) - FAR (False Alarm Rate) - MAR (Missed Alarm Rate) - function activation in a test scenario

B.1.15.Technical research questions and hypotheses: Perception		INCA-REAR-END COLLISION AVOIDANCE
	HYPOTHESES	**INDICATORS**
RQ_T_INC_RECA_Perc_01: What are the scenarios---specific ranges for detecting reference obstacles?	**Hyp_T_gen_Perf_07:** The function detects threats and target scenarios according to the specifications	- CAR (Correct Alarm Rate) - FAR (False Alarm Rate) - MAR (Missed Alarm Rate) - function activation in a test scenario
	Hyp_T_INC_Safe_01: The function selects the appropriate method to avoid collisions or driving---off---road accidents	- function activation in a test scenario - minimum distance to threat during manoeuvre - Max. acceleration during manoeuvre - Max. braking force/steering torque during manoeuvre

B.1.16.Technical research questions and hypotheses: Safety Logic		INCA- REAR-END COLLISION AVOIDANCE
	HYPOTHESES	**INDICATORS**
RQ_T_INC_RECA_Safe_01: What's the reliability for detecting a free lane / shoulder and how does this affect Logic?	**Hyp_T_INC_Perc_01:** The function correctly detects a free lane or road shoulder in target scenarios (the system	- incorrect route planning or intervention in a test case - amount of time that the vehicle is outside the lane

	does not move into occupied lanes or outside road)	
RQ_T_INC_RECA_Safe_02: Is the lateral accuracy of the function good enough to cover target scenarios?	**Hyp_T_INC_Perf_01:** The function works within the specified speed and acceleration range	- vehicle speed and relative longitudinal and lateral speed at start of manoeuvre - max. longitudinal and lateral acceleration during manoeuvre
	Hyp_T_INC_Perc_01: The function correctly detects a free lane or road shoulder in target scenarios (the system does not move into occupied lanes or outside road)	- incorrect route planning or intervention in a test case - amount of time that the vehicle is outside the lane
RQ_T_INC_RECA_Safe_03: How does road shape affect trajectory planning?	**Hyp_T_INC_Perf_03:** The functionality of the function is not influenced by road curvature	- road curvature - vehicle speed and acceleration - relative longitudinal and lateral speed of host and target vehicle at the start of the manoeuvre - CAR (Correct Alarm Rate), FAR (False Alarm Rate), MAR (Missed Alarm Rate) - minimum TTC during the manoeuvre - vehicle speed at start of manoeuvre
RQ_T_INC_RECA_Safe_05: Can the function avoid dynamic obstacles?	**Hyp_T_INC_Perf_02:** The function is able to avoid collisions with moving obstacles	- relative longitudinal and lateral speed of host and target vehicle at start of manoeuvre and at the end of the manoeuvre - minimum TTC during the manoeuvre - target vehicle speed

B.1.17.Technical research questions and hypotheses: Technical user---related		**INCA- REAR-END COLLISION AVOIDANCE**
	HYPOTHESES	**INDICATORS**
RQ_T_INC_RECA_TecU_02: How does machine intervention vary in different event flows?	**Hyp_T_gen_Perf_07:** The function detects threats and target scenarios according to the specifications	- CAR (Correct Alarm Rate) - FAR (False Alarm Rate) - MAR (Missed Alarm Rate) - function activation in a test scenario
	Hyp_T_INC_Safe_01: The function selects the appropriate method to avoid collisions or driving---off---	- function activation in a test scenario - minimum distance to threat during

	road accidents	manoeuvre - Max. acceleration during manoeuvre - Max. braking force/steering torque during manoeuvre
	Hyp_T_INC_Safe_02: After intervention the situation was correctly perceived to be safe enough to return the control back to the driver.	- distance to threat (at returning of control) - lateral position in lane (at returning of control) - longitudinal speed (at returning of control) - longitudinal acceleration (at returning of control) - lateral acceleration (at returning of control) - yaw rate (at returning of control) - yaw angle (at returning of control) - steering wheel angle (at returning of control) - brake pedal angle (at returning of control) - brake pressure / force (at returning of control)

B.1.18.Technical research questions and hypotheses: Full function performance		INCA- LANE CHANGE COLLISION AVOIDANCE+SIDE IMPACT AVOIDANCE
	HYPOTHESES	**INDICATORS**
RQ_T_INC_LCCA_Perf_01: How large are the margins to avoid a collision (to ensure it is avoided and actual performance)?	**Hyp_T_INC_Perf_04:** The function is able to avoid rear and side collisions according to the specifications	- minimum distance between vehicles during manoeuvre - minimum TTC during manoeuvre

B.1.19.Technical research questions and hypotheses: Perception		INCA- LANE CHANGE COLLISION AVOIDANCE+SIDE IMPACT AVOIDANCE
	HYPOTHESES	**INDICATORS**

RQ_T_INC_LCCA_Perc_01: What is the performance for side detection?	**Hyp_T_INC_Perf_04:** The function is able to avoid rear and side collisions according to the specifications	- minimum distance between vehicles during manoeuvre - minimum TTC during manoeuvre
RQ_T_INC_LCCA_Perc_02: How reliably does the system detect an obstacle in the blind spot?	**Hyp_T_INC_Perf_04:** The function is able to avoid rear and side collisions according to the specifications	- minimum distance between vehicles during manoeuvre - minimum TTC during manoeuvre

B.1.20.Technical research questions and hypotheses: Safety Logic		INCA- ONCOMING VEHICLE COLLISION AVOIDANCE/MITIGATION
	HYPOTHESES	**INDICATORS**
RQ_T_INC_OVCA_Safe_01: Are the trajectory calculation ranges sufficient?	**Hyp_T_gen_Perf_07:** The function detects threats and target scenarios according to the specifications	- CAR (Correct Alarm Rate) - FAR (False Alarm Rate) - MAR (Missed Alarm Rate) - function activation in a test scenario
	Hyp_T_INC_Safe_01: The function selects the appropriate method to avoid collisions or driving---off---road accidents	- function activation in a test scenario - minimum distance to threat during manoeuvre - Max. acceleration during manoeuvre - Max. braking force/steering torque during manoeuvre

B.1.21.Technical research questions and hypotheses: Full function performance		INCA- RUN-OFF ROAD PREVENTION
	HYPOTHESES	**INDICATORS**
RQ_T_INC_RoRP_Perf_01: How often can driving off the road accidents be prevented in different traffic scenarios?	**Hyp_T_INC_Safe_04:** The function activates when the speed is too high to negotiate an upcoming curve	---

B.1.22.Technical research questions and hypotheses: Full function performance		EMIC--General
	HYPOTHESES	INDICATORS
RQ_T_EMI_Gen_Perf_01: Does the steering intervention indeed mitigate and not aggravate the collision as compared to braking or doing nothing?	**Hyp_T_EMI_gen_04:** The (steering) intervention mitigates the collision and does not aggravate it.	- TTC (at intervention) - impact speed - impact orientation - speed reduction (mean)
RQ_T_EMI_Gen_Perf_02: How much is the collision mitigated?	**Hyp_T_gen_safe_01:** The function reduces the impact speed.	- impact speed
RQ_T_Gen_Perf_03: What are the performance limitations of the function in relation to intervention in longitudinal and in lateral direction?	**Hyp_T_EMI_gen_03:** After intervention the situation was correctly perceived to be safe enough to stop the driver support.	- driver status (at returning of control) - longitudinal acceleration (at returning of control) - lateral acceleration (at returning of control) - yaw rate (at returning of control) - yaw angle (at returning of control) - steering wheel angle (at returning of control) - brake pedal angle (at returning of control) - brake pressure / force (at returning of control)

B.1.23.Technical research questions and hypotheses: Perception		EMIC--General
	HYPOTHESES	INDICATORS
RQ_T_EMI_Gen_Perc_01: Is an avoiding steering reaction of the driver recognised?	**Hyp_T_EMI_gen_01:** The function always recognizes the avoiding steering action of the driver (in the scenarios).	- steering wheel angle (at intervention)
RQ_T_EMI_Gen_TecU_01: Is a too weak/strong reaction of the driver recognised?	**Hyp_T_EMI_gen_02:** Too weak or too strong reaction of the driver is recognized.	- error between driver input and required input as calculated by the logic (max)
	Hyp_T_EMI_gen_03: After intervention the situation was correctly perceived to be safe enough to stop the driver support.	- driver status (at returning of control) - longitudinal acceleration (at returning of control) - lateral acceleration (at returning of

		control) - yaw rate (at returning of control) - yaw angle (at returning of control) - steering wheel angle (at returning of control) - brake pedal angle (at returning of control) - brake pressure / force (at returning of control)
	Hyp_T_EMI_gen_04: The (steering) intervention mitigates the collision and does not aggravate it.	- TTC (at intervention) - impact speed - impact orientation - speed reduction (mean)
RQ_T_EMI_Gen_Perc_03, RQ_T_EMI_Gen_TecU_02: How is the situation assessed to be safe enough to terminate the assistance and give back the control to the driver?	**Hyp_T_EMI_gen_03:** After intervention the situation was correctly perceived to be safe enough to stop the driver support.	- driver status (at returning of control) - longitudinal acceleration (at returning of control) - lateral acceleration (at returning of control) - yaw rate (at returning of control) - yaw angle (at returning of control) - steering wheel angle (at returning of control) - brake pedal angle (at returning of control) - brake pressure / force (at returning of control)
RQ_T_EMI_Gen_Perc_04: Is an avoidance manoeuvre of the driver recognised well?	**Hyp_T_EMI_gen_01:** The function always recognizes the avoiding steering action of the driver (in the scenarios).	- steering wheel angle (at intervention)

B.1.24.Technical research questions and hypotheses: Full function performance		**EMIC-- COLLISION MITIGATION SYSTEM**
	HYPOTHESES	**INDICATORS**
RQ_T_EMI_CMS_Perf_01: Does the function intervene in a way to mitigate the collision?	**Hyp_T_gen_safe_09:** The function intervenes before the accident (in the scenario).	- TTC (at start of activation) - Distance to target object - (longitudinal - at start of activation) - THW (at start of activation)

RQ_T_EMI_CMS_Perf_02: Is the crash compatibility improved by the autonomous steering action?	**Hyp_T_gen_safe_01:** The function reduces the impact speed.	- impact speed
	Hyp_T_gen_safe_03: The function improves the orientation of the car for impact.	- impact orientation

B.1.25.Technical research questions and hypotheses: Perception		**EMIC---EMERGENCY STEER ASSIST**
	HYPOTHESES	**INDICATORS**
RQ_T_EMI_ESA_Perc_02: After intervention is the situation correctly perceived to be safe enough to stop the driver support?	**Hyp_T_EMI_gen_03:** After intervention the situation was correctly perceived to be safe enough to stop the driver support.	- driver status (at returning of control) - longitudinal acceleration (at returning of control) - lateral acceleration (at returning of control) - yaw rate (at returning of control) - yaw angle (at returning of control) - steering wheel angle (at returning of control) - brake pedal angle (at returning of control) - brake pressure / force (at returning of control)

B.2. User-related research questions and hypotheses

B.2.1. User-related research questions and hypotheses: Driver behaviour		**General**
	HYPOTHESES	**INDICATORS**
RQ_U_Gen_Beh_02: Is there any difference in speed behaviour when driving with the system / function compared to driving without the	**Hyp_U_Gen_Beh_01:** Driving speed does not differ when driving with the function compared to driving without the function.	- speed profile - spot speed at selected sections - speed variance

system?		
RQ_U_Gen_Beh_03: Is there any difference in the number of traffic conflicts when driving with the system / function compared to driving without the system?	**Hyp_U_Gen_Beh_02:** The number and/or the severity of traffic conflicts do not differ when driving with the function compared to driving without the function.	- number of traffic conflicts - severity of traffic conflicts
RQ_U_Gen_Beh_04: Is there any difference in the alarm lengths when driving with the system / function output activated compared to driving with deactivated system / function output?	**Hyp_U_Gen_Beh_03:** There is no difference in alarm length when driving with the function compared to driving without the function.	- alarm length (s)
RQ_U_Gen_Beh_05: What is the driver's time of reaction to warnings?	**Hyp_U_Gen_Beh_04[21]:** There is no difference in temporal point of reaction (TPR) when driving with the function compared to driving without the function.	- TPR (s), warning to accelerator release - TPR(s), warning to brake press - TPR (s). warning to steering wheel response
RQ_U_Gen_Beh_06: Is there any difference in headway when driving with the system / function compared to driving without the system?	**Hyp_U_Gen_Beh_05:** There is no difference in time distance to the vehicle ahead when driving with the function compared to driving without the function.	- time distance (s) to the vehicle ahead
RQ_U_Gen_Beh_07: Is there any difference in lane keeping behaviour when driving with the system / function compared to driving without the system?	**Hyp_U_Gen_Beh_06:** There is no difference in lane keeping when driving with the function compared to driving without the function.	- standard deviation of side position in the lane - mean side position in the lane
RQ_U_Gen_Beh_08: Is there any difference in lane change behaviour	**Hyp_U_Gen_Beh_07:** There is no difference in lane changing behaviour when driving with the function	- rate correct lane changes/total lane changes

[21] The temporal point of reaction is measured from the moment the sensor detects a critical situation until driver response

when driving with the system / function compared to driving without the system?	compared to driving without the function.	
RQ_U_Gen_Beh_09: Is there any difference in interaction with other road users when driving with the system / function compared to driving without the system?	**Hyp_Hyp_U_Gen_Beh_08:** There is no difference in correct interaction behaviour when driving with the function compared to driving without the function.	- number of correct interactions with other road users

B.2.2. User-related research questions and hypotheses: Trust and acceptance		General
	HYPOTHESES	**INDICATORS**
RQ_U_Gen_T&A_01: To which extent does the driver trust the system / function?	**Hyp_U_Gen_T&A_01:** The driver trusts the function	- interview - questionnaire items
RQ_U_Gen_T&A_02: What is the perceived safeness of the driver?	**Hyp_U_Gen_T&A_03:** The driver perceives the function as being safe	- questionnaire items
RQ_U_Gen_T&A_03: Does the driver correctly perceive the way or level of control that the system / function provides (delegation of responsibility)	**Hyp_U_Gen_Use_02:** The driver does not delegate responsibility for tasks that the function is not designed for.	- number of looks in rear / side mirrors - use of turning indicator - gear changing behaviour
RQ_U_Gen_T&A_04: To what extent the driver finds the system / function useful and / or satisfying?	**Hyp_U_Gen_T&A_02:** The driver finds the function useful and satisfying	- van der Laan acceptance questionnaire
RQ_U_Gen_T&A_05: What advantages and what disadvantages does the driver feel when driving with the system?	**Hyp_U_Gen_T&A_04:** What are the advantages and disadvantages with the function	- interview questions regarding advantages/disadvantages

RQ_U_Gen_T&A_06: Would the drivers like to have the system in their own cars?	**Hyp_U_Gen_T&A_05:** The driver would like to have this function installed in his/her car/truck if it was available in the aftermarket.	- questionnaire items on willingness to buy
RQ_U_Gen_T&A_07: What price would they be willing to pay for the system?	**Hyp_U_Gen_T&A_06:** The price the driver is willing to pay for the function is the same as the price of a currently available ADAS designed for a similar target scenario.	- questionnaire item with willing---to---pay price ranges

B.2.3. User-related research questions and hypotheses: System usage		**General**
	HYPOTHESES	**INDICATORS**
RQ_U_Gen_Use_01: Does the driver use the system as it was intended to be used?	**Hyp_U_Gen_Use_01:** The driver uses the function as it is intended to be used.	- number of times the driver uses/reacts to the function as intended.
RQ_U_Gen_Use_02: Is the driver's emotional state influenced when driving with the system?	**Hyp_U_Gen_Use_03:** The driver's emotional state is not influenced when driving with the function compared to driving without the function.	- self assessed emotional response (valence/activation) - physiological response (valence/activation)
RQ_U_Gen_Use_03: Is work---load influenced when driving with the system?	**Hyp_U_Gen_Use_02:** The driver does not delegate responsibility for tasks that the function is not designed for.	- number of looks in rear / side mirrors - use of turning indicator - gear changing behaviour
	Hyp_U_Gen_Use_04: The driver's mental workload is not influenced when driving with the function compared to driving without the function.	- Raw Task Load Index (RTLX)
RQ_U_Gen_Use_04: How does the driver perceive and understand the transition of control between the driver and the vehicle?	**Hyp_U_Gen_Use_05:** The driver perceives and understands the transition of control between the driver and the vehicle in the correct way	- interviews - questionnaire items - online ratings

B.2.4. User-related research questions and hypotheses: Driver behaviour		SECONDS-CONTINUOUS SUPPORT
	HYPOTHESES	**INDICATORS**
RQ_U_Gen_Beh_01: How does the system affect driver behaviour in the different scenarios defined? (Both intended and unintended effects should be considered)	**Hyp_U_SEC_CS_Beh_01:** Driver attention to blind spot does not differ when driving with the function compared to driving without the function.	- number of gazes at rear mirrors - number of blind spot checks above shoulder
	Hyp_U_SEC_CS_Beh_02: Yield/stop behaviour at intersections does not differ when driving with the function compared to driving without the function.	- Percentage correct yield/stop behaviour of total at intersections
	Hyp_U_SEC_CS_Beh_03: Speed adaptation at critical sites does not differ when driving with the function compared to driving without the function.	- speed profile, spot speed at selected sites
	Hyp_U_SEC_CS_Beh_04: Speed limit exceeding does not differ when driving with the function compared to driving without the function.	- percentage of driving time above speed limit - Maximum speed exceeding - Mean of difference between driven speed and given speed limit

B.2.5. User-related research questions and hypotheses: Driver behaviour		SECONDS-CURVE SPEED CONTROL
	HYPOTHESES	**INDICATORS**
RQ_U_Gen_Beh_01: How does the system affect driver behaviour in the different scenarios defined? (Both intended and unintended effects should be considered)	**Hyp_U_SEC_CSC_Beh_01:** Speed adaptation in curves does not differ when driving with the function compared to driving without the function.	- speed profile, spot speed at curve entry and curve apex

B.2.6. User-related research questions and hypotheses: Driver behaviour		SECONDS-ENHANCED DYNAMIC PASS PREDICTOR
	HYPOTHESES	**INDICATORS**
RQ_U_Gen_Beh_01: How does the system affect driver behaviour in the different scenarios defined? (Both intended and unintended effects should be considered)	**Hyp_U_SEC_eDPP_Beh_01:** Overtaking behaviour does not differ when driving with the function compared to driving without the function.	- number of initiated/aborted overtakings - Minimum distance to an upcoming vehicle

B.2.7. User-related research questions and hypotheses: Driver behaviour		SECONDS-SAFE CRUISE
	HYPOTHESES	**INDICATORS**
RQ_U_Gen_Beh_01: How does the system affect driver behaviour in the different scenarios defined? (Both intended and unintended effects should be considered)	**Hyp_U_SEC_SC_Beh_01:** The driver is engaged in no more/less secondary task when driving with the function compared to driving without the function.	- number of initiated secondary tasks during driving - Accumulated time for conducting secondary tasks
	Hyp_U_SEC_SC_Beh_02: Speed limit exceeding does not differ when driving with the function compared to driving without the function.	- percentage of driving time above speed limit - Maximum speed exceeding - Mean of difference between driven speed and given speed limit

B.2.8. User-related research questions and hypotheses: Driver behaviour		INCA
	HYPOTHESES	**INDICATORS**
RQ_U_Gen_Beh_01: How does the system affect driver behaviour in the	**Hyp_U_INC_Beh_01:** The driver does not (try to) override the active intervention. (by accelerating, counter	- driver counteractions (accelerate, brake, steer)

different scenarios defined? (Both intended and unintended effects should be considered)	steering)	- interview (corroborative)
	Hyp_U_INC_Beh_02: Situational control during intervention is not modulated by a (pre-) warning.	- driver counteractions (accelerate, brake, steer) - alarm length (see Hyp_U_Gen_Beh_03) - number/severity of traffic conflicts (see Hyp_U_Gen_Beh_02) - interview (corroborative)
	Hyp_U_INC_Beh_03: Driver attention to blind spot does not differ when driving with the function compared to driving without the function.	- number of gazes at rear mirrors - number of blind spot checks above shoulder (applicable to car demonstrators only
B.2.9. User--related research questions and hypotheses: Driver behaviour		**EMIC--COLLISION MITIGATION SYSTEM**
	HYPOTHESES	**INDICATORS**
RQ_U_Gen_Beh_06: Is there any difference in headway when driving with the system / function compared to driving without the system?	**Hyp_U_EMI_CMS_Beh_01[22]:** Driver behaviour at intersections doesn't change with the function compared to driving without the function.	- Number of lane changes at intersections - Mean distance to lead vehicle at intersections - Lane position in intersections - Idle time at intersections -
RQ_U_Gen_Beh_07: Is there any difference in lane keeping behaviour when driving with the system / function compared to driving without the system?	**Hyp_U_EMI_CMS_Beh_01:** Driver behaviour at intersections doesn't change with the function compared to driving without the function**.**	- Number of lane changes at intersections - Mean distance to lead vehicle at intersections - Lane position in intersections - Idle time at intersections
	Hyp_U_EMI_CMS_Beh_02[23]: There is no difference in lane keeping when driving with the function compared to driving without the function.	- standard deviation of side position in the lane

[22] This hypothesis is not relevant for CMS function

[23] This hypothesis is not relevant for CMS function

RQ_U_Gen_Beh_08: Is there any difference in lane change behaviour when driving with the system / function compared to driving without the system?	**Hyp_U_EMI_CMS_Beh_01:** Driver behaviour at intersections doesn't change with the function compared to driving without the function.	- Number of lane changes at intersections - Mean distance to lead vehicle at intersections - Lane position in intersections - Idle time at intersections
RQ_U_Gen_Beh_09: Is there any difference in interaction with other road users when driving with the system / function compared to driving without the system?	**Hyp_U_EMI_CMS_Beh_01:** Driver behaviour at intersections doesn't change with the function compared to driving without the function.	- Number of lane changes at intersections - Mean distance to lead vehicle at intersections - Lane position in intersections - Idle time at intersections
B.2.10. User-related research questions and hypotheses: Driver behaviour		**EMIC--EMERGENCY STEER ASSIST**
	HYPOTHESES	**INDICATORS**
RQ_U_Gen_Beh_09: Is there any difference in interaction with other road users when driving with the system / function compared to driving without the system?	**Hyp_U_EMI_ESA_Beh_01:** The driver behaviour in front of an obstacle (pedestrian, unparked vehicle, end of traffic jam) in the road doesn't change with the function compared to driving without the function.	- behaviour in front an obstacle in terms of speed, steering wheel angle and maximum steering velocity

B.2.11. User-related research questions and hypotheses: Trust and acceptance		**EMIC--GENERAL**
	HYPOTHESES	**INDICATORS**
RQ_U_Gen_T&A_03: Does the driver correctly perceive the way or level of control that the system / function provides (delegation of responsibility)	**Hyp_U_EMI_T&A_01:** The driver perceives correctly the level of control that the function provides.	- level of control

B.3. Safety Impact assessment questions and hypotheses

B.3.1. Safety Impact assessment questions and hypotheses		General
	HYPOTHESES	**INDICATORS**
RQ_I_GEN_01: Does the function improve the traffic safety?	**Hyp_I_Gen_01:** The function improves the traffic safety.	- number of accidents - reduction of the accident severity
RQ_I_GEN_02: Does the function reduce the number of accidents?	**Hyp_I_Gen_02:** The function decreases the number of accidents.	- Accidents rate; - max longitudinal relative velocity at which an accident is avoided - max lateral relative velocity at which an accident is avoided; - lateral acceleration required to avoid collision, when warning is given or the function starts to intervene - longitudinal acceleration required to avoid collision, when warning is given or the function starts to intervene
RQ_I_GEN_03: Does the function reduce the accident severity?	**Hyp_I_Gen_03:** The function decreases the severity of accidents.	- mean (impact speed) - max speed reduction - mean speed reduction - speed at warning - speed at starting of intervention - reduction of kinematic energy by intervention - min speed reduction - location point of impact - impact orientation - mass of vehicle

RQ_I_GEN_04: Is the safety impact of a function influenced by another function, which is integrated in the demonstrator vehicle?	**Hyp_I_Gen_04**[24]**:** The safety impact of the function is not negatively influenced by another function.	- function warning status - function intervention status - function specification
RQ_I_GEN_05: In which way do the interactIVe functions try to avoid accidents or mitigate the accidents' consequences?	**Hyp_I_Gen_07:** Evasive manoeuvre will not be executed in congested traffic situations.	- function intervention status; - intervention rate
	Hyp_I_INC_02: The function will try to avoid imminent accidents more often by braking than steering.	- maximum longitudinal acceleration - maximum lateral acceleration - function intervention status
	Hyp_I_INC_03: The function will try to mitigate accident more often by braking than steering.	- maximum longitudinal acceleration - maximum lateral acceleration - function intervention status
	Hyp_I_EMI_01: The function will try to mitigate accident more often by braking than steering.	- maximum longitudinal acceleration - maximum lateral acceleration - function intervention status
RQ_I_GEN_06: Is the safety effect of the function compensated by a change in the driver behaviour?	**Hyp_I_Gen_06:** The function will avoid also accidents in scenarios, in which more than one other vehicle is involved.	- accident status in test scenarios - function intervention status
RQ_I_GEN_07: Could an intervention of the function result in a situation worse than the initial situation?	**Hyp_I_Gen_16:** The intervention of the function will not result in a worse situation.	- impact orientation; - location point of impact - impact speed
RQ_I_GEN_08: Does the intervention rate increases over time?	**Hyp_I_Gen_13:** The number of warnings will not increase as a consequence of the driver relying too much on the function	- Alarm rate
	Hyp_I_Gen_14: The number of interventions will not increase as a consequence of the driver relying too much on the function.	- Intervention rate

[24] Only relevant if more than one function are integrated in the demonstrator vehicle

	Hyp_I_Gen_15: The intervention rate will not increase over time.	- intervention rate

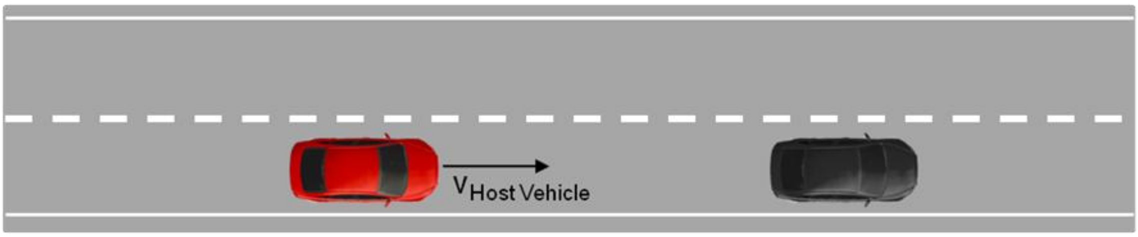
B.3.2. Safety Impact assessment questions and hypotheses		SECONDS
	HYPOTHESES	**INDICATORS**
RQ_I_SEC_11: Does the Safe Cruise function influence the average THW?	**Hyp_I_SEC_01:** Safe Cruise increases the average THW.	- average THW
RQ_I_SEC_12: Does the Safe Cruise function influence the average speed?	**Hyp_I_SEC_02:** Safe Cruise decreases average speed.	- Mean speed -
RQ_I_SEC_13: Does the Curve Speed Control function increase fuel efficiency?	**Hyp_I_SEC_03:** The usage of the function reduces the fuel consumption.	- fuel consumption - mean speed - standard deviation speed - mean longitudinal acceleration - standard deviation longitudinal acceleration

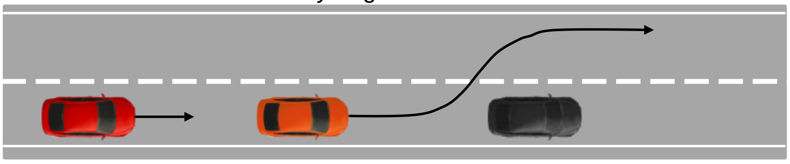
B.3.3. Safety Impact assessment questions and hypotheses		INCA
	HYPOTHESES	**INDICATORS**
RQ_I_INC_07: Is there a difference related to the safety impact between the INCA function for the passenger cars and for the commercial trucks?	**Hyp_I_INC_01:** The safety impact of the function will be equal for passenger cars and trucks.	- number of accidents - reduction of the accident severity

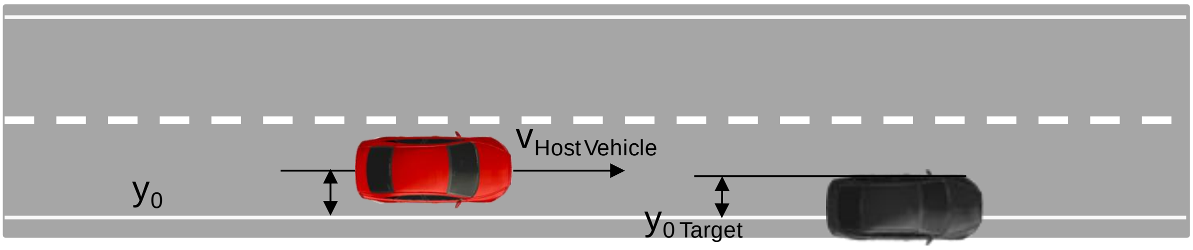
Annex D: Updated test scenarios

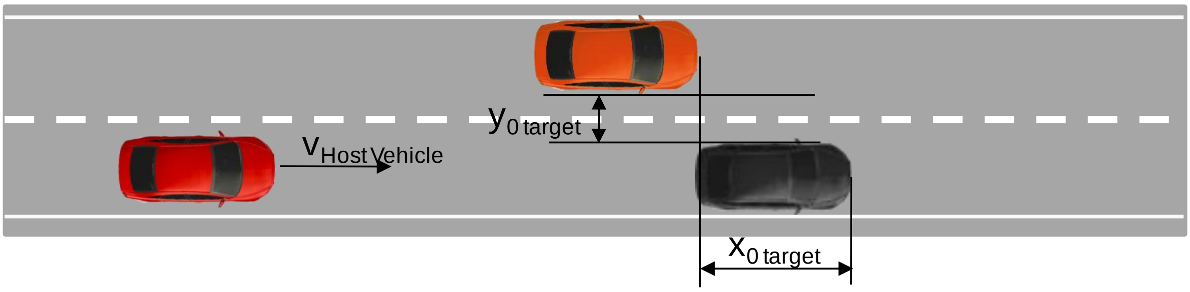
In the following sections the test cases for the interactIVe functions are described. The test case will be conducted within the technical and user-related assessment. For the impact assessment no specific tests will be conducted. But the impact assessment will base on the test results of the technical and user-related assessment. Therefore the test cases are indirectly also relevant for the impact assessment.

