interactIVe
Accident avoidance by active intervention for Intelligent Vehicles

Deliverable 7.1 | Requirements for the Evaluation Framework

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SEVENTH FRAMEWORK PROGRAMME

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Summary

interactIVe has the objective to develop new integrated Advanced Driver Assistance Systems (ADAS). In order to evaluate these ADAS, an evaluation framework is required. Therefore, a horizontal subproject called “Evaluation and Legal Aspects” is part of interactIVe, with the main objective to provide this framework and give support to the vertical subprojects in their evaluation work.

The purpose of this deliverable is to define the relevant aspects for the development of the common and centralized evaluation framework. The goal is not to have the final document for evaluating the systems and functions, but to define and establish available methods and tools.

Based on the defined Use Cases and the description of the developed interactIVe functions, research questions are formulated and included in this deliverable 7.1. Based on these research questions, corresponding hypothesis will be included in Deliverable 7.2.

Evaluation has been divided in three main categories:

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

The challenge when dealing with the above-mentioned assessments is the fact that every system (SECONDS, INCA and EMIC) includes various functions. These different functions can be assessed individually or being part of the complete system, so interactions between them have to be taken into account. Moreover, the availability of tools and prototype vehicles has to be assured.

The outcome of this deliverable is a list of methods, tools and research questions.

1 Introduction

interactIVe has the objective to develop new integrated Advanced Driver Assistance Systems (ADAS). In order to evaluate these ADAS, an evaluation framework is required. This document is dealing with the requirements for the evaluation framework and will be further developed in Deliverables 7.2 and 7.4.

interactIVe is dividing its development activities in horizontal and vertical subprojects. Vertical SubProjects (VSP) develop the interactIVe systems. These systems are:

- SECONDS, dealing with continuous driving support
- INCA, which combines 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

Horizontal SubProjects (HSP) deal with tasks common for all systems. Therefore, activities such as perception layer or IWI (Information, Warning and Intervention) strategies are HSPs. Also the subproject "Evaluation and Legal Aspects" is a HSP, because the systems of all three VSP are evaluated.

1.1 Document structure

This document basically deals with the definition of the relevant aspects for the development of a common and centralized evaluation framework for all VSPs. It is structured in the following way:

- Chapter 2 provides an overview on the objectives of the evaluation framework and the methodology. To set this up, a specific meeting has been held with VSP leaders in order to introduce them to the activities and intentions of SP7. The content of that meeting is collected in the Internal Report 3.
- Chapter 3 deals with the system and function descriptions. This is a key part for understanding the deliverable, as basic questions such as the difference between systems, functions and aspects are defined. Systems and functions are furthermore described by the means of their foreseen Use Cases (see Deliverable 1.5). Expected prototype vehicles, sensors and target scenarios are also described in Chapter 3. This chapter is of special relevance for the Evaluation HSP, as the evaluation team is not involved in the development and needs to know what can be expected of the developed functions.
- Chapter 4 is related to Technical Assessment. In this chapter, a description of the general requirements for the technical evaluation is included. Methods, tools and research questions (general RQs and specific RQs for the systems as well as for the functions) are also described.
- Chapter 5 describes the Methods and Tools proposed for the User-Related Assessment. Key performance indicators are as well outlined before describing research questions from a general point of view.
- Chapter 6 deals with Impact Assessment. As in the previous chapters, methods, tools and research questions are outlined.
- Chapter 7 is collecting all methods and tools in a comprehensive table

Finally, one annex is included, listing the identified research questions.

1.2 Notes and comments

The current status of the project does not allow considering all the definitions provided in Chapter 3 as the final definitions for functions. There is information that will be updated in the upcoming Deliverable 7.2, such as expected HMI, etc.

This document is also describing the research questions at a general level. More specification and the corresponding hypotheses will be delivered in Deliverable 7.2.

2 Objectives of the evaluation framework

This chapter describes the scope of SP7 (section 2.1) followed by a short introduction to the evaluation method of PReVAL (section 2.2) [PRE08]. This method was presented to the other SPs of interactIVe in a workshop (November 2010) and agreed upon. The chapter concludes on how the necessary PReVAL steps will be realised in SP7 (section 2.3).

2.1 Scope

SP7 Evaluation and legal aspects will provide a test and evaluation framework for the assessment of the interactIVe applications with respect to technical performance, user-related performance and safety impact. Legal aspects will be considered in a separate work package. Assessment, or evaluation, is always done 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 (see Figure 2.1).

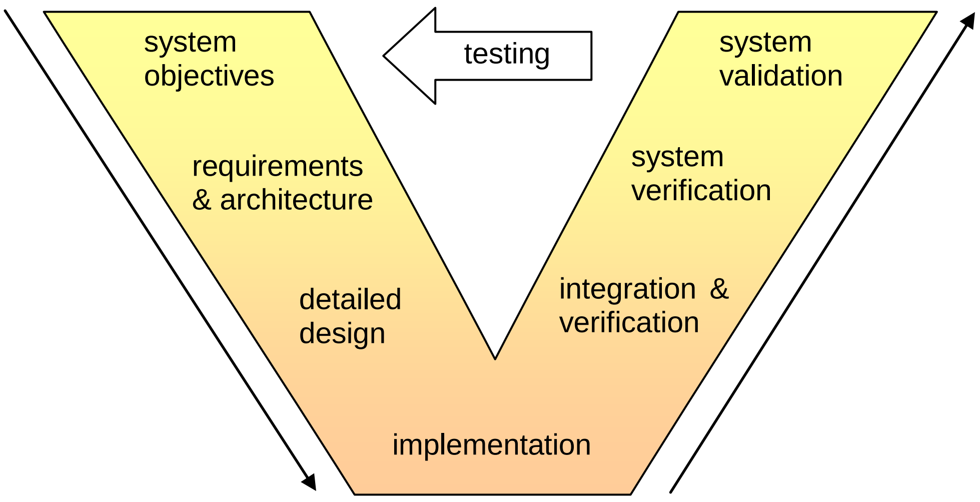

Figure 2.1: Generic V-model for system development

SP7 will use existing evaluation methods to evaluate the interactIVe functions systems in the system validation phase of Figure 2.1. As reported in the Internal Report I-3 – Draft Evaluation Plan and discussed at the November 2010 workshop with the other SPs, SP7 will base the evaluation on the PReVAL evaluation scheme. It provides a thorough framework containing technical, user-related and safety impact evaluation (see Figure 2.2).

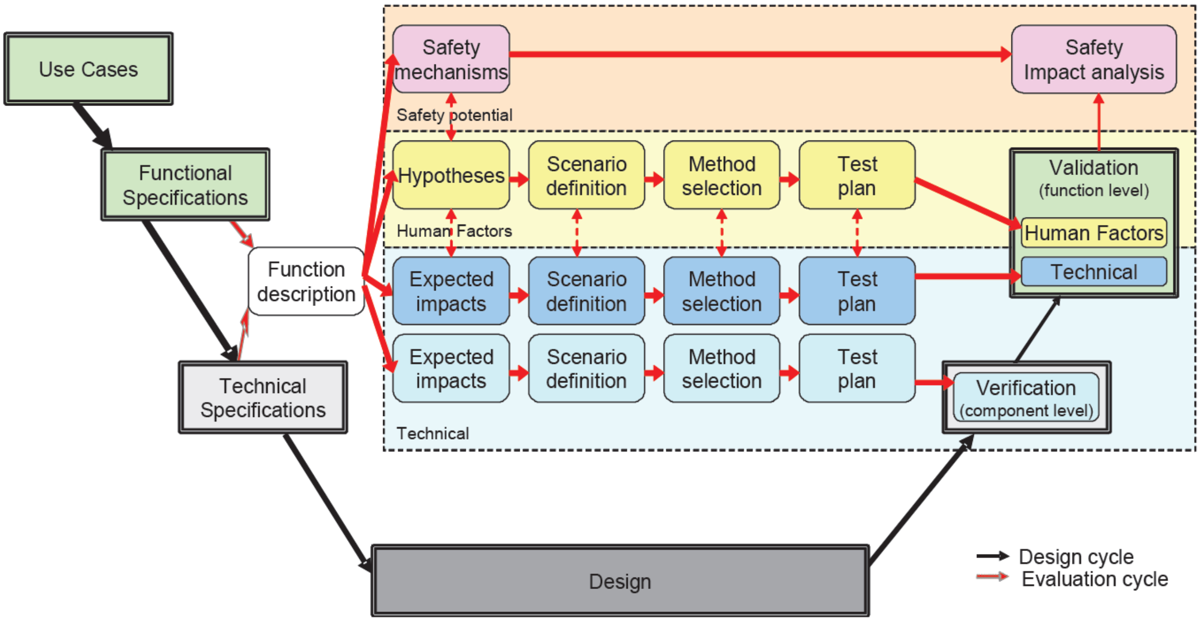

Figure 2.2: The PReVAL evaluation framework [PRE08]

As agreed in the November 2010 workshop SP7 will concentrate on functional evaluation. The responsible SPs will conduct the component level verifications. Many different functions will be developed in interactIVe. VSP 4 SECONDS targets functions that continuously support the driver. VSP 5 INCA targets functions for integrated collision avoidance and vehicle path control. VSP 6 EMIC develops functions for cost-efficient emergency intervention for collision mitigation. These functions will be implemented in seven different demonstrator vehicles, where each vehicle will have different (combinations of) functions. Hence the first hurdle to be taken for the evaluation is to address how to carry out the assessments and evaluations given all the different functions and vehicles. This was also discussed in the November 2010 workshop, resulting in the approach that mainly the functions by themselves are evaluated and, if time and budget allow this, some specific combinations of functions will be assessed. Furthermore, the types of assessment or evaluation per function need to be specified. A later deliverable such as D7.2, Specification of the evaluation framework, or D7.4, the Measurement Plan, will address this.

The 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). 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. [ASS]) may provide useful insights for the evaluation framework and will be taken into consideration along with other projects (see Internal Report I-3 – Draft Evaluation Plan).

2.2 Evaluation framework

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
- subsystems

Step 1: Expected impact and hypotheses

Here the evaluations are split up into technical, user-related and 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.

Once the expected impacts have been identified and hypotheses formulated, the indicators for establishing the impact or testing the hypotheses can be defined. This needs to be carried out for each function. In the end, there may be 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 measurements in the vehicle.

Step 2: Test scenario definition

In this step the test scenarios for the evaluations are defined. Indeed these scenarios must be defined so that they are relevant for evaluating the hypotheses/expected impacts. 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 [ASS].

The role of test scenarios in evaluation differs by each type of evaluation. Test scenarios are directly applicable to the technical tests and to some extent to the user tests. They are also directly applicable in the safety assessment, but only for a part. The safety impact related to direct impact on driver behaviour, such as speed changes, braking behaviour, speed or time headways, 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. Therefore, test scenario definitions should to the extent possible take into account indirect effects as well.

Step 3: Evaluation method selection

With the hypothesis, 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 road, either with 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 amount of equipped vehicles for a scenario,
- availability of suitable targets (dummy vehicles),
- availability of simulators,

- time and budget constraints.

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

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.

Step 5: Test execution and analysis

This is the final step and consists of conducting the tests and the analyses of the results. The challenge here 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.

In the work process, first the available function descriptions, target scenarios and use cases were analysed. From these the requirements for the framework were derived in the form of research questions (RQs). This comprises step 0 and part of step 1 of the PReVAL approach and is reported in this deliverable, D7.1. Then, the hypotheses and Performance Indicators (PIs) are derived from the RQs (step 0 and 1). With these known according test scenarios and methods will be derived (step 2 and 3). In D7.2, the specifications of the evaluation framework, will document these steps. D7.4 will report the measurement plan. Finally, D7.5 will conclude on the results of the evaluation. D7.3 will analyse which regulations and directives may have an impact on the introduction of the interactIVe systems.

In structuring the research questions, the following abbreviations and tagging rules have been selected to be used along this document:

<table>
<tr><th colspan="6">Tagging for research questions</th></tr>
<tr><td>Field #1</td><td>Field #2</td><td>Field #3</td><td>Field #4</td><td>Field #5</td><td>Field #6</td></tr>
<tr><td>RQ</td><td>Nature</td><td>System</td><td>Function</td><td>Type</td><td>Number</td></tr>
<tr><td rowspan="6">RQ</td><td rowspan="4">T</td><td>SEC</td><td>CS, CSC, EDPP, SC</td><td rowspan="4">Perf, Perc, Safe, TecU</td><td rowspan="6">01, 02, 03…</td></tr>
<tr><td>INC</td><td>RECA. LCCA, SIA, OVCA, RORP</td></tr>
<tr><td>EMI</td><td>CMS, ESA</td></tr>
<tr><td colspan="2">Gen</td></tr>
<tr><td>U</td><td colspan="2">Gen</td><td>Beh, T&A, Use</td></tr>
<tr><td>I</td><td colspan="3">SEC, INC, EMI</td></tr>
</table>

Table 2.1: Tagging for the research questions

Being:

- T: technical
- U: User Related
- I: Impact Assessment
- SEC: Seconds
- INC: INCA
- EMI: EMIC
- Gen: General or Generic
- Perf: Performance
- Perc: Perception
- Safe: Safety Logic
- TecU: Technical User-related
- Beh: Driver Behaviour
- T&A: Trust and Acceptance
- Use: Usage

2.3 Next steps for the development of the test and evaluation plan

This chapter describes the next steps towards deliverable D7.4 “Test and evaluation plans”. Deliverable D7.4 is also the first milestone for subproject “Evaluation and Legal Aspects” and is intended to describe the test and evaluation plan for the in the interactIVe project developed functions and systems. Hence this document will be the basis for all test activities as well as the assessment of the interactIVe functions. The due date of the deliverable D7.4 is October 2011.

The development process of the test and evaluation plan is divided into four main steps. These four steps are the internal report I-3, the deliverables D7.1 and D7.2 and finally the deliverable D7.4. An overview about the deliverables and the internal report of SP7 are given in Figure 2.3 “Schedule of SP7 Evaluation” and Table 2.2. The deliverable D7.3 “Legal aspects” deals with the legal aspects of the developed function. This deliverable is not directly related to the development process of the test and evaluation plan. Due to this D7.3 will not be described in detail in this chapter.

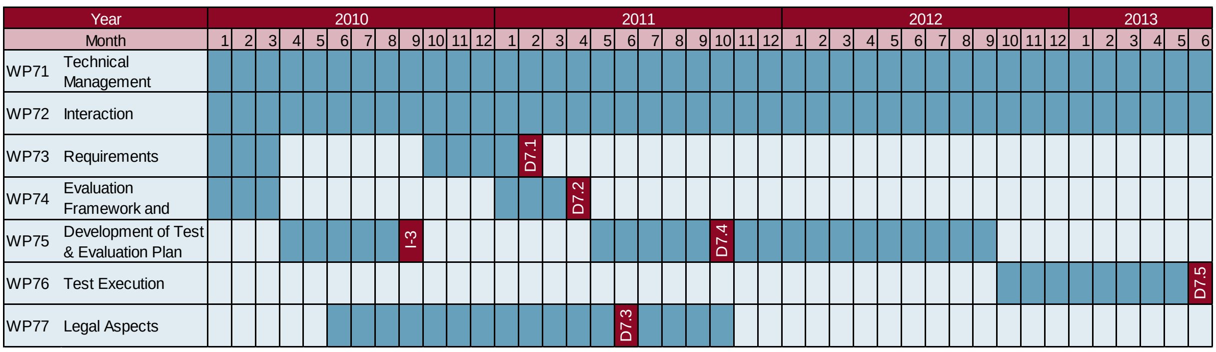

Figure 2.3: Schedule of SP7 “Evaluation”

Deliverable	Description	Due Date	Partner
D7.1	Requirements for the evaluation framework	M14	CTAG + All
D7.2	Specification of the evaluation framework	M16	TNO + All
D7.3	Legal aspects	M18	BASt
D7.4	Test and evaluation plans	M22	VTEC + All
D7.5	Impact assessment of the developed application – Overall interactIVe assessment	M42	IKA +All
Internal report	Description	Due Date	Partner
I-3	Draft evaluation plan	M09	IKA + All

Table 2.2: Deliverables and internal report of SP7

The first step of the development process was the internal report I-3 - Draft evaluation plan. The draft evaluation plan describes the first ideas and plans of SP7 for the technical, user-related and safety-impact assessment. The basis for the described evaluation methodology of the internal report has been a literature review of other research projects, e.g. PREVENT.

Further the internal report was the fundament for the discussion with the VSPs on the evaluation methodology. A continuous and close contact between the VSPs and SP7 is essential in order to adjust the testing process, which is needed for the final evaluation of the functions and is conducted by the VSP. Therefore the feedback of the VSPs on the internal report is considered in the deliverables D7.1, D7.2 and D7.4.

This deliverable “D7.1 Requirements for the evaluation framework” is the second step of the development process for the evaluation plan (steps 0 and the beginning of step 1 of the PReVAL procedure). The objective of this document is to describe the functions and the research questions, which concern the evaluation of the interactIVe functions. This document is not intended to specify the testing method in detail.

Deliverable D7.2 “Specification of the evaluation framework” will describe the evaluation plan more specific for the interactIVe systems. The focus of this document will be especially on step 1, 2 and 3 of the PReVAL: hypotheses, test scenario definition and evaluation method selection.

The final step of the development process for the evaluation plan is the deliverable D7.4 “Test and evaluation plan” (step 4 of the PReVAL procedure). This document will describe the whole evaluation process for the three vertical subproject SECONDS, INCA and EMIC in detail. Therefore the results of the deliverables D7.1 and D7.2 as well as the feedback on these deliverables will be considered for D7.4.

