FESTA

D3 – Common Vision regarding vehicle systems FOTs

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Glossary

Subject	Definition
function	implementation of a set of rules to achieve a specified goal unambiguously defined partial behaviour of one or more electronic control units.
system	combination of hardware and software enabling one or more functions Set of elements (at least sensor, controller, and actuator) in relation with each other according to design. An element of a system can be another system at the same time. Then, it is called subsystem which can be a controlling or controlled system or which can contain hardware, software and manual operations.
use case	target condition in which a system is expected to behave according to a specified function
situation	combination of certain characteristics of a use case Situations can be derived from use cases compiling a reasonable permutation of the use cases characteristics
scenario	use case in a specific situation
research question	general question to be answered by compiling and testing related specific hypotheses
hypothesis	specific statement which can be tested with statistical means by analysing measures and performance indicators
baseline	scenario with system under evaluation "turned off"
performance indicator	quantitative or qualitative measurements, agreed on beforehand, expressed as a percentage, index, rate or other value, which is monitored at regular or irregular intervals and can be compared to one or more criteria
event	occurrence based on a combination of measures and/or pre-processed measures; can extend over time
trigger	"marker" in the data, indicating instances that can be of interest for research
measure	a measure can either be direct or pre-processed A direct measure is logged directly from a sensor, while a pre-processed measure is a combination of different direct or other pre-processed measures. A measure does not have a “denominator” which makes it comparable to other instances of the same measure or to external criteria.
subjective data	data collected from the drivers/passengers, usually via questionnaires
DBQ	Driving Behaviour Questionnaire
TLOC	Traffic Locus of Control
SSS	Sensation Seeking Scale
FFM	Five Factor Model

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Executive Summary

Individuating the most relevant functions and connected hypothesis to successfully address the above-mentioned research questions is one of the major challenges in a Field Operational Test (FOT). In this deliverable, the process of individuating the vehicle functions to be tested in an FOT and the relevant connected hypotheses will be elucidated. Specifically, the reader will be guided in the process of:

1) selecting the vehicle functions to be tested,
2) defining the connected use cases to test these vehicle functions,
3) identifying the research questions related to these use cases,
4) formulating the hypothesis associated to these research questions, and
5) linking these hypothesis to the correspondent performance indicators.

Each of these steps needs to be undertaken sequentially.

Everyone who is interested to undertake an FOT will find templates to define and describe the necessary details for all of the above mentioned steps in the Annex of this deliverable.

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1 Introduction

The objective of an FOT is to evaluate in-vehicle functions based on Information Communication Technology (ICT) in order to address specific research questions. These research questions can be related to safety, environment, mobility, traffic efficiency, usage, and acceptance. By addressing the research questions, FOTs promise to furnish the major stakeholders (customers, public authorities, OEMs, suppliers, and the scientific community) with valuable information able to improve their policy-making and market strategies. Individuating the most relevant functions and connected hypothesis to successfully address the above-mentioned research questions is one of the major challenges in an FOT. In this deliverable, the process of individuating the vehicle functions to be tested in an FOT and the relevant connected hypotheses will be elucidated. Specifically, the reader will be guided in the process of 1) selecting the vehicle functions to be tested, 2) defining the connected use cases to test these vehicle functions, 3) identifying the research questions related to these use cases, 4) formulating the hypothesis associated to these research questions, and 5) linking these hypothesis to the correspondent performance indicators. The FOT chain shows specifically the steps reported above (see Figure 1.1).

In the last few years, the number of ICT functions available on standard vehicles has been rapidly increasing. ICT functions are intrinsically designed to provide the driver with new, additional information or support him actively in his driving task. However, the extent to which this increased amount of information and support from these ICT functions results in clear and positive effects on safety, environment, mobility, usage, and acceptance in real traffic situation is unknown.

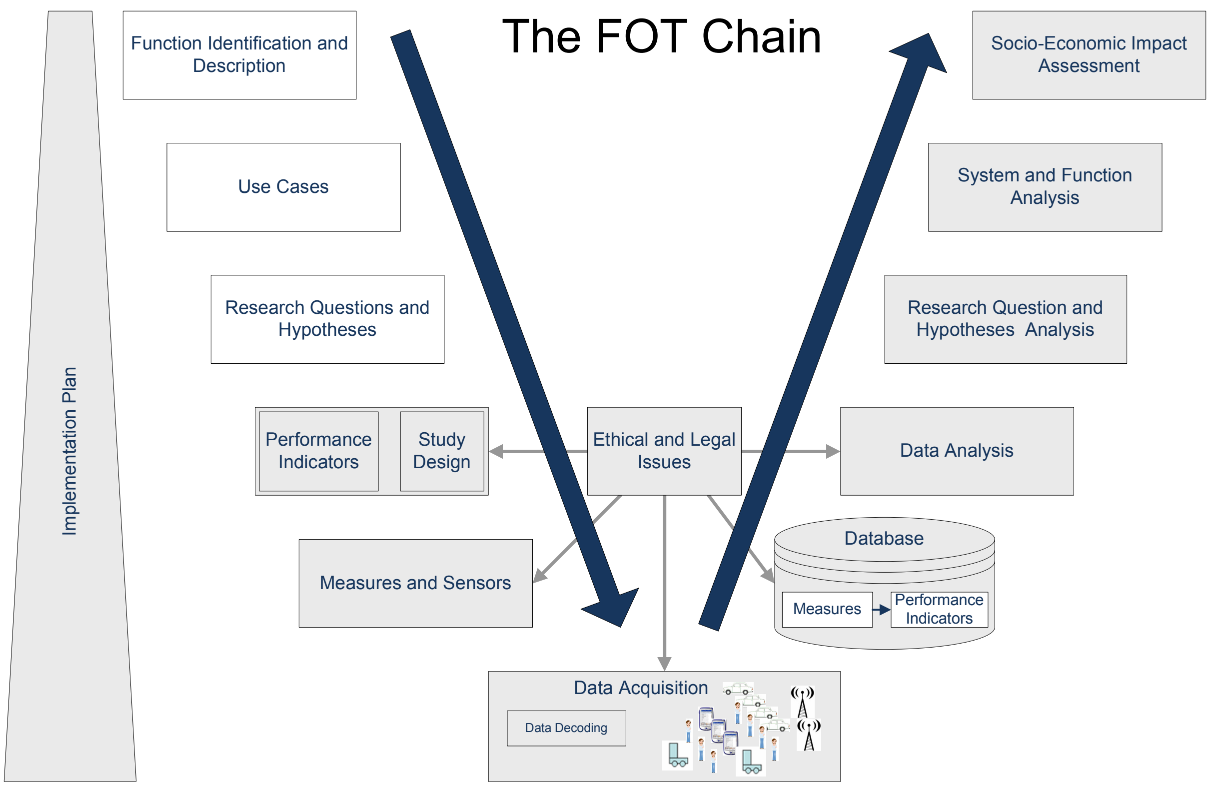

Figure 1.1: The FOT chain and the relevant steps from function identification to hypotheses covered by this deliverable.

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FOTs warrant to evaluate, for the first time, these ICT functions in a real traffic situation during naturalistic driving. In this deliverable we refer to in-vehicle systems intended as a combination of hardware and software enabling one or more ICT functions. Depending on the different systems implementing a specific function, different challenges may have to be faced during the FOT design.

Vehicle Systems are a combination of hardware and software enabling one or more functions aimed at increasing driver's safety, comfort and mobility, some of them even to increase the use of resources and hence to improve environmental friendliness. Vehicle Systems promise 1) to increase driver safety by increasing driver's attention in potentially hazardous scenarios (such as the Forward Collision Warning), 2) to improve the driver's comfort by automating some of the operational driving tasks (such as the Adaptive Cruise Control function), 3) to increase driver mobility by furnishing timely traffic information (such as the Dynamic Navigation function), and 4) to increase safety in critical situation by automating the vehicle response (such as the Collision Mitigation function).

Vehicle Systems are becoming more and more standard equipment, even in middle class vehicles and commercial vehicles. However, their impact on the driver, the traffic system, the society, and the environment in the short-, but especially in the long term is not fully understood. FOTs can help quantifying the impact of Vehicle Systems on driver's workload and to understand how different functions interact with each other in a real complex traffic situation. Further, FOTs will expose these functions to many improbable and unforeseen scenarios which are not possible to be tested during the functions evaluation phase.

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2 Methodology

The main advantage of an FOT is that it has the potential to give insight in system performance in naturalistic driving situations, as free as possible from any artefact resulting from noticeable measurement equipment or observers in the car. Therefore the first step when planning an FOT is to identify systems and functions where considerable knowledge about their impacts and effects in realistic (driving) situations is of major interest, but is still lacking (see Section 2.1).

After the identification of the functions and system, which should be tested in an FOT, the goal is to define statistically testable hypotheses and find measurable indicators to test the hypotheses. To reach this goal, several steps need to be taken, starting from a description of the functions down to an adequate level of detail (see Section 2.1). This means that the main aspects of the functions, its intended benefits and the intrinsic limitations have to be described to fully understand objectives and limitations and to derive reasonable use cases.

Secondly, these use cases need to be defined (see Section 2.2). Use cases are a means to describe the boundary conditions under which a function is intended to be analysed. A general starting point is given by the functional specifications from the function description part. But it might also be of interest how a function performs when certain preconditions are not met and to identify unintended and unforeseen effects.

Starting from the use case definitions specific research questions need to be identified (see Section 2.3). Research questions are general question to be answered by compiling and testing related specific hypotheses. While research questions are phrased as real questions ending with a question mark, hypotheses are statements which can either be true or false. This will be tested by statistical means (see D2.4). One might already have a very clear idea from the beginning which hypotheses are to be tested in a very specific situation during the FOT. However, this very focused view might result in an extreme limited experimental design, where important unintended effects will not be considered. The process to define hypotheses developed in FESTA aims to prevent these potential issues (see Section 2.4).

Finally, hypotheses can only be tested by means of reasonable indicators (see Section 2.5).

These steps are shown as parts of the complete FOT and are elaborated further in the following sections. The Annex consists of the results of the FESTA methodology to identify functions and systems and to develop hypotheses for the experimental design. All steps, from the description of the systems and functions, the development of use cases and scenarios, as well as the research questions and hypotheses and the proposal of related performance indicators have been accomplished. This Annex shall provide an example on how to proceed according to the proposed FESTA methodology.

2.1 Step 1: Selection of Functions/Systems relevant for Vehicle System FOTs

Usually it is quite clear from the beginning what functions or at least what type of functions will be the object of an FOT. However, to select the specific functions but also in case the type of functions has not yet been decided, a Stakeholders Analysis is recommended. During this analysis, the needs of the different stakeholders need to be identified and merged into a common requirements description. Stakeholders are those whose interests are affected by the issue or

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those whose activities strongly affect the issue, those who possess information, resources and expertise needed for strategy formulation and implementation, and those who control relevant implementations or instruments, like customers, public authorities, OEMs, suppliers, and the scientific community. It is of vital importance that all relevant stakeholders are included in the analysis to guarantee that the selection process will not itself bias from the beginning the appraisal of the gained results.

It is recommended to evaluate the stakeholders' needs by means of questionnaires, workshops or well documented interviews of stakeholders' representatives. It is also quite important to sufficiently describe the selection process to prevent from misjudgement.

The basis for all following steps is a sufficient description of the selected functions. For these purposes a template has been prepared and is presented in the Annex A.1 to collect the necessary information. It provides two main parts: First, the functional classification, where a short high level description of the main aspects of the function should be given. The second part of the description comprises of limitations, boundary conditions and additional information which is necessary to understand how the function works. This information is usually provided through the system specifications given by the system vendor or OEM.

The boundary condition part describes where and under which circumstances the system/ function will operate according to its specifications, where the FOT should take place and which type of information about the vehicle, the driver, the traffic system and the environmental situation needs to be recorded during the FOT to enable a good interpretation of the results. It consists of:

- Infrastructure requirements: Here all required actors besides the actual system need to mentioned, which might have an impact on system performance, service availability or similar. It is intended to trigger the consideration of factors which are external to the system/ function under evaluation;
- Demographical requirements/ driver requirements: Especially the user or driver recruitment needs to take into account, whether a function is particularly designed for a specific group of users or drivers. Drivers differ on a large variety of characteristics, which may all have an influence on how they drive and use different systems and services. These differences may be important to take into account when planning a FOT. Four categories of driver characteristics may be distinguished:
    - Demographic characteristics: gender, age, country, educational level, income, socio-cultural background, life and living situation, etc.;
    - Driving experience, and driving situation and motivation: experience in years and in mileage, professional, tourist, with or without passengers and children etc.;
    - Personality traits and physical characteristics: sensation seeking, locus of control, cognitive skills, physical impairments or weaknesses etc.;
    - Attitudes and intentions: attitudes towards safety, environment, technology etc.
- Geographical requirements/ road context: This description is necessary for systems which, concerning their functionality, depend strongly on the horizontal or vertical curves of the road layout or on the road type. For example, certain speed limit information systems depend largely on the availability of speed limit information in a digital map, which is up to

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now only commercially available on high class roads, but not on the secondary road network.