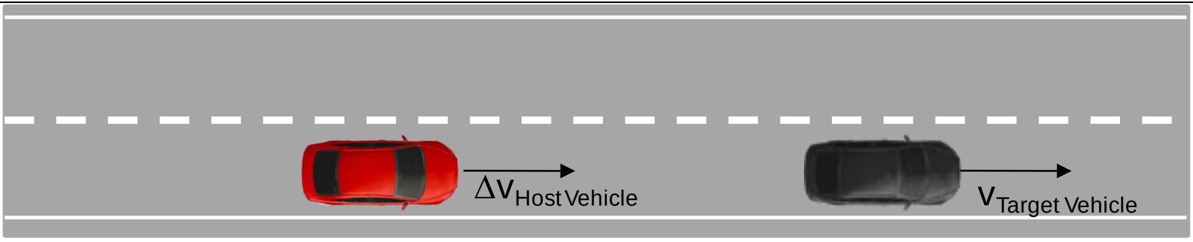
1. Rear-end collision

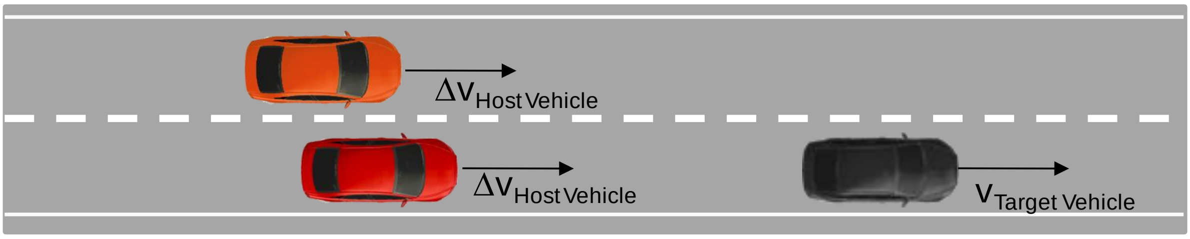
<table>
<tr><td>Test Scenario</td><td>Rear-end collision</td></tr>
<tr><td>Test Case</td><td>1.1</td></tr>
<tr><td colspan="2">Approaching stationary target</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Description</td><td>Host vehicle approaches a stand still target object. The host vehicle drives in the centre of the lane and the target is positioned in the centre of the lane.</td></tr>
<tr><td>Relevant functions</td><td>CS, RECA, CM, ESA</td></tr>
<tr><td>Use case</td><td>UC_01_531_v1, UC_01_601_v2, UC_01_602_v2, UC_01_603_v3</td></tr>
<tr><td>Vehicle initial parameters</td><td><table><tr><td>$v_{Host\ Vehicle}$[4] [km/h]</td><td>50[2]</td><td>60</td><td>70[1]</td><td>80[1]</td><td>100[1]</td></tr></table></td></tr>
<tr><td>Number vehicles</td><td>1 (+ 1 stationary target)</td></tr>
<tr><td>Required Equipment</td><td>1 stationary target (balloon car)</td></tr>
<tr><td>Environmental initial parameters</td><td><table>
<tr><td>Road radius</td><td>∞</td><td>500 m [5]</td><td></td></tr>
<tr><td>driven lane</td><td>right</td><td>left</td><td>middle[3]</td></tr>
<tr><td>number of lanes</td><td>1</td><td>2</td><td>3[3]</td></tr>
<tr><td>loading of vehicle (only relevant for trucks)</td><td>Basic</td><td>Fully loaded</td><td></td></tr>
</table>
The tests for the environmental initial parameters should only be conducted for one velocity (velocity at which the vehicle intervenes by steering - if the function only intervenes by braking the different environmental parameters don’t have to be tested) If the function intervenes by a combination of braking and steering a second test of the environmental parameters with this velocity is necessary.
Standard scenario (use for all other tests): straight road with 2 lanes and the vehicle is driving in the right lane.</td></tr>
<tr><td>Assessment</td><td>☒ Technical ☒ User-related</td></tr>
<tr><td>Driver reaction (only relevant for the technical assessment)</td><td>a) Normal scenario
• No reaction of the driver on any warning or intervention before the highest warning level is reached (afterwards the reaction of the driver depends on function).
• Driving with constant speed
b) In order to check, whether the function is overrideable the driver should press after warning / intervention of the function:
• Brake pedal (kick down)
• Accelerator pedal (kick down)</td></tr>
</table>

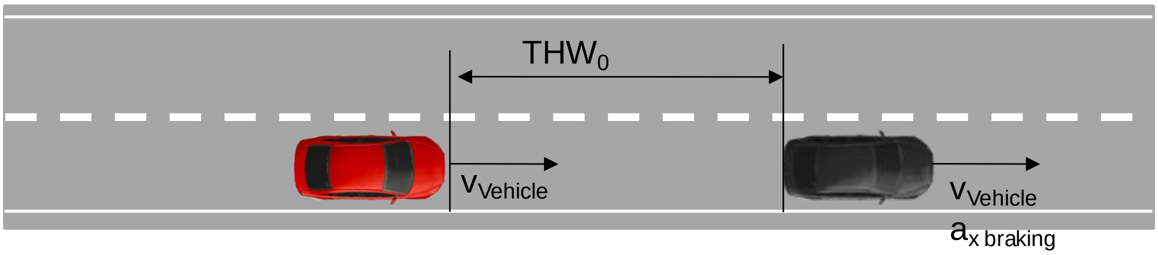
	• Steering wheel (evasive manoeuvre by driver) Only tested for one or two parameter configurations (e.g. 50 km/h straight; right lane; 1 lane)
Comment	1: It need to be verified, whether the tests could be done without damaging the demonstrator vehicle. 2: Speed range of the function need to be considered 3: 3 lanes scenario is only tested in combination with driving lane "middle" 4: The speed range should cover all possible scenarios (automatic braking and steering). If steering at 50 kph, additional test at 30 kph. First test with full load. If successful, no test for empty load needed. 5: first tested for maximum speed (empty load?). If there is no effect on behaviour, no further tests for this parameter is needed. c) For the user-related test in INCA on a test track the test case will be adapted: In this test there is a vehicle with a covered back windshield in front of the host vehicle. The driver should perform some subtasks (e.g. change CD). In this moment the lead vehicle suddenly gears of track and the driver notice the stationary target in front of the host vehicle.  Sequence of testing: In order to reduce the testing effort the following test sequence is proposed 1. Start testing with standard scenario and $v_{Host\ Vehicle}$ 50 km/h 2. Increase $v_{Host\ Vehicle}$ step by step up to the point, when the function intervenes only by steering. After this tests can be stopped, because it is assumed that there is no change in the function behaviour. 3. Test for the velocity, at which the function reacts by only by a steering manoeuvre the different environmental conditions.

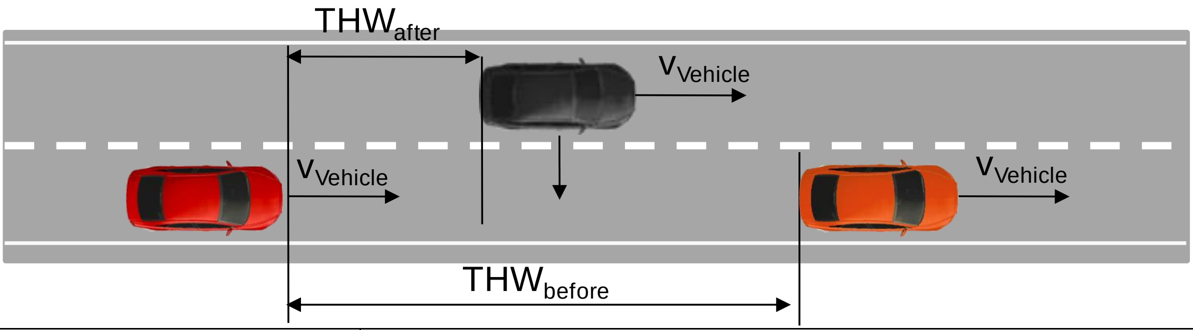
<table>
<tr><td>Test Scenario</td><td>Rear-end collision</td></tr>
<tr><td>Test Case</td><td>1.2</td></tr>
<tr><td colspan="2">Approaching parking target</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Description</td><td>Host vehicle approaches a stand still target object. The position of the target vehicle depends on the test. But there is an offset between the host vehicle and the target.</td></tr>
<tr><td>Relevant functions</td><td>CS, SC, RECA, CM, ESA</td></tr>
<tr><td>Use case</td><td>UC_01_531_v1, UC_01_601_v2, UC_01_602_v2, UC_01_603_v3</td></tr>
<tr><td>Vehicle initial parameters</td><td><table>
<tr><td>y_0 [m]</td><td colspan="3">Middle of the lane (1,85 m)</td></tr>
<tr><td>$v_{Host Vehicle}$ [km/h]</td><td>50</td><td>80[1]</td><td></td></tr>
<tr><td>$y_{0\ Target}$ [m]</td><td>0</td><td>0.75</td><td>1.5</td></tr>
</table></td></tr>
<tr><td>Number vehicles</td><td>1 (+ 1 stationary target (balloon car))</td></tr>
<tr><td>Required Equipment</td><td>1 stationary target (balloon car) or real vehicle can be used for not crash relevant scenarios</td></tr>
<tr><td>Environmental initial parameters</td><td><table>
<tr><td>Road radius</td><td>∞</td><td></td></tr>
<tr><td>driven lane</td><td>Right</td><td></td></tr>
<tr><td>number of lanes</td><td>2</td><td></td></tr>
<tr><td>loading of vehicle (only relevant for trucks)</td><td>Basic</td><td>Fully loaded</td></tr>
</table>
For SC: driver view direction should also be changed in order to test the function switch off behaviour.</td></tr>
<tr><td>Assessment</td><td>☒ Technical ☒ User-related</td></tr>
<tr><td>Driver reaction (only relevant for the technical assessment)</td><td>No reaction of the driver on any warning or intervention before the highest warning level is reached (afterwards the reaction of the driver depends on function).
Driving with constant speed
The driver should drive straight and no perform any evasive manoeuvre</td></tr>
<tr><td>Comment</td><td>1: It need to be verified, whether the tests could be done without damaging the demonstrator vehicle.
This test case includes tests with the danger of a collision (activation of the function required) and test without a danger of collision (no activation of the function required)</td></tr>
</table>

<table>
<tr><th>Test Scenario</th><th>Rear-end collision</th></tr>
<tr><th>Test Case</th><th>1.3</th></tr>
<tr><td colspan="2">Approaching end of traffic jam</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Description</td><td>Host vehicle approaches the end of a traffic jam. Both lanes are blocked by other vehicles. The position of the targets depends on the test.</td></tr>
<tr><td>Relevant functions</td><td>CS, SC, RECA, CMS</td></tr>
<tr><td>Use case</td><td>UC_01_531_v1, UC_01_601_v2, UC_01_602_v2, UC_01_603_v3</td></tr>
<tr><td>Vehicle initial parameters</td><td><table>
<tr><td>$v_{Host Vehicle}$ [km/h]</td><td>50</td><td>80[1]</td><td></td></tr>
<tr><td>$x_{0\ Traget}$ [m]</td><td>-25</td><td>0</td><td>25</td></tr>
<tr><td>$y_{0\ Traget}$ [m]</td><td>1.5</td><td>3[2]</td><td></td></tr>
</table></td></tr>
<tr><td>Number vehicles</td><td>1 (+ 2 stationary targets)</td></tr>
<tr><td>Required Equipment</td><td>2 stationary targets (balloon car)</td></tr>
<tr><td>Environmental initial parameters</td><td><table>
<tr><td>Road radius</td><td>∞</td><td></td></tr>
<tr><td>driven lane</td><td>Right</td><td></td></tr>
<tr><td>number of lanes</td><td>2</td><td></td></tr>
<tr><td>loading of vehicle (only relevant for trucks)</td><td>Basic</td><td>Fully loaded</td></tr>
</table></td></tr>
<tr><td>Assessment</td><td>☒ Technical ☐ User-related</td></tr>
<tr><td>Driver reaction (only relevant for the technical assessment)</td><td>No reaction of the driver on any warning or intervention before the highest warning level is reached (afterwards the reaction of the driver depends on function).
Driving with constant speed</td></tr>
<tr><td>Comment</td><td>In at least one test the $\Delta y_{0\ Target}$ should be too small for an evasive manoeuvre and in at least one test the gap should be sufficient for an evasive manoeuvre.
1: It need to be verified, whether the tests could be done without damaging the demonstrator vehicle.
2: longitudinal distance between static vehicles.</td></tr>
</table>

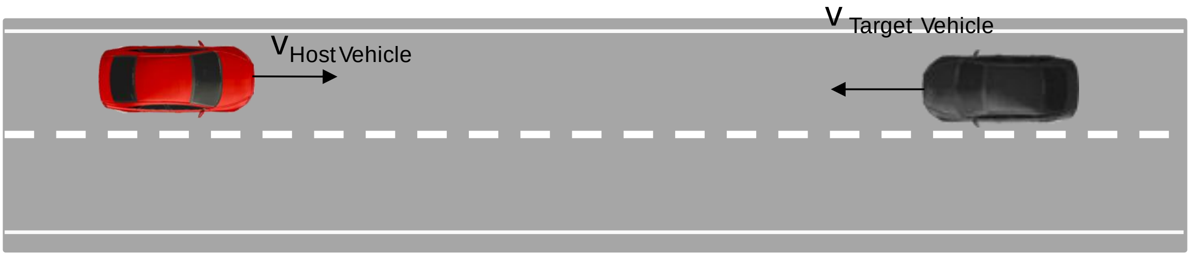
<table>
<tr><th>Test Scenario</th><th>Rear-end collision</th></tr>
<tr><td>Test Case</td><td>1.4</td></tr>
<tr><td colspan="2">Approaching slower vehicle</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Description</td><td>The host vehicle approaches a front vehicle with a higher speed. Both vehicles drive in the centre of the lane. The target keeps a constant speed during the whole manoeuvre</td></tr>
<tr><td>Relevant functions</td><td>CS, SC, RECA, CM, ESA</td></tr>
<tr><td>Use case</td><td>UC_01_401_v2, UC_01_531_v1</td></tr>
<tr><td>Vehicle initial parameters</td><td><table><tr><td>$\Delta v_{Host\ Vehicle}$ [km/h]</td><td>20</td><td>30[1]</td><td>50[1]</td></tr><tr><td>$v_{Target\ vehicle}$ [km/h]</td><td>20</td><td>50[1]</td><td>80[1]</td></tr></table></td></tr>
<tr><td>Number vehicles</td><td>1 (+1 moving target)</td></tr>
<tr><td>Required Equipment</td><td>1 moving target (moving balloon car / rabbit vehicle)</td></tr>
<tr><td>Environmental initial parameters</td><td><table><tr><td>Road radius</td><td>∞</td><td></td><td></td></tr><tr><td>driven lane</td><td>right</td><td>left</td><td>middle[2]</td></tr><tr><td>Number of lanes</td><td>1</td><td>2</td><td>3[2]</td></tr><tr><td>loading of vehicle (only relevant for trucks)</td><td>Basic</td><td>Fully loaded</td><td></td></tr></table>The tests for the environmental initial parameters should only be conducted for one velocity (velocity at which the vehicle intervenes by steering - if the function only intervenes by braking the different environmental parameters don’t have to be tested) If the function intervenes by a combination of braking and steering a second test of the environmental parameters with this velocity is necessary.</td></tr>
<tr><td>Assessment</td><td>☒ Technical ☐ User-related</td></tr>
<tr><td>Driver reaction (only relevant for the technical assessment)</td><td>No reaction of the driver on any warning or intervention before the highest warning level is reached (afterwards the reaction of the driver depends on function).
Driving with constant speed</td></tr>
<tr><td>Comment</td><td>1: It needs to be verified, whether the tests could be done without damaging the demonstrator vehicle and if the available Target could reach this speed.
2: 3 lanes scenario is only tested in combination with driving lane “middle”</td></tr>
</table>

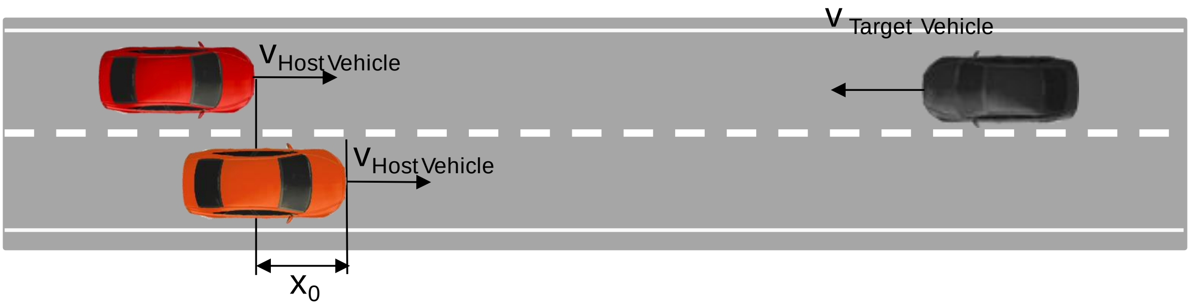
<table>
<tr><td>Test Scenario</td><td>Rear-end collision</td></tr>
<tr><td>Test Case</td><td>1.5</td></tr>
<tr><td colspan="2">Approaching slower vehicle, left lane blocked by other vehicle</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Description</td><td>The host vehicle approaches a front vehicle with a higher speed. Both vehicles drive in the centre of the lane. The target keeps a constant speed during the whole manoeuvre. An evasive manoeuvre is not possible, because the left lane is blocked by another vehicle</td></tr>
<tr><td>Relevant functions</td><td>CS, SC, RECA</td></tr>
<tr><td>Use case</td><td>UC_01_401_v2, UC_01_531_v1</td></tr>
<tr><td>Vehicle initial parameters</td><td><table><tr><td>$\Delta v_{Host\ Vehicle}$ [km/h]</td><td>30[1]</td><td>50[1]</td></tr><tr><td>$v_{Target\ vehicle}$ [km/h]</td><td>20</td><td>50[1]</td></tr></table></td></tr>
<tr><td>Number vehicles</td><td>1 (+ 2 moving target)</td></tr>
<tr><td>Required Equipment</td><td>2 moving target (moving balloon car / rabbit vehicle) or one real vehicle instead of a target object</td></tr>
<tr><td>Environmental initial parameters</td><td><table><tr><td>Road radius</td><td>∞</td><td></td></tr><tr><td>Number of lanes</td><td>2</td><td></td></tr><tr><td>Driven lane</td><td>right</td><td></td></tr><tr><td>loading of vehicle (only relevant for trucks)</td><td>Basic</td><td>Fully loaded</td></tr></table></td></tr>
<tr><td>Assessment</td><td>☒ Technical ☐ User-related</td></tr>
<tr><td>Driver reaction (only relevant for the technical assessment)</td><td>• No reaction of the driver on any warning or intervention before the highest warning level is reached (afterwards the reaction of the driver depends on function).
• Driving with constant speed</td></tr>
<tr><td>Relevant Indicators</td><td></td></tr>
<tr><td>Comment</td><td>1: It needs to be verified, whether the tests could be done without damaging the demonstrator vehicle and if the available Target could reach this speed.</td></tr>
</table>

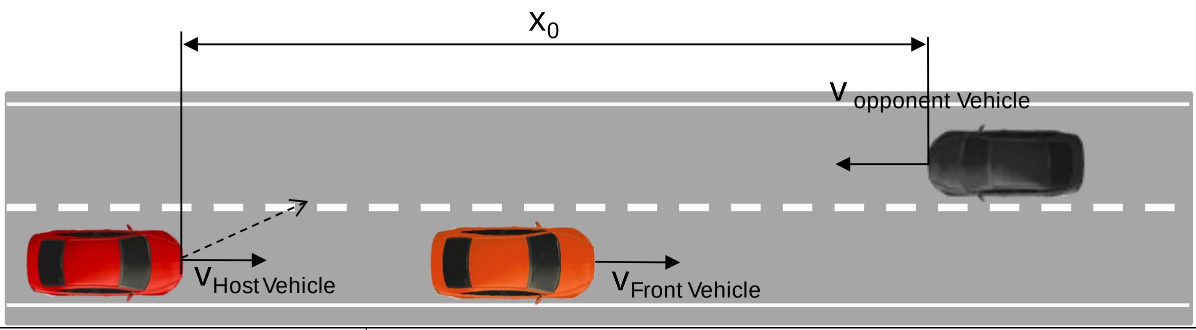
<table>
<tr><td>Test Scenario</td><td>Rear-end collision</td></tr>
<tr><td>Test Case</td><td>1.7</td></tr>
<tr><td colspan="2">Braking front vehicle</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Description</td><td>The host vehicle follows a lead vehicle with at short THW (~ 1s or less). The front vehicle suddenly starts to brake with a defined deceleration.</td></tr>
<tr><td>Relevant functions</td><td>CS, SC, RECA, CM, ESA</td></tr>
<tr><td>Use case</td><td>UC_01_402_v0, UC_01_504_v2, UC_01_531_v1, UC_01_601_v2</td></tr>
<tr><td>Vehicle initial parameters</td><td><table>
<tr><td>$v_{Host\ Vehicle}$ [km/h]</td><td>50</td><td>80[1]</td></tr>
<tr><td>$a_{x\ Target\ Vehicle}$ [m/s²]</td><td>-4</td><td>-7[4]</td></tr>
<tr><td>THW_0 [s] (Distance at start of Braking)</td><td>1[4]</td><td>2</td></tr>
</table>4:Not tested with 80 km/h</td></tr>
<tr><td>Number vehicles</td><td>1 (+ 1 moving target)</td></tr>
<tr><td>Required Equipment</td><td>1 moving target (balloon car)</td></tr>
<tr><td>Environmental initial parameters</td><td><table>
<tr><td>Road radius</td><td>∞</td><td></td><td></td></tr>
<tr><td>driven lane</td><td>right</td><td>left</td><td>middle[3]</td></tr>
<tr><td>Number of lanes</td><td>1</td><td>2</td><td>3[3]</td></tr>
<tr><td>loading of vehicle (only relevant for trucks)</td><td>Basic</td><td>Fully loaded</td><td></td></tr>
</table>The tests for the environmental initial parameters should only be conducted for one velocity (velocity at which the vehicle intervenes by steering - if the function only intervenes by braking the different environmental parameters don’t have to be tested) If the function intervenes by a combination of braking and steering a second test of the environmental parameters with this velocity is necessary.</td></tr>
<tr><td>Assessment</td><td>☒ Technical ☒ User-related</td></tr>
<tr><td>Driver reaction (only relevant for the technical assessment)</td><td>• No reaction of the driver on any warning or intervention before the highest warning level is reached (afterwards the reaction of the driver depends on function).
• Driving with constant speed</td></tr>
<tr><td>Comment</td><td>1: It needs to be verified, whether the tests could be done without damaging the demonstrator vehicle and if the available Target could reach this speed.
2: only tested for velocities high
3: 3 lanes scenario is only tested in combination with driving lane “middle”</td></tr>
</table>

<table>
<tr><td>Test Scenario</td><td>Rear-end collision</td></tr>
<tr><td>Test Case</td><td>1.8</td></tr>
<tr><td colspan="2">Cut-in</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Description</td><td>The host vehicle follows a lead vehicle at a certain distance. A second vehicle performs a cut-in manoeuvre. The host vehicle should detect the new target and adjust the distance according to the new target</td></tr>
<tr><td>Relevant functions</td><td>SC</td></tr>
<tr><td>Use case</td><td>-</td></tr>
<tr><td>Vehicle initial parameters</td><td><table>
<tr><td>$v_{Vehicle}$ [km/h]</td><td>50</td><td>80[1]</td></tr>
<tr><td>THW_{After} [s]</td><td>1[4]</td><td>1,5</td></tr>
<tr><td>THW_{Before} [s]</td><td>2[4]</td><td>3[1]</td></tr>
</table></td></tr>
<tr><td>Number vehicles</td><td>1 (+ 2 moving target)</td></tr>
<tr><td>Required Equipment</td><td>1 moving target (balloon car) / 2 real vehicle</td></tr>
<tr><td>Environmental initial parameters</td><td><table>
<tr><td>Road radius</td><td>∞</td><td></td><td></td></tr>
<tr><td>driven lane</td><td>right</td><td></td><td></td></tr>
<tr><td>Number of lanes</td><td></td><td>2</td><td></td></tr>
</table></td></tr>
<tr><td>Assessment</td><td>☒ Technical ☐ User-related</td></tr>
<tr><td>Driver reaction (only relevant for the technical assessment)</td><td>• No reaction of the driver on any warning or intervention before the highest warning level is reached (afterwards the reaction of the driver depends on function).
• Driving with constant speed</td></tr>
<tr><td>Comment</td><td>1: Or highest time gap setting.</td></tr>
</table>

2. Head on collisions

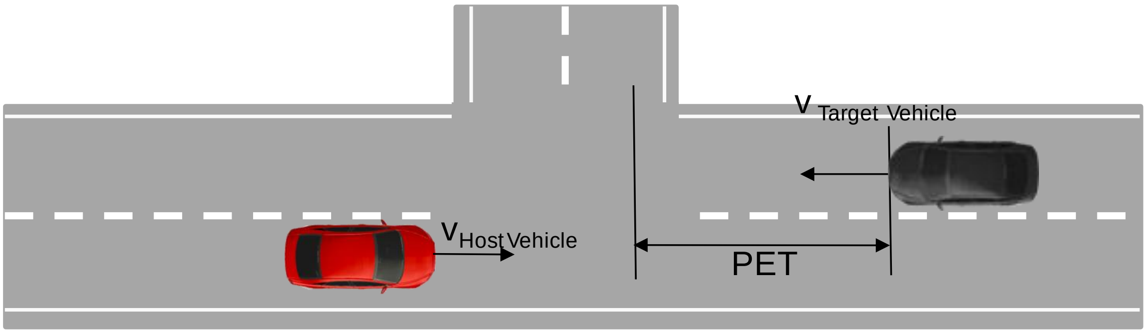
<table>
<tr><td>Test Scenario</td><td>Head on collisions</td></tr>
<tr><td>Test Case</td><td>2.1</td></tr>
<tr><td colspan="2">Oncoming vehicle while overtaking</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Description</td><td>Host vehicle drives in the opposite lane while there is oncoming vehicle in the same lane</td></tr>
<tr><td>Relevant functions</td><td>OCVA, CMS, eDPP</td></tr>
<tr><td>Use case</td><td>UC_02_434_v0, UC_02_501_v2, UC_02_532_v1, UC_02_534_v1, UC_02_604_v0</td></tr>
<tr><td>Vehicle initial parameters</td><td><table>
<tr><td>$v_{Host\ Vehicle}$ [km/h]</td><td>40[1]</td><td>64[1]</td><td>80[1]</td></tr>
<tr><td>$v_{Target\ Vehicle}$ [km/h]</td><td>40[1]</td><td>64[1]</td><td></td></tr>
</table></td></tr>
<tr><td>Number vehicles</td><td>1 (+ 1 moving target)</td></tr>
<tr><td>Required Equipment</td><td>1 moving target</td></tr>
<tr><td>Environmental initial parameters</td><td><table>
<tr><td>Road radius</td><td>∞</td><td></td></tr>
<tr><td>driven lane</td><td>left</td><td>right</td></tr>
<tr><td>Number of lanes</td><td>1 per driving direction</td><td></td></tr>
<tr><td>loading of vehicle (only relevant for trucks)</td><td>Basic</td><td>Fully loaded</td></tr>
</table></td></tr>
<tr><td>Assessment</td><td>☒ Technical ☒ User-related</td></tr>
<tr><td>Driver reaction (only relevant for the technical assessment)</td><td>• No reaction of the driver on any warning or intervention before the highest warning level is reached (afterwards the reaction of the driver depends on function).
• Driving with constant speed</td></tr>
<tr><td>Comment</td><td>Depending on available test tools additional safety actions might be necessary.
1: It needs to be verified, whether the tests could be done without damaging the demonstrator vehicle.</td></tr>
</table>