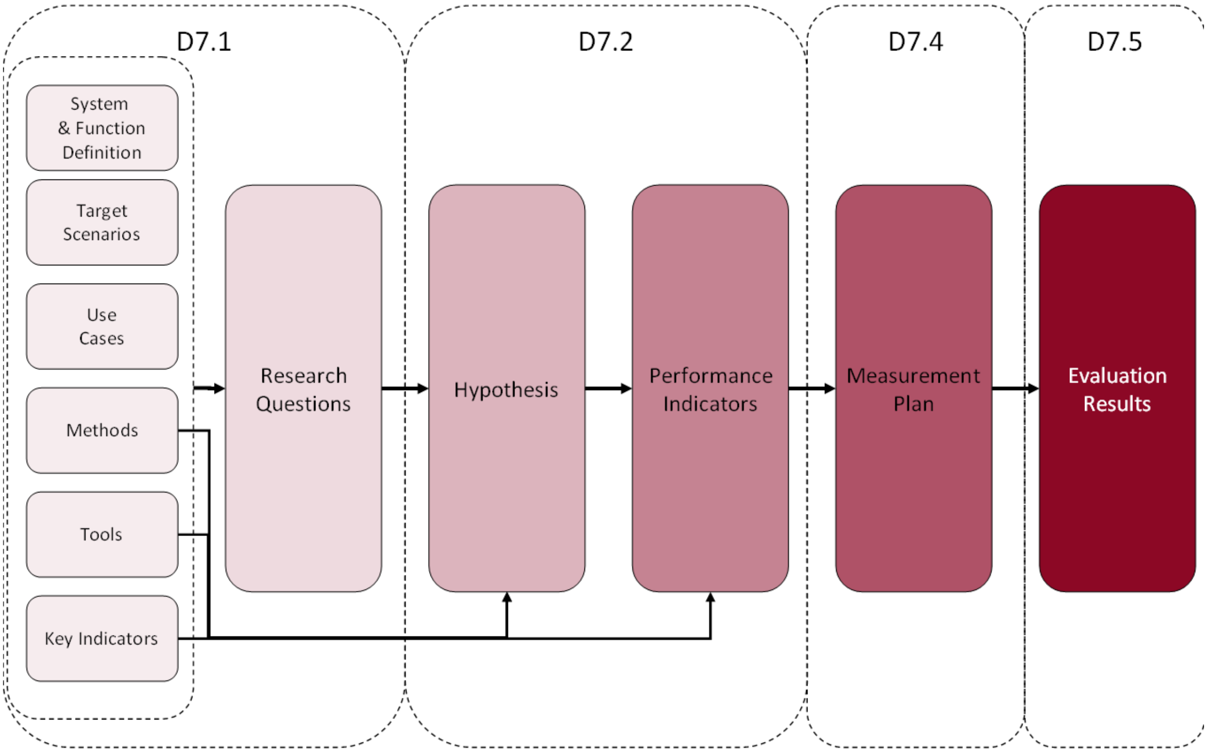

Figure 2.4: Overview on the next steps and deliverables on SP7

3 System & Function description

In this chapter, a first description of both interactIVe systems and functions is included. It will be the basis for the further definition of technical, user-related and impact assessment in chapters 4, 5 and 6.

interactIVe is divided in vertical and horizontal subprojects. While the vertical subprojects are focused on developing the functionalities considered in the project, the latter deal with technical or methodological aspects common to all applications. SP7 “Evaluation and Legal Aspects” is a horizontal subproject.

There are three VSPs in interactIVe: SECONDS (Safety Enhacement through CONtinuous Support), INCA (INtegrated Collision Avoidance and vehicle path control) and EMIC (cost-efficient EMergency Intervention for Collision mitigation). These three VSPs define the systems to be assessed in SP7.

Each system includes a set of functions, which is defined as a task, action, or activity that must be accomplished to achieve a desired outcome. In this case, several functions together implement a system. Finally, each function can be formed by different aspects that can also be common for different functions.

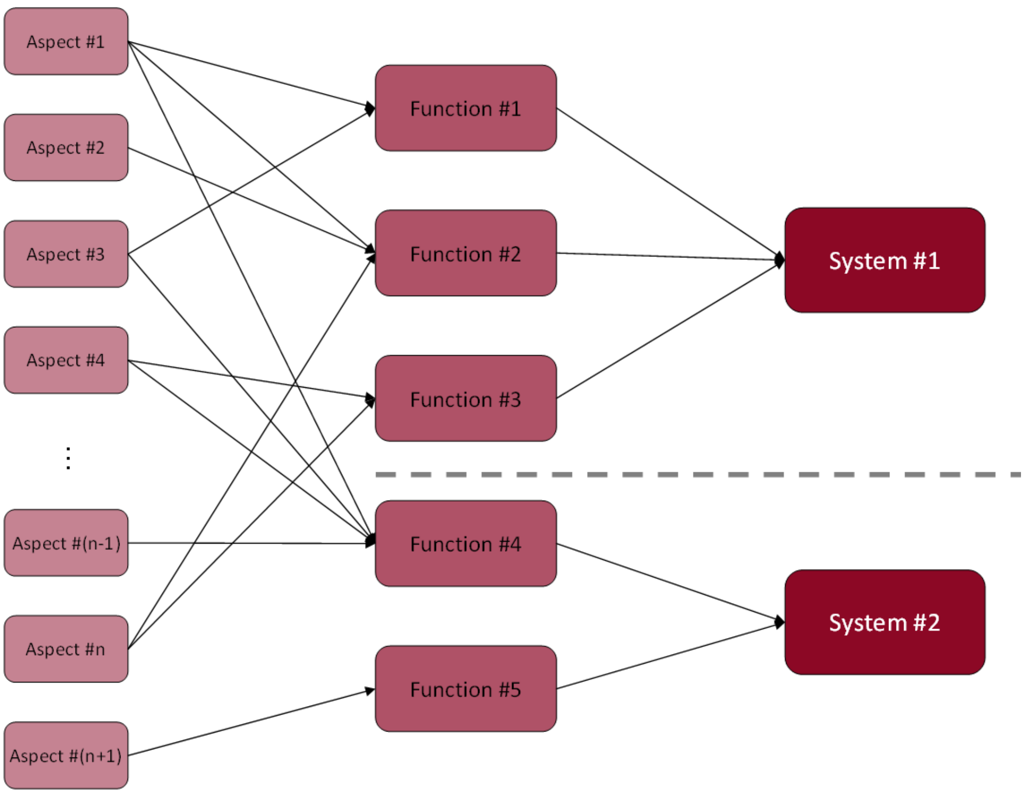

Figure 3.1: Aspect – Function – System outlook

This chapter has the goal to describe the systems to be developed at a functional level, including the Use Cases foreseen for each of these functions and the expected demonstrators. The descriptions here are based on a questionnaire which was distributed at an early stage of the project, and on the information in D1.5.

3.1 SECONDS

The VSP SECONDS develops functions, which should support the driver continuously through the process of driving. The three basic aspects of SECONDS are the integration of functions, continuous support and the form of interaction between the vehicle and the driver, based as much as possible on normal vehicle controls.

The general idea of SECONDS is to integrate a full set of support functions. These functions are intended to inform the driver in every driving situation in order to avoid dangerous situations. Hence, the main focus of this subproject is on safety aspects. Besides the safety aspects the subproject considers also other aspects of driving, such as fuel saving and driver comfort.

The interaction between the driver and the vehicle operates in a natural way, mainly based on haptic feedback. Therefore the feedback is given by the same component that is used for control, such as the steering wheel, accelerator pedal and braking system.

The functions, which are developed in this subproject, are:

1. Continuous Support
2. Curve Speed Control
3. Enhanced Dynamic Pass Predictor
4. Safe Cruise

These functions will be realised and tested in 4 demonstrator vehicles. The tested functions and demonstrator vehicles are listed below:

Diver Assistant functions	Demonstrator vehicle
Continuous Support	FFA car, CRF car, Volvo car
Curve Speed Control	FFA car
Safe Cruise + Anti-Collision (developed in INCA)	Volvo car
Enhanced Dynamic Pass Predictor	BMW car

Table 3.1: functions and demonstrator vehicles in “SECONDS“

The SECONDS functions are intended to warn the driver in different situations. In order to identify the relevant driving situation, different accident databases have been analysed. Based on this evaluation relevant accident types for the SECONDS functions were determined. These accident types or target scenarios, as they are called in interactIVe, are the basis for the use cases of the function.

For the SECONDS functions the target scenarios are:

- Rear-end collision (TS_SP4_3.1 and 3.2): Rear-end collision due to high speed difference or tentative evasive manoeuvre
- Unintended lane departure (TS_SP4_1, TS_SP4_1.1 and TS_SP4_1.2): unintended lane departure to the right or left side of the lane.
- Accident during a lane change (TS_SP4_2.1 and TS_SP4_2.2): Hitting another vehicle during an intended lane change due to high speed difference or due to the position of the other vehicle (vehicle is in the blind spot).

- Accidents in curves (TS_SP4_4.1 and TS_SP4_4.2): Losing control of the vehicle, because of high speed driving.
- Overtaking accidents (TS_SP4_5, TS_SP4_5.1, TS_SP4_5.2, TS_SP4_5.3 and TS_SP4_5.4): Collision with oncoming traffic while overtaking another vehicle.
- Exceeding speed limit (TS_SP4_6.2)
- Accident with crossing traffic (TS_SP4_7.1, TS_SP4_7.2): Vehicle enters road with crossing priority traffic or exits parking lot with crossing priority traffic
- Accidents with VRUs (TS_SP4_8.2, TS_SP4_9.1): Pedestrians or animals that are on the road

3.1.1 "Continuous Support"

Continuous Support (CS) assists the driver in many different driving situations in order to prevent the occurrence of dangerous situations. The situations, which should be avoided by the function, are various. Continuous Support should prevent rear-end collision, head-on collision, collision at intersections, collision at crossings, and the drift out of lane. Also when the driver is exceeding the speed limit, the functions will intervene.

One important part of Continuous Support is that assisting the driver is performed in a discrete way. During non-critical situations the function should be in the background. Thus, the driver should be exposed to the same driving experience as in a standard vehicle. Facing a dangerous situation the system becomes active and tries to keep the driver out of danger.

Therefore the driver will be informed or warned by the use of multiple feedbacks through actuators like the braking system, accelerator pedal, steering wheel or vibrating seat-belt. The exact modalities of these methods will be defined in the IWI Strategies SP, with different levels of support and interaction depending on the situation.

The driver should have the overall impression that the vehicle is reacting with continuously increasing strength in order to stay away from the danger.

This function is based on a wide perception of the environment around the vehicle, including the road and potential obstacles, which is collected and delivered by the Perception Platform. The sensors, which are used by the Continuous Support functions, differ per demonstrator vehicle as listed in the following table:

Used sensors	Demonstrator vehicle
Front radar (76 GHz)	FFA, VCC
Front radar (24 GHz)	CRF
Camera	FFA, VCC
Rear/Side radar	FFA, VCC
Front LIDAR	CRF, FFA, VCC
eHorizon	CRF, FFA, VCC

Table 3.2. Used Sensors per demonstrator vehicle for the Continuous Support functions

The use cases for Continuous support are the following ones:

- UC_01_401_v1 Preventing rear-end collision due to speed difference

- UC_01_402_v0 Rear-end collision due to unsafe distance
- UC_03_404_v0 Hitting a vehicle in blind spot
- UC_03_435_v0 Collision with a fast approaching vehicle
- UC_04_436_v1 Preventing collision when vehicle enters road with crossing priority traffic
- UC_04_437_v1 Vehicle exits parking lot with crossing priority traffic
- UC_05_405_v1 Preventing collision with pedestrian walking on the road
- UC_05_438_v1 Preventing animal accident
- UC_06_450_v0 Drift to lane alongside with following vehicle approaching
- UC_06_451_v0 Drift to lane alongside with following vehicle
- UC_06_452_v0 Drift to opposite lane with oncoming vehicle
- UC_06_453_v0 Drift to opposite lane without oncoming vehicle
- UC_06_454_v0 Drift to side barrier
- UC_07_455_v1 Excessive speed at road bumper
- UC_08_457_v0 Exceeding speed limits

The following use cases are not covered by the system requirements for the demonstrator vehicles:

- UC_04_437_v1 Vehicle exits parking lot with crossing priority traffic
- UC_05_405_v1 Preventing collision with pedestrian walking on the road
- UC_05_438_v1 Preventing animal accident

For this reason it is not clear at the moment if the Continuous Support function would warn the driver also in these situations.

3.1.2 “Curve Speed Control”

The Curve Speed Control (CSC) is an active safety function that aims to reduce the number of accidents that occur from negotiating curves at high speed.

The system determines the current position of the vehicle by the means of the Global Positioning System (GPS). These data are needed to extract information about the upcoming curve from the digital map database. Further the information from a camera sensor is also taken into account in order to determine the position in the lane. Based on this information the function determines the maximum speed at which the vehicle can drive safely through the bend.

If the vehicle is driving outside the estimated safety boundaries, an active intervention is applied in order to slow down the vehicle before entering the curve. Depending on the exceeding of the determined speed, this intervention ranges from inhibiting the acceleration to active braking.

The use cases, for which the system is intended, are:

- UC_07_406_v0 Accidents in curves due to high speed
- UC_07_456_v0 Automatic speed adaptation in curves

3.1.3 “Enhanced Dynamic Pass Predictor“

The Enhanced Dynamic Pass Predictor (eDPP) supports the driver in overtaking manoeuvres. For this purpose the system allows or inhibits overtaking manoeuvres based on the availability of an overtaking path. For the determination of the overtaking path the eDPP uses different information, e.g. road geometry and legal limitations. This information is provided by the vehicle sensors, which are:

- Front long range radar
- Front short range radar
- Camera-based subsystem supporting legal speed limit traffic sign and lane recognition
- Rain sensor
- Temperature sensor
- ADASIS v2 Horizon Provider

The use cases for the Enhanced Dynamic Pass Predictor are:

- UC_02_403_v1 Preventing overtaking crashes when there is an unknown curve ahead
- UC_02_431_v1 Preventing overtaking crashes on roads with unknown problems
- UC_02_432_v1 Preventing overtaking crashes at a crossing
- UC_02_433_v1 Preventing overtaking crashes in hill sections
- UC_02_434_v1 Preventing overtaking crashes on a straight lane

3.1.4 “Safe Cruise”

The function Safe Cruise (SC) implements automatic following of vehicles on main roads at a safe distance. In order to follow the lead vehicle automatically the function takes over the control of the steering, brakes and power train. Hence, it is expected that the function will reduce the driver’s workload and that this will result in enhanced traffic safety.

This function requires a significant understanding of the environment, as well as an enhanced monitoring and surveillance of the driver, because it has to be ensured that the driver does not conduct secondary tasks. Therefore the driver is monitored by a camera sensor, which detects the driver’s eye, eyelid and head position. For the detection of the environment a front radar, a rear/side radar, a camera as well as a front LIDAR sensor are used. If the driver performs excessive secondary tasks, the automated following will be deactivated in order to not compromise the system/traffic safety.

The Safe Cruise is intended to be used in the following cases:

- UC_01_401_v1 Preventing rear-end collision due to speed difference
- UC_01_402_v0 Rear-end collision due to unsafe distance
- UC_06_457_v0 Exceeding speed limits

3.2 INCA

The vertical subproject "INCA" (Integrated Collision Avoidance and Vehicle Path Control) develops active safety functions for passenger cars and commercial vehicles. The developed functions shall prevent possible accidents by combining lateral (autonomous steering) and longitudinal (autonomous braking) interventions. The combination of lateral and longitudinal interventions will offer new possibilities to not only mitigate the severity of accidents, but also to avoid the accident in a wide range of situations.

The functions that are developed in this subproject for collision avoidance are the following ones:

- Rear-End Collision Avoidance (RECA), where system applies brakes and/or changes lane
- Oncoming Vehicle Collision Avoidance/Mitigation (OVCA), where overtaking the preceding vehicle is prevented or aborted when there are oncoming vehicles. The function also includes crash prioritization when an oncoming collision would be more severe than a side impact.
- Lane Change Collision Avoidance (LCCA) and Side Impact Avoidance (SIA), where lane change is aborted due to an obstacle in a blind spot or approaching rapidly.

Calculation of free paths and vehicle dynamics are important parts of the collision avoidance logic development.

The functions for preventing the driver from accidentally driving off the road are divided in two types:

- *Run-off Road Prevention (RoRP), Type 1,* includes detection of sharp curves and reduces speed
- *RoRP Type 2* for lane keeping in other situations.

These functions will be tested with three demonstrator vehicles (situation January 2011):

Diver Assistant functions	Demonstrator vehicle
Run-off road prevention, Lane Change Collision Avoidance	VCC car (shared with SECONDS)
Truck rear-end collision avoidance, Run-off-road prevention, Side impact avoidance, Oncoming vehicle collision avoidance/mitigation	VTEC truck
All INCA functions	FFA car (shared with SECONDS)

Table 3.3. Functions and demonstrator vehicles in INCA

For the INCA functions, the target scenarios for passenger car demonstrators are:

- Rear-end collisions (TS_SP5CAR_1.1-1.3): rear-end crash with stopped lead vehicle due to inattention, rear-end crash due to distraction and rear-end collision due to a slower vehicle in front
- Intended lane change scenario (TS_SP5CAR_2.1-2.4): cutting in/out and resulting in rear/side/frontal impact for lane changer, cutting in due to parking scenario
- Head-on collisions with oncoming traffic (TS_SP5CAR_3.1-3.2): collision with oncoming traffic, collision after overtaking a vehicle

- Unintended lane departure (Collision with static obstacle) (TS_SP5CAR_4.1-4.2): Collision with an off-road obstacle after veering off road to the right/left

The target scenarios for truck demonstrators are:

- Rear-end collisions (TS_SP5TRUCK_1.1-1.3): rear-end collision due to slowing vehicle in front, rear-end collision due to vehicle in front moving slowly at constant speed, rear-end collision due to a stopped vehicle in front
- Run-off road accidents (TS_SP5TRUCK_2.1-2.2): losing control on a straight road, losing control in a curve
- Head-on collisions with oncoming traffic (TS_SP5TRUCK_3.1-3.2): accident with oncoming traffic due to loss of control, accident with oncoming traffic due to wrongly initiated overtaking manoeuvre
- Lane change accidents (TS_SP5TRUCK_4.1): accident with oncoming traffic due to loss of control
- Accidents with pedestrians (TS_SP5TRUCK_5.1-5.2): accident with pedestrians while the truck travels straight, accident with pedestrians while the truck is turning to the right

3.2.1 “Rear End Collision Avoidance” (RECA)

A lead vehicle suddenly brakes/slows down when the host vehicle driver is inattentive. The system issues a warning. If the driver doesn’t react, the system brakes or steers to avoid the accident.

Use cases:

- UC_01_504_v2 Truck rear-end collision avoidance by warning, braking or steering
- UC_01_531_v1 Rear-end collision avoidance by warning, braking or steering

3.2.2 “Lane Change Collision Avoidance” (LCCA)

The lane change collision avoidance function prevents accidents by warning the driver or autonomously steering the vehicle back into lane if a lane change is attempted when a vehicle which is approaching rapidly from behind in the adjacent lane.

Use cases:

- UC_02_501_v2 Head-on collision prevention by autonomous steering (intervenes a lane change)
- UC_02_532_v1 Head-on collision prevention by autonomous steering
- UC_02_511_v1 Lane change accident prevention by autonomous steering

3.2.3 ”Oncoming vehicle Collision Avoidance / Mitigation (OVCA)

Function OVCA prevents collisions with oncoming vehicles by warning, braking autonomously and/or restricting the possibility to overtake when oncoming traffic is present.