- Geographical requirements/ environmental restrictions: Certain systems are especially designed for specific environmental conditions or, on the other hand, specifications might indicate that the system under evaluation will not work under certain environmental conditions. In this case the location of the FOT needs to be selected carefully and the relevant data must be recorded during the FOT. E. g., most of the functions using optical perception systems will be affected by adverse weather conditions. If this is the case it is necessary to log respective data and take it into account for later data analysis.
- Geographical requirements/ traffic context: The performance of certain systems might depend on the traffic context, that is, the traffic density (e. g. given by the Level of Service) or might even be designed to work in specific traffic densities only. Like the other geographical requirements, this needs to be taken into account when an FOT is planned, performed and the data is analysed.
- Other limitations: All other limitations need to be mentioned, which might have considerable impact on the performance of functions or systems, since these limitations have major impact on the experimental design and data analysis.

2.2 Step 2: Definition of use cases and situations

FOTs will primarily test technically mature ICT systems. Therefore, systems and functions to be tested are on the market or close to market and can be easily implemented. But the list grows too long if all possible implementation variations and technologies are considered separately. The use cases are putting the systems and functions at a suitable level of abstraction in order to group technology-independent functionalities and answer more holistic research questions described later.

A use case is a textual presentation or a story about the usage of the system told from an end user's perspective. Jacobson et al (1995) defined the use cases: "When a user uses the system, she or he will perform a behaviourally related sequence of transactions in a dialogue with the system. We call such a special sequence a use case." Use cases are technology-independent and the implementation of the system is not described. Use cases provide a tool for people with different background (e. g. software developers and non-technology oriented people) to communicate with each other. Use cases form the basic test case set for the system testing. There are number of different ways to define a use case. Use cases in FESTA are very general descriptions, like e. g. "car following". This general description needs to be refined to a reasonable level of detail. This refinement is done by describing so called situations (see Table 2.1). It is the detailed scenario description which triggers the development of specific hypotheses for later analysis.

The situational descriptors are selected in a way that relevant information can be gathered to distinguish between main differences while evaluating systems. The situational descriptors can be distinguished in static and dynamic, while the static describe attributes which will not change significantly during one ride of the vehicle, like age or gender of the driver. Nevertheless this information needs to be stated, since it is one of the main inputs to filter the huge amounts of data in the later stage of data analysis. The second part of attributes is dynamic, since it can change

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during a ride of the vehicle, like the system action status (system on or off), the traffic conditions, road characteristics or the environmental situation and also whether interaction between different ICT functions can occur and need to be considered.

Table 2.1: Use Cases, Situations, Scenarios, and their mutual dependence.

Subject	Definition	Comment	Example
Use Case	Target condition in which a system is expected to behave according to a specified function	A use case is a system and driver state, where "system" includes the road and traffic environment.	Car following
Situation	A combination of certain characteristics of a use case. Situations can be derived from use cases compiling a reasonable permutation of the use cases characteristics.	Thus a situation is a state of the environment or system.	Speed above 70Km/h + sunny day + FCW on
Scenario	A use case in a specific situation	Use case + situation = scenario	Car following with speed above 70Km/h + sunny day + FCW on

Annex A.2 shows examples of use cases which have been collected during the FESTA project and provides a template to collect those use cases.

The situations are defined as a combination of certain characteristics of a use case. Situations can be derived from use cases compiling a reasonable permutation of the use cases characteristics. The identification of possible situations was covered from three viewpoints:

1. systems and vehicle specification,
2. environmental conditions specification and
3. driver characteristics and status specification.

The situational descriptors in FESTA conforms the following structure:

IDENTIFICATION AND DESCRIPTION

Use case name	A name for identification purposes.
Description	General description of the use cases with necessary depth of information to get a quick overview.
Occurrence	Information about the anticipated quantity of occurrences has implications for the amount of data to analyse.

SYSTEMS AND VEHICLES

System status	Depending on the hypotheses the analysis might concentrate on situations where the system is activated or present. *Example: on/off(baseline) or IDLE/on/off*
System action status	Depending on the hypotheses the analysis might want to compare the driving performance between different system statuses, e. g. whether the system is actively controlling the vehicle or not. *Example: acting/ not acting (meaning e. g. ACC controlling car speed or*

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	not)
System/ function characteristics	Depending on the hypotheses an analysis of system or driver performance with respect to special system/ function characteristics might be conducted depending on the vehicle type. *Example: passenger vehicle/ truck/ bus*
Interaction between systems	System and especially driver behaviour might change depending on whether the system under evaluation is the only active support system or whether interactions between two or more systems are foreseen. *Example: interaction between Blind Spot Warning and Lane Departure Warning.*
ENVIRONMENTAL CONDITIONS	
Traffic conditions	Performance of some systems might differ depending on traffic density. Others might only be reasonable with a minimal traffic density. *Example: Level of Service A and B*
Environmental situation	System performance differs depending on lighting and weather conditions like rain/ snowfall/ icy roads, etc. *Example: normal/ adverse weather conditions*
Road characteristics	e. g. type of road gradient, super elevation, curvature, curviness, …, since some systems are dedicated to improve driving performance in curves etc. *Example: urban roads/ rural roads/ highways*
Geographical characteristics	Information about geographical characteristics relevant for testing the systems. *Example: mountained/ flat areas, metropolises with high street canyons.*
DRIVER CHARACTERISTICS AND STATUS	
Driver specification	Characteristics of the users have an impact on the driving performance. Even if no specific impacts are expected of certain characteristics, some outcomes may be explained better with more knowledge about the participants. A minimum set of data such as age, gender, income group and educational level is easy to gather from participants. Information about driving experience is also important. For further understanding of driver behaviour one may consider to use questionnaires on attitudes, driving behaviour and personality traits. A well-known questionnaire about (self-reported) driving behaviour is the Driving Behaviour Questionnaire (DBQ). Some widely used personality tests are the Five Factor Model (FFM) test and the Traffic Locus of Control (T-LOC) test. Special attention may be given to the personality trait of sensation seeking, which is correlated with risky driving. The Sensation Seeking Scale (SSS) measures this trait. These questionnaires are available in many different languages, but they are not always standardized, and cultural differences may play a role. Personality traits are very easy to measure, just by administering a short questionnaire. However, the concepts and interrelations of factors are very complex, and results should be treated with caution.

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	When evaluating the acceptance and use of new systems in the car, drivers' acceptability of technology is important. Both social and practical aspects play a role. Technology acceptance has different dimensions, such as diffusion of technology in the drivers' reference group, the intention of using the technology, and the context of use (both personal and interpersonal). Measuring acceptability can be realized via (existing) standardized questionnaires, in-depth interviews before and after "use" (driving), and focus groups.
Driver status	Mindset of the driver *Example: attentive/ distracted/ impaired*
Purpose, distance, duration	Describes the different attributes of a trip (time between ignition on and ignition off). All three aspects have an impact on driver behaviour and hence on patterns in the data.

A set of basic rules has been set for the design of the situations for an FOT:

1. Exclusiveness/ Complementarity: situations are not allowed to overlap.
2. Exhaustiveness: the sum of all situations should describe the complete use case.
3. Baseline: The same situation without the use of the systems (system off or non-present) is defined as the baseline. The baseline is the basis for the benefit assessment of the system and the comparison between systems. Therefore, for the same use case, there can be many baselines depending on the number of situations.
4. Comparability: functions compared in an FOT need to have the same use case and therefore same baseline and situations.
5. Variability of situation parameters: depending on the point of view (user, trip, vehicle, single FOT, multiple FOTs, etc…), attributes describing a situation can vary considerably or not.

This list is non-exhaustive and might be extended if necessary.

Finally, out of all the possible situations, one will need to select the relevant ones for scenarios of interest in an FOT. The scenarios are defined as a use case in a specific situation and therefore one or more scenarios should be considered from each use case. All other situations should be considered out of the scope of the FOT study. However, if possible data should still be collected in all situations in case an alternative study would like to reuse the same data.

During FESTA a list of functions and use cases was produced based on technically mature ICT systems and functions on the market. The list was consolidated based on the feedback from a stakeholders workshop and a dedicated questionnaire.

The process of defining the use cases will help the FOT for the next steps: the definition of the research questions and hypotheses and finally the identification of the needed indicators. The scenarios as they are defined at this stage of the FOT are not detailed enough for data analysis purposes. For this reason, after the definition of the indicators, the scenarios (and their situations) will need to be further described in terms of *events* for data analysis purposes. Only then, the scenarios can be classified with a quantitative measurement tools in function of the defined indicators. The concrete identification of events, their classification and the triggers for an event

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need to be defined by every FOT itself, since needs for data analysis and hence definitions might change depending on the objective of the data analysis.

2.3 Step 3: Identification of the Research Questions

The research questions specific to an FOT can only be identified once the overall goal of an FOT has been established.

In general terms the goal of any FOT is to investigate the impacts of mature ICT technologies in real use. The core research questions should therefore focus on impacts but there are other questions that 'surround' this core. The range of possible questions is listed below. This list below should be considered a first step in any FOT and not a comprehensive set of questions.

LEVEL OF SYSTEM USAGE

Which factors affect usage of the functions? Examples are

- Purpose of journeys where system is used
- Familiarity with routes where system is used
- Portion of journey for which system is used
- Types of road on which system is used
- Traffic density
- Headway
- Weather condition
- Ambient lighting

How do driver characteristics affect usage of the functions? Examples are

- Personal characteristics (e. g. age, vision)
- Socio-economic characteristics (e. g. family, friends, employment status)
- Journey-related characteristics (e. g. other car occupants, shared driving)

IMPACTS OF SYSTEM USAGE

What are the impacts on safety?

- exposure
- risk of accident or injury
- incidents and near accidents
- accidents?

What are the impacts on personal mobility?

- individual driving behaviour
- travel behaviour
- Comfort

What are the impacts on traffic efficiency?

- traffic flow (speed, travel time, punctuality)
- traffic volume
- Accessibility

What are the impacts on the environment?

- CO_2 emissions
- Particles
- Noise

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IMPLICATIONS OF MEASURED IMPACTS

What are the implications for policy?

- Policy decisions
- Laws, directives & enforcement
- Future funding
- Public authority implications
- Emergency service implications

What are the implications for business models?

- Predictions for system uptake
- User expectations
- Pricing models

What are the implications for system design & development?

- HMI design & usability
- Perceived value of service
- Device design
- Communications networks
- Interoperability issues

What are the implications for the public

- Public information/education
- Changes in legislation
- Inclusive access to systems
- Data protection

2.4 Step 4: Formulation of Hypotheses

Once the key research questions for the FOT have been identified, hypotheses can be derived. The process of formulating hypotheses translates the general research questions into more specific and statistically testable hypotheses.

There is no process that can assure that all the "correct" hypotheses are formulated. To a large extent, creating hypotheses is an intuitive process, in which a combination of knowledge and judgement is applied. Nevertheless, a number of recommendations can be made about how this process should be conducted. These recommendations have been tested in a FESTA workshop and modified based on the experience of and feedback from that workshop. Annex A.3 consists of hypotheses related to the systems and use cases and provides a template for hypotheses collection and description. One might notice that the number of hypotheses connected to the use cases and systems differ considerably in the Annex. The reason is, that for some function extensive studies have been conducted and the impact of these systems on the user is understood better than for other functions. Especially the ACC function has been analysed deeply. ACC, its use cases, research questions and hypotheses can hence be seen as a best practice example for the complete chain from functions to hypotheses.

In general, hypotheses should be based as much as possible on a thorough examination of theoretical and empirical previous studies. Two complementary ways to develop hypotheses have been used, as described in sections2.4.1 and 2.4.2. Both ways need to be followed, while it is not of importance which step is taken first. One of the steps follows the sequential check of specific

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areas in which functions can have an impact; the other step is based on the description of specific scenarios. While the first results mainly in general hypotheses, the latter triggers the development of very specific hypotheses in specific driving situations or scenarios.

2.4.1 Deriving hypotheses from the scenarios

The main reasoning to describe functions, their use cases, situations and scenarios in detail according to Steps 1 and 2 is to trigger the generation of hypotheses for very specific scenarios. The hypotheses generation should be conducted by a team of experts, consisting of at least human factors experts, development engineers and traffic engineers and all of them need to fully understand the functions/ systems with all aspects and limitations.

Scenarios should be covered systematically. It is recommended that a structured approach be used and that the situations are checked sequentially for related hypotheses.

2.4.2 The six areas of impact

The six areas of impact defined by FESTA are based on Draskóczy et al. (1998). Although this approach was originally designed for formulating hypotheses on traffic safety impacts, it is in fact equally applicable for efficiency and environmental impacts.