<table>
<tr><th>Test Scenario</th><th>Head on collisions</th></tr>
<tr><th>Test Case</th><th>2.3</th></tr>
<tr><td colspan="2">Oncoming vehicle (traffic) while overtaking</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Description</td><td>Host vehicle drives in its own lane while there is oncoming vehicle in the same lane. In the adjacent lane is another vehicle. Hence the host vehicle cannot evade into the initial lane.</td></tr>
<tr><td>Relevant functions</td><td>LCCA, OVCA</td></tr>
<tr><td>Use case</td><td>UC_02_434_v0, UC_02_501_v2, UC_02_532_v1, UC_02_534_v1, UC_02_604_v0</td></tr>
<tr><td>Vehicle initial parameters</td><td><table>
<tr><td>$v_{Host\ Vehicle}$ [km/h]</td><td>40[1]</td><td></td><td></td></tr>
<tr><td>$v_{Target\ Vehicle}$ [km/h]</td><td>40[1]</td><td></td><td></td></tr>
<tr><td>x_0 [m]</td><td>-2</td><td>0</td><td>2</td></tr>
</table></td></tr>
<tr><td>Number vehicles</td><td>1 (+ 2 moving target)</td></tr>
<tr><td>Required Equipment</td><td>2 moving targets (if only one is available, static vehicle or real vehicle should be used for the 3rd vehicle)</td></tr>
<tr><td>Environmental initial parameters</td><td><table>
<tr><td>Road radius</td><td>∞</td></tr>
<tr><td>driven lane</td><td>left</td></tr>
<tr><td>Number of lanes</td><td>1 per driving direction</td></tr>
</table></td></tr>
<tr><td>Assessment</td><td>☒ Technical ☒ User-related</td></tr>
<tr><td>Driver reaction (only relevant for the technical assessment)</td><td>No reaction of the driver on any warning or intervention before the highest warning level is reached (afterwards the reaction of the driver depends on function).
Driving with constant speed</td></tr>
<tr><td>Comment</td><td>For technical assessment only relevant if the function is able to intervene by steering.
Depending on available test tools additional safety actions might be necessary.
1: It needs to be verified, whether the tests could be done without damaging the demonstrator vehicle and if the available</td></tr>
</table>

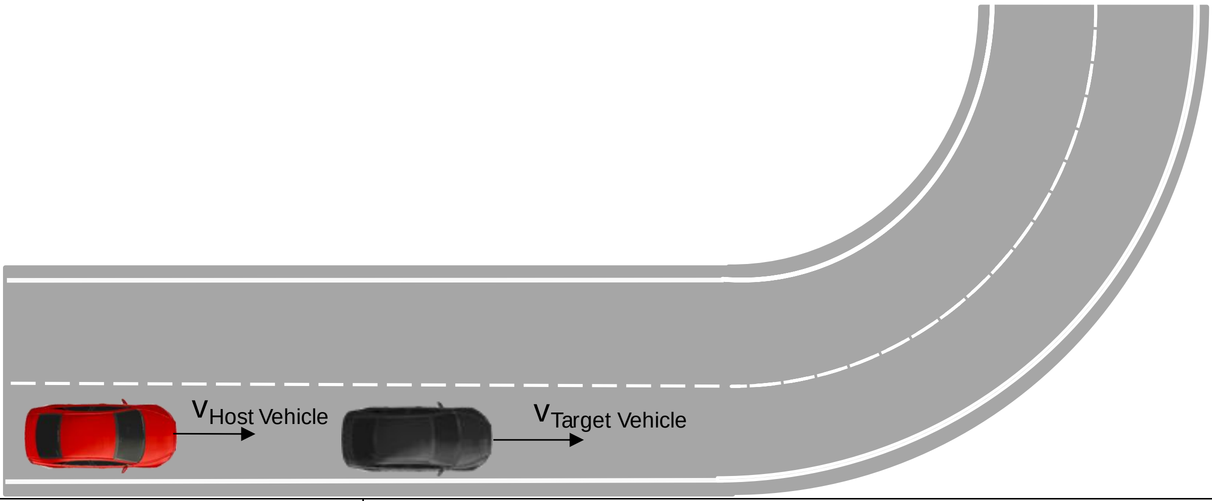
<table>
<tr><td>Test Scenario</td><td>Head on collisions</td></tr>
<tr><td>Test Case</td><td>2.4</td></tr>
<tr><td colspan="2">Intended lane change with oncoming traffic</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Description</td><td>Host vehicle follows lead vehicle (at the same speed) and decides to overtake, but vehicle is approaching in the opposite direction.</td></tr>
<tr><td>Relevant functions</td><td>eDPP, CMS</td></tr>
<tr><td>Use case</td><td>UC_02_501_v2</td></tr>
<tr><td>Vehicle initial parameters</td><td>for eDPP:
<table>
<tr><td>$v_{Host\ Vehicle}$ [km/h]
$v_{Front\ Vehicle}$ [km/h]</td><td>64</td><td>80</td><td>100</td></tr>
<tr><td>$v_{Target\ Vehicle}$ [km/h]</td><td>64</td><td>80</td><td></td></tr>
</table>
For CMS:
<table>
<tr><td>$v_{Host\ Vehicle}$ [km/h]</td><td>40[1]</td><td>64[1]</td></tr>
<tr><td>$v_{Front\ Vehicle}$ [km/h]</td><td>$v_{Host\ Vehicle}$ – 10</td><td>$v_{Host\ Vehicle}$ – 20</td></tr>
<tr><td>$v_{Target\ Vehicle}$ [km/h]</td><td>40[1]</td><td></td></tr>
</table>
X_0: Will be defined to a later stage</td></tr>
<tr><td>Number vehicles</td><td>3 (or 1 + 2 moving targets)</td></tr>
<tr><td>Required Equipment</td><td>At least 2 vehicles equipped with V2V communication. If the host vehicle stays behind the predecessor no target objects are necessary, because there is no danger of a collision.</td></tr>
<tr><td>Environmental initial parameters</td><td>
<table>
<tr><td>Road radius</td><td>∞</td></tr>
<tr><td>driven lane</td><td>right</td></tr>
<tr><td>Number of lanes</td><td>1 per driving direction</td></tr>
</table></td></tr>
<tr><td>Assessment</td><td>☒ Technical ☐ User-related</td></tr>
<tr><td>Driver reaction (only relevant for the technical assessment)</td><td>No reaction of the driver on any warning or intervention before the highest warning level is reached (afterwards the reaction of the driver depends on function).
Following the predecessor with constant speed
For the eDPP function:
The driver should stay behind the front vehicle and should not perform a lane change. (Depending on the implementation it might be necessary to activate the turn indicator in order to indicate the overtaking intention.)</td></tr>
<tr><td>Comment</td><td>Depending on available test tools additional safety actions might be necessary.</td></tr>
</table>

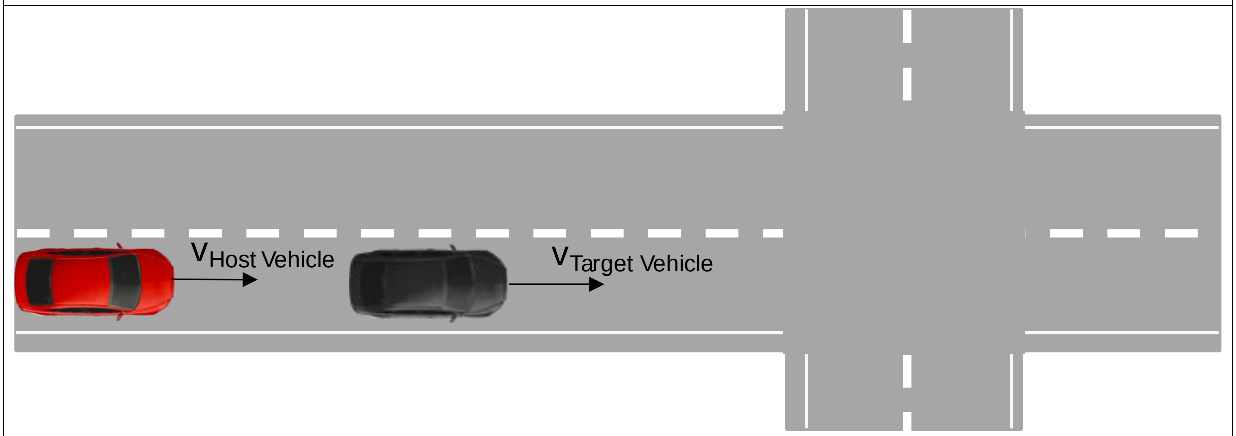
Test Scenario	Head on collisions
Test Case	2.5

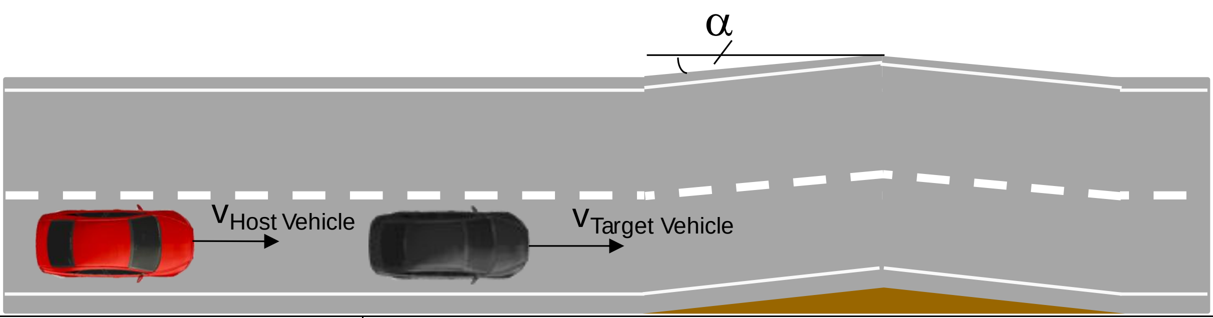
Conflict with oncoming vehicle while left turn

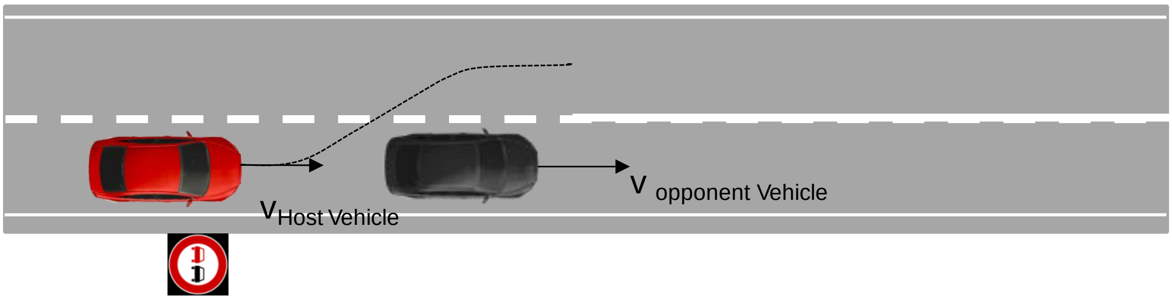


Description	Host vehicle performing a left turn, while an target vehicle is approaching
Relevant functions	CMS
Use case	UC_02_605_v1
Vehicle initial parameters	$v_{Host\ Vehicle}$ [km/h]: 30 $v_{Target\ Vehicle}$ [km/h]: 50 PET [s]: 0, 1
Number vehicles	1 (+ 1 moving target)
Required Equipment	1 moving target (balloon car)
Environmental initial parameters	Road radius: ∞ driven lane: right Number of lanes: 1 per driving direction
Assessment	☒ Technical ☒ User-related
Driver reaction (only relevant for the technical assessment)	• No reaction of the driver on any warning or intervention before turning manoeuvre • Turn indicator should be used • Driving with constant speed • Normal turn manoeuvre with constant speed
Comment	Post Encroachment Time (PET) represents a measure of the temporal difference between two road-users, who pass a common spatial point or area.

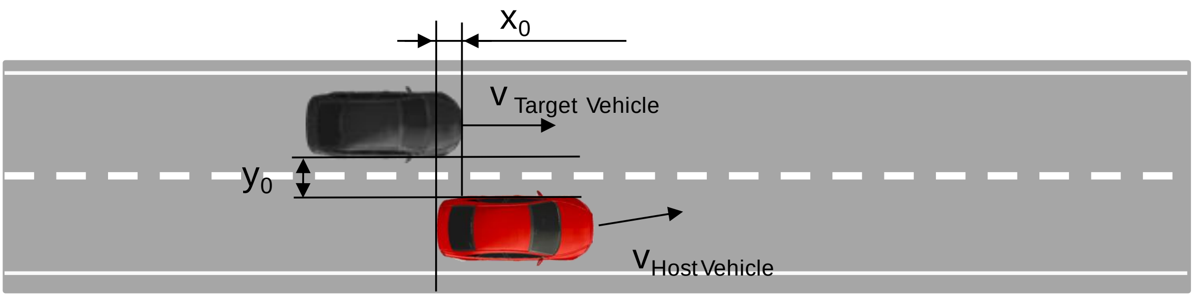
Test Scenario	Head on collisions
Test Case	2.7
Upcoming curve	
	
Description	Host vehicle is driving in the opposite lane due to an overtaking manoeuvre. There is a curve in front of the host vehicles.
Relevant functions	eDPP
Use case	UC_02_403_v0
Vehicle initial parameters	$v_{Host\ Vehicle}$ [km/h] | 50 | 70 | 100 $v_{Host\ Vehicle} = v_{Target\ Vehicle}$
Number vehicles	2
Required Equipment	none (no intervention of eDPP)
Environmental initial parameters	Road radius: ∞ driven lane: right Number of lanes: 1 per driving direction
Assessment	☒ Technical ☐ User-related
Driver reaction (only relevant for the technical assessment)	• The driver should stay behind the front vehicle and should not perform a lane change. • Driving with constant speed
Comment	It need to be ensure that there is no oncoming car

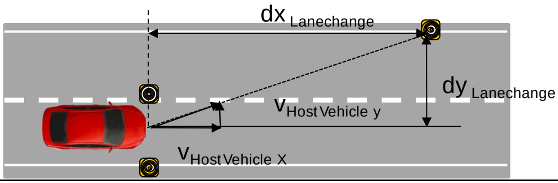
<table>
<tr><td>Test Scenario</td><td>Head on collisions</td></tr>
<tr><td>Test Case</td><td>2.8</td></tr>
<tr><td colspan="2">Upcoming intersection</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Description</td><td>Host vehicle is driving in the opposite lane due to an overtaking manoeuvre. There is an intersection in front of the host vehicles.</td></tr>
<tr><td>Relevant functions</td><td>eDPP</td></tr>
<tr><td>Use case</td><td>UC_02_432_v0</td></tr>
<tr><td>Vehicle initial parameters</td><td><table><tr><td>$v_{Host\ Vehicle}$ [km/h]</td><td>50</td><td>70</td><td>100</td></tr></table>$v_{Host\ Vehicle} = v_{Target\ Vehicle}$</td></tr>
<tr><td>Number vehicles</td><td>2</td></tr>
<tr><td>Required Equipment</td><td>none (no intervention of eDPP)</td></tr>
<tr><td>Environmental initial parameters</td><td><table><tr><td>Road radius</td><td>∞</td></tr><tr><td>driven lane</td><td>right</td></tr><tr><td>Number o lanes</td><td>1 per driving direction</td></tr></table></td></tr>
<tr><td>Assessment</td><td>☒ Technical ☐ User-related</td></tr>
<tr><td>Driver reaction (only relevant for the technical assessment)</td><td>• The driver should stay behind the front vehicle and should not perform a lane change.
• Driving with constant speed</td></tr>
<tr><td>Comment</td><td>It need to be ensure that there is no oncoming car</td></tr>
</table>

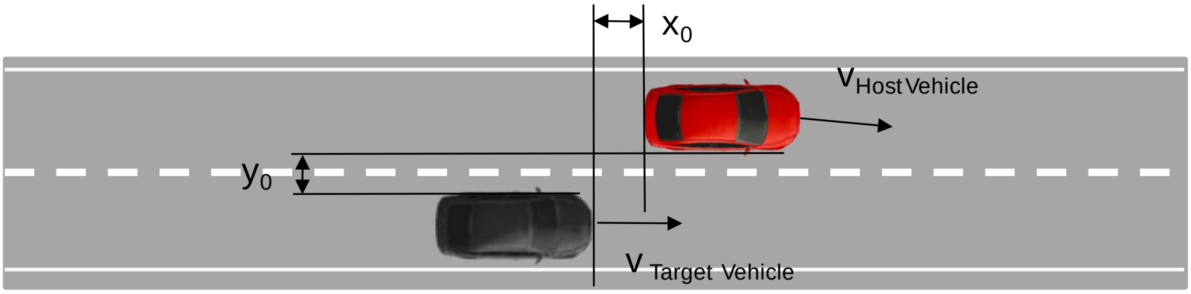
<table>
<tr><th>Test Scenario</th><th>Head on collisions</th></tr>
<tr><td>Test Case</td><td>2.9</td></tr>
<tr><td colspan="2">Upcoming hill</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Description</td><td>Host vehicle is driving in the opposite lane due to an overtaking manoeuvre. There is a hill in front of the host vehicles.</td></tr>
<tr><td>Relevant functions</td><td>eDPP</td></tr>
<tr><td>Use case</td><td>UC_02_433_v0</td></tr>
<tr><td>Vehicle initial parameters</td><td><table><tr><td>$v_{Host\ Vehicle}$ [km/h]</td><td>50</td><td>70</td><td>100</td></tr></table>$v_{Host\ Vehicle} = v_{Target\ Vehicle}$</td></tr>
<tr><td>Number vehicles</td><td>2</td></tr>
<tr><td>Required Equipment</td><td>none (no intervention of eDPP)</td></tr>
<tr><td>Environmental initial parameters</td><td><table><tr><td>Gradient of road</td><td>> x %</td></tr><tr><td>Road radius</td><td>∞</td></tr><tr><td>driven lane</td><td>right</td></tr><tr><td>Number of lanes</td><td>1 per driving direction</td></tr></table></td></tr>
<tr><td>Assessment</td><td>☒ Technical ☐ User-related</td></tr>
<tr><td>Driver reaction (only relevant for the technical assessment)</td><td>The driver should stay behind the front vehicle and should not perform a lane change.
Driving with constant speed</td></tr>
<tr><td>Comment</td><td>It need to be ensure that there is no oncoming car</td></tr>
</table>

<table>
<tr><td>Test Scenario</td><td>Head on collisions</td></tr>
<tr><td>Test Case</td><td>2.10</td></tr>
<tr><td colspan="2">Overtaking prohibition</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Description</td><td>The driver in the host vehicle wants to overtake a slower vehicle in front of him. Due to this he/she conducts a lane change. But there is overtaking prohibition.</td></tr>
<tr><td>Relevant functions</td><td>eDPP, CMS</td></tr>
<tr><td>Use case</td><td>UC_02_434_v0, UC_02_501_v2, UC_02_532_v1, UC_02_534_v1, UC_02_604_v0</td></tr>
<tr><td>Vehicle initial parameters</td><td><table><tr><td>$v_{Host\ Vehicle}$ [km/h]</td><td>50</td><td>70</td><td>100</td></tr></table>$v_{Host\ Vehicle} = v_{Target\ Vehicle}$</td></tr>
<tr><td>Number vehicles</td><td>2</td></tr>
<tr><td>Required Equipment</td><td>none</td></tr>
<tr><td>Environmental initial parameters</td><td><table><tr><td>Kind of overtaking prohibition</td><td>Lane marking</td><td>sign</td></tr><tr><td>Road radius</td><td>∞</td><td></td></tr><tr><td>driven lane</td><td>right</td><td></td></tr><tr><td>Number of lanes</td><td>1 per driving direction</td><td></td></tr></table></td></tr>
<tr><td>Assessment</td><td>☒ Technical ☐ User-related</td></tr>
<tr><td>Driver reaction (only relevant for the technical assessment)</td><td>• The driver should stay behind the front vehicle and should not perform a lane change.
• Driving with constant speed</td></tr>
<tr><td>Comment</td><td></td></tr>
</table>

3. Lane change collisions

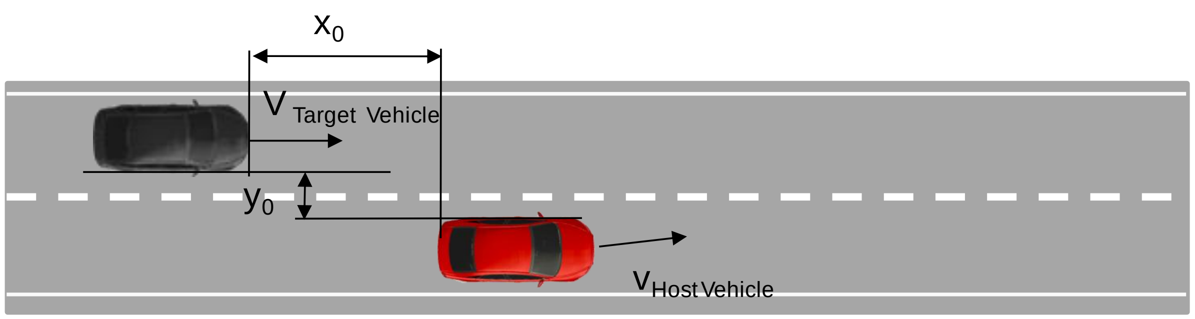
<table>
<tr><th>Test Scenario</th><th>Lane change collisions</th></tr>
<tr><th>Test Case</th><th>3.1</th></tr>
<tr><td colspan="2">Vehicle in left blind spot</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Description</td><td>The driver of the host vehicle wants to perform a lane change to the left lane (or drifts unintentionally towards the lane). But there is an opponent vehicle in blind spot.</td></tr>
<tr><td>Relevant functions</td><td>CS, LCCA, SIA</td></tr>
<tr><td>Use case</td><td>UC_03_404_v0, UC_03_507_v2, UC_03_533_v1, UC_06_503_v2, UC_06_535</td></tr>
<tr><td>Vehicle initial parameters</td><td><table>
<tr><td>$v_{Host\ Vehicle}$ [km/h]</td><td>30</td><td>50</td><td>70</td></tr>
<tr><td>$v_{Target\ Vehicle}$ [km/h]</td><td>30</td><td>50</td><td>70</td></tr>
<tr><td>x_0 [m]</td><td>-2.5 (- 7.5[2])</td><td>0</td><td>2.5</td></tr>
<tr><td>y_0 [m]</td><td>2</td><td></td><td></td></tr>
<tr><td>Status turn indicator[1]</td><td>on</td><td>off</td><td></td></tr>
</table>
$v_{Host\ Vehicle} = v_{Target\ Vehicle}$</td></tr>
<tr><td>Number vehicles</td><td>1 (+ 1 moving target)</td></tr>
<tr><td>Required Equipment</td><td>(1 moving target (balloon car))</td></tr>
<tr><td>Environmental initial parameters</td><td><table>
<tr><td>Road radius</td><td>∞</td><td></td></tr>
<tr><td>driven lane</td><td>right</td><td></td></tr>
<tr><td>Number o lanes</td><td>2</td><td></td></tr>
<tr><td>loading of vehicle (only relevant for trucks)</td><td>Basic</td><td>Fully loaded</td></tr>
</table></td></tr>
<tr><td>Assessment</td><td>☒ Technical ☒ User-related</td></tr>
<tr><td>Driver reaction (only relevant for the technical assessment)</td><td>
No reaction of the driver on any warning or intervention before the highest warning level is reached (afterwards the reaction of the driver depends on function).
Driving with constant speed
Driver should try to do a normal "lane change" manoeuvre. This manoeuvre starts, when the distance x_0 between both vehicles is reached and the vehicle reaches defined point. At this point the driver should start to steer and drive afterwards straight ahead towards the target in order to ensure the correct lateral velocity. The lateral and longitudinal distance of the target should be chosen based on the chosen angle of the test (in order to simulate a standard lane change (average duration of lane change according to [PFE07] on motorways ca. 5 s) $v_{Host\ Vehicle\ y}$ should be ca. 2.7 km/h).


</td></tr>
<tr><td>Comment</td><td>1: Need only be tested, if the turn indicator can affect the function.
2: For trucks</td></tr>
</table>

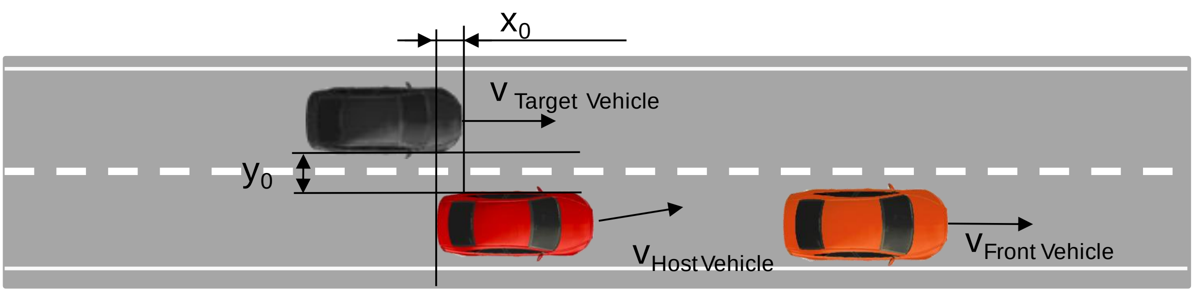
<table>
<tr><td>Test Scenario</td><td>Lane change collisions</td></tr>
<tr><td>Test Case</td><td>3.2</td></tr>
<tr><td colspan="2">Vehicle in right blind spot</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Description</td><td>The driver of the host vehicle wants to perform a lane change to the right lane. But there is an opponent vehicle in blind spot.</td></tr>
<tr><td>Relevant functions</td><td>CS, LCCA, SIA</td></tr>
<tr><td>Use case</td><td>UC_03_404_v0, UC_03_507_v2, UC_03_533_v1</td></tr>
<tr><td>Vehicle initial parameters</td><td>
<table>
<tr><td>$v_{Host Vehicle}$ [km/h]</td><td>50</td><td>70</td><td></td></tr>
<tr><td>$v_{Target Vehicle}$ [km/h]</td><td>50</td><td>70</td><td></td></tr>
<tr><td>x_0 [m]</td><td>3</td><td>0</td><td>-3</td></tr>
<tr><td>y_0 [m]</td><td>2</td><td></td><td></td></tr>
<tr><td>Status turn indicator [1]</td><td>on</td><td>off</td><td></td></tr>
</table>
$v_{Host Vehicle} = v_{Target Vehicle}$</td></tr>
<tr><td>Number vehicles</td><td>1 (+ 1 moving target)</td></tr>
<tr><td>Required Equipment</td><td>(1 moving target (balloon car))</td></tr>
<tr><td>Environmental initial parameters</td><td>
<table>
<tr><td>Road radius</td><td>∞</td><td></td></tr>
<tr><td>driven lane</td><td>left</td><td></td></tr>
<tr><td>Number of lanes</td><td>2</td><td></td></tr>
<tr><td>loading of vehicle (only relevant for trucks)</td><td>Basic</td><td>Fully loaded</td></tr>
</table></td></tr>
<tr><td>Assessment</td><td>☒ Technical ☒ User-related</td></tr>
<tr><td>Driver reaction (only relevant for the technical assessment)</td><td>

No reaction of the driver on any warning or intervention before the highest warning level is reached (afterwards the reaction of the driver depends on function).
Driving with constant speed
Driver should try to do a normal "lane change" manoeuvre. This manoeuvre starts, when the distance x_0 between both vehicles is reached and the vehicle reaches defined point. At this point the driver should start to steer and drive afterwards straight ahead towards the target in order to ensure the correct lateral velocity. The lateral and longitudinal distance of the target should be chosen based on the chosen angle of the test (in order to simulate a standard lane change (average duration of lane change according to [PFE07] on motorways ca. 5 s) $v_{Host Vehicle\ y}$ should be ca. 2.7 km/h).