The use cases defined for OVCA are:

- UC_02_506_v2 Head-on collision avoidance/mitigation by warning and enhanced braking
- UC_02_534_v1 Head-on collision avoidance/mitigation by preventing lane change

- UC_02_535_v1 Head-on collision avoidance/mitigation by warning and enhanced braking

3.2.4 "Side Impact Avoidance" (SIA)

The host vehicle driver decides to change lanes on a dual lane road when another vehicle is present in the blind spot of the host vehicle. The system issues a warning and if the host vehicle driver does not notice the warning, the system prevents the accident by steering the host vehicle back into its lane.

Use cases:

- UC_03_507_v1 Side impact avoidance
- UC_03_533_v1 Side impact avoidance

3.2.5 "Run-off Road Prevention" (RoRP)

The driver drifts out of the lane due to drowsiness or distraction. The system prevents a crash by steering the vehicle back into its lane. Alternatively, the system detects that the vehicle has too high speed to be able to successfully negotiate an upcoming curve. The system warns the driver and if the warning is not detected, the system brakes and leads the vehicle to a safe speed.

Use cases:

- UC_06_503_v2 Unattended lane departure prevention by autonomous steering (passenger car)
- UC_06_509_v2 Run-off road prevention in a curve (truck)
- UC_06_510_v2 Run-off road prevention on a straight road (truck)
- UC_06_535 Untended lane departure prevention by autonomous steering (passenger car)
- UC_06_536 Run-off road prevention on a straight road (passenger cars)

3.3 EMIC

The vertical subproject EMIC, which stands for Cost-Efficient Emergency Intervention for Collision Mitigation, focuses primarily on critical pre-crash situations where collision mitigation can be realised at very reasonable cost.

This horizontal subproject will develop two functions:

1. Collision Mitigation System (CMS): an automatic emergency safety system that applies the brakes and can additionally steer if the driver fails to react to an imminent head-on collision. This function is further described in section 3.3.1.
2. Emergency Steer Assist (ESA): supports the driver during an emergency steering manoeuvre. This function is further described in section 3.3.2.

For EMIC the defined target scenarios are (in short):

- Rear-end collision (TS_SP6_1.1, 1.2 and 1.3): rear-end crash with a stopped lead vehicle due to inattention or distraction of the HV driver, or due to blocked view; wrong steering to avoid the end of traffic jam is also included.

- Unintended lane departure (Head-on collision with static obstacle, TS_SP6_2.1 and 2.2): collision with an off-road obstacle after veering off road to the right/left.
- Head-on collision with oncoming traffic (TS_SP6_3.1, 3.2 and 3.3): collision with oncoming traffic due to a suddenly disabled driver or view obstructions during overtaking or driving through crossings.
- Cross traffic collision (TS_SP6_4.1): due to visual obstruction.
- Unparking vehicle from the side (TS_SP6_5.1).
- Pedestrian from the side (TS_SP6_6.1): ‘trespassing’ pedestrians.

In the functional description the functions of EMIC are further outlined (sections 3.3.1 and 3.3.2).

Interaction with the driver is not yet clearly outlined, as far as the system action is not autonomous (without required driver action); the driver is foreseen to be warned acoustically, visually and haptically.

These functions will be implemented and tested in two demonstrator vehicles. The tested functions and demonstrator vehicles are listed below:

Diver Assistant functions	Demonstrator vehicle
Collision Mitigation System (CMS)	VW. Based on a cost-efficient sensor and algorithm approach, based on vision sensors and other existing sensor techniques. Autonomous braking and steering will be performed using these sensors and actuators. In addition, a driver model will be integrated.
Emergency Steer Assist (ESA)	CONTIT

Table 3.4: Functions and demonstrator vehicles in EMIC

The sensors foreseen within EMIC are as follows:

Demonstrator vehicle	Sensor system
VW	Cameras (stereo vision and mono vision) and a low cost radar (probably 24 GHz)
CONTIT	Camera and radar (long range)

Table 3.5. Used Sensors per demonstrator vehicle for EMIC

3.3.1 “Collision Mitigation System”

The Collision Mitigation System (CMS) of EMIC perceives its environment through a camera and a radar sensor. From these inputs an assessment of the situation is done and a manoeuvre prediction algorithm combined with a driver model, trigger the function. The function can take control over the brakes and the steering wheel.

The CMS should work over the complete pre-collision phase, from informing/warning the driver in an early stage, through supporting the driver to avoid an imminent accident, till taking control if the driver fails to react and the collision cannot be prevented anymore.

For CMS following Use Cases (UC) are defined:

- UC_01_602_v2 Rear-end collision mitigation by warning and intervention.
- UC_01_603_v2 Rear-end collision mitigation by warning and intervention.
- UC_02_604_v0 Head-on collision mitigation during overtaking by intervention
- UC_02_605_v1 Head-on collision mitigation at intersection by warning and intervention
- UC_02_606_v2 Head-on collision mitigation by intervention
- UC_04_607_v1 Cross traffic collision mitigation by intervention
- UC_06_610_v1 Mitigation of collision with off road obstacle by warning and intervention

3.3.2 “Emergency Steer Assist”

Different from CMS, ESA aims to support the driver during a steering manoeuvre by increasing the stability of the vehicle. It is not a collision avoidance system, the driver has to initiate the manoeuvre by steering and ESA supports the driver in avoiding a collision.

For ESA following Use Cases are defined and will be summarised in the tables of next section:

- UC_01_601_v1 Rear-end collision avoidance by intervention
- UC_04_608_v1 Cross traffic collision avoidance with unparking car by intervention
- UC_05_609_v2 Avoidance of collision with pedestrian by intervention

4 Technical Assessment

This chapter describes the general requirements for the technical evaluation of the developed functions of interactIVe. The objective of the technical assessment is twofold:

1. The first objective is to evaluate the performance and technical potential of the developed functions. This includes investigating under which situational and environmental conditions a function can operate as well as determining technical performance (e.g. maximum deceleration and maximum detection range). These values are compared to the specifications of the functions in order to check, if the specifications are fulfilled. One issue for the evaluation of a function's performance in the technical assessment is that most functions' behaviour depends on the reactions of the driver. However, the aim of the technical assessment is not evaluate the driver's performance, but the performance of the function. Hence the technical assessment should as far as possible be independent of the driver.
2. The second objective is to collect information and data for the safety impact assessment. For calculating safety impacts a deep understanding of the technical as well as the user-related behaviour of the functions is necessary. Therefore, it is indispensable to collect data of the functions' warning and intervention strategies (when and how does a function react on a situation). In this chapter the technical behaviour of a function is investigated and not the interaction between the function and the user. This topic will be investigated in the user-related assessment. Besides the general understanding of the function, the performance data from the technical assessment is important for implementing scenarios in the simulation tools, which are used in the safety impact assessment.

The technical assessment will mainly focus on evaluation of whole functions and not on components of the functions (subfunctions). This restriction is made, because the functionality of the developed functions must be given for the whole function and not only for parts of the functions.

Even though the objective is to focus on the whole function, this approach does not suit all cases. For example, in case the behaviour of the functions differs from the expected behaviour, more information is needed about the reasons for this deviation. Furthermore information about subfunctions is required for the evaluation of the VSP "EMIC", as the conducted tests are also needed for the development of the function itself.

Therefore the second step of the technical assessment – if required – is to evaluate also components of the functions. In such a case the assessment of every component of the functions is not feasible, because of limited resources and time. Therefore the components need to be summarized on a certain level. For the technical assessment of the functions, which are developed in interactIVe, a division into the components "Perception" and "Logic" is appropriate, especially with regard to subprojects SP2 "Perception" and SP3 "IWI Strategies". New actuating or communication elements won't be analysed in detail, because the focus in interactIVe is not on the development of these components. In the following, a detailed definition of the components "Perception" and "Logic" is given.

- Perception: The component "Perception" consists of all components which collect information from the environment. Important aspects related to the perception are, the time necessary to identify the relevant object and the distance to the object, at which the relevant object is identified.
- Logic: The component "Logic" combines all components which determine the functions' reaction by means of data which is provided by Perception. In the technical assessment it should be determined how the functions assess the situation based on the available perception data and how the function reacts on the perception data. For example, a relevant question can be, how often Logic calculates an intervention by

means of a new strategy and how often Logic makes the right or respectively a safe decision and helps to avoid an accident.

4.1 Method

The proposed method for the technical assessment follows the PReVAL approach, which has already been described in Chapter 2. The starting point for the technical assessment is the description of the developed function, described in Chapter 3.

The objective of this chapter is to provide information on the expected impact of technical assessment, hence the relevant research question for the technical assessment are described. The research questions are the basis for the development of the hypotheses and the Performance Indicators (PIs), which are derived based on the hypotheses

For the technical assessment, in general four different types of tests can be used:

1. Hardware in the loop tests,
2. Tests in a driving simulator,
3. Tests on test track,
4. Tests in real traffic.

The last step of the technical assessment after the test execution is the data analysis. The tests will be conducted by the vertical subprojects with support from SP7. Based on the gathered data the relevant performance indicators are calculated in order to evaluate the defined hypotheses and finally the functions.

The presented approach is a general approach and needs to be elaborated for the interactIVe project. Different issues must be solved or clarified.

- Access to the demonstrators: It must be clear, for which kind of test the different demonstrator vehicles can be used. Depending on the access to the demonstrator it must be decided, which kind of test is appropriate, and which information can be expected from this test. For example a test in real traffic can provide information about the performance of the perception components under real traffic conditions.
- Test planning: It must be decided in which order the tests are conducted. This issue is related to the availability of the demonstrator vehicles as well as planning of conducting the assessment. Further it should be tried to combine the tests for the technical and the user related assessment as much as possible in order to reduce the effort.
- Standardization of the tests: The standardization of the tests is an important aspect, because the tests with demonstrator vehicles will take place at different test facilities. Therefore the tests and conditions must be standardized. Furthermore, it must be investigated if requirements for the test tracks are necessary. Also for the target object and other equipment, which will be used during the tests, standardization might be necessary in order to ensure the comparability between the tests. interactIVe will have a close look at the tests and test setup developed in the EC project ASSESS. ASSESS aims to develop standard tests for pre-crash systems suitable for regulatory and consumer testing as for example EuroNCAP. Because of this, ASSESS can be a good source of information on standardization of the tests for interactIVe. This issue is closely related to the issue of the access to the demonstrator vehicles, because it will have a big influence on the place where the tests are conducted.
- Reference measurement system: It must be decided in which tests a reference measurement system is necessary and which type of reference measurement system should be used in the test.

- Determination of Performance Indicators: One issue is to define appropriate PIs, because this project does not only deal with collision mitigation but also with collision avoidance. Therefore it must be checked, if already existing PIs (e.g. TTC, Mean of THW local minima, steering angle velocity, max. acceleration or max. brake force) are sufficient or if new indicators are required to investigate the collision avoidance potential of the function (e.g. duration of machine intervention, timeliness of warning or intervention). This step must also be done for the Perception and the Logic components, if they are investigated. But the indicators cannot be determined before the hypotheses have been defined.

The final method for the technical assessment will be provided in the deliverable D7.4. Now that the methods for the technical assessment have been described, the next subchapter will deal with the tools, which will be used for the technical assessment.

4.2 Tools

For the technical assessment various tools are needed in order to conduct test drives and collect necessary data. This chapter will provide information about the test facilities, which will be used in the technical assessment of interactIVe, and first information about logging requirements.

Besides the logging and the different test facilities, further equipment is necessary for conducting the test drives. Because the evaluation plan is not yet finalized only a short overview about additional test equipment is possible. Further needed test equipment will be described in the following deliverables.

4.2.1 Data acquisition system

For the evaluation of the interactIVe functions it is obviously necessary to store signals. Therefore the seven demonstrator vehicles must be equipped with a data logging system, which stores data from the vehicle bus and additional sensor data if not available on the vehicle bus, information about the current position of the vehicle and video data.

At least the following aspects need to be ensured in order to guarantee a smooth evaluation of the functions:

- All CAN and sensor data should be stored in a common data structure and data file
- It must be possible to load and work with the data in evaluation software tools such as MATLAB.
- A common time stamp (e.g. GPS-based UTC) is needed, if different logging systems (e.g. data and video logging) are used. This is important to synchronise data from different sources after the test (like e.g. different participating vehicles).

The specification of the hardware for the data store systems is not the task of this subproject. The hardware is chosen in the vertical subprojects. Also the logging of the data during the test will be done by the vertical subproject. After the test the vertical subproject will provide a (MATLAB readable) data file, which will contain all necessary signals that have been logged during the tests. The structure and content of this data file will be jointly defined between SP7 and the VSPs and described in D7.4.

Besides the data acquisition system, a reference positioning system and a video system are often required in a demonstrator vehicle for the real world tests.

For some test cases it will be necessary to determine the vehicle’s position with a high accuracy. This is important in order to compare the sensor and system outputs with a reference system. Not only the position of the demonstrator vehicle is important, but also the positions of other vehicles and targets in the test.

Furthermore a system to store video data is required for the tests in order to reconstruct what happened during the test. Because video data should only support the process of the technical assessment, a high quality of the video data is not required in SP7. The number and the position of the cameras are under discussion. Details will be provided in D7.4.

The technical assessment will be conducted on different test facilities. An overview about different possible test facilities is given in the following subchapters.

4.2.2 Hardware-in-the-loop testing

Hardware-in-the-loop (HIL) tests provide reproducible, safe and efficient testing. HIL testing is done in very different stages of system development and requires special devices to simulate the required system inputs. Since the technical evaluation will concentrate on the developed functions and not as much on the comprising subsystems, a HIL laboratory like VeHIL can offer the step between full simulation and real world testing for active safety systems integrated in a vehicle.

VeHIL (Vehicle Hardware In the Loop, see Internal Report I-3 – Draft Evaluation Plan) is TNOs indoor test track where the complete vehicle with the ADAS is placed on a 4WD dynamometer. The traffic around the vehicle under test is simulated through special bullet vehicles; called moving bases. The moving base has to be able to drive very specific paths dictated by the relative motion between the vehicle under test and the bullet vehicle.

4.2.3 Driving simulator

The different functions will not only be tested with the demonstrator vehicles. Also tests in the driving simulator are a useful way for the technical assessment. The driving simulator will be used especially for tests which have a potential risk of damaging the demonstrator vehicle or of personal injuries. Both situations have to be excluded from testing. The driving simulator offers the possibility to test the functions without the risk to have real life damages. It must be ensured that driving simulator tests provide the same behaviour of the function in the simulator as in the real word.

The tests in simulators can be conducted at different facilities of the interactive project partners.

4.2.4 Test track

For the technical assessment the tests of the developed function in reality is indispensable. Most of the tests in reality with the demonstrator vehicles will be conducted on test tracks. The test scenarios, which will be tested on the test track, will be developed by SP7 during this project.

For the tests on the test track various test facilities from the side of the interactIVe project partners are available. On which test track the tests will be conducted in the end needs to be decided for each demonstrator vehicle. For this decision different aspects must be taken into account. For example the possibility to conduct the required tests on the test track and the regulation regarding the access to the demonstrator vehicle are important aspects, which will influence the choice of the test track.

One important issue is that the tests are performed without causing damage to the demonstrator vehicles and without endangering the health of the test participants. This is especially important for the functions, which intervene shortly before a collision.

4.2.5 Tests in real traffic

Besides the tests on test tracks also tests in real traffic can be conducted. But the possibility of conducting tests in real traffic is limited by legal aspects. Because this is a research project and the developed functions are not market-ready a special permission may be required for the test in real traffic. Otherwise it may only be allowed to drive in real traffic with deactivated functions or not at all.

This subchapter described the methods as well as the tools for technical evaluation. Next subchapter will deal with research questions of the technical assessment for the three interactIVe vertical subprojects.

4.3 Research questions

This chapter deals with the research questions for the technical assessment. The research questions are the first step of the evaluation and provide information on what is evaluated in the technical assessment. Based on the research questions the hypotheses and the Performance Indicators, which are closely related to the hypotheses, will be defined.

This chapter is divided into two parts. The first part covers general research questions which are common for all analyzed functions. The second part covers research questions that are related to a certain system. For each system the relevant research questions are described in a subchapter.

The technical research questions are divided in the following four categories:

1. Full function performance

   In the first category “full function performance” research questions are presented, which investigate the overall function behaviour. Example questions are: How effective is the system in avoiding or mitigating different types of accidents, how often does it make a safe decision and what are its operational limitations?

2. Perception

   In this category of research questions performance of the perception components is investigated. For example: how reliable is the environmental perception, can it detect and classify different objects, estimate their speeds and model the road, or how is the situational awareness of the function?

3. Safety logic

   The research questions regarding the safety logic deal with the safety strategy of the function and decisions, made by the function. Relevant questions can be for example: How often are trajectories and avoidance strategies reliably and accurately calculated? Does the calculation handle dynamics, moving obstacles and road shape?

4. Technical user-related

   For some research questions a distinction between the technical and the user-related assessment is not always possible, because the function’s reaction depends on the driver’s behaviour. However, the objective with these questions is not to investigate the driver’s behaviour. Research questions of this category are for example: How does the interaction with the driver work and in which event flows would the system take control? Can it detect the driver's status (inattention, distraction, drowsiness) and possible intentions?

In order to identify for which category of use cases a research question is valid, the related category of use cases is written in brackets. If a research question is marked as general, this means that the research question is valid for all categories of use cases as long as it makes sense.

In any case, research questions are applying to complete functions and not to specific components or aspects.

Full function Performance

One of the main objectives of the technical assessment is to check, whether the system specifications are fulfilled. This information is also important for the safety impact assessment, because the safety impact assessment requires a profound understanding of the functionality in order to avoid an over- or underestimation of the safety impacts. And therefore it is necessary to verify, if the written specification is realized in the actual function. Therefore the first research question derives directly from this objective:

- **RQ_T_Gen_Perf_01: Does the function fulfil its functional specifications?** (general – performance)

For a deeper analysis this research question needs to be split into further and more specific research questions. First the functionality of the function is analyzed under different environmental conditions.

- **RQ_T_Gen_Perf_02: How do different environmental conditions affect the function's availability and performance?** (general – performance)
  - Road type (e.g. urban road, rural road and motorway)
  - Road layout (.e.g. tunnel, road barrier layout)
  - Lane markings (available or not)
  - Road condition (dry road, icy road, banked road, etc.)
  - Weather conditions (e.g. dry, not dry)
  - Lighting conditions (e.g. daylight and night)

In addition to the environmental conditions also function's boundary conditions (like e.g. speed range of the function) must be investigated.

Regarding the full function performance it must further be clarified, what are the technical limitations of the functions?

- **RQ_T_Gen_Perf_03: What are the performance limitations of the function in relation to intervention in longitudinal and in lateral direction?** (general – performance)

For the analysis of this RQ the longitudinal and lateral acceleration and velocity have to be considered. Additionally in order to answer of this research question the road conditions (e.g. friction coefficient and gradient of the test track or test route) need to be taken into account.