The six areas are:

- Direct effects of a system on the user and driving.
- Indirect (behavioural adaptation) effects of the system on the user.
- Indirect (behavioural adaptation) effects of the system on the non-user (imitating effect).
- Modification of interaction between users and non-users (including vulnerable road users).
- Modifying accident consequences (e. g. by improving rescue, etc. — note that this can effect efficiency and environment as well as safety).
- Effects of combination with other systems.

It is not of particular importance to which of these areas a particular hypotheses is allocated. The six areas are instead to be used as a checklist to ensure consideration of multiple aspects of system impact.

In applying this procedure, it should be noted that:

- Area 1 includes the human-machine interaction aspects of system use.
- The driving task (see Table 2.2) can be defined, following Michon (1985) into the three levels of strategic, tactical and control (operational) aspects.
- Consideration should be given to such mediating factors as user/driver state, experience, journey purpose, etc.

It should also be noted that the effects of system use may be:

- Short-term or long-term in terms of duration and
- Intended or unintended in terms of system design.

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Table 2.2: Levels of the Driving Task by Michon (1985)

Level	Explanation/ example
Strategic	Finding the way through a road network (navigation) including • Modifying modal choice • Modifying route choice • Modifying exposure (frequency and/or length of travel)
Tactical	e. g. changing lanes, keeping the vehicle on the lanes, including modifying speed choice
Control/ Operational	Maintaining speed/ headway and distance to other vehicles

This additional step for hypotheses generation assures that very general hypotheses are not forgotten as well as hypotheses on unintended, short term and long term effects. It is intended to serve as a means for crosschecking.

2.4.3 Prioritising the hypotheses

The prioritization among the generated hypotheses is a difficult process. No specific advice can be given on how to proceed, but there are some general guidelines:

A complete list of the hypotheses that have been developed should be registered. If it is considered that some are too trivial or too expensive to address in the subsequent study design and data collection, the reasons for not covering them should be recorded. In general, it should be left to the judgement of the experts acting as hypotheses generators which hypotheses are likely to reflect the real driving situation. *Those should then be prioritized, keeping in mind that also unintended effects are very important*.

2.5 Step 5: Link Hypotheses with indicators for quantitative analyses

Some of the hypotheses will already incorporate an indicator which needs to be measured, e. g. a very concrete hypothesis like “The function will increase time-to-collision (TTC)”. In this case it is obvious which indicator to choose, while the method to measure TTC might include complicated procedures and/ or costly measurement equipment. D2.1 gives an overview about many reasonable indicators. One should consider these indicators when planning the experimental design, since a detailed description how to calculate the indicators from measurements is also provided.

Other hypotheses might be rather unspecific, but still reasonable after rephrasing into testable ones. This rephrasing goes hand in hand with the identification of related reasonable indicators. For example, a hypothesis like “The function will increase lane changing performance” is not directly testable, since “lane change performance” is not an indicator itself. Hence, surrogate measures must be identified to evaluate lane change performance. These surrogate measures or indicators can e. g. be found in publications of corresponding research projects. If appropriate information cannot be found or is not accessible, new performance indicators need to be developed. Those indicators and the measurement methodology must be valid, reliable and sensitive, that is, the measurement must actually measure what it is supposed to measure, it must be reproducible and the measurands must be sensitive to changes of the variable. A sensitivity analysis should be performed beforehand during a pilot study to make sure that the new performance indicator is suitable. When one or more surrogate measures have been identified, the

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initial hypothesis can be reformulated into one or more testable hypotheses. In the above mentioned example, reasonable indicators associated to “lane change performance” might be: use of turning indicator or the number of lane change warnings. The initial hypothesis will then be reformulated into: “The system will increase the use of the turning indicator.” and “During the system use, the number of lane departure warnings will decrease.”. The next step is then to evaluate how the indicators “use of turning indicator” and “lane departure warnings” can be measured. In this context, D 2.1 provides useful information.

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3 Conclusions

According to the FESTA chain in Figure 3.1, an FOT, aimed at evaluating the impact of in-vehicle systems on safety, environment, mobility and usage and acceptance, starts by 1) selecting which functions should be tested; 2) by defining in which use cases these functions should be tested; and 3) by determining which research questions and hypotheses to test.

This deliverable presented a 4-steps procedure to individuate which 1) functions, 2) use cases, and 3) research questions and hypotheses should be tested in an FOT. This methodology is fundamental to start any FOT study and to define the most relevant research questions and hypothesis which will then drive the further and subsequent definition of 1) performance indicators, 2) experimental protocol, and 3) data analysis (FESTA delivrables 2.1, 2.3, and 2.4, respectively).

Further, in the annex of this deliverable, the reader can find many examples how to apply this 4-step procedure to define use cases, research questions and hypothesis for in-vehicle systems, such as adaptive cruise control, frontal collision warning, lane departure warning, etc… In these examples hot links are used to relate the functions to the corresponding use cases, research questions, and hypotheses. By following these links, the reader can browse across a wide variety of hypotheses aimed at testing the functions impact on safety, environment, mobility and usage and acceptance and also find a list of suggested performance indicators to test the abovementioned hypotheses.

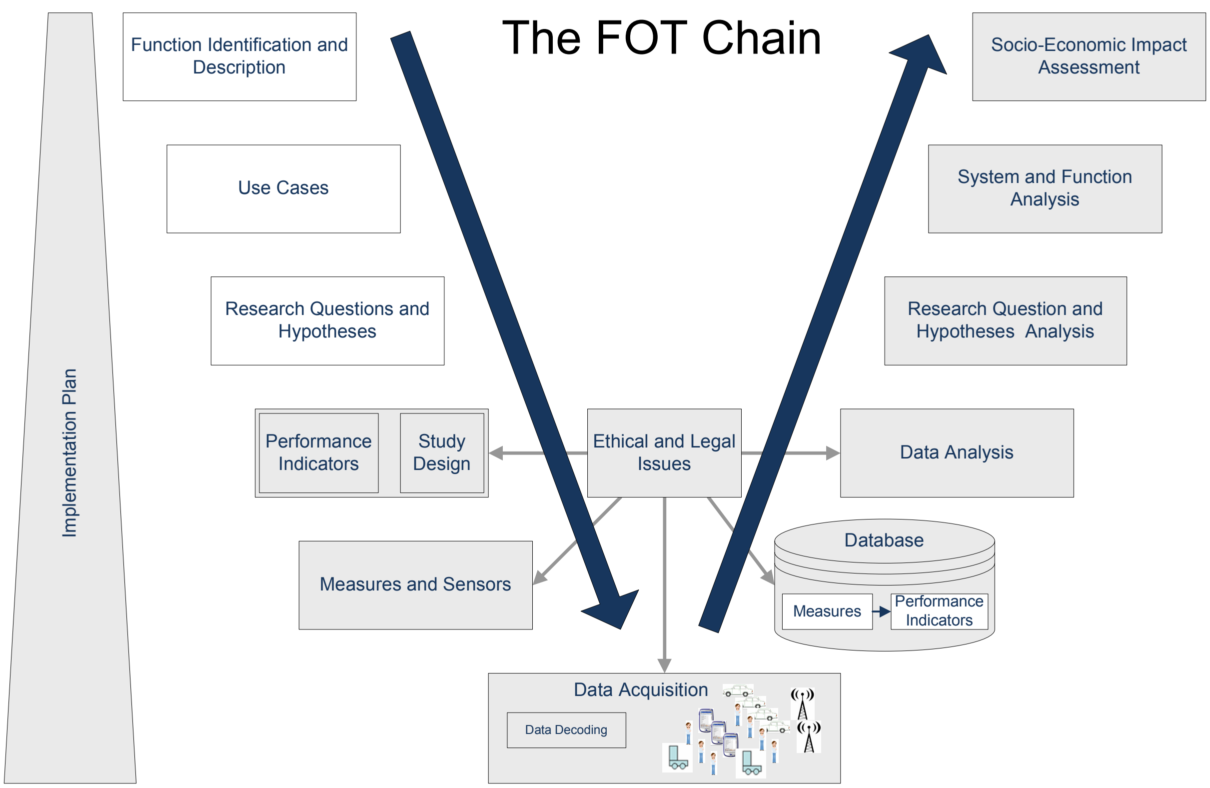

Figure 3.1: The FOT chain and the relevant steps from function identification to hypotheses covered by this deliverable.

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Michon, J. A. (1985). A critical view of driver behaviour models: what do we know, what should we do? In: L. Evans and R. C. Schwing (Eds.). Human Behaviour and Traffic Safety, pp. 485-524. New York: Plenum Press.

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Annex A

A.1 Systems and Functions

A.1.1 ACC

System Name and Abbreviation	Function Classification	KEY
Adaptive Cruise Control, ACC	**Vehicle System**	**S01**

Connected Use Cases	Connected Hypotheses
USE_ACC_01 USE_ACC_02	H01 H02 H03 H04 H06 H07 H08 H09 H11 H12 H14 H18 H19 H23 H24 H25 H27 H28 H29 H30 H36 H39 H40 H41 H47 H48 H49 H50 H51 H52 H53 H56 H57

Description	Adaptive Cruise Control supports the driver in selecting an appropriate speed and distance to the vehicle in front depending on his/her preferences and the current traffic situation.
Functionality	It controls actively the vehicle speed to adapt to drivers target speed and following distance. This function detects and tracks if a vehicle is in front and adjusts the speed accordingly (e. g. by controlling the throttle). If the leading vehicle accelerates, the system follows up to the target speed and keeping the pre-selected following distance.
System/ function is designed to? Need addressed and potential benefits	This function is intended to keep a preselected speed and following distance. It supports the driver at the operational level. The main benefits from this function are a reduction of: • exposure time to under-running critical headways, response time gaps to the leading vehicle • drivers workload

Boundary Conditions	Infrastructure requirements	n/a
	Demographical requirements/ driver requirements	no specific restrictions.
	Road context	Depending on the viewing angle of the used sensors, e. g. radar, the function can lose track of the vehicle ahead in (narrow) curves.
	Environmental restrictions	This function should not be sensitive to temperature, humidity, and air presssure (at least in normal driving sistuation). However, depending on the perception sensors of the system implementing this function, heavy rain, snow, and fog may limit the function performance.
	Traffic context	This function is not intended to be operated when the traffic situation implies many stops or continuous modification of speed. As a consequence, for instance, this function may be more appropriate when traffic is not intense than during rush hour.
	Other limitations	Depending on the system performance the lower limit of the velocity is between 0 and 30 km/h. An adaptive cruise control with a lower limit of e. g. 30 km/h should not be tested in high traffic, urban areas.

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A.1.2 Collision Warning

System Name and Abbreviation	Function Classification	KEY
Collision Warning	**Vehicle System**	**S02**

Connected Use Cases	Connected Hypotheses
USE_CW_01 USE_CW_02	H01 H02 H03 H10 H23 H24 H30

Description		A collision warning system provides alerts to assist drivers in avoiding or reducing the severity of crashes involving the equipped vehicle striking the rear-end of aleading vehicle.
Functionality		This function detects and tracks obstacles in front of the vehicle. In case the evaluation of trajectories and speed of the subject vehicle and the obstacle show a high probability of a collision, a warning is issued to the driver.
System/ function is designed to? Need addressed and potential benefits		This function is intended to decrease drivers reaction time in case of potential rear-end accidents. It supports the driver at the operational level.
Boundary Conditions	Infrastructure requirements	n/a
	Demographical requirements/ driver requirements	no specific restrictions.
	Road context	Depending on the viewing angle of the used sensors, e. g. radar, the function can lose track of the vehicle ahead in (narrow) curve
	Environmental restrictions	This function should not be sensitive to temperature, humidity, and air presssure (at least in normal driving sistuation). However, depending on the perception sensors of the system implementing this function, heavy rain, snow, and fog may limit the function performance.
	Traffic context	n/a
	Other limitations	System application concerning warning trigger parameter must be considered and possibly adapted to the driver

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A.1.3 Collision Mitigation

System Name and Abbreviation	Function Classification	KEY
Collision Mitigation	**Vehicle System**	**S03**

Connected Use Cases	Connected Hypotheses
USE_CM_01 USE_CM_02	H01 H02 H03

Description	A collision mitigation system supports the driver to reduce the severity of crashes involving the equipped vehicle strinking the rear-end of another vehicle by braking when the crash is unavoidable.
Functionality	This function detects and tracks obstacles in front of the vehicle. In case the evaluation of trajectories and speed of the subject vehicle and the obstacle show a high probability of a collision, an automatic braking is initiated.
System/ function is designed to? Need addressed and potential benefits	The system is intended to prevent or mitigate consequences of rear-end accidents by actively controling the vehicle in case a rear-end crash seems to be unavoidable.