</td></tr>
<tr><td>Comment</td><td>1: Need only be tested, if the turn indicator can affect the function.</td></tr>
</table>

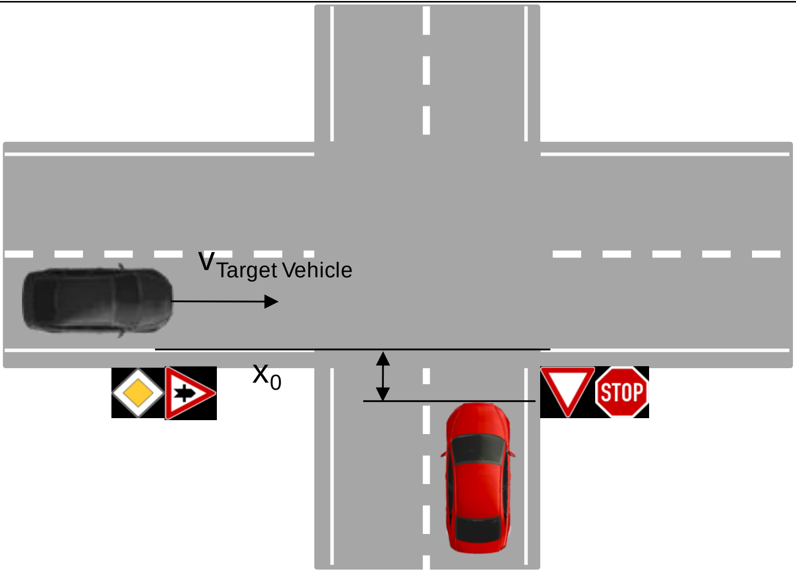
<table>
<tr><td>Test Scenario</td><td>Lane change collisions</td></tr>
<tr><td>Test Case</td><td>3.3</td></tr>
<tr><td colspan="2">Fast approaching vehicle</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Description</td><td>The driver of the host vehicle wants to perform a lane change to the left lane. But there is a fast approaching opponent vehicle in the other lane.</td></tr>
<tr><td>Relevant functions</td><td>CS, LCCA, SIA</td></tr>
<tr><td>Use case</td><td>UC_03_435_v0, UC_03_511_v1, UC_06_450_V1</td></tr>
<tr><td>Vehicle initial parameters</td><td>
<table>
<tr><td>$v_{Host\ Vehicle}$ [km/h]</td><td>30[2]</td><td>50</td><td>70</td></tr>
<tr><td>$v_{Target\ Vehicle}$ [km/h]</td><td>$v_{Host\ Vehicle}$ + 20</td><td>$v_{Host\ Vehicle}$ + 40</td><td>$v_{Host\ Vehicle}$ + 60</td></tr>
<tr><td>x_0 [m]</td><td>-6[1] / -11[2] / -17[3]</td><td>-11[1] / -22[2] / -33[3]</td><td>-17[1] / -33[2] / -50[3]</td></tr>
<tr><td>Status turn indicator[1]</td><td>on</td><td>off</td><td></td></tr>
</table>
x_0 (distance between two vehicles at start of manoeuvre/when crossing the lane)
Always $v_{Host\ Vehicle} < v_{Target\ Vehicle}$
1: relative velocity 20 km/h
2: relative velocity 40 km/h
3: relative velocity 60 km/h</td></tr>
<tr><td>Number vehicles</td><td>1 (+ 1 moving target)</td></tr>
<tr><td>Required Equipment</td><td>(1 moving target (balloon car))</td></tr>
<tr><td>Environmental initial parameters</td><td>
<table>
<tr><td>Road radius</td><td>∞</td><td></td></tr>
<tr><td>driven lane</td><td>right</td><td></td></tr>
<tr><td>Number of lanes</td><td>2</td><td></td></tr>
<tr><td>loading of vehicle (only relevant for trucks)</td><td>Basic</td><td>Fully loaded</td></tr>
</table></td></tr>
<tr><td>Assessment</td><td>☒ Technical ☐ User-related</td></tr>
<tr><td>Driver reaction (only relevant for the technical assessment)</td><td>

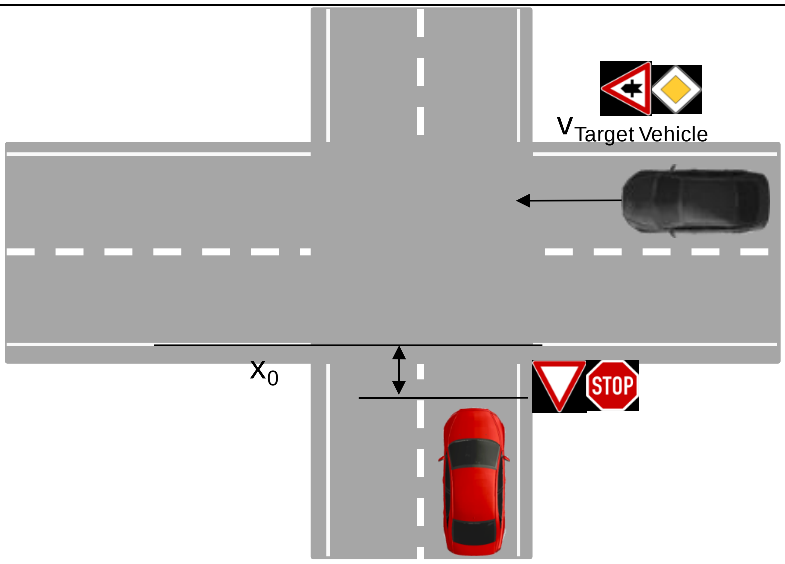
No reaction of the driver on any warning or intervention before the highest warning level is reached (afterwards the reaction of the driver depends on function).
At start both vehicles are driving in the middle of the lane
Driving with constant speed (→ ca. y_0 = 1.75 m)
Driver should try to do a normal "lane change" manoeuvre. This manoeuvre starts, when the distance x_0 between both vehicles is reached and the vehicle reaches defined point. At this point the driver should start to steer and drive afterwards straight ahead towards the target in order to ensure the correct lateral velocity. The lateral and longitudinal distance of the target should be chosen based on the chosen angle of the test (in order to simulate a standard lane change (average duration of lane change according to [PFE07] on motorways ca. 5 s) $v_{Host\ Vehicle\ y}$ should be ca. 2.7 km/h).
</td></tr>
<tr><td>Comment</td><td>1: Need only be tested, if the turn indicator can affect the function.
2: If the function is available at this speed.</td></tr>
</table>

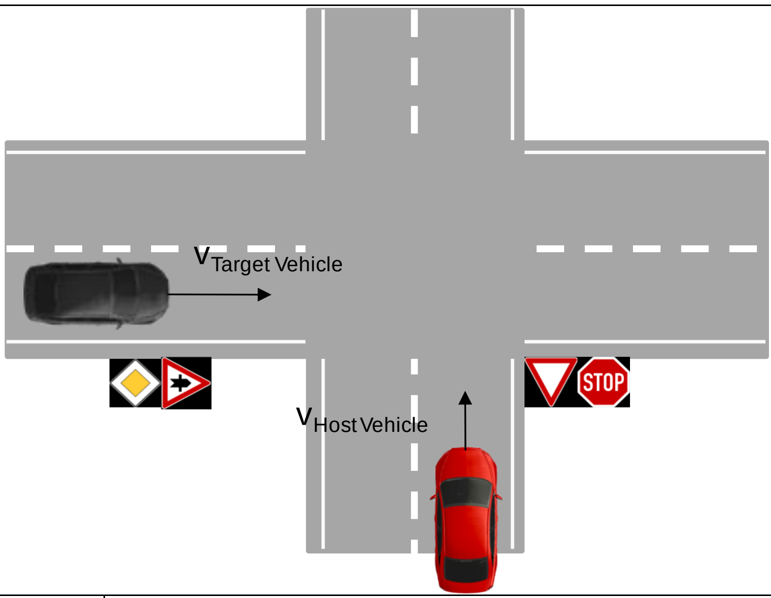
<table>
<tr><td>Test Scenario</td><td>Lane change collisions</td></tr>
<tr><td>Test Case</td><td>3.4</td></tr>
<tr><td colspan="2">Vehicle in blind spot 1 with lead vehicle</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Description</td><td>The driver of the host vehicle wants to perform a lane change to the left lane (or drifts unintentionally towards the lane) in order to overtake the vehicle in front. But there is an opponent vehicle in blind spot.</td></tr>
<tr><td>Relevant functions</td><td>LCCA, CS</td></tr>
<tr><td>Use case</td><td>UC_06_511_v1, UC_03_404_v2</td></tr>
<tr><td>Vehicle initial parameters</td><td>
<table>
<tr><td>$v_{Host\ Vehicle}$ [km/h]</td><td>50</td><td>70</td><td></td></tr>
<tr><td>$v_{Target\ Vehicle}$ [km/h]</td><td>50</td><td>70</td><td></td></tr>
<tr><td>x_0 [m]</td><td>-2.5 (-7.5[2])</td><td>0</td><td>2.5</td></tr>
<tr><td>y_0 [m]</td><td>2</td><td></td><td></td></tr>
<tr><td>Status turn indicator[1]</td><td>on</td><td>off</td><td></td></tr>
</table>
$v_{Host\ Vehicle} = v_{Target\ Vehicle}$
$v_{Front\ Vehicle} < v_{Host\ Vehicle}$</td></tr>
<tr><td>Number vehicles</td><td>1 (+ 2 moving target)</td></tr>
<tr><td>Required Equipment</td><td>2 moving targets</td></tr>
<tr><td>Environmental initial parameters</td><td>
<table>
<tr><td>Warning status</td><td>Warning given</td><td>Warning not given</td></tr>
<tr><td>Road radius</td><td>∞</td><td></td></tr>
<tr><td>driven lane</td><td>right</td><td></td></tr>
<tr><td>Number of lanes</td><td>2</td><td></td></tr>
</table></td></tr>
<tr><td>Assessment</td><td>☒ Technical ☒ User-related</td></tr>
<tr><td>Driver reaction (only relevant for the technical assessment)</td><td>

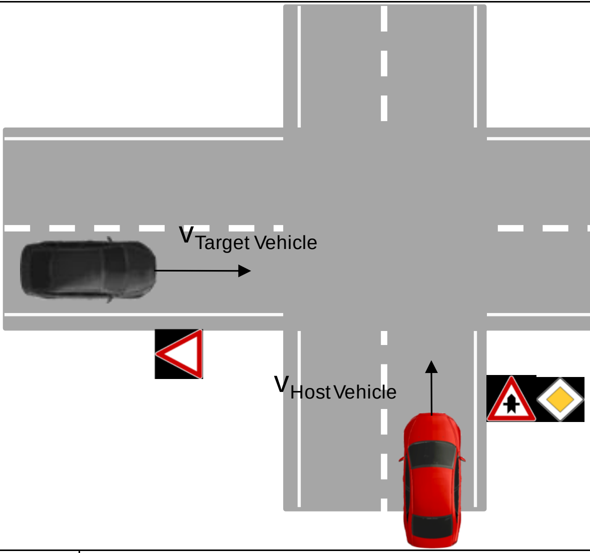
No reaction of the driver on any warning or intervention before the highest warning level is reached (afterwards the reaction of the driver depends on function).
Driving with constant speed
Driver should try to do a normal "lane change" manoeuvre. This manoeuvre starts, when the distance x_0 between both vehicles is reached and the vehicle reaches defined point. At this point the driver should start to steer and drive afterwards straight ahead towards the target in order to ensure the correct lateral velocity. The lateral and longitudinal distance of the target should be chosen based on the chosen angle of the test (in order to simulate a standard lane change (average duration of lane change according to [PFE07] on motorways ca. 5 s) $v_{Host\ Vehicle\ y}$ should be ca. 2.7 km/h).
</td></tr>
<tr><td>Comment</td><td>Test environment: Simulator or test track
1: Need only be tested, if the turn indicator can affect the function.
2: For trucks</td></tr>
</table>

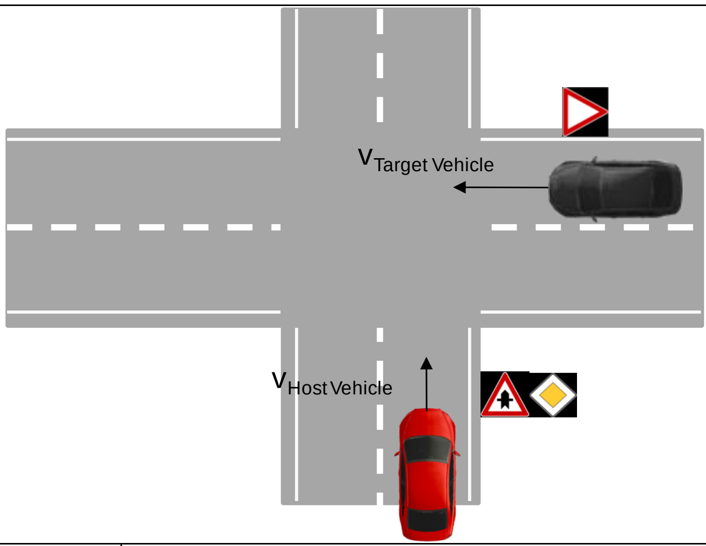
4. Cross traffic collisions

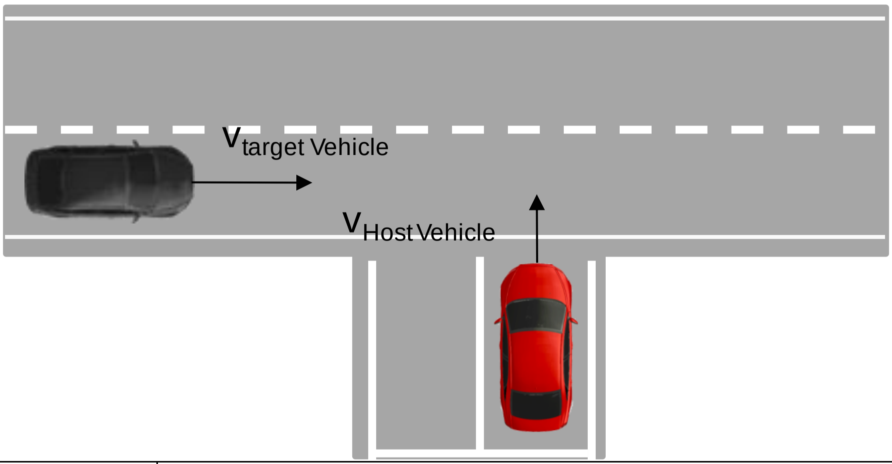
<table>
<tr><th>Test Scenario</th><th>Cross traffic collisions</th></tr>
<tr><td>Test Case</td><td>4.1</td></tr>
<tr><td colspan="2">Crossing traffic (stand still) 1</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Description</td><td>The host vehicle stands still at intersection. There is crossing traffic from the lefts side.</td></tr>
<tr><td>Relevant functions</td><td>CS</td></tr>
<tr><td>Use case</td><td>UC_04_436_v1</td></tr>
<tr><td>Vehicle initial parameters</td><td><table>
<tr><td>$v_{Target Vehicle}$ [km/h]</td><td>30</td><td>50</td><td>70</td></tr>
<tr><td>x_0 [m]</td><td>0</td><td>-3</td><td>-10</td></tr>
</table>
x_0 (distance to intersection)</td></tr>
<tr><td>Number vehicles</td><td>2</td></tr>
<tr><td>Required Equipment</td><td>No</td></tr>
<tr><td>Environmental initial parameters</td><td><table>
<tr><td>traffic sign1[1]</td><td>Major street</td><td>Have right of way sign</td></tr>
<tr><td>traffic sign2[1]</td><td>Stop sign</td><td>Yield sign</td></tr>
<tr><td>V2V status</td><td>Not available</td><td>available</td></tr>
<tr><td>Road radius</td><td>∞</td><td></td></tr>
<tr><td>driven lane</td><td>right</td><td></td></tr>
<tr><td>Number of lanes</td><td>2</td><td></td></tr>
</table></td></tr>
<tr><td>Assessment</td><td>☒ Technical ☐ User-related</td></tr>
<tr><td>Driver reaction (only relevant for the technical assessment)</td><td>No reaction of the driver on any warning or intervention before the highest warning level is reached (afterwards the reaction of the driver depends on function).
Vehicle stands still</td></tr>
<tr><td>Comment</td><td>1: Only one of two traffic signs should be used.</td></tr>
</table>

<table>
<tr><td>Test Scenario</td><td>Cross traffic collisions</td></tr>
<tr><td>Test Case</td><td>4.2</td></tr>
<tr><td colspan="2">Crossing traffic (stand still) 2</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Description</td><td>The host vehicle stands at intersection. There is crossing traffic from the right side.</td></tr>
<tr><td>Relevant functions</td><td>CS</td></tr>
<tr><td>Use case</td><td>UC_04_436_v0</td></tr>
<tr><td>Vehicle initial parameters</td><td><table>
<tr><td>$v_{Target Vehicle}$ [km/h]</td><td>30</td><td>70</td><td></td><td></td></tr>
<tr><td>x_0 [m]</td><td>0</td><td>-10</td><td></td><td></td></tr>
</table>
x_0 (distance to intersection)</td></tr>
<tr><td>Number vehicles</td><td>2</td></tr>
<tr><td>Required Equipment</td><td>No</td></tr>
<tr><td>Environmental initial parameters</td><td><table>
<tr><td>traffic sign1[1]</td><td>Major street</td><td>Have right of way sign</td></tr>
<tr><td>traffic sign2[1]</td><td>Stop sign</td><td>Yield sign</td></tr>
<tr><td>V2V status</td><td>Not available</td><td>available</td></tr>
<tr><td>Road radius</td><td>∞</td><td></td></tr>
<tr><td>driven la e</td><td>right</td><td></td></tr>
<tr><td>Number of lanes</td><td>2</td><td></td></tr>
</table></td></tr>
<tr><td>Assessment</td><td>☒ Technical ☐ User-related</td></tr>
<tr><td>Driver reaction (only relevant for the technical assessment)</td><td>No reaction of the driver on any warning or intervention before the highest warning level is reached (afterwards the reaction of the driver depends on function).
Vehicle stands still</td></tr>
<tr><td>Comment</td><td>1: Only one of two traffic signs should be used.</td></tr>
</table>

<table>
<tr><td>Test Scenario</td><td>Cross traffic collisions</td></tr>
<tr><td>Test Case</td><td>4.3</td></tr>
<tr><td colspan="2">Crossing traffic (moving) 1</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Description</td><td>The host vehicle approaches an intersection. There is another vehicle, which has the right of way, crossing from the left side.</td></tr>
<tr><td>Relevant functions</td><td>CS, CMS</td></tr>
<tr><td>Use case</td><td>UC_04_436_v0</td></tr>
<tr><td>Vehicle initial parameters</td><td><table>
<tr><td>$v_{Host\ Vehicle}$ [km/h]</td><td>30</td><td>50</td><td></td></tr>
<tr><td>$v_{Target\ Vehicle}$ [km/h]</td><td>30</td><td>50</td><td></td></tr>
<tr><td>PET [s]</td><td>0</td><td>1</td><td>2</td></tr>
</table></td></tr>
<tr><td>Number vehicles</td><td>1 (+ 1 moving target)</td></tr>
<tr><td>Required Equipment</td><td>1 moving target (balloon car)</td></tr>
<tr><td>Environmental initial parameters</td><td><table>
<tr><td>traffic sign1[1]</td><td>Major street</td><td>Have right of way sign</td></tr>
<tr><td>traffic sign2[1]</td><td>Stop sign</td><td>Yield sign</td></tr>
<tr><td>V2V status</td><td>Not available</td><td>available</td></tr>
<tr><td>Road radius</td><td>∞</td><td></td></tr>
<tr><td>driven lane</td><td>right</td><td></td></tr>
<tr><td>Number of lanes</td><td>2</td><td></td></tr>
</table></td></tr>
<tr><td>Assessment</td><td>☒ Technical ☐ User-related</td></tr>
<tr><td>Driver reaction (only relevant for the technical assessment)</td><td>• No reaction of the driver on any warning or intervention before the highest warning level is reached (afterwards the reaction of the driver depends on function).
• Driving with constant speed</td></tr>
<tr><td>Comment</td><td>1: Only one of two traffic signs should be used.</td></tr>
</table>

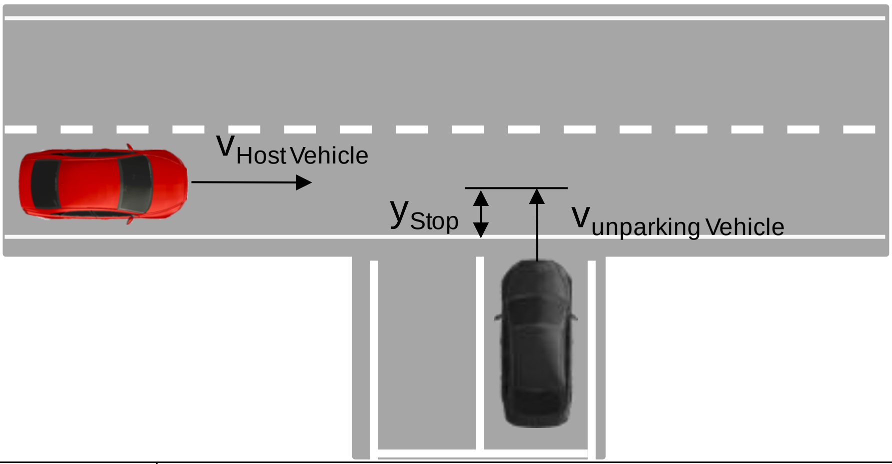
<table>
<tr><td>Test Scenario</td><td>Cross traffic collisions</td></tr>
<tr><td>Test Case</td><td>4.4</td></tr>
<tr><td colspan="2">Crossing traffic (moving) 2</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Description</td><td>The host vehicle, which has the way of right, approaches an intersection. There is also another vehicle crossing from the left side.</td></tr>
<tr><td>Relevant functions</td><td>CS, CMS (traffic signs are not considered → same as TC 4.3)</td></tr>
<tr><td>Use case</td><td>UC_04_436_v0, UC_04_607_v2</td></tr>
<tr><td>Vehicle initial parameters</td><td><table>
<tr><td>$v_{Host\ Vehicle}$ [km/h]</td><td>30</td><td>50</td></tr>
<tr><td>$v_{Target\ Vehicle}$ [km/h]</td><td>30</td><td>50</td></tr>
<tr><td>PET [s]</td><td>0</td><td>2</td></tr>
</table></td></tr>
<tr><td>Number vehicles</td><td>1 (+ 1 moving target)</td></tr>
<tr><td>Required Equipment</td><td>1 moving target (balloon car)</td></tr>
<tr><td>Environmental initial parameters</td><td><table>
<tr><td>traffic sign1</td><td>Yield sign</td><td></td></tr>
<tr><td>traffic sign2</td><td>Have right of way sign</td><td></td></tr>
<tr><td>V2V status</td><td>Not available</td><td>available</td></tr>
<tr><td>Road radius</td><td>∞</td><td></td></tr>
<tr><td>driven lane</td><td>right</td><td></td></tr>
<tr><td>Number of lanes</td><td>2</td><td></td></tr>
</table></td></tr>
<tr><td>Assessment</td><td>☒ Technical ☐ User-related</td></tr>
<tr><td>Driver reaction (only relevant for the technical assessment)</td><td>• No reaction of the driver on any warning or intervention before the highest warning level is reached (afterwards the reaction of the driver depends on function).
• Driving with constant speed</td></tr>
<tr><td>Comment</td><td>If traffic signs are not considered by the function, same as TC 4.3. In this case this test case is not needed.
1: Only one of two traffic signs should be used.</td></tr>
</table>

<table>
<tr><td>Test Scenario</td><td>Cross traffic collisions</td></tr>
<tr><td>Test Case</td><td>4.5</td></tr>
<tr><td colspan="2">Crossing traffic (moving) 3</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Description</td><td>The host vehicle, which has the way of right, approaches an intersection. There is also another vehicle crossing from the right side.</td></tr>
<tr><td>Relevant functions</td><td>CS, CMS</td></tr>
<tr><td>Use case</td><td>UC_04_436_v0, UC_04_607_v2</td></tr>
<tr><td>Vehicle initial parameters</td><td><table>
<tr><td>$v_{Host\ Vehicle}$ [km/h]</td><td>30</td><td>50[1]</td></tr>
<tr><td>$v_{Target\ Vehicle}$ [km/h]</td><td>30</td><td>50[1]</td></tr>
<tr><td>PET [s]</td><td>0</td><td>2</td></tr>
</table></td></tr>
<tr><td>Number vehicles</td><td>1 (+ 1 moving target)</td></tr>
<tr><td>Required Equipment</td><td>1 moving target (balloon car)</td></tr>
<tr><td>Environmental initial parameters</td><td><table>
<tr><td>traffic sign1</td><td>Yield sign</td><td></td></tr>
<tr><td>traffic sign2</td><td>Have right of way sign</td><td></td></tr>
<tr><td>V2V status</td><td>Not available</td><td>available</td></tr>
<tr><td>Road radius</td><td>∞</td><td></td></tr>
<tr><td>driven lane</td><td>right</td><td></td></tr>
<tr><td>Number of lanes</td><td>2</td><td></td></tr>
</table></td></tr>
<tr><td>Assessment</td><td>☒ Technical ☒ User-related</td></tr>
<tr><td>Driver reaction (only relevant for the technical assessment)</td><td>• No reaction of the driver on any warning or intervention before the highest warning level is reached (afterwards the reaction of the driver depends on function).
• Driving with constant speed</td></tr>
<tr><td>Comment</td><td>1: A test, in which both vehicles drive at a speed of 50 km/h, might be too difficult to</td></tr>
</table>

<table>
<tr><td>Test Scenario</td><td>Cross traffic collisions</td></tr>
<tr><td>Test Case</td><td>4.6</td></tr>
<tr><td colspan="2">Parking 1</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Description</td><td>Driver of the host vehicle leaves the parking lot. But there is crossing traffic from the lefts side.</td></tr>
<tr><td>Relevant functions</td><td>CS</td></tr>
<tr><td>Use case</td><td>UC_04_437_v1</td></tr>
<tr><td>Vehicle initial parameters</td><td><table>
<tr><td>$v_{Host Vehicle}$ [km/h]</td><td>5</td><td></td><td></td></tr>
<tr><td>$v_{Target Vehicle}$ [km/h]</td><td>30</td><td>50</td><td></td></tr>
<tr><td>x_0 [m]</td><td>6[1] / 9[2]</td><td>12[1] / 18[2]</td><td>13[1] / 27[2]</td></tr>
</table>
x_0 (distance to target vehicle when crossing lane border): 1 used at 30 km/h and 2 used at 50 km/h</td></tr>
<tr><td>Number vehicles</td><td>1 (+ 1 moving target)</td></tr>
<tr><td>Required Equipment</td><td>1 moving target (balloon car)</td></tr>
<tr><td>Environmental initial parameters</td><td><table>
<tr><td>Road radius</td><td>∞</td></tr>
<tr><td>driven lane</td><td>right</td></tr>
<tr><td>Number of lanes</td><td>2</td></tr>
</table></td></tr>
<tr><td>Assessment</td><td>☒ Technical ☐ User-related</td></tr>
<tr><td>Driver reaction (only relevant for the technical assessment)</td><td>No reaction of the driver on any warning or intervention before the highest warning level is reached (afterwards the reaction of the driver depends on function).
Driving with constant speed</td></tr>
<tr><td>Comment</td><td></td></tr>
</table>

Test Scenario	Cross traffic collisions
Test Case	4.8

Parking 3: Unparking vehicle



Description	Host vehicle drives on main road, unparking car leaves the parking lot and is on collision course. The driver reacts by applying an inappropriate steering torque.
Relevant functions	ESA
Use case	UC_04_608_v2
Vehicle initial parameters	see table below
Number vehicles	1 (+ 1 moving target)
Required Equipment	
Environmental initial parameters	see table below
Assessment	☒ Technical ☒ User-related
Driver reaction (only relevant for the technical assessment)	• Driver should react in defined way(distance and steering torque) • Driving with constant speed (at least up to time point of intervention)
Comment	3: Steering torque is applied by the driver. The amount of the applied steering torque needs to be defined to a later stage.