Perception

During the technical assessment it must also be investigated if the data provided by the perception layer is correct. Hence the following research question is:

- **RQ_T_Gen_Perc_01: Is the relevant target detected by the function during the test?** (general – perception)

The time point and the distance, at which the target is detected, are of importance. Depending on the category of use cases either the longitudinal PI (e.g. Time-To-Collision (TTC)) or the lateral PIs (e.g. Time-to-Lane-Crossing (TLC)) should be considered.

- **RQ_T_Gen_Perc_02: At which time point / at which distance is the relevant target detected by the function?** (general – perception)

Although interactIVe is a research project and it is not possible to expect the same quality from prototypes as from market-ready applications, documentation of sensor failures is required for complete documentation of the tests. Therefore it must also be investigated:

- **RQ_T_Gen_Perc_03: does the function correctly recognize its target scenarios?** (general – perception)
- **RQ_T_Gen_Perc_04: Are there false negative detections during the tests?** (general – perception)
- **RQ_T_Gen_Perc_05: Are there false positive detections during the test?** (general – perception)

Safety Logic

Besides the assessment against the specifications, the second objective of the technical assessment is to collect data for the impact assessment. Additional tests may be necessary in order to collect specific information for the safety impact assessment. The main research question related to this topic is:

- **RQ_T_Gen_Safe_01: In what way is the function expected to improve traffic safety?** (general – safety logic)

This research question is closely linked to the information/warning and intervention strategy. This aspect is especially important for the functions developed in the VSP SECONDS, because the aim of SECONDS is to avoid critical situations in advance by supporting the driver However, all three VSPs include functions intervening in the dynamic behaviour. The research questions regarding the warning and intervention strategy about how are the information and warning, and the intervention strategy of the function implemented?

This research question refers only to the technical implementation of the warning/intervention strategy and not to the interaction between the function and the driver. This research question can further be divided into more detailed research questions, which need to be investigated in different scenarios:

- **RQ_T_Gen_Safe_02: In which tested scenarios the functions warn the driver?** (general – safety logic)
- **RQ_T_Gen_Safe_03: In which tested scenarios the functions intervenes in the driving behaviour?** (general – safety logic)
- **RQ_T_Gen_Safe_04: Are there tested scenarios, in which the function intervenes without warning?** (general – safety logic)

Another important issue is, if the result, which has been achieved in one test run, can be reproduced in further test runs. This is an important aspect, because it must be determined, if the function behaviour is common in similar situations or if it differs and if so, how much it differs.

- **RQ_T_Gen_Safe_05: Is the function's reaction in a specific situation different under similar conditions?** (general – safety logic)

During the technical assessment also the time point, at which the warning is given, must be evaluated.

Depending on the category of use cases either the Time-To-Collision (TTC) or the Time-to-Lane-Crossing (TLC) should be considered.

- **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?** (general – safety logic)

Besides to the time-based distances also the spatial distance (distance to relevant object at warning) should be assessed during the tests. Hence the research questions related to the spatial distance are:

- **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?** (general – safety logic)

Technical User-Related

An important aspect of this category is to investigate, if the driver has the chance from the technical point of view to react on a situation after warning has been issued by the function. Therefore the point of time at the warning as well as the reaction, which is required to defuse the situation, has to be considered. By means of following questions it should be investigated, if the driver has the chance to avoid an imminent collision, after a warning is issued.

- **RQ_T_Gen_TecU_01: Is there, after a warning, enough time left for an intervention by the driver?** (general – technical user-related)
- **RQ_T_Gen_TecU_02: What reaction (deceleration or steering wheel velocity) is required from the vehicle/driver in a tested scenario in order to avoid an accident, when a warning is given by the function?** (general – technical user-related)

A close related research question to the topic warning and intervention is:

- **RQ_T_Gen_TecU_03: Is it possible to override the function?** (general – technical user-related)

This question is important for the controllability of the function, which describes the likelihood that the driver can cope with driving situations including ADAS-assisted driving, function limits and function failures [KNA09]. However, it is not the aim of the technical assessment to investigate the controllability of the function in detail.

In the next subchapter the research questions, which are related to a certain system or respectively to a certain function, are defined.

4.3.1 SECONDS

It is important to first identify the relevant use cases for the technical assessment of the vertical subproject SECONDS. The use cases describe the situations, in which the functions are intended to be used. The natural approach is to investigate the functions in these use cases. Because of the high number of use cases – especially for SECONDS – and accompanying testing effort, it is not suitable to test and evaluate all use cases in detail. In order to reduce the testing and evaluation effort the use cases have to be merged into different categories. For these categories tests are to be developed.

One approach is to use the categories of use cases that are used in D1.5. This approach offers the opportunity to combine use cases which base on similar accident scenarios. An overview over the functions and the related categories of use cases is given in Table 4.1

Categories of use cases	Continuous Support (CS)	Curve Speed Control (CSC)	enhanced Dynamic Pass Predictor (eDPP)	Safe Cruise (SC)
Rear-end collision	X			X
Head-on collision			X	
Collision during lane change	X			
Collision with crossing traffic	X			
Collision with pedestrian or animals	X			
Drift out of lane	X			
Unsafe speed	X	X		
Traffic rule violations	X			X

Table 4.1: Categories of use cases of SECONDS

In the following part the research question for the different SECONDS functions are present. It is also described for which category of use cases each research question is relevant

Continuous Support

One of the main challenges for technical assessment of the Continuous Support (CS) function is the high amount of different use cases, in which the function should support the driver in order to avoid imminent conflicts. Because the main objective of this function is to avoid dangerous situations, the driver must be warned in time to have enough time to react. Hence the first research question is:

- **RQ_T_SEC_CS_Perf_01: Does the Continuous Support function warn the driver in time, so that he has enough time to react?** (general – full function performance)

This question involves also the point in time at which the driver is warned.

Besides the general research questions, which are relevant for all categories of use case, for the rear-end collision it must be further determined, if the Continuous Support function warns about static obstacles.

- **RQ_T_SEC_CS_Perc_01: Does the function react on stationary objects in the tested scenarios (especially vehicles)?** (rear-end collision – perception)

Regarding the use cases which are related to category “Collision during lane change” the relevant research questions are:

- **RQ_T_SEC_CS_Perc_02: Does the function detect further objects besides cars (e.g. motorcycles)?** (collision during lane change – perception)

Further in the technical assessment it must be determined, what are the function’s boundaries regarding the detection of other vehicles.

- **RQ_T_SEC_CS_Perc_03: Which is maximum lateral distance between both vehicles at which a vehicle is detected in the blind spot?** (collision during lane change – perception)

Regarding the support at intersections the research questions deal mainly with the detection of the other vehicles at the intersection.

- **RQ_T_SEC_CS_Perc_04: How well are crossing vehicles detected comparing with and without using C2C communication?** (collision with crossing traffic – perception)

Because a penetration rate of 100 % is not realistic, it must also investigate, if only one vehicle is equipped with the function

- **RQ_T_SEC_CS_Perf_02: How does the function behave, if a second vehicle is not able to communicate with the ego-vehicle?** (collision with crossing traffic – full function performance)

For support of the driver in intersection situations the function must also be able to determine the right of way situation correctly.

- **RQ_T_SEC_CS_Safe_01: Does the function determine the right of way situation correctly? Are traffic signs correctly considered?** (collision with crossing traffic – safety logic)

Regarding the prevention of collision with road users and animals, it must be investigated if the function can detect different objects. The research question is:

- **RQ_T_SEC_CS_Perc_05: How well are vulnerable road users detected depending on e.g. size, or movement?** (collision with pedestrian or animals – perception)

The research questions, which are related to the category “drift out of lane”, deal with the functional behaviour in different situations.

- **RQ_T_SEC_CS_Perf_03: How does the function react, if the vehicle drives in a lane that ends and the driver does not react on this situation?** (drift out of lane – full function performance)

For the category of use cases “unsafe speed” it must be investigated, how the function reacts on speed bumps. Therefore it is important to investigate, which speed is suggested by the function as safe speed.

- **RQ_T_SEC_CS_Safe_02: What is a safe speed for passing over a speed bump?** (unsafe speed – safety logic)

And besides to the characteristic of the speed bump, it must also be determined, how well the speed bumps are detected by the function.

- **RQ_T_SEC_CS_Perf_04: How well does the function detect speed bumps?** (unsafe speed – full function performance)

With regards to the speed limit support the research questions investigate how the speed limit is detected and which limitations exist regarding the speed limit detection.

- **RQ_T_SEC_CS_Perf_05: How does the function react if the information of the speed limit from the digital map and from the camera differs?** (traffic rule violations – full function performance)
- **RQ_T_SEC_CS_Perc_06: Is the speed limit always detected correctly?** (traffic rule violations – perception)

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)? (traffic rule violations – perception)

Curve Speed Control

The use cases of the Curve Speed Control function are all related to the category “unsafe speed”. The scope of this function is to prevent accident in curve due to improper velocity. The function will reduce the speed before a curve, if the vehicle speed is too high for the curve and there is high danger of losing control. Therefore the natural research question, which derives directly from the use cases, is to check, whether the function prevents losing of control over the vehicle in curves. But this research question is already analysed with the RQ_T_Gen_Perf_01.

In order to analyse, whether the function prevents accidents in curves, it will be necessary to investigate the system behaviour in different types of curves. Therefore is must be determined, how high the function provided safe speed is. The safe speed must also be compared to the physical possible speed in the curve, in order to estimate, how accurate the function estimate the upcoming curves.

- **RQ_T_SEC_CSC_Safe_01: What speed is suggested by the function as a safe speed depending on curve radius?** (unsafe speed – safety logic)
- **RQ_T_SEC_CSC_Safe_02: How high is the recommended safe speed compared to the physical possible speed?** (unsafe speed – safety logic)

Because the maximum velocity, which can be driven in a curve, depends on the road condition and vehicle condition (bad/worn tyres), this issue must also be investigated during the tests. Furthermore the influence of the environmental condition on the function and the determined safe speed must be analysed (see RQ_T_Gen_Perf_02).

Regarding the intervention of the function it must further be determined, when the function intervenes (see RQ_T_Gen_Safe_08**)** and if an intervention could have a negative influence on the dynamic behaviour of the vehicle.

- **RQ_T_SEC_CSC_Perf_01: Has an intervention of the function a negative influence on the dynamic behaviour of the vehicle?** (unsafe speed – full function performance)

One of the further issues, which need to be clarified through testing, is the reaction of the function on curves which are not on the map. Thus the following question needs also to be considered in the technical assessment.

- **RQ_T_SEC_CSC_Perc_01: How does the Curve Speed Control react on curves which are not (accurately) in the map?** (unsafe speed – perception)

This research question is also important for the safety impact assessment.

Enhanced Dynamic Pass Predictor

The enhance Dynamic Pass Predictor function should prevent head-on collision during an overtaking manoeuvre. Hence the function is only linked to the category “head-on collision”. The two main research questions for the technical evaluation of the eDPP function are derived directly from the related use cases. The function should warn or inform the driver, if the overtaking path, which is needed for the overtaking manoeuvre, is too short due to an oncoming vehicle or infrastructure limitations (e.g. curves).

For the eDPP function the relevant RQ have be already presented under the general research question. Important for the technical assessment of the eDPP function is to analyse, whether all relevant limitations of the overtaking path (oncoming vehicle, curves, intersection or hill section) are detected by the function (RQ_T_Gen_Perc_01), and whether the driver is warned due to the limitations (RQ_T_Gen_Safe_08).

Besides the question, if a warning or respectively information is shown to driver, the time point, at which the warning is shown, is also important for the technical assessment. The driver needs a certain time to react on the situation. It must be considered that in the worst case scenario the driver has to abort the overtaking manoeuvre by braking. Therefore this must also be evaluated, whether the driver is warned respectively informed in time by the function (see RQ_T_Gen_TecU_01).

Because the function use also car-2-car communication, the effects of this technology on the functionality of the function needs to be examined.

- **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?** (head-on collision – perception)

Safe Cruise

The Safe Cruise function should take over the vehicle control in longitudinal as well as lateral direction and therefore enhancing safety by reducing driver workload thus releasing perception resources for environmental surveillance task. One important aspect for a function, which takes over the driving task from the driver, is that it must be ensured that the driver still focuses on the road and is not performing secondary tasks.

- **RQ_T_SEC_SC_TecU_01: Is the function inhibited, if the driver is not focused on the road?** (general – technical user-related)
- **RQ_T_SEC_SC_TecU_02: Is the driver warned well in time when the function switches itself off?** (general – safety / technical user-related)

Regarding the two categories of use cases, for which the Safe Cruise function is intended, there are two important research questions:

- **RQ_T_SEC_SC_Perf_01: Can the SC function prevent imminent rear-end collision before the situation becomes critical?** (rear-end collision – full function performance)

This research question derives from the objective of the Safe Cruise function to take over the vehicle control from the driver. Therefore it must be tested, if the function can handle situations, in which the distance to the front vehicle decreases fast due to a high difference in speed or a strong deceleration. Further situations must be tested, in which the vehicle approaches a stand still vehicle or an opponent vehicle cuts in front of the host vehicle.

- **RQ_T_SEC_SC_Perf_02: Does the SC prevent speeding autonomously?** (traffic rule violations – full function performance)

This research question implicates a working traffic sign recognition and an appropriate reaction on a new speed limit. This means, that the function has to reduce or increase the speed of the vehicle in time without support of the driver.

Furthermore it must therefore be checked, if the traffic sign recognition is operating correctly.

- **RQ_T_SEC_SC_Perc_01: Is the speed limit always detected correctly?** (Traffic rule violations – perception)
- **RQ_T_SEC_SC_Perc_02: Are there limitations of the speed limit detection (e.g. coverage of the sign, lateral position of the traffic sign)?** (Traffic rule violations – perception)

4.3.2 INCA

Five INCA functions apply to six categories of use cases:

Categories of use cases	Rear End Collision Avoidance (RECA)	Lane Change Collision Avoidance (LCCA)	Oncoming Vehicle Collision Avoidance / Mitigation (OVCA)	Side Impact Avoidance (SIA)	Run-off Road Prevention (RoRP)
Rear-end collision	X				
Head-on collision		X	X		
Collision during lane change		X		X	
Collision with crossing traffic					
Collision with pedestrian or animals					
Drift out of lane					X
Unsafe speed					
Traffic rule violations					

Table 4.2: Categories of use cases for INCA

The INCA subproject develops four types of collision avoidance functions; rear-end, head-on, lane change and side impact. Additionally it includes a function for preventing loss of control and driving off the road accidents. The technical basis for implementing these functions could in principle be similar, but additional logic is likely to be needed to implement rules and strategies for each situation. The prevention for accidental road departure places slightly higher emphasis for detection of lane markings, road curvature and driver's behaviour (distraction or commonly drives close to lane markings), but also this function benefits from similar software and sensor components. At the moment the detailed implementation of the functions is not fixed.

The main research question for technical assessment of INCA functions is: **RQ_T_INC_Gen_Perf_01: what is the capability and performance to avoid or mitigate collisions in various dangerous traffic scenarios?** Percentual estimates could be given for both parts of the question; how many accidents are avoided and what is the drop in impact speeds. The effectiveness must be studied for each target scenario or more specifically in different event flows, as driver's correct actions can prevent the functions from activating. The functions should also be tested for reliability in generic traffic scenarios (for false activation) and possibly in scenarios that are expected to be difficult.

The other research questions target specific aspects of the system, aiming to provide more information to answer the high-level question.

Breaking this down to specific functions developed in the INCA subproject, we get e.g. the following research questions:

Rear-end Collision Avoidance (RECA)

- **RQ_T_INC_RECA_Perf_01: What’s the reaction time of the function in sudden situations and how does it affect collision avoidance?** (rear-end collision, collision with pedestrian or animals – full function performance, perception)
- **RQ_T_INC_RECA_Perc_01: What are the scenarios-specific ranges for detecting reference obstacles?** (rear-end collision, collision with pedestrian or animals – perception)
- **RQ_T_INC_RECA_Safe_01: What's the reliability for detecting a free lane / shoulder and how does this affect Logic?** (rear-end collision, collision with pedestrian or animals – perception, safety logic)
- **RQ_T_INC_RECA_Safe_02: Is the lateral accuracy of the function good enough to cover target scenarios?** (rear-end collision, collision with pedestrian or animals – perception & safety logic)
- **RQ_T_INC_RECA_Safe_03: How does road shape affect trajectory planning?** (rear-end collision, collision with pedestrian or animals – perception & safety logic)
- **RQ_T_INC_RECA_Perf_02: How does road shape affect impact speeds?** (rear-end collision, collision with pedestrian or animals – performance)
- **RQ_T_INC_RECA_TecU_01: Can the function warn earlier if the driver is not focused?** (rear-end collision, collision with pedestrian or animals – technical user-related)
- **RQ_T_INC_RECA_TecU_02: How does machine intervention vary in different event flows?** (rear-end collision, collision with pedestrian or animals – technical user-related)
- **RQ_T_INC_RECA_Perf_03: What's the reduction of impact speed in different event flows?** (rear-end collision, collision with pedestrian or animals – performance)
- **RQ_T_INC_RECA_Perf_04: How accurately does the car follow planned trajectories?** (rear-end collision, collision with pedestrian or animals – performance)

There’s also some background information required for assessment that lead to other research questions:

- What's the frequency of Logic calculations?
- Crash prioritization, does the function know traffic rules?
- How are "partial collisions"[1] calculated? **RQ_T_INC_RECA_Perf_05: Is the performance different in partial collisions?**
- How many turns can trajectories include? **RQ_T_INC_RECA_Safe_04: Can the function avoid more than one obstacle?**
- How's the potential movement of other objects handled? **RQ_T_INC_RECA_Safe_05: can the function avoid dynamic obstacles?**
- How accurate is the detection of relative speeds?
- How does the function model the road?

[1] The case where only a small part of another vehicle is in ego vehicle trajectory.

Lane Change Collision Avoidance (LCCA) and Side Impact Avoidance (SIA)

Many of the previous research questions are also valid for these functions.

- **RQ_T_INC_LCCA_Perc_01: What is the performance for side detection?** (collision during lane change, drift out of lane – perception)
- **RQ_T_INC_LCCA_Perc_02: How reliably does the system detect an obstacle in the blind spot?** (collision during lane change, drift out of lane – perception)
- **RQ_T_INC_LCCA_Perf_01: How large are the margins to avoid a collision (to ensure it is avoided and actual performance)?** (collision during lane change, drift out of lane – performance)
- **RQ_T_INC_LCCA_TecU_01: Does the function detect driver's gaze reliably and in which situations can it assist lane change?** (collision during lane change, drift out of lane – technical user-related)

Oncoming Vehicle Collision Avoidance / Mitigation (OVCA)

Since head-on accidents occur at high speeds, the speeds and distances of Perception and Logic are critical. Many of the previous research questions are also valid for this function.