Boundary Conditions	Infrastructure requirements	n/a
	Demographical requirements/ driver requirements	No specific restrictions
	Road context	Depending on the viewing angle of the used sensors, e. g. radar, the function can lose track of the vehicle ahead in (narrow) curves.
	Environmental restrictions	This function should not be sensitive to temperature, humidity, and air presssure (at least in normal driving sistuation). However, depending on the perception sensors of the system implementing this function, heavy rain, snow, and fog may limit the function performance.
	Traffic context	n/a
	Other limitations	System application concerning intervening trigger parameter must be considered and possibly adapted to the driver

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A.1.4 Speed Limiter

System Name and Abbreviation	Function Classification	KEY
Speed Limiter	**Vehicle System**	**S04**

Connected Use Cases	Connected Hypotheses
USE_SL_01	H01 H02 H03 H04 H05 H06 H11 H19 H23 H28 H29 H36 H39 H42 H47 H56 H57 H58

Description		Driver-operated speed limiter enables the driver to control the vehicle speed and maintain it below a defined limit.
Functionality		This function allows the driver to set a speed limit for each type of road. Once set by the driver, the maximum speed is displayed on the dashboard. If the vehicle attempts to exceed the set speed, the accelerator pedal becomes inactive. If necessary, however, the driver can break the set limit by pressing down hard on the accelerator. A maximum speed can then be reprogrammed as required. The driver is free to turn the system on or off, using a manual switch.
System/ function is designed to? Need addressed and potential benefits		Driver-operated speed limiter is an easy-to-use speed control. In ensuring that defined speed can not be exceeded, the system is expected to improve driver relaxation. The main expected benefits from using this function are: - reduced speed limit violations and potential associated risks - improved driving comfort - reduced fuel consumption
Boundary Conditions	Infrastructure requirements	n/a (However, for more advanced systems, awareness of the surrounding speed limits could be required to enable a real-time updating of selected speed).
	Demographical requirements/ driver requirements	Usage might be related to driver profiles: - (self-reported) speed violators vs (self reported) speed respectful - young drivers (techno-adept) vs mature drivers (assistance-seeker) - urban (and suburban) drivers vs motorway drivers
	Road context	The function is expected to be operated mainly in areas where low speed limit can easily be infringed in low traffic situations (e. g. ring roads).
	Environmental restrictions	The system should be operated in all weather and lighting conditions. However, practice could differ in various conditions (e. g. more or less degree of freedom in speed selection)
	Traffic context	The system is intended to be operated in low and medium traffic conditions (when speed limit can be easily infringed). The system is not expected to be operated in high traffic condition (traffic jam). Presence of speed monitoring (mobile and fixed) is expected to increase the usage of the system.
	Other limitations	n/a

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A.1.5 Lane Departure Warning

System Name and Abbreviation	Function Classification	KEY
Lane Departure Warning	**Vehicle System**	**S05**

Connected Use Cases	Connected Hypotheses
USE_LDW_01	H01 H02 H03 H05 H06 H15 H16 H17 H20 H23 H26 H28 H31 H32 H47 H48 H54 H55 H56 H57

Description		A lane departure warning system provides feedback to the driver in case the vehicle is unintentionally leaving the own lane.
Functionality		This function evaluates the trajectory of the subject vehicle in relation to the lane boundaries like road markings or guard rails. In case an unintentional lane departure is detected (taking into account TLC (Time to Line Crossing) and turning indicators), a warning is issued to the driver. This warning can be given acoustically, optically or in a haptic way.
System/ function is designed to? Need addressed and potential benefits		This function is intended to reduce crashes or incidents resulting from unintended lane departures.
Boundary Conditions	Infrastructure requirements	n/a
	Demographical requirements/ driver requirements	No specific requirements
	Road context	This function needs to recognize the road boundaries in order to work. As a consequence, lack of lane marking or of a clear road boundary may impair this function. It may have hard time recognizing lane marking in specific situations such as under a tunnel.
	Environmental restrictions	This function should not be sensitive to temperature, humidity, and air presssure (at least in normal driving sistuation). However, if the system implementing this function relies on cameras, then heavy rain, snow, and fog may limit the function performance.
	Traffic context	n/a
	Other limitations	Function might not be active below certain speed threshold.

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A.1.6 Blind Spot Warning

System Name and Abbreviation	Function Classification	KEY
Blind Spot Warning	**Vehicle System**	**S06**
Connected Use Cases	Connected Hypotheses	
USE_BSM_01	H01 H02 H03 H06 H10 H13 H21 H34 H38 H47 H56 H57	

Description		A blind spot warning system provides feedback to the driver in case an object has been detected in one of the blind spots of the vehicle.
Functionality		This function continuously monitors the rear blind spots on both sides of the vehicle. In case an obstacle is detected in the blind spot an information/ warning is issued to the driver. Some systems also provide a warning in case an intended lane change is detected (turning indicator engaged).
System/ function is designed to? Need addressed and potential benefits		This function aim is to prevent lateral accidents between a vehicle leaving the own lane and an obstacle (e. g. other vehicle) traveling in the lane next to it.
Boundary Conditions	Infrastructure requirements	n/a
	Demographical requirements/ driver requirements	n/a
	Road context	n/a
	Environmental restrictions	This function should not be sensitive to temperature, humidity, and air presssure (at least in normal driving sisuation). However, if the system implementing this function relies on cameras, then heavy rain, snow, and fog may limit the function performance.
	Traffic context	No restrictions
	Other limitations	Function might not be active below certain speed threshold, system might also not be able to detect other objects below a certain speed

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A.1.7 Dynamic Navigation

System Name and Abbreviation	Function Classification	KEY
Dynamic Navigation	**Vehicle System**	**S07**

Connected Use Cases	Connected Hypotheses
USE_NAV_01 USE_NAV_02	H02 H04 H15 H23 H28 H29 H33 H35 H36 H38 H39 H43 H44 H45 H46 H56 H57 H59

Description		(Dynamic) navigation guides the user to his destination according to the objective function, which typically optimises travel time or travel distance. A dynamic navigation system takes also dynamic traffic information into account and reroutes if necessary.
Functionality		This function uses a positioning system to estimate the own position, and certain algorithms to calulate the "best" (shortest) path to the destination in terms of travel time, distance or even safety. The calucation is based on information stored in a digital map, whose attributes (costs in terms of time an length) might be updated dynamically
System/ function is designed to? Need addressed and potential benefits		This function aims to reduce the vehicles time in traffic by finding the "best" (shortest/fastest) route between origin and destination. It prevents drivers from detours, and avoids traffic jams in case up-to-date traffic information is available. The system might also increase safety and decrease drivers stress. Depending on the penetration rate the systems might also decrease the overall amount of vehicle use of fuel.
Boundary Conditions	Infrastructure requirements	For dynamic navigation traffic information shall be available. This is usually derived from a network of infrastructural sensors (sometimes connected to traffic light controllers) or from FCD (Floating Car Data).
	Demographical requirements/ driver requirements	n/a
	Road context	n/a
	Environmental restrictions	Depending on the transmission technology used by this function bad weather can interfere with this function.
	Traffic context	No restrictions
	Other limitations	Dynamic navigation needs high quality traffic state information, otherwise the possible rerouting might result in suboptimal routes. Maps used for route caluculations should be as up-to-date as possible to avoid mistakes resulting from outdated attributation. Anytime the position esitmation is below an acceptable accuracy (for instance due to long time absence of GPS informaiton).

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A.1.8 Electronic Stability Control

System Name and Abbreviation	Function Classification	KEY
Electronic Stability Control	**Vehicle System**	**S08**

Connected Use Cases	Connected Hypotheses
USE_ESC_01 USE_ESC_02	H01 H02 H03

Description	Electronic Stability Control stabilizes the vehicle in critical driving conditions and driving situations within the physical limits. It helps to stabilize the vehicle and prevent skidding when cornering or driving off through active brake intervention on one or more wheels and intelligent engine torque management.
Functionality	This function detects the deviation between the vehicle's trajectory and the intended direction. Without any action on the part of the driver, small amounts of braking are applied separately to each wheel and this can bring the vehicle back to the intended course. The driver maintains control of the vehicle and often does not even notice that the Stability Control system has intervened.
System/ function is designed to? Need addressed and potential benefits	This function adresses driving situations and accidents resulting from a loss of control of the vehicle. It is intended to prevent accidents and mitigate accident consequences.

Boundary Conditions	Infrastructure requirements	n/a
	Demographical requirements/ driver requirements	n/a
	Road context	n/a
	Environmental restrictions	n/a
	Traffic context	n/a
	Other limitations	n/a

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A.1.9 Driver Impairment Warning

<table>
<tr><td>System Name and Abbreviation</td><td>Function Classification</td><td>KEY</td></tr>
<tr><td>Driver Impairment Warning</td><td>Vehicle System</td><td>S09</td></tr>
<tr><td colspan="2">Connected Use Cases</td><td>Connected Hypotheses</td></tr>
<tr><td colspan="2">USE_DIW_01
USE_DIW_02
USE_DIW_03</td><td>H01 H02 H03</td></tr>
<tr><td colspan="2">Description</td><td>The Impairment Warning system alert tired and unconcentrated drivers and advises them to increase their concentration or even to take a break.</td></tr>
<tr><td colspan="2">Functionality</td><td>Depending on the concrete implementation the system either evaluates the risk control of the vehicle by monitoring the vehicles movements between the lane markings or by evaluating his fatigue through the eye and eyelid movements.</td></tr>
<tr><td colspan="2">System/ function is designed to?
Need addressed and potential benefits</td><td>The function adresses accidents and incidents resulting from driver unawareness and fatigue.</td></tr>
<tr><td rowspan="6">Boundary Conditions</td><td>Infrastructure requirements</td><td>n/a</td></tr>
<tr><td>Demographical requirements/ driver requirements</td><td>n/a</td></tr>
<tr><td>Road context</td><td>n/a</td></tr>
<tr><td>Environmental restrictions</td><td>This function should not be sensitive to temperature, humidity, and air presssure (at least in normal driving situation). However, if the system implementing this function relies on cameras, then heavy rain, snow, and fog may limit the function performance.</td></tr>
<tr><td>Traffic context</td><td>n/a</td></tr>
<tr><td>Other limitations</td><td>n/a</td></tr>
</table>

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A.2 Use Cases

A.2.1 USE_ACC_01

Use Case Name and Abbreviation		KEY
ACC – normal driving		**USE_ACC_01**
Connected Systems		Connected Hypotheses
Adaptive Cruise Control		H01 H02 H03 H04 H06 H07 H08 H09 H11 H12 H14 H18 H19 H23 H24 H25 H27 H28 H29 H30 H36 H39 H40 H41 H47 H48 H49 H50 H51 H52 H53 H56 H57
Description		The vehicle under test is driving in almost any situations, preferrable in extra-urban areas.
System and Vehicle Specification	System Status	on on
	System Action Status	acting not acting
	Vehicle Characteristics	passenger vehicle truck bus
	Interaction between Systems	Interaction with collision warning or collision mitigations system can happen, when integrated.
Environmental Specifications	Traffic Conditions	No special conditions concerning traffic density, but effects will be more visible with low to medium dense traffic.
	Environmental Situation	day night normal weather conditions adverse weather conditions
	Road Characteristics	rural roads highways
	Geographical Characteristics	no specifications
Driver	Driver Specification	age and gender of drivers should be considered The driver's determination to use the ACC system is required.
	Driver Status	
Frequency		continously

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A.2.2 USE_ACC_02

Use Case Name and Abbreviation		KEY
ACC – lane changing		**USE_ACC_02**
Connected Systems		Connected Hypotheses
Adaptive Cruise Control		H22
Description		The vehicle under test is driving in almost any situations, preferrable in extra-urban areas and performing a lane change manoeuvre.
System and Vehicle Specification	System Status	on on
	System Action Status	acting not acting
	Vehicle Characteristics	passenger vehicle truck bus
	Interaction between Systems	Interaction with collision warning or collision mitigations system can happen, when integrated.
Environmental Specifications	Traffic Conditions	lane change situation
	Environmental Situation	day night normal weather conditions adverse weather conditions
	Road Characteristics	rural roads highways
	Geographical Characteristics	no specifications
Driver	Driver Specification	Age and gender of drivers should be considered The driver's determination to use the ACC system is required.
	Driver Status	
Frequency		continously

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A.2.3 USE_CW_01

Use Case Name and Abbreviation		KEY
CW – normal driving		**USE_CW_01**
Connected Systems		Connected Hypotheses
Collision Warning		H01 H02 H03 H23 H24 H30
Description		The vehicle under test is driving in normal driving situations.
System and Vehicle Specification	System Status	On On
	System Action Status	acting not acting
	Vehicle Characteristics	passenger vehicle truck bus
	Interaction between Systems	No interaction with other systems foreseen
Environmental Specifications	Traffic Conditions	no specifications
	Environmental Situation	Day night normal weather conditions adverse weather conditions
	Road Characteristics	no specifications
	Geographical Characteristics	urban roads extra urban roads
Driver	Driver Specification	age and gender to be considered
	Driver Status	attentive distracted impaired
Frequency		Rare