Vehicle initial parameters:

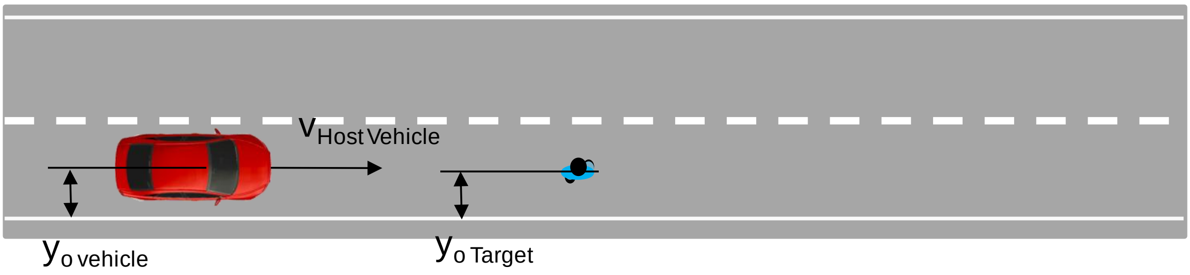
$v_{Host Vehicle}$ [km/h]	30	50	
$v_{Target Vehicle}$ [km/h]	5		
y_{Stop} [m]	1.85		
x_0 [m]	$6^1 / 9^2$	$12^1 / 18^2$	$13^1 / 27^2$
Steering torque [3] [Nm]	Too weak	correct	Too strong

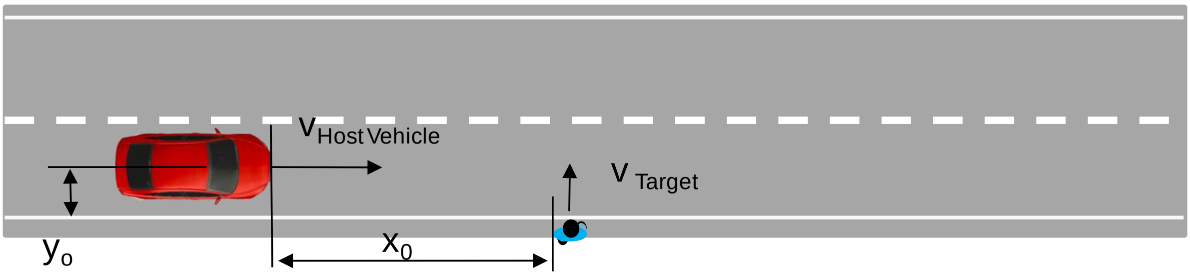
x0 (distance to target vehicle when crossing lane border) : 1 used at 30 km/h and 2 used at 50 km/h

Environmental initial parameters:

Road radius	∞
driven lane	right
Number of lanes	2

5. Collisions with vulnerable road users

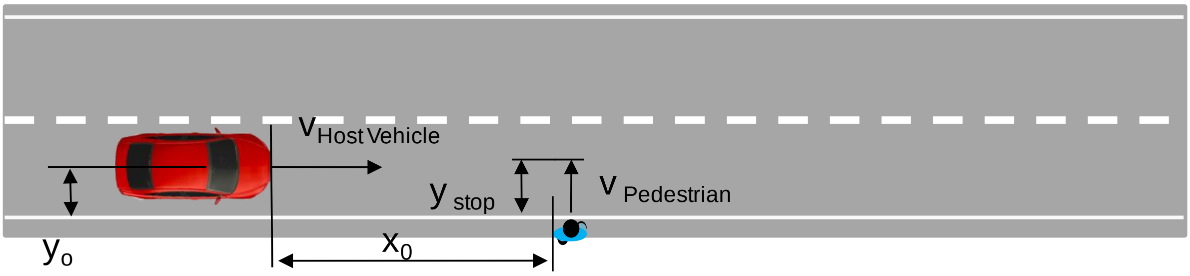
<table>
<tr><th>Test Scenario</th><th>Collisions with vulnerable road users</th></tr>
<tr><td>Test Case</td><td>5.1</td></tr>
<tr><td colspan="2">Standstill pedestrian</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Description</td><td>Host vehicle approaches a pedestrian, who stands in the middle of the road.</td></tr>
<tr><td>Relevant functions</td><td>CS, ESA</td></tr>
<tr><td>Use case</td><td>UC_05_405_v1, UC_05_609v2</td></tr>
<tr><td>Vehicle initial parameters</td><td><table>
<tr><td>$v_{Host Vehicle}$ [km/h]</td><td>30</td><td>50</td><td></td></tr>
<tr><td>y_o [m]</td><td colspan="3">1.925 (middle of the road)</td></tr>
<tr><td>$y_{o\ Target}$</td><td>1.925</td><td>1</td><td>0</td></tr>
</table></td></tr>
<tr><td>Number vehicles</td><td>1</td></tr>
<tr><td>Required Equipment</td><td>Pedestrian dummy (stationary)</td></tr>
<tr><td>Environmental initial parameters</td><td><table>
<tr><td>Size of pedestrian [m]</td><td>1.75 (HIII 50 % middle adult male)</td></tr>
<tr><td>Road radius</td><td>∞</td></tr>
<tr><td>driven lane</td><td>right</td></tr>
<tr><td>Number of lanes</td><td>2</td></tr>
</table></td></tr>
<tr><td>Assessment</td><td>☒ Technical ☐ User-related</td></tr>
<tr><td>Driver reaction (only relevant for the technical assessment)</td><td>
No reaction of the driver on any warning or intervention before the highest warning level is reached (afterwards the reaction of the driver depends on function).
Driving with constant speed
For ESA: the driver should apply at a defined distance a defined steering torque, which is either too weak, correct or too strong.
</td></tr>
<tr><td>Comment</td><td></td></tr>
</table>

<table>
<tr><td>Test Scenario</td><td>Collisions with vulnerable road users</td></tr>
<tr><td>Test Case</td><td>5.2</td></tr>
<tr><td colspan="2">Moving pedestrian (crossing)</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Description</td><td>Host vehicle approaches a pedestrian, who crossed the road.</td></tr>
<tr><td>Relevant functions</td><td>CS, ESA</td></tr>
<tr><td>Use case</td><td>UC_05_405_v1, UC_05_609v2</td></tr>
<tr><td>Vehicle initial parameters</td><td>
<table>
<tr><td>$v_{Host\ Vehicle}$ [km/h]</td><td>30</td><td>50</td><td></td></tr>
<tr><td>y_o [m]</td><td colspan="3">1.925 (middle of the road)</td></tr>
<tr><td>v_{Target} [km/h]</td><td>3</td><td>10</td><td></td></tr>
<tr><td>x_o [m]</td><td colspan="3">different</td></tr>
</table>
x_0 (Distance to pedestrian when crosses border, has to be adjust to the vehicle's speed and the pedestrian's speed. Vehicle should hit the pedestrian on the right side)
<table>
<tr><td>x_o [m]</td><td>v_{HV} =30 km/h</td><td>v_{HV} =50 km/h</td></tr>
<tr><td>v_{Target} =3 km/h</td><td>14.5</td><td>24.2</td></tr>
<tr><td>v_{Target} = 10 km/h</td><td>4.4</td><td>7.3</td></tr>
</table></td></tr>
<tr><td>Number vehicles</td><td>1</td></tr>
<tr><td>Required Equipment</td><td>Pedestrian dummy (moving)</td></tr>
<tr><td>Environmental initial parameters</td><td>
<table>
<tr><td>Size of pedestrian [m]</td><td>1.75 (HIII 50 % middle adult male)</td></tr>
<tr><td>Road radius</td><td>∞</td></tr>
<tr><td>driven lane</td><td>right</td></tr>
<tr><td>Number of lanes</td><td>2</td></tr>
</table></td></tr>
<tr><td>Assessment</td><td>☒ Technical ☐ User-related</td></tr>
<tr><td>Driver reaction (only relevant for the technical assessment)</td><td>

No reaction of the driver on any warning or intervention before the highest warning level is reached (afterwards the reaction of the driver depends on function).
Driving with constant speed
For ESA: the driver should apply at a defined distance a defined steering torque, which is either too weak, correct or too strong.
</td></tr>
<tr><td>Comment</td><td>1: It pedestrian dummy is available</td></tr>
</table>

Test Scenario	Collisions with vulnerable road users
Test Case	5.3

Stopped pedestrian



Description	Host vehicle approaches a pedestrian, who moves on the road and then stops on the road. b) The driver steers to avoid the pedestrian, but with an inappropriate torque.
Relevant functions	a) CS b) ESA (steering assist)
Use case	a) UC_05_405_v0, UC_06_610_V1 b) UC_06_610_V1
Vehicle initial parameters	see tables below

$v_{Host\ Vehicle}$ [km/h]	30	50
y_o [m]	1.925 (middle of road)	
v_{Target} [km/h]	3	10
x_o [m]	s. Table below	
y_{Stop} [m]	1.45	

x_0 (Distance to pedestrian when crosses border, has to be adjust to the vehicle's speed and the pedestrian's speed. Vehicle should hit the pedestrian on the right side)

x_o [m]	v_{HV} =30 km/h	v_{HV} =50 km/h
v_{Target} =3 km/h	18.7	31.1
v_{Target} = 10 km/h	8.5	14.2

For b) also the applied steering torque needs to be defined

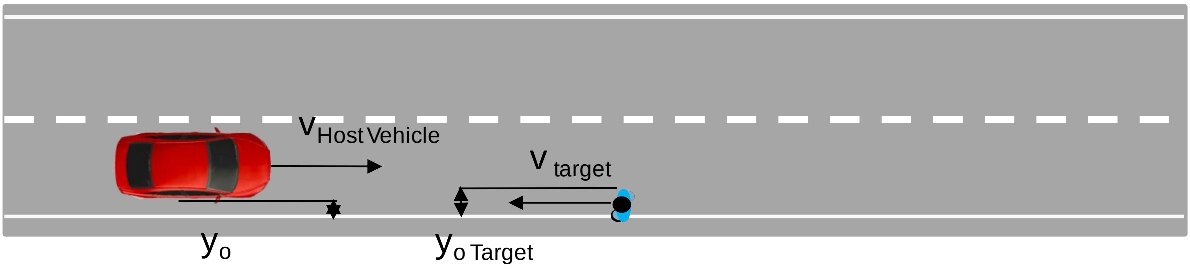
Applied torque [Nm]	too weak	correct	too strong
x_1 [m]	10	20	50

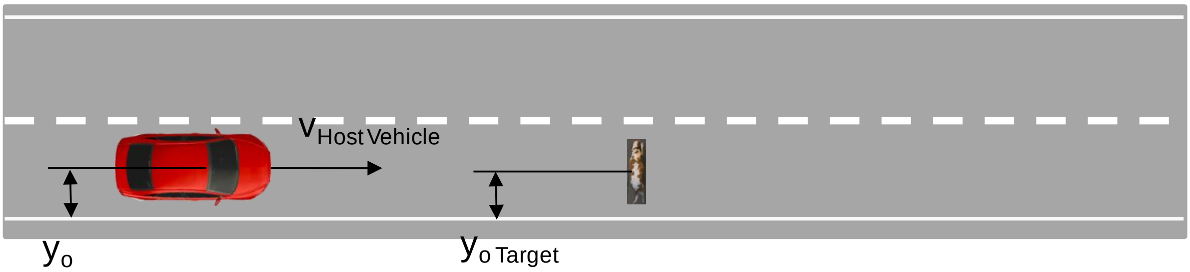
$x_1$distance to pedestrian when starting to apply torque

Number vehicles	1
Required Equipment	Pedestrian dummy (moving)
Environmental initial parameters	see table below

Size of pedestrian [m]	1.75 (HIII 50 % middle adult male)
Road radius	∞
driven lane	right
Number of lanes	2

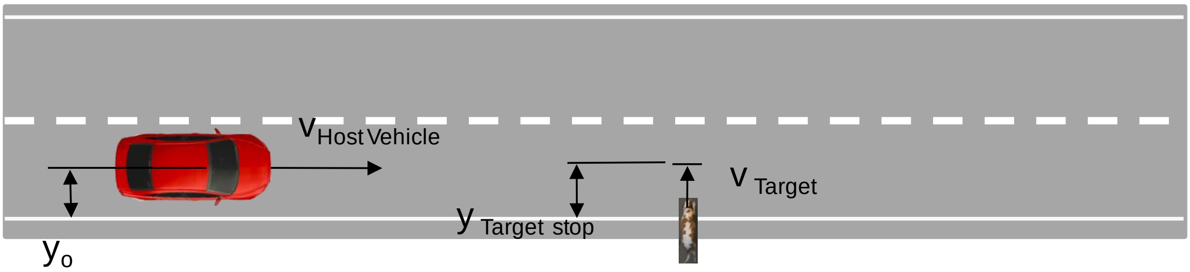
Assessment	☒ Technical ☒ User-related
Driver reaction (only relevant for the technical assessment)	a) • No reaction of the driver on any warning or intervention before the highest warning level is reached (afterwards the reaction of the driver depends on function). • Driving with constant speed b) • Driver should apply a certain steering torque at a certain distance • Driving with constant speed
Comment	

<table>
<tr><td>Test Scenario</td><td>Collisions with vulnerable road users</td></tr>
<tr><td>Test Case</td><td>5.4</td></tr>
<tr><td colspan="2">Moving pedestrian (oncoming)</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Description</td><td>Host vehicle approaches a pedestrian, who walks on the road (e.g. rural road without sidewalk).</td></tr>
<tr><td>Relevant functions</td><td>CS</td></tr>
<tr><td>Use case</td><td>UC_05_405_v1</td></tr>
<tr><td>Vehicle initial parameters</td><td><table>
<tr><td>$v_{Host\ Vehicle}$ [km/h]</td><td>50</td><td>70</td><td></td></tr>
<tr><td>y_o [m]</td><td colspan="3">1.925 (middle of road)</td></tr>
<tr><td>v_{Target} [km/h]</td><td>6</td><td></td><td></td></tr>
<tr><td>$y_{o\ Target}$ [m]</td><td>0</td><td>1.5</td><td></td></tr>
</table></td></tr>
<tr><td>Number vehicles</td><td>1</td></tr>
<tr><td>Required Equipment</td><td>Pedestrian dummy (moving)</td></tr>
<tr><td>Environmental initial parameters</td><td><table>
<tr><td>Size of pedestrian [m]</td><td>1.75 (HIII 50 % middle adult male)</td></tr>
<tr><td>Road radius</td><td>∞</td></tr>
<tr><td>driven lane</td><td>right</td></tr>
<tr><td>Number of lanes</td><td>2</td></tr>
</table></td></tr>
<tr><td>Assessment</td><td>☒ Technical ☐ User-related</td></tr>
<tr><td>Driver reaction (only relevant for the technical assessment)</td><td>No reaction of the driver on any warning or intervention before the highest warning level is reached (afterwards the reaction of the driver depends on function).
Driving with constant speed</td></tr>
<tr><td>Comment</td><td></td></tr>
</table>

<table>
<tr><td>Test Scenario</td><td>Collisions with vulnerable road users</td></tr>
<tr><td>Test Case</td><td>5.5</td></tr>
<tr><td colspan="2">Moving animal</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Description</td><td>Host vehicle approaches an animal, which stands in the middle of the road respectively lane.</td></tr>
<tr><td>Relevant functions</td><td>CS</td></tr>
<tr><td>Use case</td><td>UC_05_438_v1</td></tr>
<tr><td>Vehicle initial parameters</td><td><table>
<tr><td>$v_{Host Vehicle}$ [km/h]</td><td>30</td><td>50</td><td></td></tr>
<tr><td>y_o [m]</td><td colspan="3">1.925 (middle of the road)</td></tr>
<tr><td>$y_{o\ Target}$</td><td>1.925</td><td>1</td><td>0</td></tr>
</table></td></tr>
<tr><td>Number vehicles</td><td>1</td></tr>
<tr><td>Required Equipment</td><td>Animal dummy (stationary)</td></tr>
<tr><td>Environmental initial parameters</td><td><table>
<tr><td>Animal (or)</td><td>Wild boar</td><td>Roe Deer</td></tr>
<tr><td>Road radius</td><td>∞</td><td></td></tr>
<tr><td>driven lane</td><td>right</td><td></td></tr>
<tr><td>Number of lanes</td><td>2</td><td></td></tr>
</table></td></tr>
<tr><td>Assessment</td><td>☒ Technical ☐ User-related</td></tr>
<tr><td>Driver reaction (only relevant for the technical assessment)</td><td>• No reaction of the driver on any warning or intervention before the highest warning level is reached (afterwards the reaction of the driver depends on function).
• Driving with constant speed</td></tr>
<tr><td>Comment</td><td></td></tr>
</table>

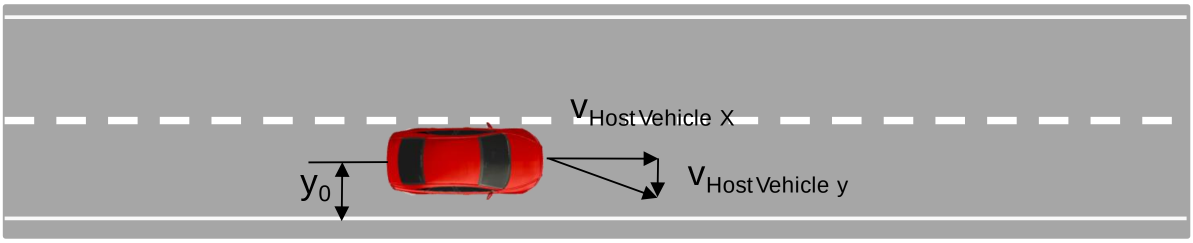
Test Scenario	Collisions with vulnerable road users
Test Case	5.6

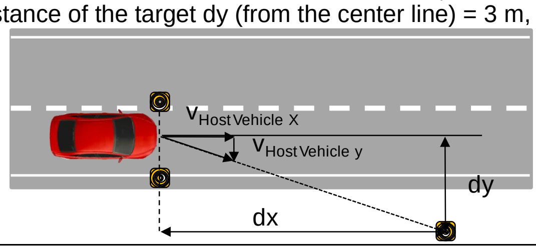
Stopped animal

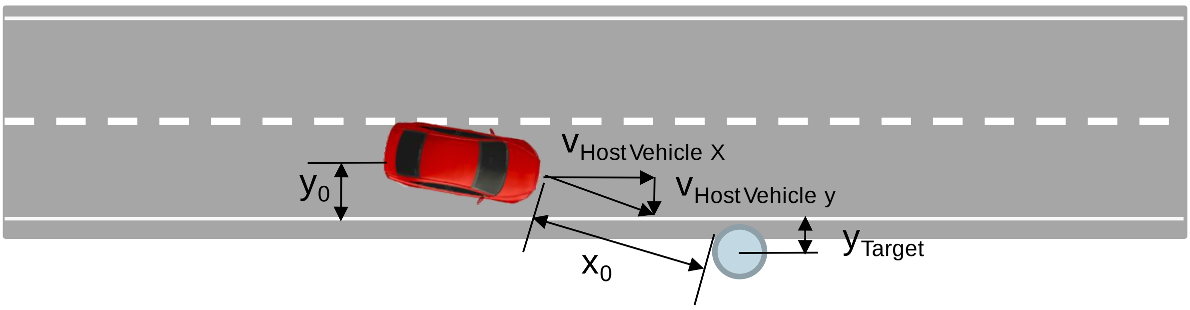


Description	Host vehicle approaches an animal, (or a herd of animals), which moves on the road and then stops on the road.
Relevant functions	CS
Use case	UC_05_438_v1
Vehicle initial parameters	<table><tr><td>$v_{Host\ Vehicle}$ [km/h]</td><td>50</td><td></td></tr><tr><td>y_o [m]</td><td colspan="2">1.925 (middle of road)</td></tr><tr><td>v_{Target} [km/h]</td><td>3</td><td>10</td></tr><tr><td>x_o [m]</td><td colspan="2">See table below</td></tr><tr><td>y_{Stop} [m]</td><td>1.45</td><td></td></tr></table>x_0 (Distance to pedestrian when crosses border, has to be adjust to the vehicle's speed and the pedestrian's speed. Vehicle should hit the pedestrian on the right side)<table><tr><td>x_o [m]</td><td>v_{HV} =50 km/h</td></tr><tr><td>v_{Target} =3 km/h</td><td>31.1</td></tr><tr><td>v_{Target} = 10 km/h</td><td>14.2</td></tr></table>
Number vehicles	1
Required Equipment	Animal dummy (moving)
Environmental initial parameters	<table><tr><td>Animal (or)</td><td>Wild boar</td><td>Roe Deer</td></tr><tr><td>Road radius</td><td>∞</td><td></td></tr><tr><td>driven lane</td><td>right</td><td></td></tr><tr><td>Number of lanes</td><td>2</td><td></td></tr></table>
Assessment	☒ Technical ☐ User-related
Driver reaction (only relevant for the technical assessment)	• No reaction of the driver on any warning or intervention before the highest warning level is reached (afterwards the reaction of the driver depends on function). • Driving with constant speed
Comment	

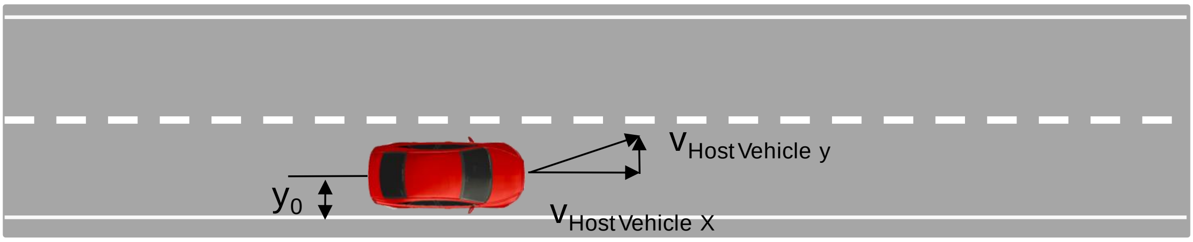
6. Unintended lane departure-accidents

<table>
<tr><th>Test Scenario</th><th>Unintended lane departure-accidents</th></tr>
<tr><th>Test Case</th><th>6.1</th></tr>
<tr><td colspan="2">Unintended lane / road departure (right)</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Description</td><td>Unintended lane departure of the host vehicle to the right side.</td></tr>
<tr><td>Relevant functions</td><td>CS, RORP</td></tr>
<tr><td>Use case</td><td>UC_06_454_v0, UC_06_503_v2, UC_06_536_v1, UC_06_510_v2, UC_06_535, UC_06_536_v1</td></tr>
<tr><td>Vehicle initial parameters</td><td><table>
<tr><td>$v_{Host\ Vehicle\ x}$ [km/h]</td><td>30</td><td>50</td><td>70</td></tr>
<tr><td>$v_{Host\ Vehicle\ y}$ [km/h]</td><td>1</td><td>2</td><td>5</td></tr>
<tr><td>y_0 [m]</td><td>2.5[2]</td><td></td><td></td></tr>
<tr><td>Status turn indicator [-]</td><td>off</td><td></td><td></td></tr>
</table></td></tr>
<tr><td>Number vehicles</td><td>1</td></tr>
<tr><td>Required Equipment</td><td>none</td></tr>
<tr><td>Environmental initial parameters</td><td><table>
<tr><td>lane marking</td><td>solid</td><td></td></tr>
<tr><td>Road radius</td><td>∞</td><td>500 m[1]</td></tr>
<tr><td>driven lane</td><td>right</td><td></td></tr>
<tr><td>Number of lanes</td><td>2</td><td></td></tr>
<tr><td>loading of vehicle (only relevant for trucks)</td><td>Basic</td><td>Fully loaded</td></tr>
</table></td></tr>
<tr><td>Assessment</td><td>☒ Technical ☒ User-related</td></tr>
<tr><td>Driver reaction (only relevant for the technical assessment)</td><td>
No reaction of the driver on any warning or intervention before the highest warning level is reached (afterwards the reaction of the driver depends on function).
Driving with constant speed
Driver should steer the vehicle to lane in the way that the defined lateral velocity is reached.

In order to ensure the correct lateral velocity during the tests a target can be placed target at the side of the road in a defined distance, see figure below. In this case the driver has to start to steer at a certain point and to drive afterwards straight ahead towards the target. The lateral and longitudinal distance of the target should be should be chosen based on the chosen angle of the test case (e.g. $v_{Host\ Vehicle\ x}$ = 50 km/h & $v_{Host\ Vehicle\ y}$ = 5 km/h → The angle is 5.74° → distance of the target dy (from the center line) = 3 m, dy = 30 m)

</td></tr>
<tr><td>Comment</td><td>1: It must be checked if this can be tested.
2: At the start the vehicle drives on the left side of the lane</td></tr>
</table>

<table>
<tr><td>Test Scenario</td><td>Unintended lane departure-accidents</td></tr>
<tr><td>Test Case</td><td>6.2</td></tr>
<tr><td colspan="2">Unintended lane / road departure to obstacle (right)</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Description</td><td>Unintended lane departure of the host vehicle to the right side and approaches an obstacle $_1$.</td></tr>
<tr><td>Relevant functions</td><td>CMS</td></tr>
<tr><td>Use case</td><td>UC_06_610_v1</td></tr>
<tr><td>Vehicle initial parameters</td><td><table>
<tr><td>$v_{Host\ Vehicle\ x}$ [km/h]</td><td>50</td><td>80</td></tr>
<tr><td>$v_{Host\ Vehicle\ y}$ [km/h]</td><td>1</td><td>5</td></tr>
<tr><td>y_0 [m]</td><td>2.5</td><td></td></tr>
<tr><td>Status turn indicator [-]</td><td>off</td><td></td></tr>
<tr><td>y_{Target} [m]</td><td>1</td><td></td></tr>
</table>
x_0 (longitudinal distance to obstacle when leaving road)</td></tr>
<tr><td>Number vehicles</td><td>1</td></tr>
<tr><td>Required Equipment</td><td>none</td></tr>
<tr><td>Environmental initial parameters</td><td><table>
<tr><td>lane marking</td><td>solid</td></tr>
<tr><td>Road radius</td><td>∞</td></tr>
<tr><td>driven lane</td><td>right</td></tr>
<tr><td>Number of lanes</td><td>2</td></tr>
</table></td></tr>
<tr><td>Assessment</td><td>☒ Technical ☒ User-related[2]</td></tr>
<tr><td>Driver reaction (only relevant for the technical assessment)</td><td>
No reaction of the driver on any warning or intervention before the highest warning level is reached (afterwards the reaction of the driver depends on function).
Driving with constant speed
Driver should steer the vehicle to lane in a defined way.

In order to ensure the correct lateral velocity during the tests a target can be placed target at the side of the road in a defined distance, see figure below. In this case the driver has to start to steer at a certain point and to drive afterwards straight ahead towards the target. The lateral and longitudinal distance of the target should be should be chosen based on the chosen angle of the test case (e.g. $v_{Host\ Vehicle\ x}$ = 50 km/h & $v_{Host\ Vehicle\ y}$ = 5 km/h → The angle is 5.74° → distance of the target dy (from the centre line) = 3 m, dy = 30 m)</td></tr>
<tr><td>Comment</td><td>1: Different kinds of obstacles are detected by the function. The obstacles for the test will be defined to a later stage.
2: If it's not possible to carry out this test case in a driving simulator, test cases 6.6 “barrier” will be tested instead.”</td></tr>
</table>

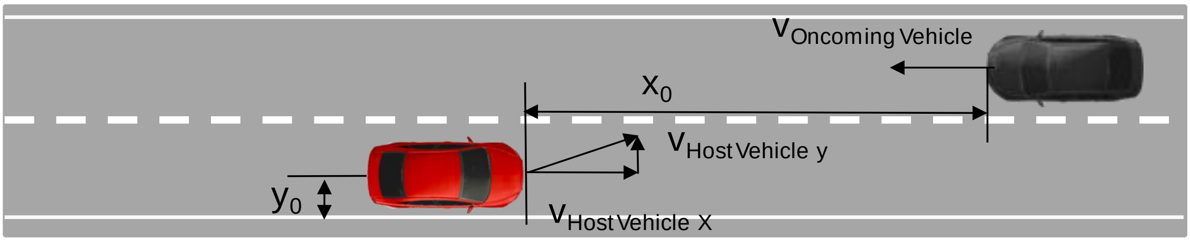
<table>
<tr><th>Test Scenario</th><th>Unintended lane departure-accidents</th></tr>
<tr><th>Test Case</th><th>6.3</th></tr>
<tr><td colspan="2">Unintended lane / road departure (left)</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Description</td><td>Unintended lane departure of the host vehicle to the left side.</td></tr>
<tr><td>Relevant functions</td><td>CS, RORP</td></tr>
<tr><td>Use case</td><td>UC_06_451_v0, UC_06_452_v0, UC_06_503_v2, UC_06_510_v2</td></tr>
<tr><td>Vehicle initial parameters</td><td>
<table>
<tr><td>$v_{Host\ Vehicle\ x}$ [km/h]</td><td>30</td><td>50</td><td>70</td></tr>
<tr><td>$v_{Host\ Vehicle\ y}$ [km/h]</td><td>1</td><td>2</td><td>5</td></tr>
<tr><td>y_o [m]</td><td>0.5</td><td></td><td></td></tr>
<tr><td>Status turn indicator [-]</td><td>on</td><td>off</td><td></td></tr>
</table></td></tr>
<tr><td>Number vehicles</td><td>1</td></tr>
<tr><td>Required Equipment</td><td>none</td></tr>
<tr><td>Environmental initial parameters</td><td>
<table>
<tr><td>lane marking</td><td>solid</td><td>Dash[1]</td><td>Solid[1] dash</td></tr>
<tr><td>Road radius</td><td>∞</td><td></td><td></td></tr>
<tr><td>driven lane</td><td>right</td><td></td><td></td></tr>
<tr><td>Number of lanes</td><td>1</td><td>2</td><td></td></tr>
<tr><td>loading of vehicle (only relevant for trucks)</td><td>Basic</td><td>Fully loaded</td><td></td></tr>
</table></td></tr>
<tr><td>Assessment</td><td>☒ Technical ☐ User-related</td></tr>
<tr><td>Driver reaction (only relevant for the technical assessment)</td><td>

No reaction of the driver on any warning or intervention before the highest warning level is reached (afterwards the reaction of the driver depends on function).
Driving with constant speed
Driver should steer the vehicle to lane in the way that the defined lateral velocity is reached.
After leaving the right lane the driver should continue (same lateral velocity) up to the moment the vehicle leaves the road on the left side

In order to ensure the correct lateral velocity during the tests a target can be placed target at the side of the road in a defined distance, see figure below. In this case the driver has to start to steer at a certain point and to drive afterwards straight ahead towards the target. The lateral and longitudinal distance of the target should be should be chosen based on the chosen angle of the test case (e.g. $v_{Host\ Vehicle\ x}$ = 50 km/h & $v_{Host\ Vehicle\ y}$ = 5 km/h → The angle is 5.74° → distance of the target dy (from the centre line) = 3 m, dy = 30 m)</td></tr>
<tr><td>Comment</td><td>After the 1: If available on the test track</td></tr>
</table>

Test Scenario	Unintended lane departure-accidents
Test Case	6.4

Unintended lane departure with oncoming traffic (left)



Description	Unintended lane departure of the host vehicle to the left lane, in which an oncoming vehicle is.
Relevant functions	CS, RORP, CMS
Use case	UC_06_452_v0, UC_06_453_v0, UC_06_535, UC_02_606_V4
Vehicle initial parameters	see table below; x_0 (Distance to oncoming vehicle at start of manoeuvre)
Number vehicles	1 (+ 1 moving target)
Required Equipment	1 moving target (balloon car)
Environmental initial parameters	see table below
Assessment	☒ Technical ☐ User-related

Vehicle initial parameters:

$v_{Host\ Vehicle\ x}$ [km/h]	50	70
$v_{Host\ Vehicle\ y}$ [km/h]	1	5
y_0 [m]	1.925	
Status turn indicator [-]	on	off
x_0 [m]	Will be defined later	
$v_{Oncoming\ vehicle}$ [m] for RORP	50	70
$v_{Oncoming\ vehicle}$ [m] for CMS	30	50

x_0 (Distance to oncoming vehicle at start of manoeuvre)

Environmental initial parameters:

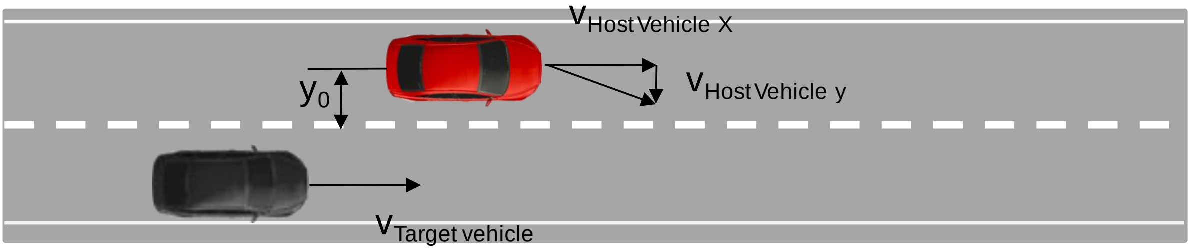
lane marking	dash
Road radius	∞
driven lane	right
Number of lanes	2

Driver reaction (only relevant for the technical assessment):

- No reaction of the driver on any warning or intervention before the highest warning level is reached (afterwards the reaction of the driver depends on function).
- Driving with constant speed
- Driver should steer the vehicle to lane in the way that the defined lateral velocity is reached.
- The manoeuvre should be start when the correct distance between the vehicle is reached

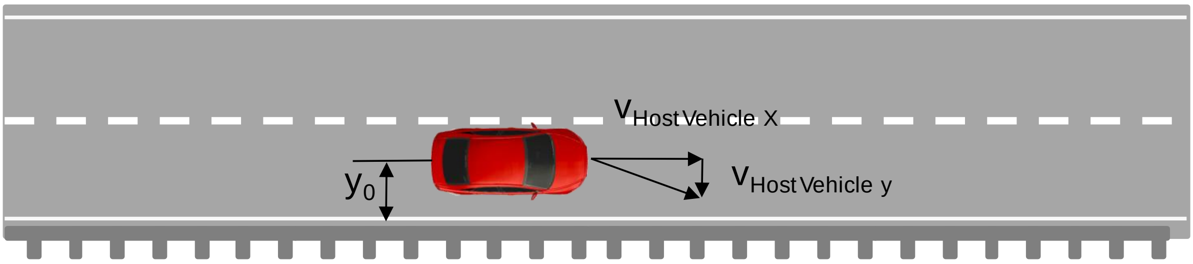
In order to ensure the correct lateral velocity during the tests a target can be placed target at the side of the road in a defined distance, see figure below. In this case the driver has to start to steer at a certain point and to drive afterwards straight ahead towards the target. The lateral and longitudinal distance of the target should be should be chosen based on the chosen angle of the test case (e.g. $v_{Host\ Vehicle\ x}$ = 50 km/h & $v_{Host\ Vehicle\ y}$ = 5 km/h → The angle is 5.74° → distance of the target dy (from the centre line) = 3 m, dy = 30 m)

Comment:

<table>
<tr><td>Test Scenario</td><td>Unintended lane departure-accidents</td></tr>
<tr><td>Test Case</td><td>6.5</td></tr>
<tr><td colspan="2">Unintended lane departure + opponent vehicle</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Description</td><td>The HV (a car) is travelling in the left lane on a straight motorway road with two lanes in the direction of travel. A distraction is provided to the test driver (message typing task) while the road is gradually displaced (y1 or y2 m) to the left to make the HV drift out of the lane and into the right lane. In the right lane, an opponent vehicle is approaching.</td></tr>
<tr><td>Relevant functions</td><td>RORP</td></tr>
<tr><td>Use case</td><td>UC_06_503_v2, UC_06_535</td></tr>
<tr><td>Vehicle initial parameters</td><td><table>
<tr><td>$v_{Host Vehicle x}$ [km/h]</td><td>30</td><td>50</td><td>70</td></tr>
<tr><td>$v_{Host Vehicle y}$ [km/h]</td><td>1</td><td>2</td><td>5</td></tr>
<tr><td>y_0 [m]</td><td>1.925</td><td></td><td></td></tr>
<tr><td>Status turn indicator [-]</td><td>on</td><td>off</td><td></td></tr>
<tr><td>$v_{Target vehicle}$ [m]</td><td>30</td><td>50</td><td></td></tr>
</table></td></tr>
<tr><td>Number vehicles</td><td>1 (+ 1 moving target)</td></tr>
<tr><td>Required Equipment</td><td>1 moving target (sedan-type passenger car)</td></tr>
<tr><td>Environmental initial parameters</td><td><table>
<tr><td>lane marking</td><td>solid</td></tr>
<tr><td>Road radius</td><td>∞</td></tr>
<tr><td>driven lane</td><td>left</td></tr>
<tr><td>Number of lanes</td><td>2</td></tr>
</table></td></tr>
<tr><td>Assessment</td><td>☐ Technical ☐ User-related</td></tr>
<tr><td>Driver reaction (only relevant for the technical assessment)</td><td>

No reaction of the driver on any warning or intervention before the highest warning level is reached (afterwards the reaction of the driver depends on function).
Driving with constant speed
Driver should steer the vehicle to lane in the way that the defined lateral velocity is reached.