- **RQ_T_INC_OVCA_Safe_01: Are the trajectory calculation ranges sufficient?** (head-on collision - perception, safety logic)
- **RQ_T_INC_OVCA_Perc_01: Does the function detect loss of control?** (head-on collision - user-related, perception)
- **RQ_T_INC_OVCA_Perf_01: How much lateral acceleration is used in different scenarios?** (head-on collision - safety logic and performance)
- **RQ_T_INC_OVCA_Safe_02: Can the system calculate a safe abort manoeuvre during overtaking?** (head-on collision – safety logic)

Run-Off Road Prevention (RORP)

This function differs somewhat from previous functions and the main questions are related to estimating the driver's state and safe speed. In a curve, estimation errors come e.g. from not being able to estimate tyre-road friction accurately and possibly not knowing the exact shape of the curve. This may lead to warning the driver in all high-speed cases even when the curve is still relatively safe to drive.

- **RQ_T_INC_RoRP_Perf_01: How often can driving off the road accidents be prevented in different traffic scenarios?** (drift out of lane, unsafe speed – performance)
- **RQ_T_INC_RoRP_Perc_01: What's the accuracy of being able to estimate maximum curve speed?** (drift out of lane, unsafe speed – perception)
- **RQ_T_INC_RoRP_Safe_01: How does the function handle situations where the driver e.g. accelerates in a curve, therefore using more friction than expected?** (drift out of lane, unsafe speed – safety logic)
- **RQ_T_INC_RoRP_TecU_01: How well does the function detect driver inattention and distraction?** (drift out of lane, unsafe speed – technical user-related)

4.3.3 EMIC

The two EMIC functions are intended for mostly the same, but also for some different categories of use cases. In Table 4.3 is an overview given, for which categories of use cases the EMIC functions are intended. For these categories different research questions have been defined.

Categories of use cases	Collision Mitigation System (CMS)	Emergency Steer Assist (ESA)
Rear-end collision	X	X
Head-on collision	X	
Collision during lane change		
Collision with crossing traffic	X	X
Collision with pedestrian or animals		X
Drift out of lane	X	
Unsafe speed		
Traffic rule violations		

Table 4.3: Categories of use cases of EMIC

Like for INCA, the main research question is **RQ_T_Gen_Perf_03: What are the performance limitations of the function in relation to intervention in longitudinal and in lateral direction?** How many accidents are avoided and to what extend are the effects of a collision alleviated? This should be evaluated for at least each target scenario taking into account possible driver actions as well.

The general research questions as formulated at the beginning of section 4.3 also hold for the EMIC functions, but will not be repeated here.

For EMIC the *rear-end collision* use cases have in common that the host vehicle is approaching a slow moving or standing still vehicle on the path of the host vehicle. The driver is thought to react in different ways: not at all, too softly or too strongly. Also, if the situation changes too fast, EMIC may start intervening immediately without warning the driver, due to too little reaction time available. The research questions for these scenarios are:

- **RQ_T_EMI_Gen_Perc_01: Is an avoiding steering reaction of the driver recognised?** (rear-end collision – perception)
- **RQ_T_EMI_Gen_Perc_02, RQ_T_EMI_Gen_TecU_01: Is a too weak/strong reaction of the driver recognised?** (rear-end collision – perception, technical user related)
- **RQ_T_EMI_Gen_Perf_01: Does the steering intervention indeed mitigate and not aggravate the collision as compared to braking or doing nothing?** (rear-end collision – full function performance)
- **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?** (rear-end collision – perception, technical user related)

- **RQ_T_EMI_Gen_Perf_02: How much is the collision mitigated?** (rear-end collision – full function performance)

The *cross traffic* scenarios for EMIC both involve a vehicle unexpectedly driving into the path of the host vehicle. The research questions for these scenarios are:

- **RQ_T_EMI_Gen_Perc_04: Is an avoidance manoeuvre of the driver recognised well?** (Collision with crossing traffic – perception, technical user related)
- **RQ_T_EMI_Gen_TecU_01: Is the situation well assessed to be safe enough to terminate the assistance and give back the control to the driver?** (Collision with crossing traffic – perception, technical user related)

Specific research questions for EMIC's functions can also be named:

Collision Mitigation System (CMS)

In EMIC only the CMS function has use cases concerning *head-on collisions*. The use cases are quite different. One use case involves an overtaking manoeuvre. The second use case describes an intersection scene and the third use case involves an impaired driver and drift to the opposite lane. However, the flow of events is basically the same. The research questions for this scenario are:

- **RQ_T_EMI_CMS_Perf_01: Does the function intervene in a way to mitigate the collision?** (head-on collision – full function performance)
- **RQ_T_EMI_CMS_Perf_02: Is the crash compatibility improved by the autonomous steering action?** (head-on collision – full function performance)

Emergency Steer Assist (ESA)

In EMIC only the ESA function takes scenarios with *pedestrians or animals* into account. It resembles very much the use case where a vehicle is *unparking* (UC 608), which is added to this section as well although it actually belongs to crossing traffic. The research questions for these two scenarios are:

- **RQ_T_EMI_ESA_Perc_01: Is the avoidance manoeuvre of the driver recognised well?** (collision with pedestrian or animals – perception, technical user related)
- **RQ_T_EMI_ESA_Perc_02: Is the situation well assessed to be safe enough to terminate the assistance and give back the control to the driver?** (collision with pedestrian or animals – perception, technical user related)

5 User-Related assessment

The user-related assessment will follow the best practices defined in PReVAL, though adapted to the specific needs of the interactIVe systems and functions.

Within this chapter, a description of the available methods and tools to assess the interactIVe systems from the user perspective is introduced. A preliminary list of key performance indicators is also included. These indicators are of a general perspective.

The systems are described individually from the perspective of the proposed methods and tools used for their user-related assessment. In this sense, general and system-related research questions are addressed.

5.1 Methods

The following methods have been identified as relevant for interactIVe:

Driving Simulator study

In a driving simulator study (in most cases a car or truck on a fixed location with a simulated traffic environment), driver behaviour is studied with a number of test persons, e.g. in different traffic situations or while using new in-vehicle technology.

A driving simulator study is most suitable for the development and testing phase of new ITS systems, since it can be tested easily and safely. Since the traffic situation can be controlled totally, systems can be tested under specific circumstances.

The aim of a driving simulator study is to get insight in the driver behaviour under different circumstances or while using different types of systems.

A driving simulator study is an experimental study, since it is carried out in experiments with predefined scenarios. In this way, the exact conditions in which the system needs to be tested can be generated. On the other hand, the aim is that the driver behaviour is as natural as possible, by using a driving simulator and simulated environment which is as close to reality as possible.

Safety effects can be derived from surrogate safety parameters, such as proportion of critical time-to-collisions, speed differences, short headways or strong decelerations. Also, specific and rare dangerous situations can be tested by predefining these situations in the driving simulator scenarios.

Small-scale field-test with instrumented vehicles

A small-scale field-test with instrumented vehicles involves observing drivers while they are using the system and comparing with their driving without the system. The field trial may be carried out unobtrusively, with – for the driver – hidden instruments in the vehicle. In this case the test driver drives alone during the test drive. Another alternative, giving the possibility of registering 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. The order of driving should be balanced (the so-called ABBA-design). The number of participants should be of a minimum of 20–25 drivers. The users just have to drive normally, but specific situations can be provoked.

The instrumented vehicles can be highly equipped with logging devices and sensors to perform accurate measurements.

The participants drive specific routes previously identified by the researchers and the data recorded can include video recordings of the drivers and the driving performance according to the specific variables to study. The test route should consist of varying driving conditions, divided into smaller parts with the same characteristics categorized into different street types. It should take appr. 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 changes because of it.

Questionnaire

In a questionnaire study to assess driver experiences or acceptance of a new system a group of people are asked about their opinions of a system throughout a set of questions that participants have to answer individually. They can also be asked about their opinions of the effect of the new system. The questionnaire may be administered by the investigator or self-administered. The questionnaires are very useful in collecting information from a large number of people. 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.

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 need to have cleared the objectives of the study and should have a good knowledge of the procedures to be followed during the interview.

Focus Group study

A Focus Group is a form of qualitative research in which a group of people are asked about their opinions and attitude towards a product, service, concept, advertisement, idea, or packaging. Questions are asked in an interactive group where participants are free to talk with other group members. The data recorded during the study will be video and audio recordings of the participants during the sessions.

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. After the test drivers that have driven with the system gather in groups of 8-10 persons discuss their experiences under the guidance of an experienced leader of focus group discussions.

5.2 Tools

Expected tools to be used within interactIVe for the User Related assessment are summarized below.

Driving Simulator

In order to test the systems in a driving simulator, some adaptations should be made in order to simulate the behaviour of the functions. Moreover, target scenarios needs to be created. Additionally, in order to check drivers’ reaction, specific equipment might be needed (equal to the equipment requested for real environment testing):

- Video recording equipment
- Eye tracking system
- Psycophysiological equipment

In this case, depending on the simulator, the data related to the vehicle could be recorded from the CAN network or directly using specific recording tools provided for the simulator environment. As in the real scenarios, the synchronization of data is needed. Normally in this controlled environment it’s easier to synchronize the data.

Instrumented vehicle

The demonstrator car, provided and equipped by the OEM partner in co-operation with technology partners, equipped with data logging facilities, where the following data can be registered:

- Time,
- Driven distance from start,
- Speed limit,
- Recommended Safe speed,
- Actual speed,
- Gap forward,
- Gap backwards,
- Studied function on/off,
- Warning for speed,
- Warning for short distance,
- Other warnings
- Gas pedal pressure,
- Brake pedal pressure,
- Turning indicator.
- Steering wheel movement
- Driver state
- Video information
- ...

This information can be obtained through different tools within the prototype vehicle:

- Data logger: This equipment records data directly from the vehicle network, allowing collecting signals as speed, accelerations, brakes, steering behaviour, etc. Depending on the integration of the functions, specific information related to the function can also be recorded, such as e.g. environment information. This vehicle network data can be synchronised with video data.
- Video recording equipment for recording front view, possibly driver face and view backwards: Video information is really valuable during data analyses in order to get accurate information about what is happening in the different situations and, in this way, analyze the driver behaviour. Video data can cover both the environment around the vehicle and the driver.
- Eye tracking systems: this devices record information of the visual behaviour of the driver
- Psycophysiological equipments: in order to identify the status of the driver in the different situations, the use of these equipments is recommended. In general some of the most relevant, already mentioned in this document, are the GSR (Galvanic Skin Response), facial EEG (measurement of facial muscles) and heart rate frequency.

All the equipment provides objective data. For the analyses of this data is relevant to synchronize all the information (with an acceptable error margin that should be defined before the integration of the systems in the vehicle), so normally an additional equipment that allows this synchronization should be included. Also, for the information storing during the tests, additional equipments should be considered: laptops, external hard drivers, etc…

Observation protocol for in-car observations

An observation protocol for the in-car observations in real traffic will be employed. The observations are carried out by two observers, riding along in the car with the driver.

Questionnaire/interview forms

Questionnaire/interview forms will be prepared for collecting data from test drivers to investigate aspects such as:

- Driver work-load - Subjective measurements of the subjects' mental workload to be recorded with help of the RTLX (Raw Task Load Index).
- How relevant the drivers think the studied function is.
- The drivers' perception of the studied function.
- To which extent the drivers' trust the function
- Usefulness and satisfaction with the function.
- Subjective opinion of using the studied function: How the driver experiences it, how it affects his driving (see statements below)
- Willingness to pay.

5.3 Key Performance Indicators

Key performance indicators for the user related assessment can be divided in objective indicators (those that can be measured) and subjective indicators (questionnaire items, interview results etc.). Key performance indicators to be finally used for the different systems within interactIVe will be derived from Hypothesis and Performance Indicators, and thus will be described in D7.2, being the aim of D7.1 to provide a description of the possible key performance indicators to be used. Among them, the following ones can be named.

5.3.1 Objective indicators

Speed

Profiles of mean speed along the different stretches to be compared when driving with/without the studied function. Mean speed and standard deviation of mean speed are the most frequently used parameters in evaluation studies, as there is a strong relationship between the speed level and accidents (see for example [FIN94], [ELV04] and [NIL04]) and speed variance and accidents (see e.g. [SAL81]; [FIN94]; [O'CI94]). Also, speed depends directly on the driver's decisions. Drivers usually pay much attention to their speed and they can control it very easily, so this parameter is directly linked with the driver's intentions. Moreover, is easy to measure.

Steering behaviour parameters

The parameters related to the steering behaviour are also closely related to the driver performance and in the special case of EMIC is closely related to function performance and gives important information about the variations of the driver behaviour using this function.

Time gap (ahead)

The distance to the vehicle in front (and behind if possible) to be compared for the conditions when driving with/without the studied function. Car-following behaviour is another important key indicator. Time gap is also a parameter which drivers focus on, so it is linked to their conscientious behaviour. It can be measured easily if the car has a radar sensor installed (e.g. in cars with ACC). The proportion of short time gaps and the gap distribution are often used to describe driver behaviour.

Number of alarms

The number of alarms/warnings generated by the system. Depending on the situation, the system will provide a number of alarm or warning issues that will be registered. When driving without the system, these alarms are not presented to the driver.

Alarm length

The alarm length is the time it takes the driver to exit from critical situations and get into a safe state. The expectation is that the length of alarms will decrease due to the timely warning to the driver, which is the point of the function.

Reaction time

Driver reaction time for initiating corrective action (braking and / or steering) to alarms is measured and driver reaction time can be extracted from this data.

Accelerations

The acceleration's first derivate, the so called jerk of a certain kind is an indicator of a traffic conflict. The number and proportion of jerks can be used as indicator of safety [BAG10].

Braking events

The number of braking events is registered and might be related to incoming events (e.g., incident). They can be matched with deceleration of the vehicle to check braking force.

Lane lateral position

Number of unintentional lane border crossings and time to lane crossing are parameters used in evaluation studies.

Eye movements

To study driver distraction, the number and frequency of fixations can be used. Also, other parameters such as deviations of the gaze, PERCLOS[2], etc will be interesting. This data provides useful information about the driver state during the different situations regarding the level of distraction or tiredness.

Travel time

Travel time along the test route to be compared for the conditions when driving with/without the studied function. This objectively measured variable can be compared with driver estimation if they feel that their travel time increases when using the system.

Behaviour towards other road users

Yielding behaviour has been shown to be an important safety indicator. [CAR88], in their in-depth study of accidents, found that erroneous yielding behaviour accounted for 26% of the accidents. [CAR89] found that failure to yield was one of the main driver failures leading to urban traffic accidents. Drivers' behaviour towards vulnerable road users is naturally an important safety indicator, but it is also an indicator of the formers' situation awareness, communication skills and, in many countries, their law abidance.

Delegation of responsibility

The phenomenon ''delegation of responsibility'' is represented by events that can be interpreted as the driver, relying on the fact that the system takes care of tasks other than

[2] PERcentage of eye CLOSure

giving support to e.g. keep a safe speed and safe distance, delegates to the system some of the tasks other than the system is designed for

Traffic conflicts

One of the strongest safety indicators possible to study by in-car observations is traffic conflicts. A conflict is defined as a near-miss accident. Serious conflicts are, like traffic accidents, a result of a breakdown in the interaction of the road user, the environment and the vehicle. A serious conflict has the same development of events as an accident, with the exception that a near-miss accident is missing the contact between the vehicles and other objects. There are between 3,000 and 40,000 conflicts for each police reported injury accident, depending on the severity and the type of the conflict. The relation between accidents and conflicts was shown by [HYD87]. Conflict technique was taken further and it was [SVE88] who validated the relationship between traffic events according to a severity hierarchy. The number of serious conflicts is approximately proportional to the number of crashes of similar type. Usually, conflicts can be recorded manually by observers in the car or by the road side, but increasingly jerks from data logger data (see accelerations) or video data are being used.

Traffic flow data for control

During the field trial traffic flow data along the test route should be kept on control. Hence, traffic volumes and speed should be measured at some representative sections.

5.3.2 Subjective indicators

Driver work-load

An objective indicator of increased driver workload is an elevated standard deviation of steering wheel movement. Subjective measurements of the subjects’ mental workload may be recorded with help of the RTLX (Raw Task Load Index).

The relevance of the system

In order to assess how relevant the drivers think the studied function is they to be asked to state in what extent they agree with some statements about the system’s relevance. These statements (e.g. “I would find the system useful in my driving”, “Using the system increases my driving performance”, etc.) will be described in further deliverables.

Usefulness and satisfaction

The drivers’ perception of the studied function may be assessed through nine bipolar items where the drivers to be asked to state their opinion of the system on a scale from 1 to 7. To assess the drivers’ opinions about the usefulness and satisfaction of the system the method proposed by [VDL97] can be used.

Usability

Perceived system usability (is it easy to activate / deactivate or regulate? Is information correctly displayed?) is relevant for the user-related assessment. To assess the drivers’ opinions about using the studied function they to be asked to state how they think different aspects of driving would change when using the system. The drivers will be asked to compare their experiences of using the system to their experience of driving without the system. Usability can be evaluated according to the System Usability Scale (SUS) suggested by Brooke [BRO96].

System effectiveness

Test subjects will be asked about their subjective impression on the system effectiveness (in avoiding or mitigating accidents).

Safety increase

Also, drivers will be inquired about the subjective safety increase feel they experiment with the studied systems.

Confidence in the system

One key element in the user-related assessment is dealing with the level confidence the system can provide the user. Subjective questions will be addressed in these terms.

Willingness to pay

To get an idea of the willingness to pay for the studied function questions will be given on this topic.

Demographic information

Information such as age, gender, driver experience, education level, purchasing power, etc…is relevant to perform a user assessment analysis.

The above-described information can be obtained through questionnaires or interviews.

5.4 Research questions

This chapter deals with the Research Questions, which will be the basis for the Hypothesis and the Performance Indicators definition (to be included in D7.2).

In this sense, a first approach to common research questions is made. These general Research Questions have the possibility to be applied to all systems. Afterwards, an individual approach to the VSPs will be made. Within this individual approach, specific chapters identifying possible methods and tools will be included.

The concept of situational control will be 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 specific 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 and driver's acceptance of the system are believed to be 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 vein, since the system exert a greater degree of control (both braking and steering) than current state-of-the-art ADAS, it will be important to investigate drivers' understanding of 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.

Common research questions identified are the following ones:

5.4.1 Driver behaviour

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)

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 in the cases when the driver is no longer able to handle the situation. In other words, this RQ is aimed at assessing the usability of the system, which is a key factor in terms of situational control. According 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)
- 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, required 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 of course expected that the INCA and SECONDS systems will reduce workload as 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, but as can be understood, this issue will be brought up in further RQs.