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A.2.4 USE_CW_02

Use Case Name and Abbreviation		KEY
CW – lane changing		**USE_CW_02**
Connected Systems		Connected Hypotheses
Collision Warning		H10
Description		The vehicle under test is driving in a lane change manoeuvre.
System and Vehicle Specification	System Status	On On
	System Action Status	acting not acting
	Vehicle Characteristics	passenger vehicle truck bus
	Interaction between Systems	No interaction with other systems foreseen
Environmental Specifications	Traffic Conditions	lane change situation
	Environmental Situation	Day night normal weather conditions adverse weather conditions
	Road Characteristics	no specifications
	Geographical Characteristics	urban roads extra urban roads
Driver	Driver Specification	age and gender to be considered
	Driver Status	attentive distracted impaired
Frequency		Rare

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A.2.5 USE_CM_01

Use Case Name and Abbreviation		KEY
CM – normal driving		**USE_CM_01**
Connected Systems		Connected Hypotheses
Collision Mitigation		H01 H02 H03
Description		The vehicle under test is driving in normal driving situations
System and Vehicle Specification	System Status	On On
	System Action Status	acting not acting
	Vehicle Characteristics	passenger vehicle truck bus
	Interaction between Systems	no interaction with other systems foreseen
Environmental Specifications	Traffic Conditions	no specifications
	Environmental Situation	Day night normal weather conditions adverse weather conditions
	Road Characteristics	no specifications
	Geographical Characteristics	urban roads extra urban roads
Driver	Driver Specification	age and gender to be considered
	Driver Status	attentive distracted impaired
Frequency		Rare

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A.2.6 USE_CM_02

Use Case Name and Abbreviation		KEY
CM – lane changing		**USE_CM_02**
Connected Systems		Connected Hypotheses
Collision Mitigation		H01 H02 H03
Description		The vehicle under test is driving in a lane change manoeuvre.
System and Vehicle Specification	System Status	On On
	System Action Status	acting not acting
	Vehicle Characteristics	passenger vehicle truck bus
	Interaction between Systems	No interaction with other systems foreseen
Environmental Specifications	Traffic Conditions	lane change situation
	Environmental Situation	Day night normal weather conditions adverse weather conditions
	Road Characteristics	no specifications
	Geographical Characteristics	urban roads extra urban roads
Driver	Driver Specification	age and gender to be considered
	Driver Status	attentive distracted impaired
Frequency		Rare

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A.2.7 USE_SL_01

Use Case Name and Abbreviation		KEY
SL – normal driving		**USE_SL_01**
Connected Systems		Connected Hypotheses
Speed Limiter		H01 H02 H03 H04 H05 H06 H11 H19 H23 H28 H29 H36 H38 H39 H42 H47 H56 H57 H58
Description		The driver is traveling on all types of roads with speed restrictions
System and Vehicle Specification	System Status	On On
	System Action Status	acting not acting
	Vehicle Characteristics	passenger vehicle truck bus
	Interaction between Systems	No expected interaction
Environmental Specifications	Traffic Conditions	low density vs medium density to assess if usage adapted to traffic level (e. g. avoid speed violation in low level, adapt to surrounding traffic in medium traffic level)
	Environmental Situation	Day night normal weather conditions adverse weather conditions
	Road Characteristics	urban road (50 - 60 km/h) Rural roads (80 - 90 km/h) motorway/ highway (110 - 130 km/h)
	Geographical Characteristics	no restrictions
Driver	Driver Specification	age and gender to be considered (self-reported) speed violators vs (self reported) speed respectful young drivers (techno-adept, but "actor" in control) vs mature drivers (assistance-seeker) urban (and suburban) drivers vs motorway drivers occasional vs daily drivers
	Driver Status	Attentive distracted impaired
Frequency		extensive usage

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A.2.8 USE_LDW_01

Use Case Name and Abbreviation		KEY
LDW – unintended lane departure		**USE_LDW_01**
Connected Systems		Connected Hypotheses
Lane Departure Warning		H01 H02 H03 H05 H06 H15 H16 H17 H20 H23 H26 H28 H31 H32 H47 H48 H54 H55 H56 H57
Description		subject vehicle is going to cross lane markings unintentionally
System and Vehicle Specification	System Status	on - road markings recognized on - road markings not recognized on - road markings not existing on
	System Action Status	warning no warning
	Vehicle Characteristics	passenger vehicle truck bus
	Interaction between Systems	Interaction with Blind Spot Warning possible
Environmental Specifications	Traffic Conditions	No restrictions
	Environmental Situation	normal weather conditions adverse weather conditions low hanging sun frequent changes in lightening conditions (e. g. due to shadows)
	Road Characteristics	road type: mainly intended to operate on highways road characteristics influencing system performance: - quality of lane markings - changes in lane markings e. g. for road works, changes in lane numbers) - road curvature - different tarmacs
	Geographical Characteristics	n/a
Driver	Driver Specification	age and gender to be considered
	Driver Status	Attentive distracted impaired
Frequency		Regular

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A.2.9 USE_BSM_01

Use Case Name and Abbreviation		KEY
BSM – lane chaning		**USE_BSM_01**
Connected Systems		Connected Hypotheses
Blind Spot Monitoring		H01 H02 H03 H05 H06 H15 H16 H17 H20 H23 H26 H28 H31 H32 H47 H48 H54 H55 H56 H57
Description		subject vehicle indicates a potentially hazardous lane change (other vehicle on target lane in close proximity)
System and Vehicle Specification	System Status	on - Information available on - Information not available on
	System Action Status	WARNING NO WARNING
	Vehicle Characteristics	passenger vehicle truck bus
	Interaction between Systems	Interaction with Lane Departure Warning possible
Environmental Specifications	Traffic Conditions	No specification
	Environmental Situation	normal weather conditions adverse weather conditions low hanging sun frequent changes in lightening conditions (e. g. due to shadows)
	Road Characteristics	road type: mainly intended to operate on highways road characteristics influencing system performance: - quality of lane markings - changes in lane markings e. g. for road works, changes in lane numbers) - road curvature - different tarmacs
	Geographical Characteristics	no specification
Driver	Driver Specification	age and gender to be considered
	Driver Status	Attentive distracted impaired
Frequency		Regular

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A.2.10 USE_NAV_01

Use Case Name and Abbreviation		KEY
NAV – driving in unfamiliar areas		**USE_NAV_01**
Connected Systems		Connected Hypotheses
Dynamic Navigation		H02 H04 H15 H23 H28 H29 H33 H44
Description		Driving in an unfamiliar area to an unfamiliar destination
System and Vehicle Specification	System Status	route guidance on - GPS signal available route guidance on - GPS signal not available route guidance on TMC service active/not active route option (e. g. shortest, fastest, dynamic) display mode
	System Action Status	distance to next route guidance point voice output rerouting due to TMC message
	Vehicle Characteristics	passenger vehicle truck bus
	Interaction between Systems	no interaction
Environmental Specifications	Traffic Conditions	no specification
	Environmental Situation	no specification
	Road Characteristics	no specification
	Geographical Characteristics	quality of GPS signal quality of available maps
Driver	Driver Specification	frequency of travelling in unfamiliar areas
	Driver Status	Attentive distracted operating system yes/ no
Frequency		Regular

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A.2.11 USE_NAV_02

Use Case Name and Abbreviation		KEY
NAV – driving in familiar areas		**USE_NAV_02**
Connected Systems		Connected Hypotheses
Dynamic Navigation		H23 H28 H35 H39 H43 H45
Description		Driving in a familiar area to an familiar destination: navigation mainly used for information about traffic conditions
System and Vehicle Specification	System Status	route guidance on - GPS signal available route guidance on - GPS signal not available route guidance on TMC service active/not active route option (shortest, fastest, dynamic) display mode
	System Action Status	distance to next route guidance point voice output rerouting due to TMC message
	Vehicle Characteristics	passenger vehicle truck bus
	Interaction between Systems	no interaction
Environmental Specifications	Traffic Conditions	low to medium traffic density without high probablity for traffic jams. high probability for traffic jams.
	Environmental Situation	no specification
	Road Characteristics	no specification
	Geographical Characteristics	quality of GPS signal quality of available maps
Driver	Driver Specification	frequency of travelling in unfamiliar areas
	Driver Status	attentive distracted impaired
Frequency		Frequently

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A.2.12 USE_ESC_01

Use Case Name and Abbreviation		KEY
ESC – unadapted speed		**USE_ESC_01**
Connected Systems		Connected Hypotheses
Electronic Stability Control		H01 H02 H03
Description		subject vehicle destabilizes due to unadapted speed
System and Vehicle Specification	System Status	On On
	System Action Status	Acting not acting
	Vehicle Characteristics	passenger vehicle truck bus
	Interaction between Systems	no interaction
Environmental Specifications	Traffic Conditions	no specification
	Environmental Situation	Day night normal weather conditions adverse weather conditions
	Road Characteristics	curves of differeny radii straight roads
	Geographical Characteristics	rural roads urban roads highways
Driver	Driver Specification	professional drivers private drivers
	Driver Status	Attentive distracted impaired
Frequency		Rare

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A.2.13 USE_ESC_02

Use Case Name and Abbreviation			KEY
ESC – slippery road			**USE_ESC_02**
Connected Systems			Connected Hypotheses
Electronic Stability Control			H01 H02 H03
Description		subject vehicle destabilizes due to differing friction gradient on the road	
System and Vehicle Specification	System Status	on on	
	System Action Status	acting not acting	
	Vehicle Characteristics	passenger vehicle truck bus	
	Interaction between Systems	No interaction	
Environmental Specifications	Traffic Conditions	no specification	
	Environmental Situation	Day night normal weather conditions adverse weather conditions	
	Road Characteristics	curves of differeny radii straight roads	
	Geographical Characteristics	rural roads urban roads highways	
Driver	Driver Specification	professional drivers private drivers	
	Driver Status	Attentive distracted impaired	
Frequency		Rare	

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A.2.14 USE_DIW_01

Use Case Name and Abbreviation			KEY
DIW – loss of control			**USE_DIW_01**
Connected Systems			Connected Hypotheses
Driver Impairment Warning			H01 H02 H03
Description		Driver loosing control over vehicle due to drowsiness	
System and Vehicle Specification	System Status	On on	
	System Action Status	Acting not acting	
	Vehicle Characteristics	passenger vehicle truck bus	
	Interaction between Systems	no interaction	
Environmental Specifications	Traffic Conditions	low density, no interaction between subject vehicle and other vehicles	
	Environmental Situation	Day night standard weather conditions adverse weather conditions	
	Road Characteristics	long straight roads inducing low workload on driver (incidents occur often at the beginning of curves) no specific situation	
	Geographical Characteristics	rural roads urban roads highways	
Driver	Driver Specification	professional drivers private drivers	
	Driver Status	Attentive distracted impaired	
Frequency		Rare	

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A.2.15 USE_DIW_02

Use Case Name and Abbreviation			KEY
DIW – approaching car ahead			**USE_DIW_02**
Connected Systems			Connected Hypotheses
Driver Impairment Warning			H01 H02 H03
Description		Unperceived approach to car ahead	
System and Vehicle Specification	System Status	on on	
	System Action Status	acting not acting	
	Vehicle Characteristics	passenger vehicle truck bus	
	Interaction between Systems	No interaction	
Environmental Specifications	Traffic Conditions	no specification	
	Environmental Situation	day night standard weather conditions adverse weather conditions	
	Road Characteristics	long straight roads inducing low workload on driver (incidents occur often at the beginning of curves) no specific situation	
	Geographical Characteristics	rural roads urban roads highways	
Driver	Driver Specification	professional drivers private drivers	
	Driver Status	attentive distracted impaired	
Frequency		rare	

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A.2.16 USE_DIW_03

Use Case Name and Abbreviation		KEY
DIW – approaching car from behind		**USE_DIW_03**
Connected Systems		Connected Hypotheses
Driver Impairment Warning		H01 H02 H03
Description		Unperceived approach of car from behind
System and Vehicle Specification	System Status	on
		on
	System Action Status	acting
		not acting
	Vehicle Characteristics	passenger vehicle
		truck
		bus
	Interaction between Systems	no interaction
Environmental Specifications	Traffic Conditions	no specification
	Environmental Situation	day
		night
		standard weather conditions
		adverse weather conditions
	Road Characteristics	long straight roads inducing low workload on driver (incidents occur often at the beginning of curves)
		no specific situation
	Geographical Characteristics	rural roads
		urban roads
		highways
Driver	Driver Specification	professional drivers
		private drivers
	Driver Status	attentive
		distracted
		impaired
Frequency		rare

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A.3 Research Questions and Hypotheses

Hypothesis			KEY
The amount of traffic accidents will decrease			**H01**
Related Research Question	Does the number of crashes and incidents change?		
Related System	S01 Adaptive Cruise Control S02 Collision Warning S03 Collision Mitigation S04 Speed Limiter S05 Lane Departure Warning S06 Blind Spot Warning S08 Electronic Stability Control S09 Driver Impairment Warning		
Related Use Case	USE_ACC_01 USE_CW_01 USE_CM_01 USE_CM_02 USE_SL_01 USE_LDW_01 USE_BSM_01 USE_ESC_01 USE_ESC_02		
Proposed indicator	number of accidents per mileage/time driven/no of drivers		
Estimated impact on: Traffic Safety and safety related driving performance	+		
Estimated impact on: Environmental impacts	+	fewer accidents means less congestion, which leads to reduced fuel consumption on a network level	
Estimated impact on: Transport and traffic efficiency	+	fewer accidents means less congestion and traffic jams, travel times decrease on a network level.	
Estimated impact on: Usage, acceptance and trust			

Legend:

- \+ positive impact expected
- \- negative impact expected
- 0 impact expected, but direction not foreseeable
- empty: no impact expected.