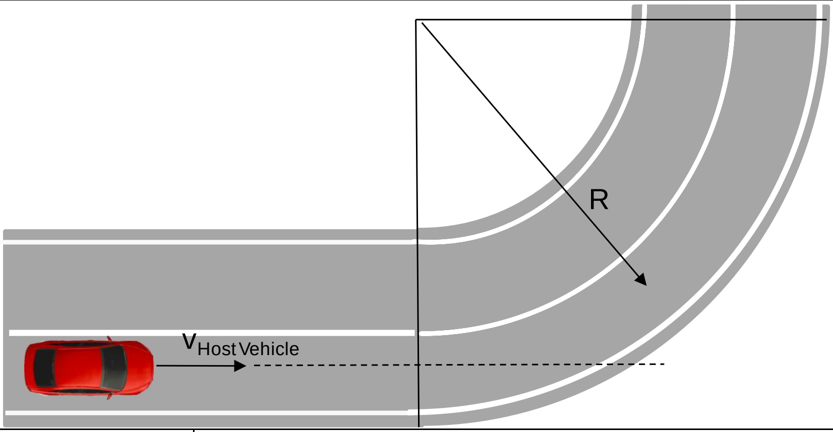
In order to ensure the correct lateral velocity during the tests a target can be placed target at the side of the road in a defined distance, see figure below. In this case the driver has to start to steer at a certain point and to drive afterwards straight ahead towards the target. The lateral and longitudinal distance of the target should be should be chosen based on the chosen angle of the test case (e.g. $v_{Host Vehicle x}$ = 50 km/h & $v_{Host Vehicle y}$ = 5 km/h → The angle is 5.74° → distance of the target dy (from the centre line) = 3 m, dy = 30 m)</td></tr>
<tr><td>Comment</td><td>Test environment simulator</td></tr>
</table>

<table>
<tr><td>Test Scenario</td><td>Unintended lane departure-accidents</td></tr>
<tr><td>Test Case</td><td>6.6</td></tr>
<tr><td colspan="2">Barrier</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Description</td><td>The host vehicle drifts unintended to the right road side, where the road is bordered by a barrier.</td></tr>
<tr><td>Relevant functions</td><td>CS, RORP, CMS</td></tr>
<tr><td>Use case</td><td>UC_06_454_v0</td></tr>
<tr><td>Vehicle initial parameters</td><td><table>
<tr><td>$v_{Host Vehicle x}$ [km/h]</td><td>30</td><td>50</td></tr>
<tr><td>$v_{Host Vehicle y}$ [km/h]</td><td>1</td><td>5</td></tr>
<tr><td>y_0 [m]</td><td>2.5</td><td></td></tr>
<tr><td>Status turn indicator [-]</td><td>on</td><td>off</td></tr>
</table></td></tr>
<tr><td>Number vehicles</td><td>1</td></tr>
<tr><td>Required Equipment</td><td>none</td></tr>
<tr><td>Environmental initial parameters</td><td><table>
<tr><td>Road radius</td><td>∞</td><td></td></tr>
<tr><td>driven lane</td><td>right</td><td></td></tr>
<tr><td>Number of lanes</td><td>2</td><td></td></tr>
<tr><td>Barrier[1]</td><td>right</td><td>left[2]</td></tr>
</table></td></tr>
<tr><td>Assessment</td><td>☒ Technical ☒ User-related[3]</td></tr>
<tr><td>Driver reaction (only relevant for the technical assessment)</td><td>
No reaction of the driver on any warning or intervention before the highest warning level is reached (afterwards the reaction of the driver depends on function).
Driving with constant speed
Driver should steer the vehicle to lane in the way that the defined lateral velocity is reached.

In order to ensure the correct lateral velocity during the tests a target can be placed target at the side of the road in a defined distance, see figure below. In this case the driver has to start to steer at a certain point and to drive afterwards straight ahead towards the target. The lateral and longitudinal distance of the target should be should be chosen based on the chosen angle of the test case (e.g. $v_{Host Vehicle x}$ = 50 km/h & $v_{Host Vehicle y}$ = 5 km/h → The angle is 5.74° → distance of the target dy (from the centre line) = 3 m, dy = 30 m)</td></tr>
<tr><td>Comment</td><td>1: also given conditions on the test track must be considered
2: in this case road departure to the left road boundary
3: Will only be tested in the user-related assessment, if it’s not possible to carry out test case 6.2 in a driving simulator.</td></tr>
</table>

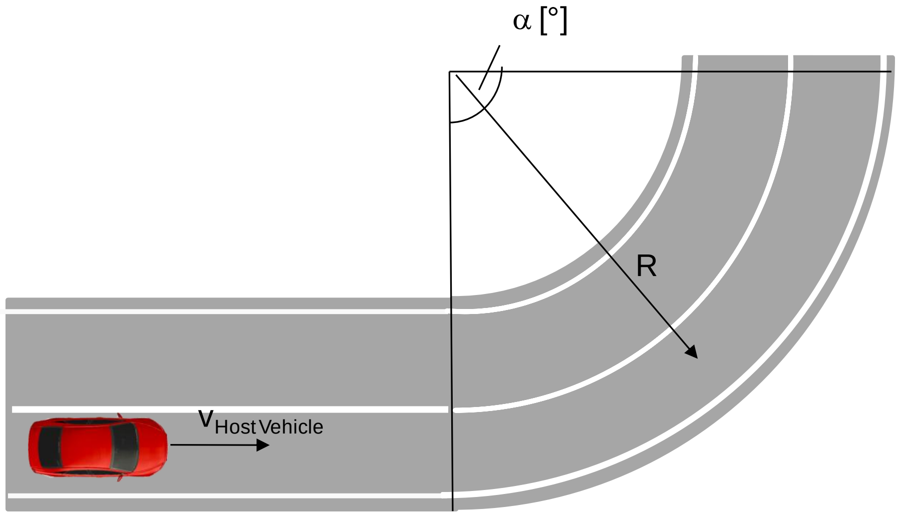
Test Scenario	Unintended lane departure-accidents
Test Case	6.8

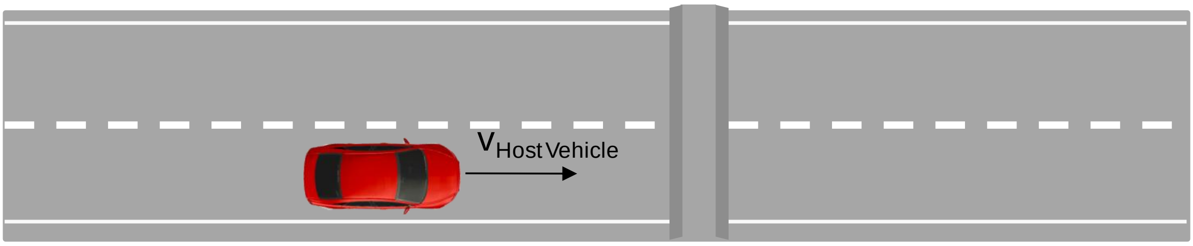
Lane departure in curve



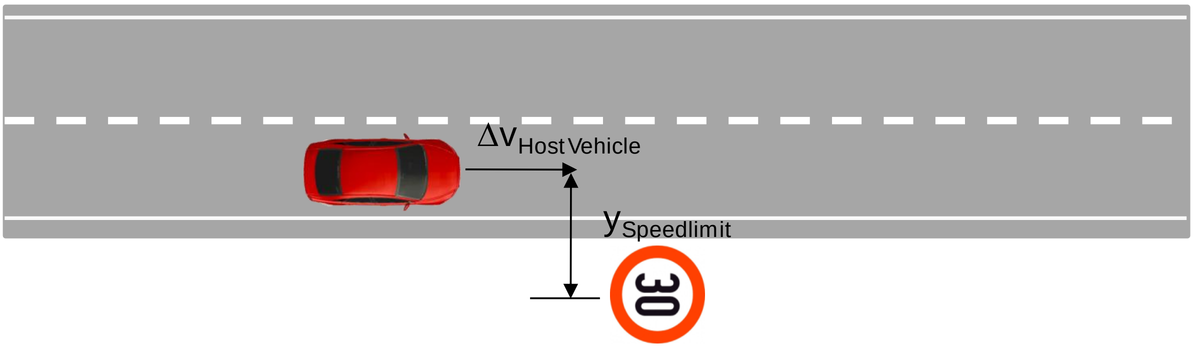
Description	Lane departure in curve.
Relevant functions	RORP
Use case	UC_06_509_v2
Vehicle initial parameters	$v_{Host\ Vehicle\ x}$ [km/h] | 30 | 50 | 70
Number vehicles	1
Required Equipment	none
Environmental initial parameters	Road radius | 30 m | 50 m | 80 m
Assessment	☒ Technical ☒ User-related
Driver reaction (only relevant for the technical assessment)	• No reaction of the driver on any warning or intervention before the highest warning level is reached (afterwards the reaction of the driver depends on function). • Driving with constant speed • The driver should drive straight ahead
Comment	

7. Excessive speed accidents

Test Scenario	Excessive speed accidents
Test Case	7.1
Speed curve	
	
Description	Host vehicle approaches with a too high (unsafe) velocity a curve.
Relevant functions	CSC, CS
Use case	UC_07_406_v1, UC_07_456_v0
Vehicle initial parameters	$v_{Host\ Vehicle\ x}$ [km/h] : Depending on the curve parameters In general the vehicle speed should be chosen in a way that each case (slow, correct speed, too fast) is tested.
Number vehicles	1
Required Equipment	none
Environmental initial parameters	Road radius: different Curve angle: different Number of lanes: 1 The curve parameters will depend strongly on the test track or test route. In order to get a clear picture of the test function behaviour as much as possible different combination should be tested.
Assessment	☒ Technical ☐ User-related
Driver reaction (only relevant for the technical assessment)	• No reaction of the driver on any warning or intervention before the highest warning level is reached (afterwards the reaction of the driver depends on function). • Driving with constant speed • The driver should try to the negotiate curve.
Comment	Test can be conducted on test track or on public road. In the second case legal issues have to be considered.

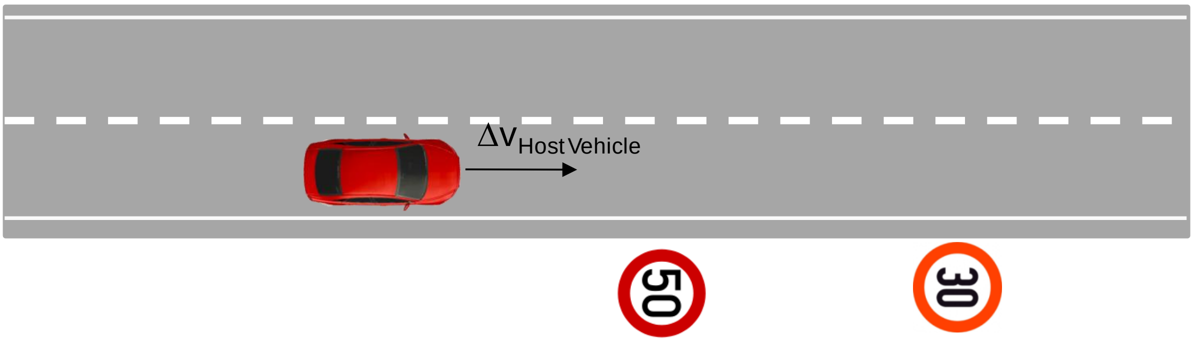
<table>
<tr><th>Test Scenario</th><th>Excessive speed accidents</th></tr>
<tr><td>Test Case</td><td>7.3</td></tr>
<tr><td colspan="2">Approaching zone, which required a lower speed (e.g. speed bump)</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Description</td><td>Host vehicle approaches a zone without traffic signs, which required a lower speed (e.g. speed bump)</td></tr>
<tr><td>Relevant functions</td><td>CS</td></tr>
<tr><td>Use case</td><td>UC_07_455_v0</td></tr>
<tr><td>Vehicle initial parameters</td><td><table><tr><td>$v_{Host\ Vehicle\ x}$ [km/h]</td><td>10</td><td>30</td><td>50</td><td>70</td></tr></table></td></tr>
<tr><td>Number vehicles</td><td>1</td></tr>
<tr><td>Required Equipment</td><td>speed bump, cross walk</td></tr>
<tr><td>Environmental initial parameters</td><td><table><tr><td>geometric of zone</td><td>Speed bump</td><td>cross walk</td></tr><tr><td>Road radius</td><td>∞</td><td></td></tr><tr><td>driven lane</td><td>right</td><td></td></tr><tr><td>Number of lanes</td><td>2</td><td></td></tr></table></td></tr>
<tr><td>Assessment</td><td>☒ Technical ☐ User-related</td></tr>
<tr><td>Driver reaction (only relevant for the technical assessment)</td><td>No reaction of the driver on any warning or intervention before the highest warning level is reached (afterwards the reaction of the driver depends on function).
Driving with constant speed</td></tr>
<tr><td>Comment</td><td></td></tr>
</table>

8. Traffic rule violations

Test Scenario	Traffic rule violations
Test Case	8.1
Approaching speed limit	
	
Description	The host vehicle approaches a speed limit with different relative velocities. The lateral distance to the speed limit is variable.
Relevant functions	CS, SC
Use case	UC_08_457_v1
Vehicle initial parameters	$\Delta v_{Host\ Vehicle}$ [km/h] | -10 | 0 | 10 | 20 | 30
Number vehicles	1
Required Equipment	Speed limit signs, digital map data
Environmental initial parameters	Road radius: ∞ Number of lanes: 2 Driven lane[1]: Left | right position of speed limits signs[1]: right | right & left $y_{Speedlimit}$ [m][1,2]: -2.45 speed limit [km/h]: 30 | 50 | 100
Assessment	☒ Technical ☐ User-related
Driver reaction (only relevant for the technical assessment)	• No reaction of the driver on any warning or intervention before the highest warning level is reached (afterwards the reaction of the driver depends on function). • Driving with constant speed
Comment	1: Only relevant if the speed limit is detected by means of a camera sensor 2: The vehicle should drive in the middle of the road

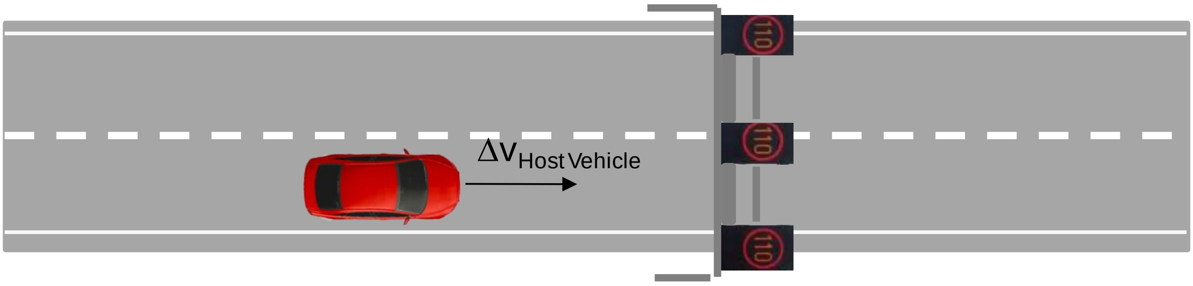
Test Scenario	Traffic rule violations
Test Case	8.2

Approaching series of speed limits



Description	The host vehicle approaches a speed limit with different relative velocities. The lateral distance to the speed limit is variable.
Relevant functions	CS, SC
Use case	UC_08_457_v1
Vehicle initial parameters	$\Delta v_{Host\ Vehicle}$ [km/h] | 10 | 0 | 10 | 20 | 30
Number vehicles	1
Required Equipment	speed limit signs, digital map data
Environmental initial parameters	Road radius: ∞ position of speed limits signs: right speed limit 1 [km/h]: 50 | 70 speed limit 2 [km/h]: 30 | 50 The difference between both speed limit should always 20 km/h
Assessment	☒ Technical ☐ User-related
Driver reaction (only relevant for the technical assessment)	• No reaction of the driver on any warning or intervention before the highest warning level is reached (afterwards the reaction of the driver depends on function). • Driving with constant speed
Comment	

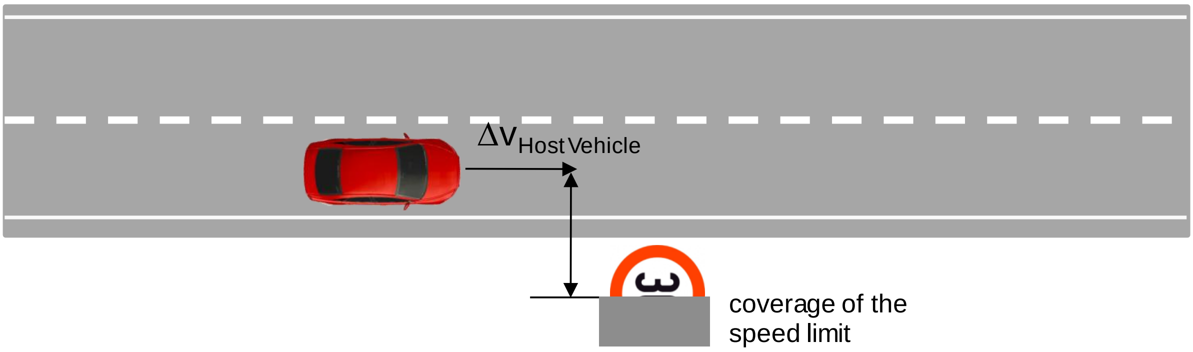
<table>
<tr><td>Test Scenario</td><td>Traffic rule violations</td></tr>
<tr><td>Test Case</td><td>8.3</td></tr>
<tr><td colspan="2">Approaching dynamic speed limit</td></tr>
<tr><td colspan="2">



</td></tr>
<tr><td>Description</td><td>Host vehicle approaches a dynamic speed limit, which is mounted over the street.</td></tr>
<tr><td>Relevant functions</td><td>CS, SC</td></tr>
<tr><td>Use case</td><td>UC_08_457_v1</td></tr>
<tr><td>Vehicle initial parameters</td><td><table><tr><td>$\Delta v_{Host\ Vehicle}$ [km/h]</td><td>10</td><td>30</td><td>50</td></tr></table></td></tr>
<tr><td>Number vehicles</td><td>1</td></tr>
<tr><td>Required Equipment</td><td>dynamic speed limit signs, digital map data</td></tr>
<tr><td>Environmental initial parameters</td><td><table><tr><td>Road radius</td><td>∞</td><td></td></tr><tr><td>position of speed limits signs</td><td>right</td><td>over the street</td></tr><tr><td>speed limit [km/h]</td><td>100</td><td>130</td></tr></table></td></tr>
<tr><td>Assessment</td><td>☒ Technical ☐ User-related</td></tr>
<tr><td>Driver reaction (only relevant for the technical assessment)</td><td>No reaction of the driver on any warning or intervention before the highest warning level is reached (afterwards the reaction of the driver depends on function).
Driving with constant speed</td></tr>
<tr><td>Comment</td><td>Test can only conducted if a dynamic speed limit sign is available.</td></tr>
</table>

Test Scenario	Traffic rule violations
Test Case	8.4

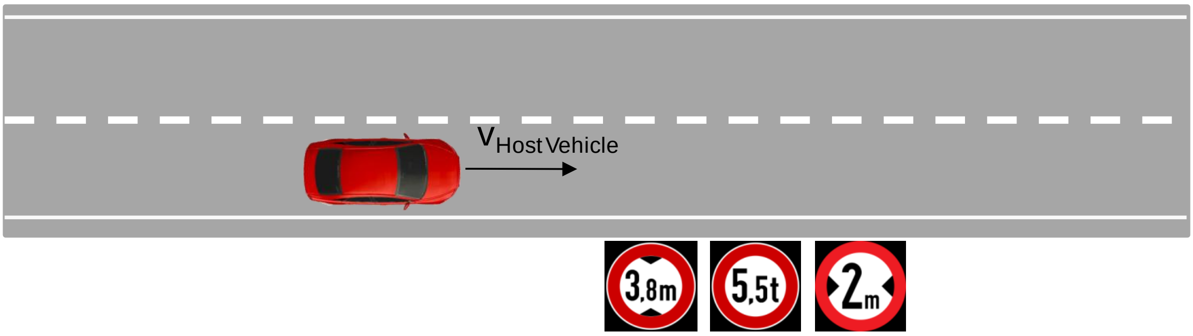
Approaching covered speed limit



Description	Host vehicle approaches a speed limit, which is covered. Therefore the whole speed limit sign is not visible.
Relevant functions	CS, SC
Use case	UC_08_457_v1
Vehicle initial parameters	$\Delta v_{Host Vehicle}$ [km/h] | 10 | 30 | | |
Number vehicles	1
Required Equipment	speed limit signs, digital map data
Environmental initial parameters	Road radius: ∞ coverage of the speed limit: 10 % | 25 % speed limit [km/h]: 50 | 100
Assessment	☒ Technical ☐ User-related
Driver reaction (only relevant for the technical assessment)	• No reaction of the driver on any warning or intervention before the highest warning level is reached (afterwards the reaction of the driver depends on function). • Driving with constant speed
Comment	

Test Scenario	Traffic rule violations
Test Case	8.5

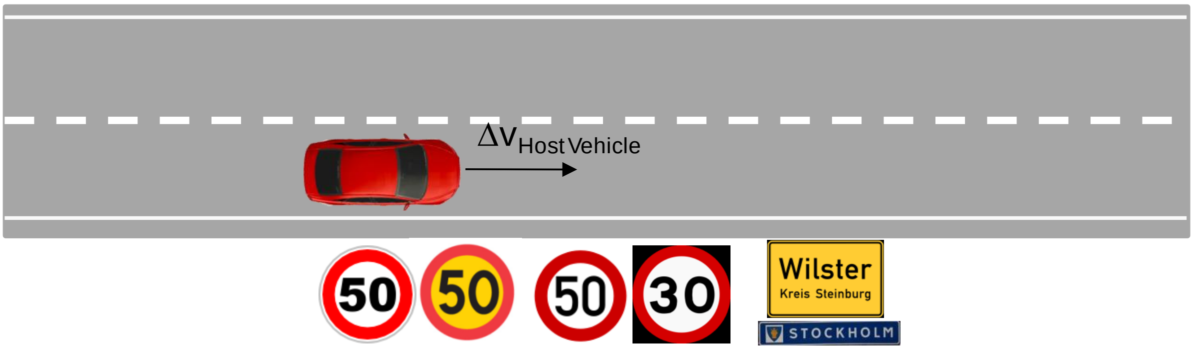
Approaching similar speed limit signs



<table>
<tr><td>Description</td><td>Host vehicle approaches different traffic signs, which looks similar to a speed limit sign.</td></tr>
<tr><td>Relevant functions</td><td>CS, SC</td></tr>
<tr><td>Use case</td><td>UC_08_457_v1</td></tr>
<tr><td>Vehicle initial parameters</td><td><table><tr><td>$\Delta v_{Host Vehicle}$ [km/h]</td><td>0</td><td></td><td></td><td></td><td></td></tr></table></td></tr>
<tr><td>Number vehicles</td><td>1</td></tr>
<tr><td>Required Equipment</td><td>traffic signs, digital map data</td></tr>
<tr><td>Environmental initial parameters</td><td><table>
<tr><td>Road radius</td><td>∞</td><td></td><td></td><td></td></tr>
<tr><td>traffic signs</td><td>Height restriction</td><td>Weight restriction</td><td>Width restriction</td><td>speed limit combined with other road sign[1]</td></tr>
<tr><td>speed limit [km/h]</td><td>50</td><td></td><td></td><td></td></tr>
</table></td></tr>
<tr><td>Assessment</td><td>☒ Technical ☐ User-related</td></tr>
<tr><td>Driver reaction (only relevant for the technical assessment)</td><td>• No reaction of the driver on any warning or intervention before the highest warning level is reached (afterwards the reaction of the driver depends on function).
• Driving with constant speed</td></tr>
<tr><td>Comment</td><td>1: For example a speed limit which is only valid in wet condition.</td></tr>
</table>

Test Scenario	Traffic rule violations
Test Case	8.6

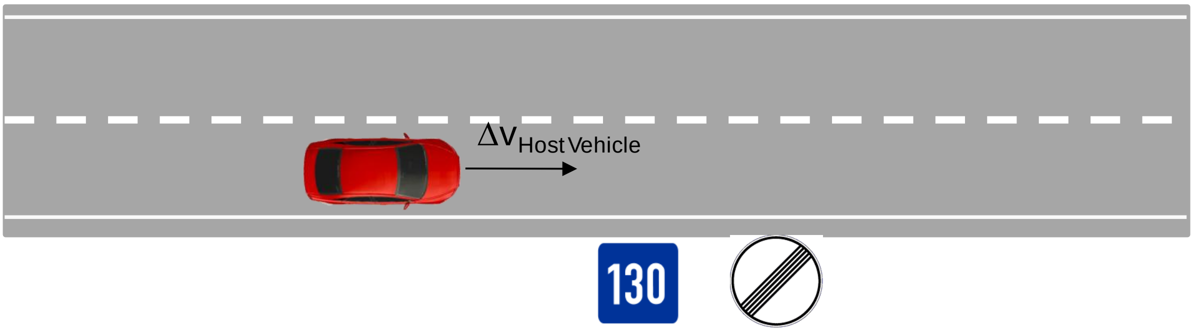
Approaching speed limit (country)



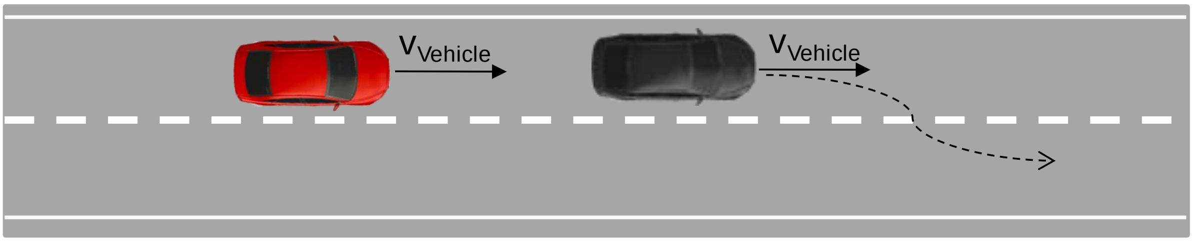
Description	Host vehicle approaches different speed limit signs, which are from different countries
Relevant functions	CS, SC
Use case	UC_08_457_v1
Vehicle initial parameters	$\Delta v_{Host\,Vehicle}$ [km/h] | 10 | 30 | 50 | |
Number vehicles	1
Required Equipment	Traffic signs of different countries, digital map data
Environmental initial parameters	Road radius: ∞ Country[1]: e.g. Germany / Italy | e.g. Sweden Kind of speed limit[1]: sign | town sign
Assessment	☒ Technical ☐ User-related
Driver reaction (only relevant for the technical assessment)	• No reaction of the driver on any warning or intervention before the highest warning level is reached (afterwards the reaction of the driver depends on function). • Driving with constant speed
Comment	Test only of one speed limit (always 50 km/h) 1: At least two countries with different speed limit signs