This RQ can be divided into several additional RQs:

- **RQ_U_Gen_Beh_02: Is there any difference in speed behaviour when driving with the system / function compared to driving without the 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?**
- **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?**
- **RQ_U_Gen_Beh_05: What is the driver's reaction time to warnings?**
- **RQ_U_Gen_Beh_06: Is there any difference in headway when driving with the system / function compared to driving without the system?**
- **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?**
- **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?**
- **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?**

5.4.2 Trust and acceptance

- **RQ_U_Gen_T&A_01: To which extent does the driver trust the system / function?**
- **RQ_U_Gen_T&A_02: What is the perceived safeness of the driver?**
- **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)**

Trust is a particularly important factor influencing the effectiveness of different strategies [DON09]. Obviously, 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 to recognize its limitations [LEE04]. This effect is sometimes also called complacency (see e.g. [DEW99]).

Trust (applying to RQ_User_General_02, RQ_User_General_03 and RQ_User_General_04) in the system can be measured by questionnaire techniques, but it is believed that the fact that users have the correct understanding of how the system works and its limitations will to great extent influence trust. In order to capture users' perceived understanding of the system, a suggested method is to let the users draw mental models of the system [BRO07]. Based on the mental models, a semi-structured interview, where users are asked about the driver-vehicle, driver-system and vehicle-system relationships can be carried out. Questions should also probe how the users experience of how driving with the system was different than/similar to the experience of driving without the system, the degree to which the participant understood the operation of the system and believed that his or her interpretation of the system's operation was accurate.

- **RQ_U_Gen_T&A_04: To what extent the driver finds the system / function useful and / or satisfying?**

To achieve users' acceptance of the new technologies which are proposed by interactIVe is obviously crucial from a commercial perspective, but as mentioned acceptance is also believed to be related to situational control. A validated method of measuring acceptance is by using the nine items described by [VDL97] which load on the two dimensions of perceived usefulness and satisfaction of the system under study.

However, acceptance naturally depends on several factors such as ease of system learning and use, perceived value, willingness to endorse, and driving performance [STE02]. Acceptance is also related to trust in such way that low acceptance may lead to disuse.

Moreover, there are inter-individual differences which should be taken into account when evaluating acceptance. In general one can differentiate between so-called "Internals" who choose to rely on their own driving skills rather than on vehicle automation technologies and people who rather "externals" who tend to rely more on external forces. This so-called Locus of control (LOC) is believed to be one of the most crucial psychological factors influencing drivers' acceptance to new in-vehicle technologies [ÖZK05]. Results have for example indicated that drivers with high safety skills and external orientation have more positive attitudes towards in-vehicle technologies than internal LOC drivers with high self-reported perceptual motor skills who might tend to resist in-vehicle technologies (ibid.).

Furthermore, it is believed that since the interactIVe system intervenes in highly hazardous situations and with strong countermeasures (both braking and steering), a special focus within this set of RQs should be put on how the driver perceives, understands and accepts the transition between driver control and system/vehicle control. The target scenarios are in most cases highly stressful and it is essential that the driver, within a short time frame, knows when and accepts that the system/vehicle is in control and when he/she is regains vehicle control. In reality, the system cannot be expected to function in all conditions, so the driver's response to situations when the accident cannot be avoided automatically due to system limitations is also of importance. Online physiological measures as well as post-drive subjective assessment, possibly supported by video sequences of the hazardous events could be a method to evaluate the driver-vehicle control transition phase.

Moreover:

- **RQ_U_Gen_T&A_05: What advantages and what disadvantages does the driver feel when driving with the system?**
- **RQ_U_Gen_T&A_06: Would the drivers like to have the system in their own cars?**
- **RQ_U_Gen_T&A_07: What price would they be willing to pay for the system?**

For safety impact evaluation purposes, one should also evaluate the willingness to pay and endorse (It should be noted though that willingness to pay may not be applicable to commercial vehicles since only a few drivers actually buy their own vehicles. The question must then be directed to e.g. the haulage company). Also, background information such as demographical data, driving experience, attitudes towards new technology and similar should be collected.

5.4.3 System usage

The utilisation of the interactIVe systems by the drivers must be safe, while assuring its effectiveness through its usage. For evaluating the system usage, four main research questions are proposed:

- **RQ_U_Gen_Use_01: Does the driver use the system as it was intended to be used?**

One of the most important aspects regarding the interaction between the driver and the system is assuring an appropriate usage of it. A non appropriate use of the system could indicate a misunderstanding of the system or its inadequate design. Added to this, an incorrect use of the system could lead to an unsafe situation. In order to measure this research question, data from the vehicle (including system activation) and video must be collected during the tests in order to analyse the situation and how the driver is using the system. Information provided through interviews and questionnaires can support the results obtained with the data collected during the trials.

- **RQ_U_Gen_Use_02: Is the driver's emotional state influenced when driving with the system?**

Some previous studies showed the relevance of the driver's emotional state in the driving behaviour, especially in the driver's process of adapting to the changes in a driving situation. In order to measure the influence of the driver's emotional state while driving with the system, it is suggested to use measurements of emotional reactions to assess the driver's feeling of control. It is suggested that both self-assessed emotional response techniques (such as the Self-Assessment Manikin, SAM) and physiological measures of valence (positive-negative reactions) and activation/arousal. These physiological measures include the Galvanic Skin Response (GSR) on fingertips or similar to measure activation and EEG (Electroencephalography) of the facial muscles to measure valence.

- **RQ_U_Gen_Use_03: Is work-load influenced when driving with the system?**

Driving workload is defined as the amount of resources (or abilities) allocated by the driver, in terms of effort and attention, to achieve the driving task.

Driving workload reflects the driving task's demands on an individual driver and his ability to cope with the demands to respect an acceptable level of performance. It depends on: Task (demands, complexity, difficulties…), driver (age, fatigue, abilities, experience…) and environment (dynamic / changing, familiar…).

From an interactIVe point of view, it is important to analyse how much driver's resources are absorbed by the systems and how this could influence the normal driving behaviour (maybe leading to an unsafe situation).

Among others (e.g. EEG), subjective measures are often used to gather information about driver workload.

- **RQ_U_Gen_Use_04: How does the driver perceive and understand the transition of control between the driver and the vehicle?**

As depicted in the introduction of this chapter (5.4), one key issue to take into account is the concept of situational control. Briefly, situational control refers to the level of control jointly exerted by the driver and the Vehicle (including ADAS) in a specific driving situation [PRE08]. Added to the technical evaluation of situational control, this research question focuses on its driver-related impacts. It is important to analyze how the driver and the system interact, but also how the driver perceives and understands the function. Erroneous perceptions of the system operation principles can lead to the driver rely completely in the system in a critical situation which is not safe or controllable (perceives the situation is safe/controllable but it is not). On the other hand if the driver doesn't accept the control of the system over the situation, possibly it will be switched off.

The evaluation of this research questions can be made using objective data collected during the tests and using post-drive semi-structured interviews and questionnaires, supported by video sequences showing the vehicle and driver behaviour in the test situation.

5.4.4 SECONDS

5.4.4.1 Research questions

An overview of the relevant research questions for SECONDS, which have been chosen from the presented general research questions, is given in the Annex.

5.4.4.2 Methods

Field trials can be employed for the evaluations of driver reactions and the effects of driver behaviour in SECONDS, specifically for those use cases that are relatively frequent in everyday traffic (CS, CSC). For the systems where the relevant use cases are rare in "normal" traffic and when testing involves some risk of collision (Safe Cruise with Anti collision and eDPP), a driving simulator should be used.

The following methods are foreseen for user-related assessment for SECONDS:

- Small-scale field-test with instrumented vehicle (CS, CSC). The design of the study would look as follows:
  - Number of test drivers: around 20–25 subjects. Order of driving should be balanced (the so-called ABBA-design).
  - Test route. A specific route (appr. 30–45 min to drive). The test route should consist of varying driving conditions, divided into smaller parts with the same characteristics categorized into different street types.
  - The test driver's behaviour will be observed by two trained observers in the test car.
- Test drives in a Driving Simulator

  Target scenarios should be created along a test route. To observe the test driver's reaction, specific equipment might be needed (equal to the equipment requested for real environment testing). The data related to the vehicle could be recorded from the

CAN network or directly using specific recording tools provided for the simulator environment.

- The test drivers, participating in either the field study or the simulator study, will be interviewed before driving, after the first drive and after the second drive. The interviews will contain questions from standard methods for investigating among others work-load, usefulness and acceptance, willingness to pay, etc.

5.4.4.3 Tools

Following the hypothesis and methods commented in the previous subchapters, the main tools needed during the tests are the following ones:

- Driving simulator (motion base, preferably with large longitudinal and lateral linear motion capabilities)
- Instrumented vehicle with all requested equipment (Physiological measurement equipment, data logging systems, etc.)
- Eye tracking device for measurement of gaze (specifically in the RoRP use cases, driver distraction is one of the key indicators), also to be integrated in the driving simulator and instrumented vehicle.
- Interview forms for pre-, between and post driving interviews.

5.4.5 INCA

5.4.5.1 Research questions

An overview of the relevant research questions for INCA, which have been chosen from the presented general research questions, is given in the Annex.

5.4.5.2 Methods

The following methods are intended for INCA user-related assessment:

- Driving simulator studies. Due to the fact that all use cases of INCA involve situations, which may be dangerous to driver and vehicle, conducting driving simulator studies will be the preferred method when evaluating the INCA systems. An issue here is to make sure that the simulator is enough ecologically valid so that the extent of the braking and steering actions performed by the INCA system are perceived as in reality. For example, it is difficult to assess users' acceptance of an emergency brake assist function if a test person cannot actually perceive that the vehicle initiates automatic braking. A requirement is thus that the simulator can provide realistic motion cueing and other cues relevant for self-motion perception so that the INCA system's actions are clearly perceivable by the test person. Ideally, the braking and steering actions should be simulated by tilting *and* large longitudinal and lateral linear motions but as these types of simulators probably will not be accessible for all testing situations, one may need to use simulators of lower fidelity (e.g. only tilting).
- Small-scale field test with instrumented vehicles**.** Excluding the head-on collision use cases (see the LCCA/OVCA functions) which are believed to be too dangerous to test on real roads, it is likely that one also can utilise driving-on-test-track methods if special measures are taken to ensure the safety of the test driver and vehicle (using e.g. balloon car targets).

Methods for assessment will in both simulated and real driving situations be a combination of online measurement of behaviour, gaze and physiology and offline questionnaire-based assessment of mental effort, trust, acceptance and willingness to pay/use.

5.4.5.3 Tools

The following tools will be needed for the user related evaluation of INCA:

- High fidelity driving simulator (motion base, preferably with large longitudinal and lateral linear motion capabilities)
- Instrumented vehicle on test track with target vehicles
- Physiological measurement equipment for GSR, EEG (if practically feasible), heart rate and blood pressure, included in both the driving simulator and the instrumented vehicle
- Eye tracking device for measurement of gaze (specifically in the RoRP use cases, driver distraction is one of the key indicators), also to be integrated in the driving simulator and instrumented vehicle.
- Pre-drive questionnaires for collecting demographical data
- Post-drive questionnaires for mental effort, trust, acceptance, willingness to endorse
- Post-drive questionnaires for personality assessment (including locus of control) and attitudes towards ADAS and similar technologies
- Post-drive questionnaires for simulator fidelity

5.4.6 EMIC

5.4.6.1 Research questions

An overview of the relevant research questions for EMIC, which have been chosen from the presented general research questions, is given in the Annex.

5.4.6.2 Methods

The methods to be used during the EMIC user-related assessment are the following ones:

- Tests with instrumented vehicles in controlled environments with dummy obstacles.
- Driving simulator study. EMIC cannot be tested in real driving conditions due to an evident risk of collision, so, in order to complement the above mentioned tests with instrumented vehicles in controlled environments, the usage of a driving simulator is foreseen.
- Structured Interviews. The structured interviews are proposed after testing the system. It's important to remark that the use of structured interviews implies the preparation of structured lists of questions to be presented in the same way to the participants and an experienced interviewer is needed.
- Questionnaires. After both, simulator study and field test study, the use of questionnaires is recommended in order to get the subjective data for the evaluation. Added to the specific questions about the system, a general questionnaire should be prepared and presented to the participants before testing the system in order to obtain general and demographic information: gender, age, driving experience, experience with the systems, etc.
- Focus Group study. Two Focus groups can be prepared, one with people who has not tested the system and one with people who has tested the system. In this way, a comparison of results could be performed after the tests in order to get additional information.

Taking into account the objectives of the study, it is usually interesting to combine methods in order to obtain different kinds of information about the studied area. For instance, driving simulators can cover some use cases in which, in real environment, the driver could be in danger. These results can be complementary to the results obtained in a field study.

Other example can be, for instance, combining expert assessment with a focus group. Thanks to this approach, it is possible to get the opinions from both experts and users of the system, resulting in a wider view of the system's impact.

Finally, it can also be interesting to combine methods with different kind of output data, e.g. a questionnaire or focus group study with a driving simulator test or a field study. The first method (questionnaire/focus group) will provide the subjective perception of the user, while the second one (simulator/on road test) will show the objective behaviour of the driver.

Regarding EMIC user-related assessment, a combination of methods is then proposed:

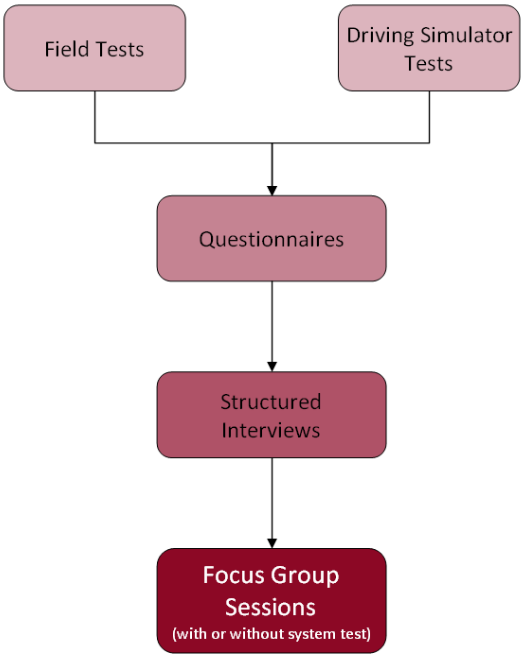

Figure 5.1: Proposal for user-related assessment for EMIC

5.4.6.3 Tools

Following the hypothesis and methods commented in the previous subchapters, the main tools needed during the tests are the following ones:

- Instrumented vehicles with all requested equipment (Physiological measurement equipment, data logging systems, etc.)
- Driving simulator with the above mentioned equipment
- Specific questionnaires (pre and post drive)

6 Safety Impact Assessment

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

1. Direct in-car modification of the driving task by giving information, advice, and assistance or taking over part of the task.
2. Direct influence by roadside systems mainly by giving information and advice.
3. Indirect modification of user behaviour in many, largely unknown ways.
4. Indirect modification of non-user behaviour.
5. Modification of interaction between users and non-users.
6. Modification of road user exposure by for example information, recommendation, restrictions, debiting.
7. Modification of modal choice by e.g. demand restrains (area access restriction, road pricing, area parking strategies), supply control by modal interchange and other public transport management measures, travel information systems.
8. Modification of route choice by demand restraints by route diversions, route guidance systems, dynamic route information systems, hazard warning systems monitoring incidents.
9. Modification of accident consequences by intelligent injury reducing systems in the vehicle, by quick and accurate crash reporting and call for rescue, by reduced rescue time, etc. [DRA98].

Through developing integrated safety functions, the interactIVe project continues the work started in PReVENT's INSAFES project and AIDE, introducing challenges that need to be addressed in the safety impact assessment. SECONDS integrates several driver assistant functions, such as Continuous Support and Curve Speed Control. The function Continuous Support also integrates several subfunctions such as a Lane Keeping Support-like and an ACC-like subfunction. This integration of subfunctions complicates the study and presents big challenges to the safety impact assessment.

For the impact assessment, a profound and general understanding of the involved trigger mechanisms is necessary in order to determine how and in which situation the function works. Besides the functions' descriptions from the VSP, the results of the technical and user-related assessment are used as well to get a deeper understanding of the way the different functions exactly operate.

One of the major methodological challenges is to decide whether to evaluate at the system level (SECONDS, INCA, EMIC), or to evaluate at the function or subfunction level. A prerequisite for evaluation at the system level is that a thorough understanding of the "system logic" is crucial: What are the priorities of the system? And how these priorities depend on the considered situations? Which situations are avoided? And due to what (sub) functions exactly? This way no double counting takes place. For example, if Continuous Support reduces speed on rural roads due to the ACC-like aspect, then losing control type accidents due to high speed can be prevented. But these accidents can also be avoided by a LKS aspect, which warns the driver in case or road leaving hazard. If both aspects are integrated in a vehicle, it is difficult to clearly identify which aspect is relevant for avoiding the accident. This necessitates a clear logical understanding of how the function and its respective aspects work.

An evaluation at the system or integrated function level necessitates methodological development. Choices will need to be made in the project, taking into account the availability of the required data and resources to carry out such an evaluation.

An alternative approach is to evaluate the (sub) function level. This approach groups use cases that are similar in terms of components and software logic involved, in the types of situations that the function will be active, and the actions taken by the function are comparable. These similar use cases are then grouped into "test cases". For example, the test case Safe Cruise Rear-end Collision covers the use cases UC_01_401 and UC_01_402, which are presented in the deliverable D1.5. Such an approach is similar to the approach taken in the EC 6th framework project eIMPACT [WIL08].

For both the system-level and function-level evaluation, technical and user tests are used to determine the restrictions of the function regarding the situations where it can be used. There are a number of situational variables that affect the working of the functions and need to be taken into account for the impact assessment:

- Road type (Is the function designed to be used on city roads, urban roads or motorways?)
- Speed dependent operational limitations (Does the function operate only at certain speeds?)
- Weather conditions (Does the function work in all weather conditions (dry, strong wind, fog, mist, rain, snow, sleet, hail)? Is the function especially effective in certain weather conditions?)
- Lighting conditions (Does the function work in all lighting conditions (daylight, twilight, darkness)? Is the function especially effective in certain lighting conditions?)
- Intersections (Is the function effective both at intersections and on road links?)
- Time of day (Does the function's effectiveness depend on the type of traffic (morning peak / evening peak / night / rest of the day)).
- Traffic density (If the function works on motorways: Does the function's effectiveness depend on traffic density (congestion / free flow)).