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Hypothesis			KEY
The amount of traffic incidents will decrease.			**H02**
Related Research Question	Does the number of crashes and incidents change?		
Related System	S01 Adaptive Cruise Control S02 Collision Warning S03 Collision Mitigation S04 Speed Limiter S05 Lane Departure Warning S06 Blind Spot Warning S07 Dynamic Navigation S08 Electronic Stability Control S09 Driver Impairment Warning		
Related Use Case	USE_ACC_01 USE_CW_01 USE_CM_01 USE_CM_02 USE_SL_01 USE_LDW_01 USE_BSM_01 USE_NAV_01 USE_ESC_01 USE_ESC_02		
Proposed indicator	number of incidents (to be defined) per mileage/time driven/no of drivers		

Estimated impact on			
	Traffic Safety and safety related driving performance	+	
	Environmental impacts	+	fewer incidents means probably fewer disturbances of the traffic flow, which in turn reduces traffic jams and hence reduces overall fuel consumption
	Transport and traffic efficiency	+	fewer incidents means probably fewer disturbances of the traffic flow, which in turn reduces traffic jams and increases the effiency of the transport network
	Usage, acceptance and trust		

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Hypothesis **The effect/outcome of traffic accidents will be mitigated.**		KEY **H03**
Related Research Question	Does the number of crashes and incidents change?	
Related System	S01 Adaptive Cruise Control S02 Collision Warning S03 Collision Mitigation S04 Speed Limiter S05 Lane Departure Warning S06 Blind Spot Warning S08 Electronic Stability Control S09 Driver Impairment Warning	
Related Use Case	USE_ACC_01 USE_CW_01 USE_CM_01 USE_CM_02 USE_SL_01 USE_LDW_01 USE_BSM_01 USE_ESC_01 USE_ESC_02	
Proposed indicator	collision velocity collision object ΔV	

Estimated impact on		
	Traffic Safety and safety related driving performance	+
	Environmental impacts	+
	Transport and traffic efficiency	+
	Usage, acceptance and trust	

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Hypothesis			KEY
Speed adaptations will be smoother/more uniform.			**H04**
Related Research Question	How does driving behaviour on the longitudinal axis change?		
Related System	S01 Adaptive Cruise Control S04 Speed Limiter S07 Dynamic Navigation		
Related Use Case	USE_ACC_01 USE_SL_01 USE_NAV_01		
Proposed indicator	number of sudden breaking events speed variance standard deviation speed acceleration profile max acceleration		
Estimated impact on	Traffic Safety and safety related driving performance	+	ACC system adjusts speed smoother/ more uniform. Driver is more in control of everything with a navigation system.
	Environmental impacts		
	Transport and traffic efficiency	+	A reduction in speed variability is expected to come about through two processes: a reduction in peak or higher speeds, and truncation of the upper and lower ends of the speed distribution. The truncation of the lower end of the distribution is expected to come about as a result of drivers who normally drive well below the speed limit increasing these lower speeds until the SL warning occur. In effect, this means they will use SL as an active speed controlling device rather than as a warning signal to obviate inadvertent speeding.
	Usage, acceptance and trust		

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Hypothesis			KEY
Speed will decrease.			**H05**
Related Research Question	How does driving behaviour on the longitudinal axis change?		
Related System	S04 Speed Limiter S05 Lane Departure Warning		
Related Use Case	USE_SL_01 USE_LDW_01		
Proposed indicator	mean speed max/min speed spot speed 85th percentile of speed		
Estimated impact on	Traffic Safety and safety related driving performance	+	A reduction of the mean speed results in a lower probability to be involved in accidents as well as it mitigates the accident consequences. higher effect for younger drivers higher effect during the day than at night Effect will dissipate over time when driving not-equipped cars.
	Environmental impacts	+	Reduced speed results in less fuel consumption.
	Transport and traffic efficiency	+	A reduction of the mean speed usually results in an increased traffic flow, especially on road with a high traffic demand.
	Usage, acceptance and trust		

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Hypothesis			KEY
Speed will increase over time.			**H06**
Related Research Question	How does driving behaviour on the longitudinal axis change?		
Related System	S01 Adaptive Cruise Control S04 Speed Limiter S05 Lane Departure Warning S06 Blind Spot Warning		
Related Use Case	USE_ACC_01 USE_SL_01 USE_LDW_01 USE_BSM_01		
Proposed indicator	mean speed median speed max/min speed spot speed 85th percentile of speed		
Estimated impact on	Traffic Safety and safety related driving performance	-	An increasing mean speed means higher probability to be involved in accidents as well as the accident consequences will be more severe. With time, unexpected and "not desired" practices might appear (e. g. set up to speed just above the limit)
	Environmental impacts		
	Transport and traffic efficiency		
	Usage, acceptance and trust		

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Hypothesis			KEY
Following distance will increase.			**H07**
Related Research Question	How does driving behaviour on the longitudinal axis change?		
Related System	S01 Adaptive Cruise Control		
Related Use Case	USE_ACC_01		
Proposed indicator	time headway (THW) mean THW minima THW minima <x s mean Time to Collision (TTC) minima TTC minima <x s		
Estimated impact on: Traffic Safety and safety related driving performance	+	increasing following distance leads to a larger time span for driver reactions	
Estimated impact on: Environmental impacts			
Estimated impact on: Transport and traffic efficiency	-	decreased road capacity due to increased time headways	
Estimated impact on: Usage, acceptance and trust			

Hypothesis			KEY
Following distance (without system) will increase over time.			**H08**
Related Research Question	How does driving behaviour on the longitudinal axis change?		
Related System	S01 Adaptive Cruise Control		
Related Use Case	USE_ACC_01		
Proposed indicator	time headway (THW) Mean THW minima THW minima <x s Mean Time to Collision (TTC) minima TTC minima <x s		
Estimated impact on: Traffic Safety and safety related driving performance	+	Following distance without system use will be longer after some system experience.	
Estimated impact on: Environmental impacts			
Estimated impact on: Transport and traffic efficiency			
Estimated impact on: Usage, acceptance and trust			

Hypothesis	KEY
Variability in following distance will decrease.	**H09**

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Related Research Question		How does driving behaviour on the longitudinal axis change?	
Related System		S01 Adaptive Cruise Control	
Related Use Case		USE_ACC_01	
Proposed indicator		standard deviation time headway (THW) standard deviation THW minima standard deviation Time to Collision (TTC) standard deviation TTC minima	
Estimated impact on	Traffic Safety and safety related driving performance	+	
	Environmental impacts	+	
	Transport and traffic efficiency	+	
	Usage, acceptance and trust		

Hypothesis			KEY
Following distance will decrease.			**H10**
Related Research Question		How does driving behaviour on the longitudinal axis change?	
Related System		S02 Collision Warning S06 Blind Spot Warning	
Related Use Case		USE_CW_02 USE_BSM_01	
Proposed indicator		time headway (THW) mean THW minima THW minima <x s mean Time to Collision (TTC) minima TTC minima <x s	
Estimated impact on	Traffic Safety and safety related driving performance	-	Leads to increased perceived safety when driving with system.
	Environmental impacts		
	Transport and traffic efficiency		
	Usage, acceptance and trust		

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Hypothesis			KEY
Speed violations will decrease.			**H11**
Related Research Question	How does driving behaviour on the longitudinal axis change?		
Related System	S01 Adaptive Cruise Control S04 Speed Limiter		
Related Use Case	USE_ACC_01 USE_SL_01		
Proposed indicator	Driving time at speeds above speed limits Number of speed limit violations		
Estimated impact on: Traffic Safety and safety related driving performance	+	speed is set according to the actual speed limit if ACC target speed is set according to the actual speed limit	
Estimated impact on: Environmental impacts			
Estimated impact on: Transport and traffic efficiency	+	overall traffic regulated (less discrepencies between vehicles respective speeds)	
Estimated impact on: Usage, acceptance and trust			

Hypothesis			KEY
Number of lane changes will increase.			**H12**
Related Research Question	How does driving behaviour on the lateral axis change?		
Related System	S01 Adaptive Cruise Control S06 Blind Spot Warning		
Related Use Case	USE_ACC_01 USE_BSM_01		
Proposed indicator	number of lane changes (time, distance) number of overtakings (time, distance)		
Estimated impact on: Traffic Safety and safety related driving performance	-	Increased number of lane changes will increase the probability for lane change accidents more relaxed driving	
Estimated impact on: Environmental impacts	+	shorter trip length + less tyre wear	
Estimated impact on: Transport and traffic efficiency			
Estimated impact on: Usage, acceptance and trust			

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Hypothesis			KEY
Number of lane changes will decrease.			**H13**
Related Research Question	How does driving behaviour on the lateral axis change?		
Related System	S01 Adaptive Cruise Control S06 Blind Spot Warning		
Related Use Case	USE_ACC_01 USE_BSM_01		
Proposed indicator	number of lane changes (time, distance) number of overtakings (time, distance)		

Estimated impact on			
Traffic Safety and safety related driving performance	+	reduced number of lane changes will decrease the probability for lane change accidents more relaxed driving	
Environmental impacts	+	shorter trip length and less tyre wear	
Transport and traffic efficiency			
Usage, acceptance and trust			

Hypothesis			KEY
Driving time in the left lane will increase.			**H14**
Related Research Question	How does driving behaviour on the lateral axis change?		
Related System	S01 Adaptive Cruise Control		
Related Use Case	USE_ACC_01		
Proposed indicator	driving time per lane		

Estimated impact on			
Traffic Safety and safety related driving performance			
Environmental impacts			
Transport and traffic efficiency	-	Slow driving on the left lane decreases traffic flow when the traffic demand is low. A more uneven distribution of traffic on the lanes will lead to a reduced use of the available road capacity.	
Usage, acceptance and trust			

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Hypothesis **Lane keeping performance will increase.**			KEY **H15**
Related Research Question		How does driving behaviour on the lateral axis change?	
Related System		S05 Lane Departure Warning S07 Dynamic Navigation	
Related Use Case		USE_LDW_01 USE_NAV_01	
Proposed indicator		mean standard deviation of lane position (SLP) mean time to line crossing (TLC) minima number of warnings (fequency of being below a certain system specific TLC + derivatives) TLC/speed conjunction frequency of lane exceedances	
Estimated impact on	Traffic Safety and safety related driving performance		
	Environmental impacts		
	Transport and traffic efficiency		
	Usage, acceptance and trust		

Hypothesis **Driving performance will decrease over time.**			KEY **H16**
Related Research Question		How does driving behaviour on the lateral axis change?	
Related System		S05 Lane Departure Warning	
Related Use Case		USE_LDW_01	
Proposed indicator		steering entropy mean standard deviation of lane position (SLP) mean time to line crossing (TLC) minima number of warnings TLC/speed conjunction frequency of lane exceedances	
Estimated impact on	Traffic Safety and safety related driving performance	-	LDW reduces driving performance in critical lane departure situations, LDW contributes to degraded lane keeping ability when driving non-equipped cars
	Environmental impacts		
	Transport and traffic efficiency		
	Usage, acceptance and trust		

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Hypothesis			KEY
Driving time in the road shoulder will decrease.			**H17**
Related Research Question	How does driving behaviour on the lateral axis change?		
Related System	S05 Lane Departure Warning		
Related Use Case	USE_LDW_01		
Proposed indicator	Driving time on road shoulder		
Estimated impact on	Traffic Safety and safety related driving performance		
	Environmental impacts		
	Transport and traffic efficiency	-	LDW prevents intentional driving on the shoulder to make space for overtaking
	Usage, acceptance and trust		