Test Scenario	Traffic rule violations
Test Case	8.7

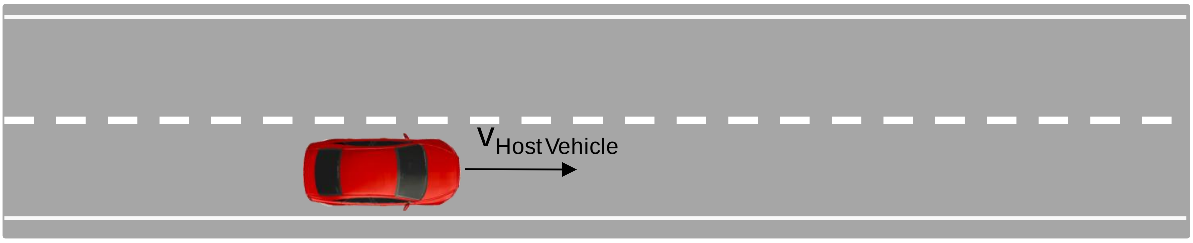
Exit speed limit



Description	Host vehicle approaches the end of speed limit
Relevant functions	CS, SC
Use case	UC_08_457_v1
Vehicle initial parameters	$\Delta v_{Host\ Vehicle}$ [1] [km/h] | -10 | 0 | 10
Number vehicles	1
Required Equipment	traffic signs, digital map data
Environmental initial parameters	road radius: ∞ Speed limit end [km/h] and new speed limit: 50 - End of town (rural road speed limit); 100 - recommended speed sign; 100 - End of speed limit sign
Assessment	☒ Technical ☐ User-related
Driver reaction (only relevant for the technical assessment)	• No reaction of the driver on any warning or intervention before the highest warning level is reached (afterwards the reaction of the driver depends on function). • Driving with constant speed
Comment	1: Compared to the old speed limit

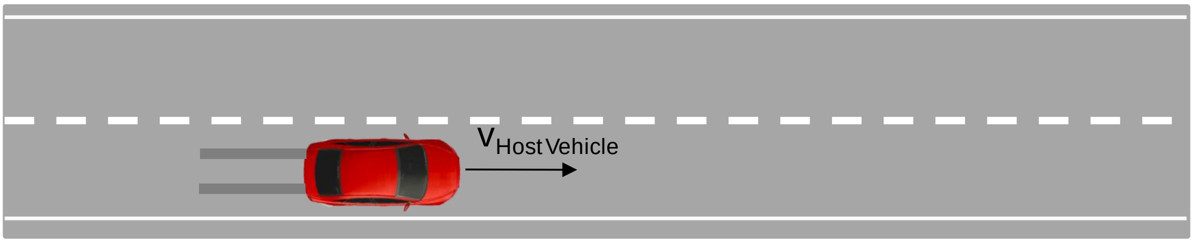
<table>
<tr><th>Test Scenario</th><th>Traffic rule violations</th></tr>
<tr><th>Test Case</th><th>8.8</th></tr>
<tr><td colspan="2">Cut-out</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Description</td><td>The host vehicle follows a lead vehicle, which drives slower than the current speed limit and the host vehicle’s set speed. The lead vehicle changes lane and the host vehicle should accelerate up to the set speed.</td></tr>
<tr><td>Relevant functions</td><td>SC</td></tr>
<tr><td>Use case</td><td>-</td></tr>
<tr><td>Vehicle initial parameters</td><td><table><tr><td>$V_{Vehicle}$ [km/h]</td><td>50</td><td>70[1]</td></tr><tr><td>Set speed [km/h]</td><td>70</td><td>90</td></tr></table></td></tr>
<tr><td>Number vehicles</td><td>1 (+ 2 moving target)</td></tr>
<tr><td>Required Equipment</td><td>1 moving target (balloon car) / 2 real vehicle</td></tr>
<tr><td>Environmental initial parameters</td><td><table><tr><td>Road radius</td><td>∞</td><td></td><td></td></tr><tr><td>driven lane</td><td>right</td><td></td><td></td></tr><tr><td>Number of lanes</td><td></td><td>2</td><td></td></tr></table></td></tr>
<tr><td>Assessment</td><td>☒ Technical ☐ User-related</td></tr>
<tr><td>Driver reaction (only relevant for the technical assessment)</td><td>No reaction of the driver on any warning or intervention before the highest warning level is reached (afterwards the reaction of the driver depends on function).</td></tr>
<tr><td>Comment</td><td></td></tr>
</table>

9. Verification test

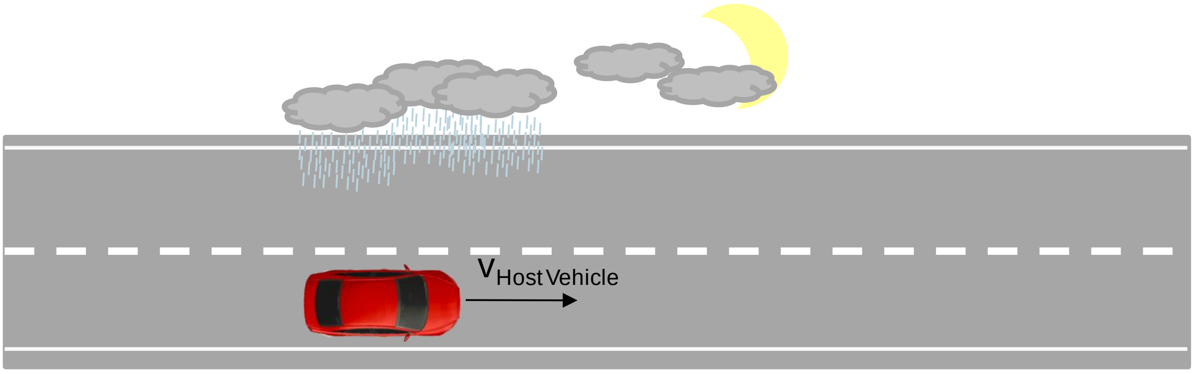
Test Scenario	Verification test
Test Case	9.1
Speed range	
	
Description	In this test it is analysed, whether the function fulfils the specification with respect to the speed range of the function
Relevant functions	All
Use case	None
Vehicle initial parameters	Vehicle speed [km/h] | different
Number vehicles	1
Required Equipment	
Environmental initial parameters	Dry test track
Assessment	☒ Technical ☐ User-related
Driver reaction (only relevant for the technical assessment)	• Driving with different velocity
Comment	

Test Scenario	Verification test
Test Case	9.2

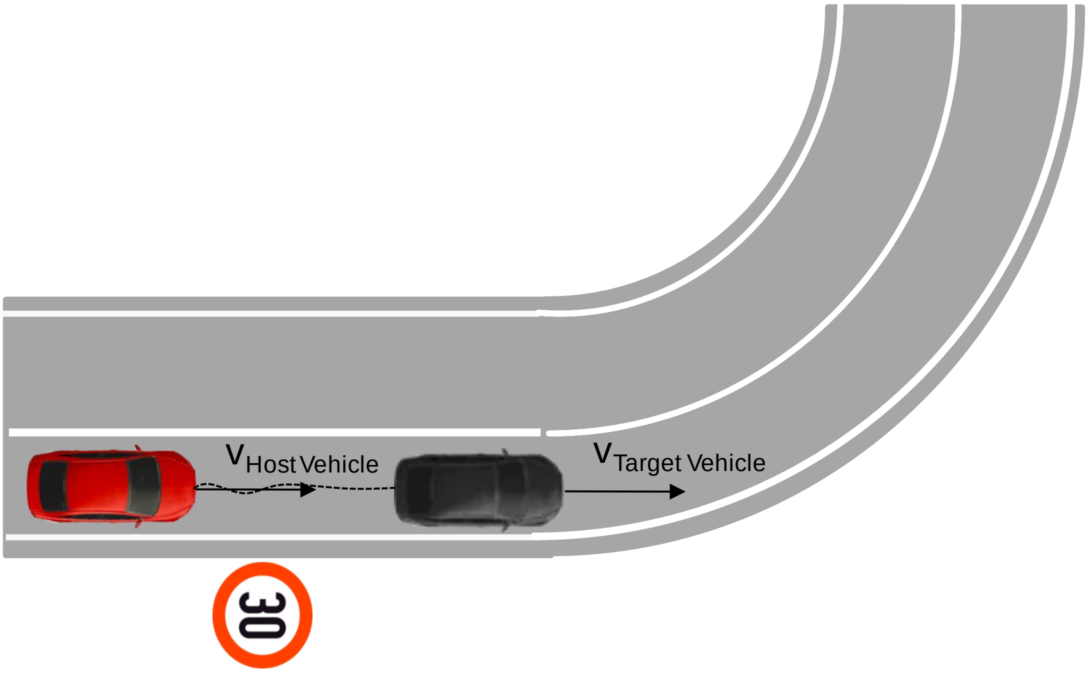
Braking capacity



Description	In this test the braking performance of the vehicle is (dependent on road condition – dry, wet, black ice)
Relevant functions	All
Use case	
Vehicle initial parameters	$v_{Host Vehicle}$ [km/h] | 100 | 70 | 50
Number vehicles	1
Required Equipment	
Environmental initial parameters	road friction | Low (< 0.4) | Medium (0.4 – 0.7) | high (>0.7) Braking by | driver | function |
Assessment	☒ Technical ☐ User-related
Driver reaction (only relevant for the technical assessment)	• Acceleration on defined velocity • Initiating emergency braking manoeuvre (by driver or by the function)
Comment	

Test Scenario	Verification test
Test Case	9.3
Weather conditions	
	
Description	Check, whether the function operates in different weather (rain, fog, snow) and lighting conditions (day/night) and road conditions (dry, wet, black ice, covered with snow/ice)
Relevant functions	All
Use case	
Vehicle initial parameters	$v_{Host\ Vehicle}$ [km/h] : 50
Number vehicles	1
Required Equipment	traffic signs, digital map data
Environmental initial parameters	Weather: dry, rain; Light condition: Daylight, Night, Dawn
Assessment	☒ Technical ☐ User-related
Driver reaction (only relevant for the technical assessment)	• Driving at constant speed
Comment	

10. Verification test

Test Scenario	Test on public road
Test Case	10.1
Test on public road	
	
Description	Driving on public road
Relevant functions	All
Use case	
Vehicle initial parameters	$V_{Host\ Vehicle}$ [km/h] | different
Number vehicles	1
Required Equipment	traffic signs, digital map data
Environmental initial parameters	road radius | different Speed limit | different Number of lane | different
Assessment	☒ Technical ☒ User-related
Driver reaction (only relevant for the technical assessment)	• Normal driving on public road

Comment	• This test case is used for different purposes
	  ○ Used in user-related assessment in SECONDS (for the other VSP it is not reasonable that test on public roads will be conducted)
	  ○ Used for test on fuel consumption
	• It must be allowed to drive on public roads with the demonstrator vehicle
	• In order to minimize the impact of the traffic test should be done at the similar times.

Annex E: Signal list

In the following table the signals, which should be logged in the tests are specified with respect to the required accuracy, range, frequency and unity. This table provides an overview on all signals. But no all signals need to be logged for each demonstrator. Therefore it is decided based on bilateral discussion between SP7 and the demonstrator responsible persons, which signals are logged in each case. It must also be considered that maybe certain signals are not available in the demonstrator vehicle. In this case it must be checked, whether alternative signals are available.

No.	Signal	Description	Accuracy [25]		Range [26]	Frequency [Hz]	Unit	HV	OV[27]
Time signals									
100	Time (GPS-Time)	global time stamp with time of day	0.01 s	measure by GPS	0 … 86400 s (D1.7 10^8 s)	10	s	x	x
101	Date (GPS-Time)	date	1 day	YYYYMMDD measured by the GPS	20100101 … 20150101	-	YYYYMMDD	x	x
102	Time since start	duration of measurement (start at test beginning)	0.01 s	s	0 … 86400 s (D1.7 10^8 s)	10	s	x	x
103	Driven distance	driven distance in the test	0.001 km	The accuracy of the mileage is maybe not sufficient	0 …. 1000 km	10	m	x	
Dynamic signals									
200	Vehicle velocity	driven velocity of the vehicle	0.01 m/s	Signal, which is used for the function	-30 … 100 m/s	10	m/s	x	x

[25] a higher accuracy is also possible

[26] a higher range is also possible (e.g. if defined in D1.7)

[27] HV = Host Vehicle, OV = Other Vehicle, * = if OV is used for test

No.	Signal	Description	Accuracy [25]		Range [26]	Frequency [Hz]	Unit	HV	OV[27]
201	Longitudinal acceleration (a_x)	acceleration along the longitudinal axis of the vehicle (measured in COG of vehicle)	0.1 m/s²	Signal, which is used for the function	-15 … 15 m/s²	10	m/s²	x	(x)
202	Lateral acceleration (a_y)	acceleration along the lateral axis of the vehicle (measured in COG of vehicle)	0.1 m/s²	Signal, which is used for the function	-15 … 15 m/s²	10	m/s²	x	
203	Yaw Rate	yaw rate of the vehicle (measured in COG of vehicle); positive are rotation against clockwise	0.001745 rad/s	Signal, which is used for the function	-3 … 3	10	°/s	x	
204	Wheel Speed	wheel speed of all 4 wheels	0.1 m/s	Signal, which is used for the function	-30 … 100 m/s	10	m/s	x	
205	Lateral velocity (v_y)	velocity along the lateral axis of the vehicle (measured in COG of the vehicle)	0.1 m/s	Signal provided by sensor	-10 … 10 m/s	10	m/s	x	
206	Lateral position in lane (left side)	distance to the left lane boundary measured from the mid of the vehicle	0.01 m	Signal, which is used for the function	-12 … 12 m	10	m	x	
206	Lateral position in lane (right side)	distance to the right lane boundary measured from the mid of the vehicle	0.01 m	Signal, which is used for the function	-12 … 12 m	10	m	x	
Driver input related signals									
301	Steering wheel angle	position of the steering wheel	0.1 °	Signal, which is used for the function	-720 … 720°	10	°	x	
302	Steering wheel velocity	angular velocity of the steering wheel	1°/s	Signal, which is used for the function	-360 … 360°/s	10	°/s	x	
303	Steering torque	steering torque	0.01 Nm	Signal, which is used for the function	-15 … 15 Nm	10	Nm	x	

No.	Signal	Description	Accuracy [25]		Range [26]	Frequency [Hz]	Unit	HV	OV[27]
304	Brake pedal position	position of the brake pedal	1%	Signal, which is used for the function	0 … 100 %	10	%	x	
305	Status Brake Light Switch	status brake light switch	0 = off 1 = on	Signal, which is used for the function	-	10	0/1	x	x
306	Brake pressure	brake pressure	1 bar	Signal, which is used for the function	0 … 205 bar	10	bar	x	
307	Accelerator pedal position	position of the accelerator pedal	1%	Signal, which is used for the function	0 … 100 %	10	%	x	
308	Gear	driven gear	-1: reverse gear 1…max: gear	Signal, which is used for the function	Car: -1 … 8 Truck:-1 … 20	10	-	x	
309	Direction indicator	Status of direction indicator.	0 = deactivated 1= left side activated 2= right side activated 3= both sides activated	Signal, which is used for the function	-	10	0/1	x	
310	ACC Set Speed	set speed of the adaptive cruise control or the cruise control (if available in the demonstrator)	0.278 m/s	Signal, which is used for the function	0 … 70 m/s	10	m/s	x	
Clearance information provided by the sensor									

No.	Signal	Description	Accuracy [25]		Range [26]	Frequency [Hz]	Unit	HV	OV[27]
401	longitudinal range to target (front sensor)	range towards target objects in longitudinal direction. Measured by the vehicle sensor (signals have to be provided for each detected target)	0.1 m	Signal, which is used for the function	0 … 200 m	10	m	x	
402	lateral Range to target (front sensor)	range towards target objects in lateral direction. Measured by the vehicle sensor (signals have to be provided for each detected target)	0.1 m	Signal, which is used for the function	0 … 200 m	10	m	x	
403	longitudinal Range to target (side sensor)	range towards target objects in longitudinal direction. Measured by the vehicle sensor (signals have to be provided for each detected target)	0.1 m	Signal, which is used for the function	0 … 200 m	10	m	x	
404	lateral range to target (side sensor)	range towards target objects in lateral direction. Measured by the vehicle sensor (signals have to be provided for each detected target)	0.1 m	Signal, which is used for the function	0 … 200 m	10	m	x	
405	longitudinal range to target (rear sensor)	range towards target objects in longitudinal direction. Measured by the vehicle sensor (signals have to be provided for each detected target)	0.1 m	Signal, which is used for the function	0 … 200 m	10	m	x	
406	lateral range to target (rear sensor)	range towards target objects in lateral direction. Measured by the vehicle sensor (signals have to be provided for each detected target)	0.1 m	Signal, which is used for the function	0 … 200 m	10	m	x	
407	longitudinal relative velocity of target (front sensor)	relative velocity of target objects in longitudinal direction. Measured by the vehicle sensor (signals have to be provided for	0.1 m	Signal, which is used for the function	-50 … 50 m/s^2	10	m	x	

No.	Signal	Description	Accuracy [25]		Range [26]	Frequency [Hz]	Unit	HV	OV[27]
		each detected target)							
408	lateral relative velocity of target (front sensor)	relative velocity of target objects in lateral direction. Measured by the vehicle sensor (signals have to be provided for each detected target)	0.1 m	Signal, which is used for the function	-50 … 50 m/s²	10	m	x	
409	longitudinal relative velocity of target (side sensor)	relative velocity of target objects in longitudinal direction. Measured by the vehicle sensor (signals have to be provided for each detected target)	0.1 m	Signal, which is used for the function	-50 … 50 m/s²	10	m	x	
410	lateral relative velocity of target (side sensor)	relative velocity of target objects in lateral direction. Measured by the vehicle sensor (signals have to be provided for each detected target)	0.1 m	Signal, which is used for the function	-50 … 50 m/s²	10	m	x	
411	longitudinal relative velocity of target (rear sensor) (signals have to be provided for each detected target)	relative velocity of target objects in longitudinal direction. Measured by the vehicle sensor (signals have to be provided for each detected target)	0.1 m	Signal, which is used for the function	-50 … 50 m/s²	10	m	x	
412	lateral relative velocity of target (rear sensor)	relative velocity of target objects in lateral direction. Measured by the vehicle sensor (signals have to be provided for each detected target)	0.1 m	Signal, which is used for the function	-50 … 50 m/s²	10	m	x	
413	ID relevant target	ID of the relevant target.	-	Signal, which is used for the function	1…20	10	-	x	

No.	Signal	Description	Accuracy [25]		Range [26]	Frequency [Hz]	Unit	HV	OV[27]
414	Target classification	type of target detected	1: cars; 2: pedestrian; 3: bus & trucks; 4: cycles & motorcycles; 5: unknown ; 6: static object flag; 7: animals;	Signal, which is used for the function	1…10	10	-	x	
GPS signals									
501	GPS Position (Latitude, Longitudinal)	position measured by the GPS. If a GPS based system (DGPS RTK-GPS) is used as a reference system, a high accuracy is required.	(0.01) as high as possible	GPS / DGPS / RTK-GPS ... UTM (WGS84) data and format	8.000.000 … 0 (north); 4.000.000 …0 (east)	10	m	x	x
502	GPS Position (Latitude, Longitudinal)	position measured by the GPS. If a GPS based system (DGPS RTK-GPS) is used as a reference system, a high accuracy is required.	(1.25 e-7°) as high as possible	GPS / DGPS / RTK-GPS ... geographic coordinate	-180 … 180°, 90 … 90°	10	°	x	x
503	GPS Altitude	altitude measured by GPS	1 m	GPS / DGPS / RTK-GPS	0 … 3000	10	m	x	x
504	GPS Velocity	speed of the GPS	0.1 m/s	GPS / DGPS / RTK-GPS	-30 … 100 m/s	10	m/s	x	x
505	Heading angle (GPS)	track angle of the GPS; with respect to "north line"	0.001745 °	GPS / DGPS / RTK-GPS	0 … 2pi	10	°	x	x
506	Dilution of Precision	quality of GPS Signal	0.1	GPS / DGPS / RTK-GPS	0…30	10	-	x	x
Map signals									
601	Speed limit of current road section	speed limit of current road section	1 km/h	Quality of digital map	0 … 250 km/h	10	km/h	x	
602	Curve Radius of current road section	curve Radius of current road section	1 m	Quality of digital map	0 …. 5000 m	10	m	x	

No.	Signal	Description	Accuracy [25]		Range [26]	Frequency [Hz]	Unit	HV	OV[27]
603	obstacle (curve / intersection / roadwork / hill)	distance to next curve/intersection	1 m	Quality of digital map or X2V communicatio ns	0 … 5000 m	10	m	x	
604	Next obstacle classification	type of next obstacle	1: curve 2: intersection 3: roadworks 4:hill 5: speed bump	Quality of digital map/ X2V communicatio ns	0…5	10	0/1	x	
605	Distance to next speed limit	distance to next speed limit	1 m	Quality of digital map/ Camera recognition	0 … 5000 m	10	m	x	
606	Speed limit of next road section/speed limit detected by camera	next speed limit	1 km/h	Signal, which is used for the function	0 … 250 km/h	10	km/h	x	
607	Next speed limit source	sensor (camera or map) used to determine the next speed limit	0: map 1: camera 2: X2V?	Signal, which is used for the function	0…2	10	km/h	x	
608	Status overtaking prohibitions	Are there any overtaking prohibitions given by lane markings or signs?	0 = no prohibitions/ 1 = overtaking prohibitions	Quality of digital map	-	10	0/1	x	
Engine signals									
701	Fuel consumption	current fuel consumption of the engine	0.1 l/100 km	Signal, which is used for the calculation of the fuel consumption (e.g. combined	0.1 - 40 l/100km	10	l/100k m	x	

No.	Signal	Description	Accuracy [25]		Range [26]	Frequency [Hz]	Unit	HV	OV[27]
				instrument)					
702	Engine Speed	rotation speed of the engine	10 rpm	Signal, which is used for the function	0 … 9000 rpm	10	rpm	x	
Function status information									
801	Function status	status of each functions	0 = off 1 = on (passive) 2 = on (active --> intervention)	-	-	10	0 / 1 / 2	x	
802	Function warning (haptic)	Haptic warning status of tested function (according to D1.7). (e.g. no warning (0),Steering wheel (1), Stalk (2), Button (4), Touch screen / pad (8), Accelerator pedal (16), Brake pedal (32), Seat(64), Seatbelt (128))	binary	-	0….11111111	10	0/1	x	
803	Type of warning (haptic)	Haptic warning status of tested function (according to D1.7). (e.g. no warning (0),Vibrations (1), Torque (2), Force (4), Active tightening (8))	binary	-	0….1111	10	0/1	x	
804	Function warning (audio)	Haptic warning status of tested function (according to D1.7). (e.g. no warning (0), Tone unitonal buzzer (1), Tonal signals (2), vocal signals (4))	binary	-	0….111	10	0/1	x	

No.	Signal	Description	Accuracy [25]		Range [26]	Frequency [Hz]	Unit	HV	OV[27]
805	Function warning (visual)	Warning status of tested function. Must be specified per demonstrator (Each warning needs a certain ID) (e.g. no intervention(0), IPC (1), Centre console (2), HUD (4), steering wheel (8))	binary	-	0….1111	10	0/1	x	
806	Type of warning (visual)	Haptic warning status of tested function (according to D1.7). (e.g. no warning (0), on/off light (1), telltale (2), Alphanumeric(4), on/off icon (8), Graphics (16))	binary	-	0….1111	10	0/1	x	
807	Functions intervention status	Intervention status of tested function. Must be specified per demonstrator (Each type of intervention needs a certain ID) (e.g. no intervention(0), preparation of intervention (e.g. pre-fill brakes) (1), longitudinal intervention (braking) (2), lateral intervention (by steering or by braking) (4), later & longitudinal intervention (8))	binary	-	0….1111	10	0/1 … 10	x	
808	Warning of other systems	warnings of other vehicle's functions / systems. Must be specified per demonstrator.	0 = off 1 = on	-	-	10	0/1	x	
809	Status ESC	status information of the ESC	0 = off 1 = on 2 = intervention	Information shown to the driver	-	10	0/1	x	
810	Status ABS	status information of the ABS	0 = off 1 = on 2 = intervention	Information shown to the driver	-	10	0/1	x	

No.	Signal	Description	Accuracy [25]		Range [26]	Frequency [Hz]	Unit	HV	OV[27]
811	Status Brake assistant	status information about the brake assistant	0 = off 1 = on	Information for the driver or function output	-	10	0 / 1	x	
812	Additional steering torque	applied steering torque by function	0.1 Nm	Output of the function	0 … 5 Nm	10	Nm	x	
813	Recommended speed	Speed, which is recommended by the function	0.01 m/s	Output of the function	0 … 70 m/s	10	m/s	x	
Signals on lane information									
901	lane number	Number of lane, in which the vehicle drives.	Lane number	Signal, which is used for the function	1…7	10	-	x	
902	lane direction	Driving direction of the lane, in which the vehicle drives	o: no information; 1: same direction; 2: opposed traffic lane	Signal, which is used for the function	0…2	10	-	x	
903	number of lanes	Number of lanes of the road	Number of lane	Signal, which is used for the function	1…5	10	-	x	
904	Type lane marking (left)	detected lane type (left)	0: none; 1: dash; 2: solid; 3: solid dash. 4: dash solid	Signal, which is used for the function	0…4	10	-	x	
905	Type lane marking (right)	detected lane type (right)	0: none; 1: dash; 2: solid; 3: solid dash. 4: dash solid	Signal, which is used for the function	0…4	10	-	x	
906	Left lane status	Calculated status of the right lane, indicating possibility to steer into left lane	0= no information 1=no left lane 2=not allowed to move into left	function output	0…4	10		x	

No.	Signal	Description	Accuracy [25]		Range [26]	Frequency [Hz]	Unit	HV	OV[27]
			lane 3=left lane occupied 4=left lane free						
907	Right lane status	Calculated status of the left lane availability, indicating possibility to steer into right lane	0= no information 1=no right lane 2=not allowed to move into right lane 3=right lane occupied 4=right lane free	function output	0…4	10		x	
908	Lane width	Road width of the driven road	0,1m	Signal, which is used for the function	0 … 6	10		x	
Video signals and environmental status signals									
1001	Video data	Camera mounted behind the windshield looking forward	-	-	-	24 fps	-	x	
1002	Video data of driver	Camera mounted looking on the driver	-	-	-	24 fps	-	x	
1003	Eye movements	Eye movements of the driver	-	-	-	24 fps	-	x	
1004	Status V2X communication	Status V2X communication (need only be stored, if the demonstrator uses V2X communication)	0 = off 1 = on (passive) 2 = on (active --> intervention)	-	-	10	0/1	x	
1005	Status V2V communication	Status V2V communication (need only be stored, if the demonstrator uses V2V communication)	0 = off 1 = on (passive) 2 = on (active --> intervention)	-	-	10	0/1	x	
Signals required by SP2									

No.	Signal	Description	Accuracy [25]		Range [26]	Frequency [Hz]	Unit	HV	OV[27]
1102	target longitudinal acceleration	Longitudinal acceleration of target relative to the ego-vehicle	0.1 m/s²	Sensor output	-9.81 ... 9.81	10	m/s²		x
1103	target lateral acceleration	lateral acceleration of target relative to the ego-vehicle	0.1 m/s²	Sensor output	-9.81 ... 9.81	10	m/s²		x
1104	target heading	GPS heading of target	0.001745 °	GPS / DGPS / RTK-GPS	0 … 2pi		°		x
1105	target lane index	indicates the lane, in which the target drives			1..7				x
1106	target width	Width of target object	0,01	Static parameter			m		x
1107	target length	length of target object	0,01	Static parameter			m		x
1108	road width	width of drivable space	0,01	Static parameter			m		
1109	Coordinates of the lane marking / road boundary	GPS coordinates of the lane boundary measured before the tests	as high as possible	Static parameter		Measure before the tests			

Annex F: Test subject experience questionnaire

1. For CRF[28]

1.1 Instructions to test drivers

The test you are going to carry out consists of driving a car along a test route, and of filling in a questionnaire concerning some of the functions available in this car.

You'll be asked to repeat the drive twice, between which there will be a break of about 15 minutes. Each drive will last around ***1 hour***, and you'll be instructed about the route by one of the assistants on board.

Before getting started with the test, you'll be able to get in confidence with the car driving it for about 15 minutes.

After each drive you will be asked to answer a questionnaire, the first one is very short and the second one more extensive. We expect the test in total (= observations & questionnaires) to take 3 hours.

In the car you will be driving, there is a driver support system. The system supports you to drive safely by giving you information, warnings and alarms.

The data collected during the test drive and the questionnaire will be anonymous.

You are requested to drive as you would in your normal and habitual driving as far as possible.

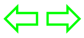
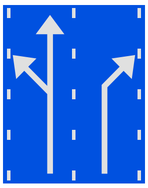
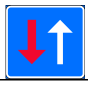
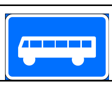
Please don't hesitate to ask the assistant on board whatever doubts or questions you may have.