The general approach, which is currently suggested, consists of 6 steps:

- Group the use cases, if the function-level assessment is chosen, or stay at the system level.
- Identify the relevant accident types, for which the functions / systems are intended. This analysis should address both the direct and indirect effects, including risk, crash risk and exposure, as in eIMPACT and PReVAL.
- Determine the number and the severity of the accident types based on different accident databases. Some of the interactIVe functions make very fine distinctions between intended and unintended manoeuvres, requiring access to in-depth databases.
- Identify the critical situation for each accident type and determine the frequency of these critical situations based on the data of the technical and user-related assessment and simulations.
- Estimate the impact on traffic safety based on the expected penetration rates and the restrictions of the function.
- Extrapolate the results to a higher level. Depending on other choices in the assessment and the quality of the data, this can be at an EU-country level or at the EU-level.

Besides the accident databases, further tools are necessary for conducting the impact assessment. These tools consist of different simulations tools, e.g. traffic flow simulation tools. One major task is to include the different functions in the simulation. There are two different options to include the function:

1. Treat the function as a black box and rebuild the functionality of the function in the simulation based on the data and results of the technical performance. This option has to be used, if information about the functions is missing
2. Use Software-in-the-Loop (SIL) or Hardware-in-the-Loop (HIL) simulations. These types of simulations might provide more realistic simulation results, but they require models of the different functions and a link to simulation.

Which approach will be chosen in the end, is not decided yet. This decision will mainly depend on the availability of information and the access to algorithms or components of the functions.

6.1 Methods

Following the PREVAL/eIMPACT methodology briefly described above, the impact on the traffic safety for the interactIVe functions is evaluated by means of the defined hypotheses. The hypotheses will on their turn be defined in the deliverable D7.2 based on the research questions, formulated in this document. Each hypothesis will be analyzed based on the available information on the functions and also on the results of the test drive and simulation. In order to conduct the safety impact assessment adequately, the following is necessary:

- Information on the function itself. Most information about the functions will be provided by the specification of the developers and by the test drives, which are conducted in the technical and user-related assessment. But besides these test drives, additional test drives could be necessary for the safety impact assessment. This depends on the design of test drives (type, number of repetition, measures etc.) and on the results of the test drives.
- Information on the expected penetration rates of the different functions. Note: In order to determine this information SP7 will need the help of the developers.
- Information on the accidents and the occurrence of critical situation. For information on the accident different accidents database (e.g. GIDAS database) can be used. For the information on the occurrence of critical situation different sources like previous studies on the natural driving behaviour, results of the test drives for the technical and user-related assessment or simulator tests can be used.

One important aspect of the test drives will be the test in real traffic in order to determine how often critical situations occur, and how often false positives and false negatives occur. But due to the nature of some interactive functions – especially the functions, which are related to crash critical situations – not many relevant situations can be expected during test drives in real traffic. Therefore traffic simulations will be needed in order to determine, how often critical situations occur.

First the focus will be on the different functions of each VSP. In the second step the results of each function are used to determine the safety benefit for the VSP overall.

euroFOT Safety Impact Assessment methodology

Besides the PREVAL/eIMPACT methodology described above, the euroFOT methodology can be used.

An aggregation based safety assessment methodology that is developed for euroFOT is the risk matrix approach combined with a physical risk model. It is explained by an example of rear-end accidents. The analysis identifies variables that influence the risk, for example the speed of the following vehicle, the following distance and the reaction time of the driver. For each variable, the feasible data range is divided into several intervals. The combination of intervals for all variables defines a “grid”. Each “box” in the grid contains a part of all car-following situations. For each “box” in the grid, it is determined how much the accident risk is changed compared to the average accident risk, leading to a (hyper-) matrix of risk modifiers.

The average risk follows from statistics about the number of traffic fatalities and injuries and the number of kilometres driven (for the same population). Note that the overall risk for the unequipped group should equal the average risk.

The difficult part is to determine the risk modifiers. The physical risk model computes the risk for a given value of the variables speed and perception-reaction-time as the expected value of the number of fatalities per kilometre. The (uncalibrated) risk modifiers can be computed without making use of the FOT data.

The effect of an ITS function on accident risk is determined by computing the overall risk as the weighted sum of the risk modifiers, where the weights are the fraction of FOT data that lies in that box. This is done for the equipped and unequipped vehicles separately, and the difference in overall risk is the effect of the ITS.

The advantage of combining the physical risk model with the risk matrix is that the risk can be computed automatically for a large number of car-following situations. It can therefore cover the whole range of possible risks. The disadvantage is that for many accident types there is not sufficient data to define a physical risk model. Within euroFOT a physical risk model has been developed for rear-end accidents.

6.2 Tools

This chapter provides information on the different kind of tools, which will be used in the safety impact assessment. The tools can be divided into three types of tools:

1. Tools to collect information about the functions
2. Accident databases
3. Simulation tools

6.2.1 Tools to collect information about the functions

The safety impact assessment will mainly use the data of the technical and user-related assessment. If the provided data of the technical and user-related assessment are not sufficient for the evaluation in the safety impact assessment, further test will be conducted. In the test same tools will be used, which have already be described for the other two assessments. The tools, which might be used during the test, are for example instrumented vehicles, test tracks and driving simulators. For the description of these tools see the previous chapters.

6.2.2 Accident databases and FOT data

GIDAS database

The German In-Depth Accident Study (GIDAS) is a project of the Federal Highway Research Institute (BASt) and the Automotive Industry Research Association (FAT). The main purpose of GIDAS is to collect information on how an accident happens, what are the causes of these accidents and which are the injury mechanisms. Therefore the accidents are analyzed by a special team, which collects the necessary data.

The database was started in the 1999. Each year ca. 2000 accidents are analyzed. In total the database includes 20.130 accidents. The study is conducted in two regions in Germany. The regions are the cities Hannover and Dresden and their outer conurbation areas.

Per accident a high number of parameters, which describes the accident in detail, are collected and stored. For example the following parameters among others are stored:

- Environmental conditions
- Road design
- Traffic control
- Accident details and cause of accident
- Vehicle deformation
- Impact contact point for passengers and pedestrians
- Technical vehicle data (e.g. vehicle type and technical equipment)
- Crash information and parameters (e.g. Collision velocity and vehicle speed, delta v and EES, degree of deformation)
- Information relating to the people involved (e.g. weight, height) [NN]

ETAC database

The European Truck Accident Causation (ETAC) database provides information about truck accidents in Europe. The objective of the study is to identify the main causes of accidents involving trucks. During a data collection period of over 2 ½ years 624 truck accidents have been collected and investigated. Truck accidents are collected from sample areas in seven different European countries, which are statistically representative of the national truck accident situation.

All relevant accidents are investigated on the accident spot as quickly as possible by a team composed of accidentology and data collection experts. For the investigation a common methodology has been used. An accident will be investigated within the study, only if at least one truck (commercial vehicle of gross weight >3.5 t) is involved.

Besides this limitation of the investigated accidents, there are further limitations. Accidents are only investigated, if at least one person has been injured. And accidents are only investigated in depth, if it is possible to aggregate the necessary data (all together, the study has collected around 3000 parameters on the infrastructure, vehicles and people involved). [NN07]

Spanish Accident data

Spanish Accident data is provided freely by the DGT (Dirección General de Tráfico, Spanish Traffic Ministry) and is reporting about the yearly figures for accidents and injuries on Spanish roads.

It is presented in excel format with all the relevant data classified in different categories:

- Overall accident data
- Overall injured and fatalities figures
- The above mentioned figures split by:
  - Type of vehicle (passenger car, truck, motorbike, VRUs…)
  - Urban areas / Interurban areas
  - Type of road (city, rural road, motorway…)
  - Time during the day
  - Light conditions

- Type of driver (experience, age, gender)
- Accident types (head-on collision, road departure, etc.)
- Causes of the accident (distraction, speeding, skidding, etc.)

The database collects figures from all Spanish road accidents during one complete year, and is a good opportunity to have some estimated figures over a great number of accidents (around 100.000 per year). Nevertheless, data in other European studies is more focused.

Data is released between the month September and November of the previous year, so the last available data at this time is from the year 2009.

Field operational Test

Besides the data from the accident databases, data from field operational tests (FOT) can also be used for the safety impact assessment. A field operational test is “a study undertaken to evaluate a function, or functions, under normal operating conditions in environments typically encountered by the host vehicle(s) using quasi experimental methods” [NN08]. This means that in the field operational tests different data are recorded from a vehicle over a certain period of time. The data can contain different measures (CAN-data, GPS information, etc) as well as video/camera data.

The FOT-data can provide (depending on the FOT) information on the general driving behaviour of drivers in a natural environment or on specific tested systems. Furthermore FOT data contain information on the occurrence of critical situations as well as the reaction of the driver on these situations. Due to the fact that the participants are observed while driving in real traffic the FOT data will also include information about accidents. However, the number of accidents within the FOT data is low compared to the number of accidents in an accident database. But thanks to the recording of the data, the FOT data provides detailed information about the time period shortly before the accidents.

Examples for FOTs are the “100-Car Naturalistic Driving Study” (including 69 Crashes and 761 near-crashes [NEA05]) and the euroFOT project.

6.2.3 Simulation tools

PELOPS

PELOPS (**P**rogram for the D**E**velopment of **LO**ngitudinal Traffic **P**rocesses in **S**ystem Relevant Environment) is a microscopic, vehicle-orientated traffic simulation program.

PELOPS represents a combination of the models of detailed sub-microscopic vehicle model and microscopic traffic model. This allows for the analytical investigation of the vehicle dynamic behaviour as well as the traffic flow. The advantage of this method is to consider all interactions that take place between the driver, vehicle and traffic.

The results of the technical and user-related assessment will be used in order to simulate the behaviour of the function as well as driver like it has been measure during the test drives. With this information it is possible to determine the function's influence on the surrounding traffic by means of PELOPS. Besides the penetration rate of the tested function can be varied in the simulations. Hence it possible to determine the effects of different penetration rates on the traffic.

ITS Modeller

ITS Modeller can be used to determine the effects of ITS systems at network level.

Roads and vehicles are both getting smarter. At the roadside, traffic management systems are used to secure safe, efficient and reliable traffic flow on the road network. Vehicles are increasingly being equipped with systems that support a driver’s journey from A to B efficiently, safely and comfortably. Drivers are well-informed about current and expected traffic conditions and are able to respond to changing conditions. The ITS Modeller is a modelling environment that can simulate intelligent transport systems.

It contains a traffic network, where each vehicle, driver and Intelligent Transport System (ITS) has its own individual model. Several roadside and in-vehicle systems, as well as cooperative systems, are available as standard

The modelling environment has several evaluation modules for this purpose. These include

- A versatile route choice module.
- Various models for vehicle, driver and ITS systems, based on realistic data from the TNO test labs.
- A message-based communication model.
- Evaluation modules for throughput, safety and noise, and calculation of emissions via the detailed emissions model VERSIT+

PreScan

PreScan is a software development environment for Advanced Driver Assistance Systems (ADAS) and Intelligent Vehicle (IV) systems. These are systems that monitor the vehicle's surroundings with environmental sensors and use the acquired information to take action. Such actions may range from warning the driver of a potentially dangerous situation to actively evading hazards by means of automatic braking or steering.

Given a specific accident scenario, it is easy to discover the cause of the accident as well as which driver support system concept could have prevented it. By changing the weather and light conditions, or by adding disturbances such as sensor noise and sensor drift, the system's robustness can be checked. By subjecting the intelligent system to other traffic scenarios, its side-effects may become clear.

VTT's collision avoidance algorithm simulation tools

VTT has been developing and comparing collision avoidance algorithms with several software tools, newest being implemented in MATLAB. These simulations with simplified vehicle dynamics but flexible road parameters, vehicle kinematics, dynamic free-form obstacles and varying tyre-road friction can be useful for estimating a system's potential to reduce impact speed and make a correct decision in different collision scenarios. For example, depending on a collision mitigation system's logic, it may be less effective in avoiding partial collisions due to the fact that the collision becomes truly unavoidable at a very late stage. The theoretic reduction of collision energy changes with host vehicle initial speed and the algorithms' capabilities to handle dynamic obstacles and slippery road.

After the method and the tools of the impact assessment have been described, the next three subchapters will deal mainly with the research questions of three related vertical subprojects.

6.3 SECONDS

The vertical subproject SECONDS develops functions to support the driver continuously through the process of driving, including a full set of functions. These functions have the goal to inform and support the driver continuously during the driving process to avoid risky situations.

Important to remark is that, in the case of SECONDS, also fuel efficiency and driver comfort will be evaluated. But this is only a side issue. It will be mainly focused on the safety impact assessment.

SECONDS functions are the following ones:

- Continuous Support
- Curve Speed Control
- Enhanced dynamic Pass Predictor
- Safe Cruise

For the safety impact assessment it is critical to identify the function's target scenarios. In this sense, the Use Cases defined in D1.5 "Use Cases and Requirements" have been used. These use cases have been derived from GIDAS accident database, taking into account the relevant accident scenarios. For SECONDS, the target scenarios can be defined as follows, depending on the UCs and the functions:

Category of use case	Function	Target scenarios	Type of vehicle
Rear-end collision	Continuous Support, Safe Cruise	Accident in Longitudinal Traffic / Rear-end collision due to speed difference	car
		Accident in Longitudinal Traffic / Rear-end collision with tentative evasive manoeuvre	car
		Accident in Longitudinal Traffic / Rear-end collision due to unsafe distance	car
Head-on collision (Overtaking)	enhanced Dynamic Pass Predictor	Overtaking in an unknown curve / Conflict between an overtaking vehicle and a vehicle from oncoming traffic with a unclear curved road	car
		Overtaking at a crossing	car
		Overtaking in hill sections/ Conflict between an overtaking vehicle and a vehicle from oncoming traffic in hill sections	car
		Overtaking on a straight lane/ Conflict between an overtaking vehicle and a vehicle from oncoming traffic, a pedestrian or a parking vehicle	car
Collision during lane change	Continuous Support, Safe Cruise	Hitting a vehicle in blind spot in lane change attempt	car
		Hitting a vehicle during an intended lane change/ Collision with fast approaching vehicle	car
Collision with crossing traffic	Continuous Support, Safe Cruise	Vehicle enters road with crossing priority traffic	car
		Vehicle exits parking lot with crossing priority traffic	car
Collision with	Continuous	Pedestrian is walking on the road	car

pedestrian o. animals	Support, Safe Cruise	Animal accident	car
Drift out of lane	Continuous Support	Drifting to a lane alongside	car
		Drifting to opposite lane alongside	car
Unsafe Speed	Curve Speed Control	Accident in curves due to high speed	car
		Road departure in curves due to high speed	car
Traffic rule violation	Continuous Support, Safe Cruise	Exceeding speed limit	car

Table 6.1: Category of use cases and the related target scenarios for SECONDS

The objective of the safety impact assessment is to find answers to the SECONDS function with regard to the following research questions:

- **RQ_I_SEC_01: Will the Safe Cruise function improve safety?**
- **RQ_I_SEC_02: Is the safety effect of the function compensated by a change in the driver behaviour?**
- **RQ_I_SEC_03: Will Continuous Support / Blind Spot warning improve safety?**
- **RQ_I_SEC_04: Will Continuous Support / Cross-traffic function improve safety?**
- **RQ_I_SEC_05: Will Continuous Support / Collision with VRUs function improve safety?**
- **RQ_I_SEC_06: Will unintended lane departures function improve safety?**
- **RQ_I_SEC_07: Will eDPP function improve safety?**
- **RQ_I_SEC_08: Will Excessive Speed Control function improve safety?**

In the case of SECONDS, it is also stressed to assess the impact of the system in terms of fuel efficiency. The impact on fuel efficiency can be derived from two aspects, one of them being the fact that a continuous support to the driver can help as well to reduce fuel consumption. The second fact can be derived from the avoided traffic jams on a macroscopic scale. The research questions that can then be raised are:

- **RQ_I_SEC_09: Does the Safe Cruise function increase fuel efficiency?**
- **RQ_I_SEC_10: Does the Continuous Support function increase fuel efficiency?**

Beside the overall analysis of the research questions, the research questions need to be considered also under different environmental conditions (road type, traffic conditions, weather and lighting conditions).

As input for the assessment of safety impact, behavioural data from field tests and driver simulator experiments will be used. For estimating fuel efficiency, important data from the test drives will be the driving pattern data, i.e. speed profiles.

6.4 INCA

The vertical subproject “INCA” (Integrated Collision Avoidance and Vehicle Path Control) develops active safety functions for passenger cars and commercial vehicles. The developed functions (see Chapter 3.2) are designed to prevent possible accidents by combining lateral (autonomous steering) and longitudinal (autonomous braking) active interventions. The combination of lateral and longitudinal active interventions should offer new possibilities to not only mitigate the severity of accidents, but also to avoid the accident in a wide range of situations.

One important issue for the impact assessment is to identify the situation, for which the developed functions are intended. One reasonable approach for identifying the relevant situations is to use defined use cases. Based on the deliverable D1.5 "Use cases and requirements" the following categories of use cases derived from the functions have been identified to be relevant for the INCA functions:

- Rear-end collision
- Head-on collision
- Collision during lane change
- Drift out of lane

The use cases, which are presented in deliverable D1.5 base on so-called "target scenarios". The target scenarios have been deducted from the data of the GIDAS accident database. Hence there is a link between the use cases and the relevant accident scenarios.

For the VSP INCA the target scenarios have been split depending on the two demonstrator vehicle classes, passenger cars and commercial vehicles. The target scenarios for INCA are presented in the following table, because of the different nature of truck and car accidents:

Category of use case	Function	Target scenarios	Type of vehicle
Rear-end collision	Rear End Collision Avoidance (RECA)	Rear-end crash with stopped lead vehicle due to inattention	car
		Rear end crash due to distraction	car
		Rear-end collision due to a slower vehicle in front	car
		Rear-end collision due to slowing vehicle in front	truck
		Rear-end collision due to vehicle in front moving slowly and at constant speed	truck
		Rear-end collision due to a stopped vehicle in front	truck
Head-on collision	Oncoming Vehicle Collision Avoidance/Mitigation (OVCA) Lane change collision avoidance (LCCA)	Collision with an oncoming traffic	car
		Collision with oncoming traffic after overtaking a vehicle	car
		Accident with oncoming traffic due to loss of control	truck

		Accident with oncoming traffic due to wrongly initiated overtaking manoeuvre	truck
Collision during lane change	Side impact avoidance (SIA) Lane change collision avoidance (LCCA)	Cutting In/Out and resulting in rear impact for lane changer	car
		Cutting In/Out and resulting side impact for lane changer	car
		Cutting In/Out and resulting n in frontal impact for lane changer	car
		Cutting In/Out due to parking scenario	car
		Accident with oncoming traffic due to loss of control	truck
Drift out of lane	Run-off road prevention (RORP)	Collision with an off-road obstacle after veering off road to the right	car
		Collision with an off-road obstacle after veering off road to the left	car
		Running-off a straight road	truck
		Running-off a curve	truck

Table 6.2: Category of use cases and the related target scenarios for INCA

The main objective of the safety impact assessment is to evaluate the influence of the developed functions on the traffic safety. Therefore the main research questions of INCA do not differ from the research question of the other VSPs (function is a placeholder for the different function, which are developed in the vertical subproject INCA, and shall be replaced by the function or system, which is evaluated)

- **RQ_I_INC_01: Does the function improve the traffic safety?**

This research question is valid in general for the INCA functions and for every category of uses cases.