Hypothesis			KEY
Time to reach the brake pedal will increase.			**H18**
Related Research Question	How does the manipulation and monitoring of vehicle controls change?		
Related System	S01 Adaptive Cruise Control		
Related Use Case	USE_ACC_01		
Proposed indicator	TTRb (Time to reach brake pedal) Brake responce time		
Estimated impact on	Traffic Safety and safety related driving performance	-	increased reaction time results in later reaction.
	Environmental impacts		
	Transport and traffic efficiency		
	Usage, acceptance and trust		lack of trust in the system if reaction time is increased

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Hypothesis			KEY
Visual monitoring of speed indicator will decrease.			**H19**
Related Research Question	How does the manipulation and monitoring of vehicle controls change?		
Related System	S01 Adaptive Cruise Control S04 Speed Limiter		
Related Use Case	USE_ACC_01 USE_SL_01		
Proposed indicator	glance frequency to instrument panel		
Estimated impact on: Traffic Safety and safety related driving performance	+		
Estimated impact on: Environmental impacts			
Estimated impact on: Transport and traffic efficiency			
Estimated impact on: Usage, acceptance and trust	+	acceptance due to increased awareness of the overall driving situation	

Hypothesis			KEY
Use of turn indicators will increase.			**H20**
Related Research Question	How does the manipulation and monitoring of vehicle controls change?		
Related System	S05 Lane Departure Warning		
Related Use Case	USE_LDW_01		
Proposed indicator	frequency of turn indicator use		
Estimated impact on: Traffic Safety and safety related driving performance	+		
Estimated impact on: Environmental impacts			
Estimated impact on: Transport and traffic efficiency			
Estimated impact on: Usage, acceptance and trust			

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Hypothesis			KEY
Use of turn indicators will decrease.			**H21**
Related Research Question	How does the manipulation and monitoring of vehicle controls change?		
Related System	S06 Blind Spot Warning		
Related Use Case	USE_BSM_01		
Proposed indicator	frequency of turn indicator use		
Estimated impact on	Traffic Safety and safety related driving performance	-	
	Environmental impacts		
	Transport and traffic efficiency		
	Usage, acceptance and trust	+	

Hypothesis			KEY
Use of turn indicators will decrease over time.			**H22**
Related Research Question	How does the manipulation and monitoring of vehicle controls change?		
Related System	S01 Adaptive Cruise Control		
Related Use Case	USE_ACC_02		
Proposed indicator	Frequency of turn indicator use for different speed segments		
Estimated impact on	Traffic Safety and safety related driving performance	-	
	Environmental impacts		
	Transport and traffic efficiency		
	Usage, acceptance and trust	-	

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Hypothesis			KEY
Time spent on secondary tasks will increase over time.			**H23**
Related Research Question	How does the availability of the driver for the primary driving task change for normal driving and critical situations?		
Related System	S01 Adaptive Cruise Control S02 Collision Warning S04 Speed Limiter S05 Lane Departure Warning S07 Dynamic Navigation		
Related Use Case	USE_ACC_01 USE_CW_01 USE_SL_01 USE_LDW_01 USE_NAV_01 USE_NAV_02		
Proposed indicator	secondary task activation over time approaching speed to critical situations indicators for driver distraction (% glance duration off road etc)		
Estimated impact on	Traffic Safety and safety related driving performance	-	misunderstandings of system activations (especially in case of similarities between different modes), misunderstandings of settings higher driver availability turnes into drivers distraction
	Environmental impacts		
	Transport and traffic efficiency		
	Usage, acceptance and trust		

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Hypothesis		KEY
The drivers reaction time will decrease.		**H24**
Related Research Question	How does the availability of the driver for the primary driving task change for normal driving and critical situations?	
Related System	S01 Adaptive Cruise Control S02 Collision Warning	
Related Use Case	USE_ACC_01 USE_CW_01	
Proposed indicator	brake response time	

Estimated impact on			
	Traffic Safety and safety related driving performance	+	driver is more alert: ACC brake intervention prepares the driver to react on events ahead
	Environmental impacts		
	Transport and traffic efficiency		
	Usage, acceptance and trust		

Hypothesis		KEY
The drivers reaction time will increase over time.		**H25**
Related Research Question	How does the availability of the driver for the primary driving task change for normal driving and critical situations?	
Related System	S01 Adaptive Cruise Control	
Related Use Case	USE_ACC_01	
Proposed indicator	brake response time	

Estimated impact on			
	Traffic Safety and safety related driving performance	-	driver relies more and more on the system over time
	Environmental impacts		
	Transport and traffic efficiency		
	Usage, acceptance and trust		

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<table>
<tr><td colspan="3">Hypothesis
Drowsy driving will increase.</td><td>KEY
H26</td></tr>
<tr><td colspan="2">Related Research Question</td><td colspan="2">How does the availability of the driver for the primary driving task change for normal driving and critical situations?</td></tr>
<tr><td colspan="2">Related System</td><td colspan="2">S01 Adaptive Cruise Control
S05 Lane Departure Warning</td></tr>
<tr><td colspan="2">Related Use Case</td><td colspan="2">USE_ACC_01
USE_LDW_01</td></tr>
<tr><td colspan="2">Proposed indicator</td><td colspan="2">percent eye closure (PERCLOS)
drowsiness according to Karolinska sleepiness scale (KSS)
driving time in darkness
trip lenght</td></tr>
<tr><td rowspan="4">Estimated impact on</td><td>Traffic Safety and safety related driving performance</td><td>-</td><td>driver relies more and more on the system over timed
driver underchallenged</td></tr>
<tr><td>Environmental impacts</td><td></td><td></td></tr>
<tr><td>Transport and traffic efficiency</td><td></td><td></td></tr>
<tr><td>Usage, acceptance and trust</td><td></td><td></td></tr>
</table>

<table>
<tr><td colspan="3">Hypothesis
Drowsy driving will decrease.</td><td>KEY
H27</td></tr>
<tr><td colspan="2">Related Research Question</td><td colspan="2">How does the availability of the driver for the primary driving task change for normal driving and critical situations?</td></tr>
<tr><td colspan="2">Related System</td><td colspan="2">S01 Adaptive Cruise Control
S05 Lane Departure Warning</td></tr>
<tr><td colspan="2">Related Use Case</td><td colspan="2">USE_ACC_01
USE_LDW_01</td></tr>
<tr><td colspan="2">Proposed indicator</td><td colspan="2">percent eye closure (PERCLOS)
drowsiness according to Karolinska sleepiness scale (KSS)
driving time in darkness
trip lenght</td></tr>
<tr><td rowspan="4">Estimated impact on</td><td>Traffic Safety and safety related driving performance</td><td>+</td><td>Driver notices increase of warnings when he is tired and avoids drowsy driving</td></tr>
<tr><td>Environmental impacts</td><td></td><td></td></tr>
<tr><td>Transport and traffic efficiency</td><td></td><td></td></tr>
<tr><td>Usage, acceptance and trust</td><td></td><td></td></tr>
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Hypothesis			KEY
Driving comfort will increase.			**H28**
Related Research Question	How does the availability of the driver for the primary driving task change for normal driving and critical situations?		
Related System	S01 Adaptive Cruise Control S04 Speed Limiter S05 Lane Departure Warning S07 Dynamic Navigation		
Related Use Case	USE_ACC_01 USE_LDW_01 USE_NAV_01 USE_NAV_02 USE_SL_01		
Proposed indicator	number of overtakings stress/ mental workload perceived safety (questionnarie)		
Estimated impact on	Traffic Safety and safety related driving performance	+	
	Environmental impacts		
	Transport and traffic efficiency		
	Usage, acceptance and trust	+	high acceptance and usage due to perceived benefits

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Hypothesis			KEY
Visual monitoring of the road will increase.			**H29**
Related Research Question	How does the availability of the driver for the primary driving task change for normal driving and critical situations?		
Related System	S01 Adaptive Cruise Control S04 Speed Limiter S07 Dynamic Navigation		
Related Use Case	USE_ACC_01 USE_SL_01		
Proposed indicator	Percentage eyes on road VDT (Visual detection task) hit rate VDT (Visual detection task) reaction time		
Estimated impact on: Traffic Safety and safety related driving performance	+	increased awareness of the overall situation enables better detection and reaction to unexpected events	
Estimated impact on: Environmental impacts			
Estimated impact on: Transport and traffic efficiency			
Estimated impact on: Usage, acceptance and trust	+	high perceived benefits by reduced workload	

Hypothesis			KEY
Traffic situation awareness (in terms of detection of slower moving vehicles ahead) will decrease over time.			**H30**
Related Research Question	How does the availability of the driver for the primary driving task change for normal driving and critical situations?		
Related System	S01 Adaptive Cruise Control S02 Collision Warning		
Related Use Case	USE_ACC_01 USE_CW_01		
Proposed indicator	shorter time to collision (TTC) at onset of hard braking mean TTC minima number of warnings		
Estimated impact on: Traffic Safety and safety related driving performance	-	longer reaction time to events ahead if they are not covered by ACC	
Estimated impact on: Environmental impacts			
Estimated impact on: Transport and traffic efficiency			
Estimated impact on: Usage, acceptance and trust			

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Hypothesis		KEY
Situation awareness will increase.		**H31**
Related Research Question	How does the availability of the driver for the primary driving task change for normal driving and critical situations?	
Related System	S05 Lane Departure Warning	
Related Use Case	USE_LDW_01	
Proposed indicator	percentage eyes on road percent eye closure (PERCLOS) StwAngleZeroCrossings mean time to line crossing (TLC) proportion of TLC min values < 1 s VDT (Visual detection task) hit rate VDT (Visual detection task) reaction time	
Estimated impact on: Traffic Safety and safety related driving performance	+	
Estimated impact on: Environmental impacts		
Estimated impact on: Transport and traffic efficiency		
Estimated impact on: Usage, acceptance and trust		

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Hypothesis **Situation awareness will decrease over time.**			KEY **H32**
Related Research Question		How does the availability of the driver for the primary driving task change for normal driving and critical situations?	
Related System		S05 Lane Departure Warning	
Related Use Case		USE_LDW_01	
Proposed indicator		percentage eyes on road percent eye closure (PERCLOS) StwAngleZeroCrossings mean time to line crossing (TLC) proportion of TLC min values < 1 s VDT (Visual detection task) hit rate VDT (Visual detection task) reaction time	
Estimated impact on	Traffic Safety and safety related driving performance	-	LDW changes drivers environmental perception (reduced scanning of lanes, lane markings)
	Environmental impacts		
	Transport and traffic efficiency		
	Usage, acceptance and trust		

Hypothesis **Time spent on secondary tasks will decrease.**			KEY **H33**
Related Research Question		How does the availability of the driver for the primary driving task change for normal driving and critical situations?	
Related System		S07 Dynamic Navigation	
Related Use Case		USE_ACC_01	
Proposed indicator		Percentage Eyes off road Percentage Eyes on road Glance duration (mean, max) off road proportion of manual distraction	
Estimated impact on	Traffic Safety and safety related driving performance	+	better road monitoring compared to conventional navigation via paper maps, printed route guidance instructions etc.
	Environmental impacts		
	Transport and traffic efficiency		
	Usage, acceptance and trust		

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Hypothesis			KEY
Glances in the rear-view side mirror will decrease over time.			**H34**
Related Research Question	How does the availability of the driver for the primary driving task change for normal driving and critical situations?		
Related System	S06 Blind Spot Warning		
Related Use Case	USE_BSM_01		
Proposed indicator	number of glances in the rear-view/side mirror		
Estimated impact on: Traffic Safety and safety related driving performance	-	at lane change (motorway, overtaking slower moving vehicle) (city traffic, multiple lanes)	
Estimated impact on: Environmental impacts			
Estimated impact on: Transport and traffic efficiency			
Estimated impact on: Usage, acceptance and trust			

Hypothesis			KEY
Use of alternative/unfamiliar routes will increase			**H35**
Related Research Question	How does route choice change?		
Related System	S07 Dynamic Navigation		
Related Use Case	USE_NAV_02		
Proposed indicator	frequency of usage of unfamiliar routes		
Estimated impact on: Traffic Safety and safety related driving performance	+	dynamic navigation changes drivers willingness to use an unfamiliar/alternative route when a traffic jam occurs on his familiar route	
Estimated impact on: Environmental impacts			
Estimated impact on: Transport and traffic efficiency			
Estimated impact on: Usage, acceptance and trust			

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Hypothesis **Fuel consumption will decrease.**			KEY **H36**
Related Research Question		How does fuel consumption and emissions change?	
Related System		S01 Adaptive Cruise Control S04 Speed Limiter S07 Dynamic Navigation S08 Electronic Stability Control	
Related Use Case		USE_ACC_01 USE_SL_01 USE_NAV_01 USE_NAV_02	
Proposed indicator		average fuel consumption, hot engine, calculated average fuel consumption, hot engine, calculated based on engine driving pattern average fuel consumption cold start calculated average fuel consumption total calculated average fuel consumption measured without fuel temp correction average fuel consumption measured with fuel temp correction	
Estimated impact on	Traffic Safety and safety related driving performance		
	Environmental impacts	+	smoother speed changes and reduced speed less loop ways efficient use of the powertrain
	Transport and traffic efficiency		
	Usage, acceptance and trust		