Thank you for your contribution!

[28] The questionnaire for EMIC will be similar to the questionnaire used for the SECONDS functions (CRF and FFA demonstrator).

1.2 Code observation sheet

Code Observation

Variables				Count	
Classification Group	**Symbol**	**Description of action**	**Values**		
INDICATORS		Use of the indicators	Too early		
			Too late		
			Not at all		
SPEED		Adaptation of speed before intersection / roundabout	Late, abrupt		
			Bad		
	RAMP	Adaptation of speed at highway ramp	Late, abrupt		
			Bad		
		Travelling speed	Too fast according to the situation		
			Too slow according to the situation		
LANE CHANGE AND LANE USE		Lane change	Too late		
			Too fast		
			Dangerous		
			Hesitant		
		Lane Keeping	Too far left		
			Too far right		
			Unsteady		
		Crosses centre line	Legal		
			Illegal		
		Wrong lane choice			
OVERTAKING (not motorways)		Illegal			
		Dangerous and illegal			
		Abort manoeuvre			
GIVE WAY		Behaviour as someone who has to yield	Narrow, dangerous		
			Hesitant, unclear		
		Sticks to own priority and causes danger			
		Position in the intersection	Inappropriate		
			Crossing stop line		
TRAFFIC LIGHT		Drives against yellow/red			
VRUS				Pedestrian	Cyclist
		Not noticed			
		Ignored crosswalk			
		Gives priority late			
		Waiting at the roadside			
		Forces to stop			
		Hazard			
BUS STATION		Behaviour at bus/tram	Dangerous		

Code Observation				
Variables				Count
Classification Group	Symbol	Description of action	Values	
		stations, gateways		
THE SYSTEM		Ignores warning	Function X…	
			Function Y…	

1.3 Questionnaire

ID:………………

Workload

The factors defined below describe different components in the driving task you carried out when you drove along the test route. Please, read the definitions of the components and make an estimation.

1a. Make an estimation on how difficult it is to drive mentally. How much ***mental activity*** (finding the way, looking for information, to handle traffic situations, thinking, calculating, deciding, etc.) is required during driving. Is the task easy or demanding, simple or complex in this respect? How large demand on thinking, deciding and looking for information is required during driving?

Very low |——————————| Very high

1b. Make an estimation on how difficult it is to drive physically. How much ***physical activity*** (pushing the pedals, steering, etc.) is required. Is the task easy or demanding, slow or brisk, restful or laborious? How large demand on physical activity is required during driving?

Very low |——————————| Very high

1c.. Make an estimation on how much ***time pressure*** you feel during driving due to the traffic conditions (e.g. do you feel other cars making you drive faster?). Is the pace slow or rapid, leisurely or frantic? How large is the time pressure during driving?

Very low |——————————| Very high

1d. Make an estimation on how successful you think you are in driving. How satisfied are you with your ***own performance*** when driving?

Very poor |——————————| Very good

1e. Make an estimation on how hard you have to work (to find the way, to look for information, to handle the traffic conditions, to think, to make decisions, to push the pedals, to turn the steering wheel, etc.) to accomplish your level of performance during when driving. How large is your ***effort*** when driving?

Very low |——————————| Very high

1f. Make an estimation on how ***frustrated*** you feel due to the driving task and to traffic conditions. Do you feel insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent? How high is your level of frustration during driving?

Very low |——————————| Very high

If You have further comments or remarks, You are welcome to make them here:

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Thank You for participating!

1.4 Driver experience questionnaire

You have now been driving both with and without the system.

Please take the experiences you did into account when answering the following questions

The questionnaire you are about to answer is split into eight different parts.

Due to different ways of analysing the data, more than one type of scale is used for answering the questions - ***please pay attention to the different scales used.***

Please read the questions carefully and don't hesitate to ask for help if needed -

Your evaluation of the system is important to us!

Your answers will be anonymous.

Effects of the system

2. **What benefits did you encounter when using the system compared to driving without the system?**

----

3. **What problems did you encounter when using the system compared to driving without the system**

----

4. What differences did you experience when using this system compared to driving without the system? Please mark your estimation with a cross on the scale.

	Decrease greatly	Neither	Increase greatly
a. Your safety in traffic			
b. The risk of getting speeding tickets			
c. Your travel time			
d. Your fuel consumption			
e. Your irritation			
f. Your stress			
g. Your enjoyment when driving			
h. Your feeling of being in the way of others			
i. Your attention on traffic			
j. Your image			
k. Your comfort when driving			

Usability of the system

5. Please indicate below to what extent you agree in the following statements

	Strongly disagree				Strongly agree
a. I think that I would like to use this system frequently	☐	☐	☐	☐	☐
b. I found the system unnecessarily complex	☐	☐	☐	☐	☐
c. I thought the system was easy to use	☐	☐	☐	☐	☐
d. I think that I would need the support of a technical person to be able to use this system	☐	☐	☐	☐	☐
e. I found the various functions in this system were well integrated	☐	☐	☐	☐	☐
f. I thought there was too much inconsistency in this system	☐	☐	☐	☐	☐
g. I would imagine that most people would learn to use this system very quickly	☐	☐	☐	☐	☐
h. I found the system very cumbersome to use	☐	☐	☐	☐	☐
i. I felt very confident using the system	☐	☐	☐	☐	☐
j. I needed to learn a lot of things before I could get going with this system	☐	☐	☐	☐	☐

Acceptance of the system

6. What do you think of the system?

Useful				Useless
Pleasant				Unpleasant
Bad				Good
Nice				Annoying
Effective				Superfluous
Irritating				Likable
Assisting				Worthless
Undesirable				Desirable
Raising alertness				Sleep inducing

7. What would you think of having the following functions in your own car?

	Very bad	Neither	Very good
a. Function 1			
b. Function 2			
c. Function 3			

8. Do you think the system can give you benefits or disadvantages in your everyday driving?

	Very large disadvantage	Neither	Very large benefit
a. Risk of being involved in an accident			
b. Risk of getting speeding tickets			
c. Fuel consumption			
d. Travel time			
e. Your feeling of being in the way of other drivers			
f. Image			
g. Comfort			
h. Enjoyment when driving			
i. Other:________________________			

9. The system will probably be sold as an optional system in cars. Please indicate at which price you would be willing to buy it.

- ☐ up to 250 Euro
- ☐ between 250 and 500 Euro
- ☐ between 500 and 750 Euro
- ☐ between 750 and 1.000 Euro
- ☐ over 1.000 Euro
- ☐ no opinion

10. Would the system be mounted in your car for free, would you use it?

- ☐ Yes, only as an informative system
- ☐ Yes, only as an informative and advisory system
- ☐ Yes, also as an intervening system
- ☐ No, not in any form

2. For Ford

2.1 Instructions to test drivers

The test you are going to carry out consists of driving a car along a test route, and of filling in a questionnaire concerning some of the functions available in this car.

You'll be asked to repeat the drive twice, between which there will be a break of about 15 minutes. Each drive will last around ***1 hour***, and you'll be instructed about the route by one of the assistants on board.

Before getting started with the test, you'll be able to get in confidence with the car driving it for about 15 minutes.

After each drive you will be asked to answer a questionnaire, the first one is very short and the second one more extensive. We expect the test in total (= observations & questionnaires) to take 3 hours.

In the car you will be driving, there is a driver support system. The system supports you to drive safely by giving you information, warnings and alarms.

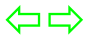
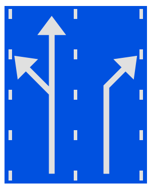
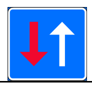
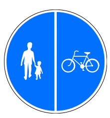
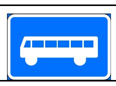
The data collected during the test drive and the questionnaire will be anonymous.

You are requested to drive as you would in your normal and habitual driving as far as possible.

Please don't hesitate to ask the assistant on board whatever doubts or questions you may have.

Thank you for your contribution!

2.2 Appendix 2 Code observation sheet

Code Observation					
Variables				Count	
Classification Group	Symbol	Description of action	Values		
INDICATORS		Use of the indicators	Too early		
			Too late		
			Not at all		
SPEED		Adaptation of speed before intersection / roundabout	Late, abrupt		
			Bad		
	RAMP	Adaptation of speed at highway ramp	Late, abrupt		
			Bad		
		Travelling speed	Too fast according to the situation		
			Too slow according to the situation		
LANE CHANGE AND LANE USE		Lane change	Too late		
			Too fast		
			Dangerous		
			Hesitant		
		Lane Keeping	Too far left		
			Too far right		
			Unsteady		
		Crosses centre line	Legal		
			Illegal		
		Wrong lane choice			
OVERTAKING (not motorways)		Illegal			
		Dangerous and illegal			
		Abort manoeuvre			
GIVE WAY		Behaviour as someone who has to yield	Narrow, dangerous		
			Hesitant, unclear		
		Sticks to own priority and causes danger			
		Position in the intersection	Inappropriate		
			Crossing stop line		
TRAFFIC LIGHT		Drives against yellow/red			
VRUS				Pedestrian	Cyclist
		Not noticed			
		Ignored crosswalk			
		Gives priority late			
		Waiting at the roadside			
		Forces to stop			
		Hazard			
BUS STATION		Behaviour at bus/tram	Dangerous		

Code Observation				
Variables				Count
Classification Group	Symbol	Description of action	Values	
		stations, gateways		
THE SYSTEM		Ignores warning	Function X…	
			Function Y…	

2.3 Questionnaire

ID:………………

Workload

The factors defined below describe different components in the driving task you carried out when you drove along the test route. Please, read the definitions of the components and make an estimation.

1a. Make an estimation on how difficult it is to drive mentally. How much ***mental activity*** (finding the way, looking for information, to handle traffic situations, thinking, calculating, deciding, etc.) is required during driving. Is the task easy or demanding, simple or complex in this respect? How large demand on thinking, deciding and looking for information is required during driving?

Very low |————————————| Very high

1b. Make an estimation on how difficult it is to drive physically. How much ***physical activity*** (pushing the pedals, steering, etc.) is required. Is the task easy or demanding, slow or brisk, restful or laborious? How large demand on physical activity is required during driving?

Very low |————————————| Very high

1c.. Make an estimation on how much ***time pressure*** you feel during driving due to the traffic conditions (e.g. do you feel other cars making you drive faster?). Is the pace slow or rapid, leisurely or frantic? How large is the time pressure during driving?

Very low |————————————| Very high

1d. Make an estimation on how successful you think you are in driving. How satisfied are you with your ***own performance*** when driving?

Very poor |————————————| Very good

1e. Make an estimation on how hard you have to work (to find the way, to look for information, to handle the traffic conditions, to think, to make decisions, to push the pedals, to turn the steering wheel, etc.) to accomplish your level of performance during when driving. How large is your ***effort*** when driving?

Very low |————————————| Very high

1f. Make an estimation on how ***frustrated*** you feel due to the driving task and to traffic conditions. Do you feel insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent? How high is your level of frustration during driving?

Very low |————————————| Very high

If You have further comments or remarks, You are welcome to make them here:

____

____

____

____

____

Thank You for participating!

2.4 Driver experience questionnaire

You have now been driving both with and without the system. Please take the experiences you did into account when answering the following questions The questionnaire you are about to answer is split into eight different parts. Due to different ways of analysing the data, more than one type of scale is used for answering the questions - ***please pay attention to the different scales used.*** **Please read the questions carefully and don't hesitate to ask for help if needed -** **Your evaluation of the system is important to us!** Your answers will be anonymous.

Effects of the system

2. **What benefits did you encounter when using the system compared to driving without the system?**

----

3. **What problems did you encounter when using the system compared to driving without the system**

----

4. What differences did you experience when using this system compared to driving without the system? Please mark your estimation with a cross on the scale.

	Decrease greatly	Neither	Increase greatly
a. Your safety in traffic			
b. The risk of getting speeding tickets			
c. Your travel time			
d. Your fuel consumption			
e. Your irritation			
f. Your stress			
g. Your enjoyment when driving			
h. Your feeling of being in the way of others			
i. Your attention on traffic			
j. Your image			
k. Your comfort when driving			

Usability of the system

5. Please indicate below to what extent you agree in the following statements

	Strongly disagree				Strongly agree
a. I think that I would like to use this system frequently	☐	☐	☐	☐	☐
b. I found the system unnecessarily complex	☐	☐	☐	☐	☐
c. I thought the system was easy to use	☐	☐	☐	☐	☐
d. I think that I would need the support of a technical person to be able to use this system	☐	☐	☐	☐	☐
e. I found the various functions in this system were well integrated	☐	☐	☐	☐	☐
f. I thought there was too much inconsistency in this system	☐	☐	☐	☐	☐
g. I would imagine that most people would learn to use this system very quickly	☐	☐	☐	☐	☐
h. I found the system very cumbersome to use	☐	☐	☐	☐	☐
i. I felt very confident using the system	☐	☐	☐	☐	☐
j. I needed to learn a lot of things before I could get going with this system	☐	☐	☐	☐	☐

4. What differences did you experience when using this system compared to driving without the system? Please mark your estimation with a cross on the scale.

	Decrease greatly	Neither	Increase greatly
a. Your safety in traffic			
b. The risk of getting speeding tickets			
c. Your travel time			
d. Your fuel consumption			
e. Your irritation			
f. Your stress			
g. Your enjoyment when driving			
h. Your feeling of being in the way of others			
i. Your attention on traffic			
j. Your image			
k. Your comfort when driving			

Usability of the system

5. Please indicate below to what extent you agree in the following statements

	Strongly disagree				Strongly agree
a. I think that I would like to use this system frequently	☐	☐	☐	☐	☐
b. I found the system unnecessarily complex	☐	☐	☐	☐	☐
c. I thought the system was easy to use	☐	☐	☐	☐	☐
d. I think that I would need the support of a technical person to be able to use this system	☐	☐	☐	☐	☐
e. I found the various functions in this system were well integrated	☐	☐	☐	☐	☐
f. I thought there was too much inconsistency in this system	☐	☐	☐	☐	☐
g. I would imagine that most people would learn to use this system very quickly	☐	☐	☐	☐	☐
h. I found the system very cumbersome to use	☐	☐	☐	☐	☐
i. I felt very confident using the system	☐	☐	☐	☐	☐
j. I needed to learn a lot of things before I could get going with this system	☐	☐	☐	☐	☐

9. The system will probably be sold as an optional system in cars. Please indicate at which price you would be willing to buy it.

☐ up to 250 Euro
☐ between 250 and 500 Euro
☐ between 500 and 750 Euro
☐ between 750 and 1.000 Euro
☐ over 1.000 Euro
☐ no opinion

10. Would the system be mounted in your car for free, would you use it?

☐ Yes, only as an informative system
☐ Yes, only as an informative and advisory system
☐ Yes, also as an intervening system
☐ No, not in any form

3. For BMW:

The questionnaire you are about to answer is split into eight different parts.

Due to different ways of analysing the data, more than one type of scale is used for answering the questions - ***please pay attention to the different scales used.***

Please read the questions carefully and don't hesitate to ask for help if needed -

Your evaluation of the system is important to us!

Your answers will be anonymous.

Effects of the system

2. What benefits driving with the system can you think of?

----

3. What problems you think you might encounter when using the system?

----

4. What differences do you think you would experience when using this system compared to driving without the system? Please mark your estimation with a cross on the scale.

	Decrease greatly	Neither	Increase greatly
a. Your safety in traffic			
b. The risk of getting speeding tickets			
c. Your travel time			
d. Your fuel consumption			
e. Your irritation			
f. Your stress			
g. Your enjoyment when driving			
h. Your feeling of being in the way of others			
i. Your attention on traffic			
j. Your image			
k. Your comfort when driving			

Usability of the system

5. Please indicate below to what extent you agree in the following statements

	Strongly disagree				Strongly agree
a. I think that I would like to use this system frequently	☐	☐	☐	☐	☐
b. I found the system unnecessarily complex	☐	☐	☐	☐	☐
c. I thought the system was easy to use	☐	☐	☐	☐	☐
d. I think that I would need the support of a technical person to be able to use this system	☐	☐	☐	☐	☐
e. I found the various functions in this system were well integrated	☐	☐	☐	☐	☐
f. I thought there was too much inconsistency in this system	☐	☐	☐	☐	☐
g. I would imagine that most people would learn to use this system very quickly	☐	☐	☐	☐	☐
h. I found the system very cumbersome to use	☐	☐	☐	☐	☐
i. I felt very confident using the system	☐	☐	☐	☐	☐
j. I needed to learn a lot of things before I could get going with this system	☐	☐	☐	☐	☐

Acceptance of the system

6. What do you think of the system?

Useful			Useless
Pleasant			Unpleasant
Bad			Good
Nice			Annoying
Effective			Superfluous
Irritating			Likable
Assisting			Worthless
Undesirable			Desirable
Raising alertness			Sleep inducing

7. What would you think of having the following functions in your own car?

	Very bad	Neither	Very good
a. Function 1			
b. Function 2			
c. Function 3			

8. Do you think the system can give you benefits or disadvantages in your everyday driving?

	Very large disadvantage	Neither	Very large benefit
a. Risk of being involved in an accident			
b. Risk of getting speeding tickets			
c. Fuel consumption			
d. Travel time			
e. Your feeling of being in the way of other drivers			
f. Image			
g. Comfort			
h. Enjoyment when driving			
i. Other:________________________			

9. **The system will probably be sold as an optional system in cars. Please indicate at which price you would be willing to buy it.**

☐ up to 250 Euro
☐ between 250 and 500 Euro
☐ between 500 and 750 Euro
☐ between 750 and 1.000 Euro
☐ over 1.000 Euro
☐ no opinion

10. **Would the system be mounted in your car for free, would you use it?**

☐ Yes, only as an informative system
☐ Yes, only as an informative and advisory system
☐ Yes, also as an intervening system
☐ No, not in any form

4. For VTEC and VCC

The interactIVe project addresses the development and evaluation of next-generation safety systems for Intelligent Vehicles based on active intervention. The general idea is basically to develop high performance and integrated ADAS applications, enhancing the intelligence of vehicles and promoting safer and more efficient driving.

Your input in this project is of high value to us and by participating in this study you will help us towards an accident- free traffic. Please respond honestly on the questions and do not hesitate to ask us if something seems unclear.

4.1 Driver instructions

The test you are going to carry out consists of driving in simulated environment along a test route, and of filling in a questionnaire concerning some of the functions available in this car.

You'll be asked to repeat the drive twice, between which there will be a break of about 15 minutes. Each drive will last around ***1 hour***, and you'll be instructed about the route by one of the assistants.

Before getting started with the test, you'll be able to get in confidence with the simulator by driving for about 15 minutes.

Before, during and after your driving, you will be asked to answer a questionnaire. The expected time for the test in total (observations & questionnaires) will take approximately 3 hours.

The data collected during the test drive and the questionnaire will be anonymous.

You are requested to drive as you would in your normal and habitual driving as far as possible. Please don't hesitate to ask the assistant on board whatever doubts or questions you may have.

Thank you for your time and your valuable opinions!

4.2 Background information

TPRE1. ☐[1] Male ☐[2] Female

TPRE2. Age: _____

PRE3. For which of the following do you currently hold a valid driver´s license and what year was it issued?

Vehicle type		Licence Year
❐	Passenger Vehicle License (B)	
❐	Commercial Truck Licence (C+CE)	
❐	Motorcycle License (A)	
❐	Bus License (D+DE)	
❐	Other (please specify):	

TPRE4. Have you ever participated in driving studies in simulator?

❐ No ❐ Yes

If yes, please provide details and what year :

____
____
____
____

TPRE5. Have you ever participated in other driving studies?

❐ No ❐ Yes

If yes, please provide details and what year :

____
____
____
____

Truck driver-related questions

TPRE6. In the last year, how frequently have you driven a truck in the following environments? *(Tick only one for each environment)*

Environment	Never	Yearly	Monthly	Weekly	Daily
Residential/city area					
Industrial area					
Rural Highway					
Motorway					

Curvy roads					

TPRE7. How many work-related km do you drive per year? (Tick only one option)

❒ Under 33.000

❒ 33.000 – 60.000

❒ 60.000 – 100.000

❒ 100.000 – 200.000

❒ 200,000 or more

Car driver-related questions

CPRE8. In the last year, how frequently have you driven in the following environments? *(Tick only one for each environment)*

Environment	**Never**	**Yearly**	**Monthly**	**Weekly**	**Daily**
Residential/city area					
Industrial area					
Rural Highway					
Motorway					
Curvy roads					

CPRE9. Approximately how many km do you drive per year in each vehicle type:

Car	Motorcycle
❒ Under 7,000	❒ Under 7,000
❒ 7,000 - 14,999	❒ 7,000 - 14,999
❒ 15,000 - 24,999	❒ 15,000 - 24,999
❒ 25,000 - 32,999	❒ 25,000 - 32,999
❒ 33,000 or more	❒ 33,000 or more

CPRE10. Within the last three years, how many incidents/accidents have you been involved in while driving? (Including those where you were not at fault) Please describe the scenario(s).

❒ None

❒ Less than 3

❒ Between 3 and 10

❒ More than 10

____

____

____

____

____

US2. Would you prefer having the system you just tested installed in your own vehicle?

❒ Yes ❒ No

Please motivate your answer:

____

____

____

____

US3. If yes, what is a reasonable price to pay for this system? __________________ €

All drivers

PRE9. Please indicate how serious you find the listed behaviours by circling the appropriate number?

Exceed the speed limit	extremely minor	1	2	3	4	5	6	7	8	9	10	extremely serious
Fail to maintain a safe headway to the vehicle in front	extremely minor	1	2	3	4	5	6	7	8	9	10	extremely serious
Fail to maintain a smooth driving speed	extremely minor	1	2	3	4	5	6	7	8	9	10	extremely serious
Fail to check your blind spot before changing lanes, pulling out etc	extremely minor	1	2	3	4	5	6	7	8	9	10	extremely serious
Drifting out of your lane	extremely minor	1	2	3	4	5	6	7	8	9	10	extremely serious
Drive without preparing a route in advance	extremely minor	1	2	3	4	5	6	7	8	9	10	extremely serious
Be so tired to the extent that you struggle to keep a straight course	extremely minor	1	2	3	4	5	6	7	8	9	10	extremely serious
Use your gears inefficiently	extremely minor	1	2	3	4	5	6	7	8	9	10	extremely serious
Drive when you are above the legal alcohol limit	extremely minor	1	2	3	4	5	6	7	8	9	10	extremely serious
Consistently accelerate hard whilst driving	extremely minor	1	2	3	4	5	6	7	8	9	10	extremely serious
Take a bend too fast	extremely minor	1	2	3	4	5	6	7	8	9	10	extremely serious
Have trouble maintaining a straight course because you are using a hand held mobile phone	extremely minor	1	2	3	4	5	6	7	8	9	10	extremely serious

4.3 Technical experience

PRE10. Which of the following devices you have (for personal ownership or working one) and how often do you use it?

	Several times a day	1-2 times per day	1-2 times per week	1-2 times per month	I never use it
Mobile phone					
Palmtop					
Personal computer					
Smartphone / Iphone					
MP3 / Ipod					
Portable navigation systems (e.g. Tom Tom)					
Vehicle mounted navigation systems					

PRE11. Think back to the last year and the use you've done of assistant systems during driving. Please indicate your level of experience with each of the following systems:

DEVICE	**Broad experience** (I use the system every time I can/It's on my own car)	**Fairly good experience** (I've used it for some months in the year)	**Little experience** (I've used it for some days in the year)	**No experience** (I don't have it/I've never used it)
Cruise Control (system able to steadily maintain the speed set by the driver)				
Adaptive Cruise Control (system that maintain the set speed and automatically adjusts the speed depending on the distance.				
Lane Departure Warning System (assists the driver to maintain lane position, giving a warning if the vehicle crosses lane markings unintentionally)				

Forward Collision Warning System (system monitors distance to vehicle in front and alerts driver or intervenes when too close)				
Lane change assistant / Blind Spot Detection (system that detects when a car or motorcycle is in the rear blind spots on both sides of the vehicle and alerts driver if an overtaking is attempted)				
Semi-Automatic / Active Parking (system able to perform parking maneuvers in a completely autonomous or semi-autonomous way)				
Others (to be specified)				

4.4 Questions during driving

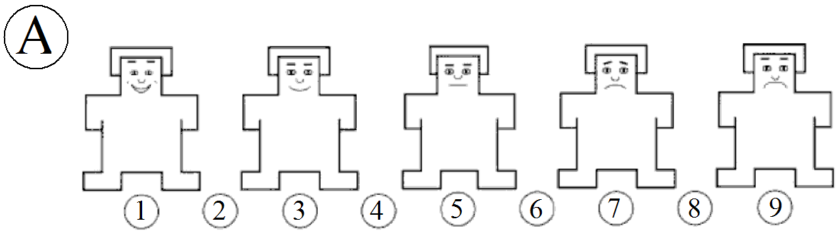
EM01. Did you notice that the system started acting?

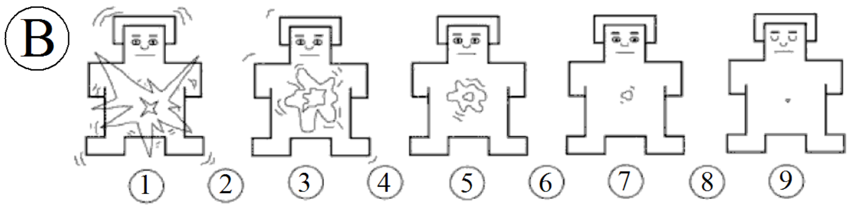
EM02. Were you comfortable with this? Why?

EM03. Was it helpful that the system handled (parts of) the situation?

EM04. Select a number from picture A below which describes your emotional attitude towards the system in that situation you just experienced.

EM05. Select a number from picture B below which describes how you felt during this situation.





For each factor, please indicate, by placing a vertical line at the appropriate point on the scale.

TC1. What level of control did you have in this situation?

FULL CONTROL		NO CO

TC2. Who was in charge during this situation?

I WAS IN CONTROL		THE S IN CON

TC3. Who would you prefer be in control during this situation?

I SHOULD BE IN CONTROL		THE SHOUL CONTF

TC4. Did you feel that your own actions had effect on the outcome of the situation?

FULL CONTROL/ RESPONSIBILITY OF THE OUTCOME		NO CO RESPC OF THE

TC5. When the system started to act, how did you experience it?

I WAS SUPPORTED BY THE SYSTEM BUT I HAD THE OVERALL CONTROL		I HAD N POSSIE ADJUS SITUAT SYSTE CONTF

TC6. What level of risk did you experience during this situation?

VERY RISKY		NO RIS

4.5 Post Questions – asked after driving

Please indicate, by placing a vertical line at the appropriate point on the scale, the level of workload that you experienced while driving.

MW1. Mental Demand refers to any mental activity required by performing the driving task. That is how much thinking, deciding, looking, searching etc was required when you were driving. Was the driving task easy/simple (low) or complex/demanding (high)?

LOW HIGH

MW2. Physical Demand refers to any physical activity required when driving. For example, operating accelerator, brake or steering wheel and adjusting stereo settings. Was it easy/restful (low) or strenuous and laborious (high)?

LOW HIGH

MW3. Time Pressure refers to how hurried or harassed you felt while driving. Was the pace of driving slow and leisurely (low) or rapid and rushed (high)

LOW HIGH

MW4. On average, how satisfied were you with your performance when driving?

GOOD POOR

MW5. Effort refers to how hard you had to work (mentally and physically) to achieve your level of performance when driving. Was little effort (low) or a large amount of effort (high) required?

LOW HIGH

MW6. Frustration Level refers to how relaxed or stressed you felt while driving. Did you feel secure, content, relaxed and complacent (low) or insecure, discourage, irritated stressed and annoyed (high)?

LOW HIGH

TOC1. If the system handled the situation, did you feel the need to break in and do something to change what the system was doing?

TOC2. Did you break in and change what the system was doing?

TOC3. Would you have been comfortable braking in?

TOC4. When do you think the system stopped acting?

TOC5. When do you think the system started acting?

TOC6. Did you think of the fact that the system started and stopped?

TOC7. Was it helpful that the system handled (parts of) the situation?

TOC8. How did you notice that the system started acting?

US1. How did you find the system?

useful						useless
pleasant						unpleasant
bad						good
nice						annoying
effective						superfluous
irritating						likeable
assisting						worthless
undesirable						desirable
raising alertness						sleep-inducing

U2. When you received a warning, what did you typically do?

U3. Did you follow the system's instructions (information/warnings)? If no, why not?

____

____

____

S1. Using the system (each INCA)…:

	Strongly Disagree	Disagree	Slightly Disagree	Neutral	Slightly Agree	Agree	Strongly Agree
… makes me a safer driver							
… makes it easier to drive							
… makes me more aware of the driving situation (other vehicles, lane position, etc.)							
… reduces speeding events							
… reduces distractions							
… reduces lane departures							
… improves my driving							
…make me more aware of the traffic around me and the position of my car in my lane							

A1. What was your overall impression of the system? (information, warnings, interventions)

____
____
____
____

A2. What do you think are the advantages and disadvantages of the system

ADVANTAGES:____
____
____

DISADVANTAGES:____
____
____

A3. Is there anything you wished had happened (intervention by the system) in a different way? If so, what and why?

4.6 Simulator fidelity

		Not at all realistic				Completely Realistic			
SF 1	How realistic was the appearance of the driving scenario (visual scene, sound, vibrations)	0	1	2	3	4	5	6	NA
SF 2	How realistic was it to manoeuvre the simulator versus a real truck/car?	0	1	2	3	4	5	6	
SF 3	How realistic was the response of the instruments in the truck/car?	0	1	2	3	4	5	6	NA