For a more detailed analysis of this research question the number of accident as well as the accident severity must be considered. Hence for the INCA functions and the different categories of use cases following sub research question must be investigate:

- **RQ_I_INC_02: Does the function reduce the number of accidents?**
- **RQ_I_INC_03: Does the function reduce the accident severity?**

Because the INCA function should be able to avoid accidents, it is important to find out, in which situation it is possible to avoid an accident and in which situations the consequences of an accident can only be mitigated. This item is important, because the avoidance and mitigation strategies of the INCA functions depend on free space and traffic situations. Hence further research questions are:

- **RQ_I_INC_04: In which way do the INCA functions try to avoid accidents or mitigate the accidents' consequences?**

Further it must be investigated whether the functionality of a function is influenced by other interactIVe functions. This may result in an increasing or decreasing of the safety benefit of the functions. The related research questions are:

- **RQ_I_INC_05: Is the safety impact of a function influenced by another function, which is integrated in the demonstrator vehicle?**
- **RQ_I_INC_06: In which way the safety impact of the function is influenced?**

For INCA also the differences between passenger cars and commercial vehicles have to be taken into account. Therefore the safety impact needs to be determined also per vehicle type besides the general evaluation of the safety impact of the INCA functions.

- **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?**

6.5 EMIC

EMIC focuses on cost-efficient collision mitigation functions, which intervenes by braking or steering. The system includes two functions:

- Collision Mitigation System
- Emergency Steer Assist

As in the case of SECONDS and INCA, Use Cases defined in D1.5 “Use Cases and Requirements” have been used as input for the target scenario definition.

Category of use case	Function	Target scenarios	Type of vehicle
Rear-end collision	Collision Mitigation System, Emergency Steer Assist	Wrong steering at traffic jam end	car
		Rear end crash due to distraction	car
		Rear end crash with stopped vehicle lead due to inattention	car
Head-on collision	Collision Mitigation System, Emergency Steer Assist	Collision with an oncoming traffic	car
		Collision with oncoming traffic after overtaking a vehicle	car
		Collision with oncoming traffic while turning left due to time pressure and sun glare	car
Collision with crossing traffic	Collision Mitigation System, Emergency Steer Assist	Cross traffic collision	car
		Crash with unparking vehicle from the side	car
Collision with pedestrian o.	Emergency Steer Assist	Trespassing pedestrians	car

animals			
Drift out of lane	Collision Mitigation System,	Collision with an off road obstacle after veering off road to the right	car
		Collision with an off road obstacle after veering off road to the left	car

Table 6.3: Category of use cases and the related target scenarios for EMIC

The objective of the safety impact assessment is to find answers for the EMIC function on the following research questions:

- **RQ_I_EMI_01: Will the CMS improve safety?**
- **RQ_I_EMI_02: Will the ESA improve safety?**
- **RQ_I_EMI_03: Will the CMS reduce the accident severity?**
- **RQ_I_EMI_04: Will the ESA reduce the accident severity?**

For the analysis of these research questions also different environmental conditions (road type, traffic conditions, weather and lighting condition) have to be taken into account.

After the research questions for the safety impact assessment have been presented, the next chapter will give an overview about the methods and tools, which are used in the different assessments.

7 Available Methods and tooling

In previous chapters, the different tools and methods proposed for the technical, the user related and the safety impact assessment were explained, taking into account the functions to be evaluated and the use cases identified. In this chapter, a summary of all the methods and tools described before is included regarding the type of evaluation and the system.

Methods / Tools		Functions										
		SECONDS CS	**SECONDS** CSC	**SECONDS** eDPP	**SECONDS** SC	**INCA** RECA	**INCA** LCCA	**INCA** OVCA	**INCA** SIA	**INCA** RORP	**EMIC** CMS	**EMIC** ESA
Technical Assessment												
M	PREVAL	X	X	X	X	X	X	X	X	X	X	X
Tools	Data Acquisition System	X	X	X	X	X	X	X	X	X	X	X
Tools	Test Track	X	X	X	X	X	X	X	X	X	X?	X
Tools	Tests in real traffic	X**	X**	X**	X**	X**	X**	X**	X**	X**	?	?
Tools	Driving Simulator	X	X	X	X	X	X	X	X	X		
Tools	Hardware in the Loop test	X*		X**	X	X	X	X*	X	X*	X	X*
User Related Assessment												
Methods	Driving Simulator Study			X	X	X	X	X	X	X	X	X
Methods	Small-Scale field test with instrumented vehicles	X	X			X**			X**	X**	X	X
Methods	Questionnaire					X	X	X	X	X	X	X
Methods	Structured Interviews	X	X	X	X	X	X	X	X	X	X	X
Methods	Focus Group Study										X	X
Tools	Instrumented Vehicle	X	X			X	X	X	X		X	X
Tools	Observation protocol for in-car observations	X	X			X	X	X	X		X	X
Tools	Questionnaire / interview forms	X	X	X	X	X	X	X	X		X	X
Tools	Driving simulators			X	X	X	X	X	X		X	X
Safety Impact Assessment												
Method	PREVAL/eImpact	X***	X***	X***	X***	X***	X***	X***	X***	X***	X***	X***
Method	euroFOT Safety impact assessment methodology	X***	X***	X***	X***	X***	X***	X***	X***	X***	X***	X***

Tools	Tools to collect information about the functions	X	X	X	X	X	X	X	X	X	X	X
	Accident databases and FOT data	X	X	X	X	X	X	X	X	X	X	X
	Simulation tools	X	X	X	X	X	X	X	X	X	X	X

Table7.1: Table of methods and tools

*: Cannot be used for all tested categories of use cases.

**: It must be first analysed, if the test are feasible due to safety aspects and limitations of the test facility

***: Method is decided based on the available information and depending on the function

?: to be decided

8 Results

interactIVe aims to the development of multiple Advanced Driver Assistance Systems (ADAS applications). Therefore interactIVe is a project that covers from the implementation of a perception platform or IWI strategies to the proper integration of safety systems with the final target to avoid respectively mitigate an accident or minimize its consequences. The functions, which are developed in interactIVe, can divided in three kinds of system:

- SECONDS (support of the driver)
- INCA (collision avoidance)
- EMIC (cost-efficient collision mitigation)

There is an evident request for evaluation of the developed systems and functions. The evaluation of the functions will focus on three main aspects:

- Technical Assessment
- User-Related Assessment
- Impact Assessment

This deliverable has settled the basis for the evaluation framework by defining the following elements:

- System definition, based on the specific questionnaire held to VSPs at the beginning of SP7 and on the outcomes of SP1 (D1.5). This definition is also complemented with the use cases and target scenarios for each system and function.
- Requirements for the technical assessment, including methods, tools and research questions.
- Requirements for the user-related Assessment, including methods, tools, key indicators and research questions
- Requirements for the impact assessment, including methods, tools and research questions.
- Comprehensive tables for methods, tools and research questions

This deliverable provides a first approach to the research questions for all systems, functions and on the different above mentioned fields of assessment. Those research questions will be the basis for the future work in the definition of hypothesis and performance indicators, which will be described later in further deliverables of SP7.

In this sense, it must be highlighted that the definition of systems and functions might be object of changes in the following deliverables dealing with evaluation (Deliverable 7.2 and 7.4), as there are still some specific aspects to be finally closed in terms of technical and functional description. Therefore SP7 is going to discuss the results of this deliverable with the VSP in order to ensure that all aspect of the developed function is correctly covered by the research questions.

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Abbreviations

Abbreviation	Description
4WD	Four Wheel Drive
ABS	Antilock Brake System
ACC	Adaptive Cruise Control
ADAS	Advanced Driver Assistance System
AV	Approaching Vehicle
BMW	Bayerische Motoren Werke
C2C	Car to Car
CAN	Controlled Area Network
CMS	Collision Mitigation System
CONTIT	Continental Teves AG & CO. OHG
CRF	Centro Ricerche Fiat
CS	Continuous Support
CSC	Curve Speed Control
CV	Crossing Vehicle
DGPS	Differential Global Positioning System
DGT	Dirección General de Tráfico
eDDP	enhanced Dynamic Pass Predictor
EC	European Commission
EEG	ElectroEncephaloGram
EMIC	EMergency Intervention for Collision mitigation
ESA	Emergency Steer Assist
ESP	Electronic Stability Program
EU	European Union
FFA	Ford Forschungszentrum Aachen GmbH
GIDAS	German In-depth Accident Study
GPS	Global Positioning System
GSR	Galvanic Skin Response
HIL	Hardware-in-the-Loop
HMI	Human Machine Interface / Interaction
HV	Host Vehicle
INCA	INtegrated Collision Avoidance and vehicle path control
IWI	Information, Warning and Intervention
JDVS	Joint driver vehicle system
LCCA	Lane Change Collision Avoidance
LKS	Lane Keeping System

Abbreviation	Description
LV	Lead Vehicle
OECD	Organisation for Economic Co- operation and Development.
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
RTK-GPS	Real Time Kinematic- Global Positioning System
SAM	Self Assessment Manikin
SC	Safe Cruise
SECONDS	Safety Enhancement through CONtinuous Driver Support
SIA	Side Impact Avoidance
SIL	Software-in-the-Loop
SP	Subproject
SUS	System Usability Scale
TET	Time Exposed Time to collision
THW	Time Headway
UA	Unattended Animal
UC	Use Case
VCC	Volvo Car Company
VRU	Vulnerable Road User
VSP	Vertical Subproject
VTEC	Volvo TEChnologies
VW	Volkswagen AG

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 scenario	Scenario where a certain aspect, function or system is tested
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 1: Listed research questions

All the research questions described in D7.1 Requirements for the Evaluation Framework are collected in this annex and classified depending on its application to the different interactIVe functions. Additionally, they are listed depending on their nature: research questions on technical assessment, user impact assessment and safety impact assessment are separated.

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Annex 1: Listed research questions

	Research questions										
		SECONDS CS	**SECONDS** CSC	**SECONDS** eDPP	**SECONDS** SC	**INCA** RECA	**INCA** LCCA/ SIA	**INCA** OVCA	**INCA** RORP	**EMIC** CMS	**EMIC** ESA
R Q Technical Assessment	RQ_T Gen_Perf_01	X	X	X	X	X	X	X	X	X	X
	RQ_T Gen_Perf_02	X	X	X	X	X	X	X	X	X	X
	RQ_T Gen_Perf_03	X	X	X	X	X	X	X	X	X	X
	RQ_T Gen_Perc_01	X	X	X	X	X	X	X	X	X	X
	RQ_T Gen_Perc_02	X	X	X	X	X	X	X	X	X	X
	RQ_T Gen_Perc_03	X	X	X	X	X	X	X	X	X	X
	RQ_T Gen_Perc_04	X	X	X	X	X	X	X	X	X	X
	RQ_T Gen_Perc_05	X	X	X	X	X	X	X	X	X	X
	RQ_T Gen_Safe_01	X	X	X	X	X	X	X	X	X	X
	RQ_T Gen_Safe_02	X	X	X	X	X	X	X	X	X	X
	RQ_T Gen_Safe_03	X	X	X	X	X	X	X	X	X	X
	RQ_T Gen_Safe_04	X	X	X	X	X	X	X	X	X	X
	RQ_T Gen_Safe_05	X	X	X	X	X	X	X	X	X	X
	RQ_T Gen_Safe_06	X	X	X	X	X	X	X	X	X	X
	RQ_T Gen_Safe_07	X	X	X	X	X	X	X	X	X	X
	RQ_T Gen_TecU_01	X	X	X	X	X	X	X	X	X	X
	RQ_T Gen_TecU_02	X	X	X	X	X	X	X	X	X	X
	RQ_T Gen_TecU_03	X	X	X	X	X	X	X	X	X	X
	RQ_T SEC_CS_Perf_01	X									

	RQ_T SEC_CS_Perf_02	X									
	RQ_T SEC_CS_Perf_03	X									
	RQ_T SEC_CS_Perf_04	X									
	RQ_T SEC_CS_Perf_05	X									
	RQ_T SEC_CS_Perc_01	X									
	RQ_T SEC_CS_Perc_02	X									
	RQ_T SEC_CS_Perc_03	X									
	RQ_T SEC_CS_Perc_04	X									
	RQ_T SEC_CS_Perc_05	X									
	RQ_T SEC_CS_Perc_06	X									
	RQ_T SEC_CS_Perc_07	X									
	RQ_T SEC_CS_Safe_01	X									
	RQ_T SEC_CS_ Safe_02	X									
	RQ_T SEC_CSC_Perf_01		X								
	RQ_T SEC_CSC_Perc_01		X								
	RQ_T SEC_CSC_Safe_01		X								
	RQ_T SEC_CSC_Safe_02		X								
	RQ_T SEC_eDPP_Perc_01			X							
	RQ_T SEC_SC_Perf_01				X						
	RQ_T SEC_SC_Perf_02				X						
	RQ_T SEC_SC_Perc_01				X						
	RQ_T SEC_SC_Perc_02				X						
	RQ_T SEC_SC_TecU_01				X						
	RQ_T SEC_SC_TecU_02				X						
	RQ_T_INC_Gen_Perf_01					X	X	X	X		
	RQ_T_INC_RECA_Perf_01					X					

	RQ_T_INC_RECA_Perf_02					X					
	RQ_T_INC_RECA_Perf_03					X					
	RQ_T_INC_RECA_Perf_04					X					
	RQ_T_INC_RECA_Perf_05					X					
	RQ_T_INC_RECA_Perc_01					X					
	RQ_T_INC_RECA_Safe_01					X					
	RQ_T_INC_RECA_Safe_02					X					
	RQ_T_INC_RECA_Safe_03					X					
	RQ_T_INC_RECA_Safe_04					X					
	RQ_T_INC_RECA_Safe_05					X					
	RQ_T_INC_RECA_TecU_01					X					
	RQ_T_INC_RECA_TecU_02					X					
	RQ_T_INC_LCCA_Perf_01						X				
	RQ_T_INC_LCCA_Perc_01						X				
	RQ_T_INC_LCCA_Perc_02						X				
	RQ_T_INC_LCCA_TecU_01						X				
	RQ_T_INC_OVCA_Perf_01							X			
	RQ_T_INC_OVCA_Perc_01							X			
	RQ_T_INC_OVCA_Safe_01							X			
	RQ_T_INC_OVCA_Safe_02							X			
	RQ_T_INC_RoRP_Perf_01								X		
	RQ_T_INC_RoRP_Perc_01								X		
	RQ_T_INC_RoRP_Safe_01								X		
	RQ_T_INC_RoRP_TecU_01								X		
	RQ_T_EMI_Gen_Perf_01									X	X
	RQ_T_EMI_Gen_Perf_02									X	X

	RQ_T_EMI_Gen_Perc_01									X	X
	RQ_T_EMI_Gen_Perc_02									X	X
	RQ_T_EMI_Gen_Perc_03									X	X
	RQ_T_EMI_Gen_Perc_04									X	X
	RQ_T_EMI_Gen_TecU_01									X	X
	RQ_T_EMI_CMS_Perf_01									X	
	RQ_T_EMI_CMS_Perf_02									X	
	RQ_T_EMI_ESA_Perc_01										X
	RQ_T_EMI_ESA_Perc_02										X
User Related Assessment	RQ_U_Gen_Beh_01	X	X	X	X	X	X	X	X	X	X
	RQ_U_Gen_Beh_02	X	X	X	X	X	X	X	X	X	X
	RQ_U_Gen_Beh_03	X	X	X	X	X	X	X	X	X	X
	RQ_U_Gen_Beh_04	X	X	X	X	X	X	X	X	X	X
	RQ_U_Gen_Beh_05	X	X	X	X	X	X	X	X	X	X
	RQ_U_Gen_Beh_06	X	X	X	X	X	X	X	X	X	X
	RQ_U_Gen_Beh_07	X	X	X	X	X	X	X	X	X	X
	RQ_U_Gen_Beh_08	X	X	X	X	X	X	X	X	X	X
	RQ_U_Gen_Beh_09	X	X	X	X	X	X	X	X	X	X
	RQ_U_Gen_T&A_01	X	X	X	X	X	X	X	X	X	X
	RQ_U_Gen_T&A_02	X	X	X	X	X	X	X	X	X	X
	RQ_U_Gen_T&A_03	X	X	X	X	X	X	X	X	X	X
	RQ_U_Gen_T&A_04	X	X	X	X	X	X	X	X	X	X
	RQ_U_Gen_T&A_05	X	X	X	X	X	X	X	X	X	X
	RQ_U_Gen_T&A_06	X	X	X	X	X	X	X	X	X	X
	RQ_U_Gen_T&A_07	X	X	X	X	X	X	X	X	X	X
	RQ_U_Gen_Use_01	X	X	X	X	X	X	X	X	X	X

	RQ_U_Gen_Use_02	X	X	X	X	X	X	X	X	X	X
	RQ_U_Gen_Use_03	X	X	X	X	X	X	X	X	X	X
	RQ_U_Gen_Use_04	X	X	X	X	X	X	X	X	X	X
RQ Safety Impact Assessment	RQ_I_SEC_01	X	X	X	X						
	RQ_I_SEC_02	X	X	X	X						
	RQ_I_SEC_03	X	X	X	X						
	RQ_I_SEC_04	X	X	X	X						
	RQ_I_SEC_05	X	X	X	X						
	RQ_I_SEC_06	X	X	X	X						
	RQ_I_SEC_07	X	X	X	X						
	RQ_I_SEC_08	X	X	X	X						
	RQ_I_SEC_09	X	X	X	X						
	RQ_I_SEC_10	X	X	X	X						
	RQ_I_INC_01					X	X	X	X		
	RQ_I_INC_02					X	X	X	X		
	RQ_I_INC_03					X	X	X	X		
	RQ_I_INC_04					X	X	X	X		
	RQ_I_INC_05					X	X	X	X		
	RQ_I_INC_06					X	X	X	X		
	RQ_I_INC_07					X	X	X	X		
	RQ_I_EMI_01									X	X
	RQ_I_EMI_02									X	X
	RQ_I_EMI_03									X	X
	RQ_I_EMI_04									X	X

Table 0.1: List of research question