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Hypothesis **Emissions will decrease.**			KEY **H38**
Related Research Question	How does fuel consumption and emissions change?		
Related System	S01 Adaptive Cruise Control S06 Blind Spot Warning S07 Dynamic Navigation S08 Electronic Stability Control		
Related Use Case	USE_ACC_01 USE_SL_01 USE_NAV_01 USE_NAV_02		
Proposed indicator	average CO2 hot calculated average CO2 cold start calculated average CO2 total calculated		
Estimated impact on: Traffic Safety and safety related driving performance			
Estimated impact on: Environmental impacts	+	smoother speed changes and reduced speed less loop ways in unfamiliar areas efficient use of the powertrain	
Estimated impact on: Transport and traffic efficiency			
Estimated impact on: Usage, acceptance and trust			

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Hypothesis			KEY
Traffic flow performance will increase.			**H39**
Related Research Question	How does the use of road capacity, travel time and travelled km in the traffic system change?		
Related System	S01 Adaptive Cruise Control S04 Speed Limiter S07 Dynamic Navigation		
Related Use Case	USE_ACC_01 USE_SL_01 USE_NAV_02		
Proposed indicator	percentage driving time in congestions mean time per km		
Estimated impact on	Traffic Safety and safety related driving performance		
	Environmental impacts		
	Transport and traffic efficiency	+	more harmonised traffic flows and smoother speed changes with ACC, traffic flow becomes more reliable (capacity becomes slightly more spread). traffic jams are scaled down due to rerouting of approching vehicles smoother speed changes and reduced speed
	Usage, acceptance and trust	+	acceptance due to perceived benefits in terms of improved overall traffic efficiency

Hypothesis			KEY
Use of motorways will increase			**H40**
Related Research Question	How does the use of road capacity, travel time and travelled km in the traffic system change?		
Related System	S01 Adaptive Cruise Control		
Related Use Case	USE_ACC_01		
Proposed indicator	route choice		
Estimated impact on	Traffic Safety and safety related driving performance		
	Environmental impacts		
	Transport and traffic efficiency	+	ACC makes motorways more appealing, this increases the use thereof.
	Usage, acceptance and trust		

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Hypothesis			KEY
Congestions will occur earlier.			**H41**
Related Research Question	How does the use of road capacity, travel time and travelled km in the traffic system change?		
Related System	S01 Adaptive Cruise Control		
Related Use Case	USE_ACC_01		
Proposed indicator	congestion releated costs		
Estimated impact on	Traffic Safety and safety related driving performance		
	Environmental impacts		
	Transport and traffic efficiency	-	Due to ACC, free capacity (before congestion occurs) is smaller; this means that congestion occurs earlier.
	Usage, acceptance and trust		

Hypothesis			KEY
Mean travel time will not change.			**H42**
Related Research Question	How does the use of road capacity, travel time and travelled km in the traffic system change?		
Related System	S04 Speed Limiter		
Related Use Case	USE_SL_01		
Proposed indicator	(mean) travel time		
Estimated impact on	Traffic Safety and safety related driving performance		
	Environmental impacts		
	Transport and traffic efficiency		
	Usage, acceptance and trust		

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Hypothesis			KEY
The amount of congestions will increase over time.			**H43**
Related Research Question	How does the use of road capacity, travel time and travelled km in the traffic system change?		
Related System	S07 Dynamic Navigation		
Related Use Case	USE_NAV_02		
Proposed indicator	congestion releated costs		
Estimated impact on	Traffic Safety and safety related driving performance		
	Environmental impacts		
	Transport and traffic efficiency	-	on alternative routes
	Usage, acceptance and trust		

Hypothesis			KEY
Use of residential roads will decrease.			**H44**
Related Research Question	How does the use of road capacity, travel time and travelled km in the traffic system change?		
Related System	S07 Dynamic Navigation		
Related Use Case	USE_NAV_01		
Proposed indicator	route choice		
Estimated impact on	Traffic Safety and safety related driving performance	-	
	Environmental impacts		
	Transport and traffic efficiency		
	Usage, acceptance and trust		

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Hypothesis **Increased number of km driven.**			KEY **H45**
Related Research Question	How does the use of road capacity, travel time and travelled km in the traffic system change?		
Related System	S07 Dynamic Navigation		
Related Use Case	USE_NAV_02		
Proposed indicator	milage		
Estimated impact on: Traffic Safety and safety related driving performance			
Estimated impact on: Environmental impacts	0	due to usage of longer alternative routes when a traffic jam occurs. Whether this has a pos. or. neg. effect depends on the specific situation.	
Estimated impact on: Transport and traffic efficiency	0	due to usage of longer alternative routes when a traffic jam occurs. Whether this has a pos. or neg. effect depends on the specific situation.	
Estimated impact on: Usage, acceptance and trust			

Hypothesis **Journey efficency will increase.**			KEY **H46**
Related Research Question	How does the use of road capacity, travel time and travelled km in the traffic system change?		
Related System	S07 Dynamic Navigation		
Related Use Case	USE_NAV_01 USE_NAV_02		
Proposed indicator	mean travel time		
Estimated impact on: Traffic Safety and safety related driving performance			
Estimated impact on: Environmental impacts	+	dynamic navigation provides more efficient routings	
Estimated impact on: Transport and traffic efficiency	+	With Dynamic Navigation mean travel time will be reduced.	
Estimated impact on: Usage, acceptance and trust			

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Hypothesis **System use will increase more and more over time.**			KEY **H47**
Related Research Question	How is the system used by different users and in different traffic environment?		
Related System	S01 Adaptive Cruise Control S04 Speed Limiter S05 Lane Departure Warning S06 Blind Spot Warning		
Related Use Case	USE_ACC_01 USE_LDW_01 USE_BSM_01 USE_SL_01		
Proposed indicator	rate of use (percentage or frequency)		
Estimated impact on: Traffic Safety and safety related driving performance			
Estimated impact on: Environmental impacts			
Estimated impact on: Transport and traffic efficiency			
Estimated impact on: Usage, acceptance and trust			

Hypothesis **Usage within urban areas is minor.**			KEY **H48**
Related Research Question	How is the system used by different users and in different traffic environment?		
Related System	S01 Adaptive Cruise Control S05 Lane Departure Warning		
Related Use Case	USE_ACC_01 USE_LDW_01		
Proposed indicator	availablity of the system in xx rate of use (percentage or frequency) in xx		
Estimated impact on: Traffic Safety and safety related driving performance			
Estimated impact on: Environmental impacts			
Estimated impact on: Transport and traffic efficiency			
Estimated impact on: Usage, acceptance and trust	-	drivers will deactivate LDW in cities and on rural roads (due to intentional "cutting corners")	

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Hypothesis			KEY
Usage is less frequent during rush hours (in heavy traffic and congested traffic).			**H49**
Related Research Question	How is the system used by different users and in different traffic environment?		
Related System	S01 Adaptive Cruise Control		
Related Use Case	USE_ACC_01		
Proposed indicator	availability of the system in xx rate of use (percentage or frequency) in xx		
Estimated impact on	Traffic Safety and safety related driving performance		
	Environmental impacts		
	Transport and traffic efficiency		
	Usage, acceptance and trust	-	

Hypothesis			KEY
"Activated and acceleration"-rate increases during rush hour.			**H50**
Related Research Question	How is the system used by different users and in different traffic environment?		
Related System	S01 Adaptive Cruise Control		
Related Use Case	USE_ACC_01		
Proposed indicator	frequency of system status "Activated and acceleration" in xx		
Estimated impact on	Traffic Safety and safety related driving performance		
	Environmental impacts		
	Transport and traffic efficiency		
	Usage, acceptance and trust	0	Drivers accelerate more often to overtake slower vehicles.

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Hypothesis			KEY
Shorter headway times are selected during rush hours.			**H51**
Related Research Question	How is the system used by different users and in different traffic environment?		
Related System	S01 Adaptive Cruise Control		
Related Use Case	USE_ACC_01		
Proposed indicator	selected headway times in xx		
Estimated impact on: Traffic Safety and safety related driving performance			
Estimated impact on: Environmental impacts			
Estimated impact on: Transport and traffic efficiency			
Estimated impact on: Usage, acceptance and trust	0	During rush hour, drivers select a shorter headway time in relation to outside of rush hour with ACC.	

Hypothesis			KEY
Selected headway time depends on the normal driving behavior of the driver.			**H52**
Related Research Question	How is the system used by different users and in different traffic environment?		
Related System	S01 Adaptive Cruise Control		
Related Use Case	USE_ACC_01		
Proposed indicator	selected headway times in xx driver characteristics		
Estimated impact on: Traffic Safety and safety related driving performance			
Estimated impact on: Environmental impacts			
Estimated impact on: Transport and traffic efficiency			
Estimated impact on: Usage, acceptance and trust	0		

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Hypothesis			KEY
Selected headway times will be shorter over time.			**H53**
Related Research Question	How is the system used by different users and in different traffic environment?		
Related System	S01 Adaptive Cruise Control		
Related Use Case	USE_ACC_01		
Proposed indicator	selected headway times in xx		
Estimated impact on	Traffic Safety and safety related driving performance		
	Environmental impacts		
	Transport and traffic efficiency		
	Usage, acceptance and trust	0	

Hypothesis			KEY
Drivers will deactivate the system if frequent warnings are issued			**H54**
Related Research Question	How is the system used by different users and in different traffic environment?		
Related System	S05 Lane Departure Warning		
Related Use Case	USE_LDW_01		
Proposed indicator	frequency of deactivations in x frequency of warnings		
Estimated impact on	Traffic Safety and safety related driving performance		
	Environmental impacts		
	Transport and traffic efficiency		
	Usage, acceptance and trust	-	

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Hypothesis		KEY
Drivers will deactivate the system on narrow roads.		**H55**
Related Research Question	How is the system used by different users and in different traffic environment?	
Related System	S05 Lane Departure Warning	
Related Use Case	USE_LDW_01	
Proposed indicator	frequency of deactivations in x	
Estimated impact on: Traffic Safety and safety related driving performance		
Estimated impact on: Environmental impacts		
Estimated impact on: Transport and traffic efficiency		
Estimated impact on: Usage, acceptance and trust	-	

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Hypothesis			KEY
Drivers rating in the xx scale will exceed nn.			**H56**
Related Research Question		How is the system used by different users and in different traffic environment?	
Related System		S01 Adaptive Cruise Control S04 Speed Limiter S05 Lane Departure Warning S06 Blind Spot Warning S07 Dynamic Navigation S08 Electronic Stability Control	
Related Use Case		USE_ACC_01 USE_SL_01 USE_LDW_01 USE_BSM_01 USE_NAV_01 USE_NAV_02	
Proposed indicator		usability rating acceptance rating comfort of use learnability aesthetics	
Estimated impact on	Traffic Safety and safety related driving performance		
	Environmental impacts		
	Transport and traffic efficiency		
	Usage, acceptance and trust	+	

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Hypothesis **Drivers rating in the xx scale will increase over time.**			KEY **H57**
Related Research Question		How is the system used by different users and in different traffic environment?	
Related System		S01 Adaptive Cruise Control S04 Speed Limiter S05 Lane Departure Warning S06 Blind Spot Warning S07 Dynamic Navigation S08 Electronic Stability Control	
Related Use Case		USE_ACC_01 USE_SL_01 USE_LDW_01 USE_BSM_01 USE_NAV_01 USE_NAV_02	
Proposed indicator		usability rating after xx weeks/months acceptance rating after xx weeks/months	
Estimated impact on	Traffic Safety and safety related driving performance		
	Environmental impacts		
	Transport and traffic efficiency		
	Usage, acceptance and trust	+	

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Hypothesis **Driver errors in system operation (limiter/control, limiter/radio) will arise.**				KEY **H58**
Related Research Question		How is the system used by different users and in different traffic environment?		
Related System		S04 Speed Limiter		
Related Use Case		USE_SL_01		
Proposed indicator		type, number and frequency of errors in system operation		
Estimated impact on	Traffic Safety and safety related driving performance			
	Environmental impacts			
	Transport and traffic efficiency			
	Usage, acceptance and trust	-	confusion between speed limiter and ACC when the car is equipped with both systems.	

Hypothesis **Driver errors in system operation will decrease over time.**				KEY **H59**
Related Research Question		How is the system used by different users and in different traffic environment?		
Related System		S07 Dynamic Navigation		
Related Use Case		USE_NAV_01 USE_NAV_02		
Proposed indicator		Number and frequency of errors in system operation after xx weeks/months		
Estimated impact on	Traffic Safety and safety related driving performance			
	Environmental impacts			
	Transport and traffic efficiency			
	Usage, acceptance and trust	+		

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