TEAM

Tomorrow's Elastic Adaptive Mobility

D5.2.1 Success criteria and evaluation methodology

Dissemination level	RE
Version	1.1
Due date	30.08.2014
Version date	26.09.2014

www.collaborative-team.eu

This project is co-funded by the European Union – DG Connect

Document information

Authors

Author 1 – Frederik Diederichs (Fraunhofer IAO)

Author 2 – Katia Paglé (ICCS – Institute of Communication and Computer Systems)

Author 3 – Villy Portouli (ICCS – Institute of Communication and Computer Systems)

Author 4 – Merja Penttinen (VTT).

Coordinator

Dr. Ilja Radusch

Head of Department Automotive Services and Communication Technologies,

Fraunhofer Institute for Open Communication Systems FOKUS

Kaiserin-Augusta-Allee 31, 10589 Berlin

Tel: +49 30 914 26 36 474

Email: ilja.radusch@fokus.fraunhofer.de

Project funding

7th Framework Programme

FP7-ICT-2011-8, objective ICT-2011.6.7.a

Large scale integrating project (IP)

Grant Agreement No. 318621

Table of contents

List of figures

List of tables

Summary

Deliverable 5.2.1 "Success criteria and evaluation methodology" provides the fundamental requirements for evaluating the TEAM applications. The introduction chapter presents the V-ISO model approach explaining the concept of high level objectives. The high level TEAM objectives are identified in chapter 2 and transformed in high level research questions which help to specify the evaluation research questions, study designs and tools for each application. Chapter 2 explains the process and how those high level research questions have been defined in TEAM. Then it concludes with an overall of 15 high level research questions clustered in three categories: technical evaluation, user acceptance evaluation and impact evaluation.

TECHNICAL HL Research Questions:

1. Does the application support (on a first level) and achieve (on a second level) the dynamic adaptation of the infrastructure?
2. Does the user receive a dynamically adapted output from the application?
3. Does the application support the interaction of multiple and different types of users?

User acceptance HL research questions determine if the users accept elasticity and collaboration.

ACCEPTANCE HL Research Questions:

1. Does the user agree to be and is an active input to the application?
2. Does the user act according to the application output?
3. Is willingness to use high?
4. Is willingness to pay high?
5. Do the users consider usability/ user experience to be good/high?

The impacts HL research questions determine the impact that the TEAM applications have on mobility, efficiency and safety.

IMPACTS HL Research Questions:

1. Does the application have impact on individual behaviour (of users and stakeholders)? (comment: all the other impacts are actually mediated through changes in behaviour)
2. Does the application have an impact (preferably positive) on traffic safety?
3. Does the application have an impact (preferably positive) on traffic efficiency?

4. Does the application have an impact (preferably positive) on environmental load of traffic?
5. Does the application have an impact (preferably positive) on mobility?
6. Do users themselves see positive a community effect from TEAM applications?
7. Which impact can be expected on future applications and use cases due to the new collaborative and social networking based TEAM approach?

Based on high level research questions an intensive process of collecting application specific detailed research questions has been started which is described in chapter 3. Those application specific research questions are reported in the annexes of the deliverable, in separated tables for technical, acceptance and impact evaluation. Tables for technical and acceptance research questions follow the format below:

RQ level 1 (high level research question)	RQ level 2	Hypotheses	Indicators	Measurements / Tools	Relevant for CMC	Relevant for COPLAN	Relevant for CCA	…	Relevant for App. X

Tables for impact assessment have a slightly different format which separates the relevance of the research questions into safety, efficiency, environment and mobility:

RQ level 1 (high level research questions)	RQ level 2	RQ level 3	Hypotheses	Indicators	Measurements / Tools	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility

The research questions are the main guide for evaluation planning and results analysis. The annexes are available as excel sheets and in this document and the research questions, hypothesis and measurements/tools can be updated according to the final state of planning of EuroEco Challenge in WP5.3.

Chapter 4 provides common guidance and specific ideas how to carry out the evaluation in general and specifically for each application. The study design plans are on the one hand generic enough to be relevant for every application and reflecting the current state of knowledge with respect to the planning at test sites and application developments.

Chapter 5 “Evaluation tools” extracted the tools which are planned to be used in the evaluation from the annex tables and delivers a description for each tool. The tools are clustered in the evaluation fields: technical evaluation, user acceptance evaluation and impact evaluation. This table provides an overview.

Technical Tools	User Acceptance Tools	Impact Analysis Tools
Data Logging Tools	Questionnaires	Questionnaires
Data Analysis Tool	Scales	Scales
Data Synchronization tools	Interview	Interview
	Behaviour Monitoring Methods	Behaviour Monitoring Methods
	Use history logging tools	Travel Diary Templates
	Use history analysis tools	Use history logging tools
		Use history analysis tools
		Data Logging Tools
		Data Analysis Tool
		Traffic simulator tools
		Driving simulator tools

The deliverable provides high level research questions and a framework for the research questions, study designs and tools for the tests to be carried out in the EuroEco Challenge of TEAM. This framework plans and structures the final evaluation of TEAM applications and ensures suitable results for the main high level research questions.

1 Introduction

TEAM introduces the new concept of collaborative and elastic mobility, aiming at developing systems for participants in transportation networks, which help them to behave better – by explicitly taking into account the needs and constraints of other participants and the network itself. Collaborative and elastic mobility should be understood as extension of cooperative systems, moving to a concept of elastic infrastructures and collaborative behaviour of travellers and drivers, meaning that information is exchanged and also transferred into decisions and behaviour that enhances the quality, comfort, safety and efficiency for mobility of the TEAM community [1].

1.1 Scope of the deliverable

To find out how users are accepting and adopting the new collaborative transport system, TEAM is developing an evaluation framework, under the EVALUATION sub-project, which addresses the multidisciplinary evaluation of the TEAM vision and applications. The evaluation method used is a progress in state of the art (2) using the framework developed earlier in FESTA [2], DRIVEC2X [4] and TeleFOT [5] projects and including the SAFESPOT evaluation approach [6]. The scope of the evaluation is not limited to private car drivers, but will cover all travellers travelling by various modes, including multimodality.

The TEAM areas of interest for the evaluation are the following:

- The assessment of technical performance and technical feasibility of TEAM applications.
- The assessment of the potential for user acceptance, namely travellers and infrastructure operators.
- The impact assessment on traffic flow, efficiency, environmental issues, and mobility.

Technical performance of applications is studied with respect to correctness, reliability and real-time performance. Besides the technical performance optimization and debugging during the adaptation and integration procedures a final technical evaluation is carried out during the Euro-EcoChallenge, monitoring the technical performance of the components and applications and comparing the results to the technical success criteria.

User acceptance of collaborative systems is studied, as well as usability, user experience and users' willingness to participate in the new collaborative transport system. The results are interpreted in terms of future potential to deploy collaborative systems.

One main focus of SP5 will be to provide evidence of the additional value of a wide system deployment for different parties. The tools to be utilized for impact evaluation have been developed in previous related projects and thus enable cost-efficient TEAM impact evaluation.

This Deliverable contributes to the generic objective of the EVALUATION sub-project as it presents the following three main outcomes of the work carried out in WP5.2:

- The TEAM High Level Objectives (HLOs) of TEAM are defined and high level research questions are specified. The research on those research questions will allow specifying the extent to which the TEAM applications reach the generic high level objectives.
- Further to this, the deliverable contains recommendations on study designs, specifically for empirical technical evaluations, user acceptance evaluations and impact evaluations.
- Finally, it contains specific tools which are planned to be used in the TEAM evaluation, reaching from data logging tools over simulations to scales and questionnaires.

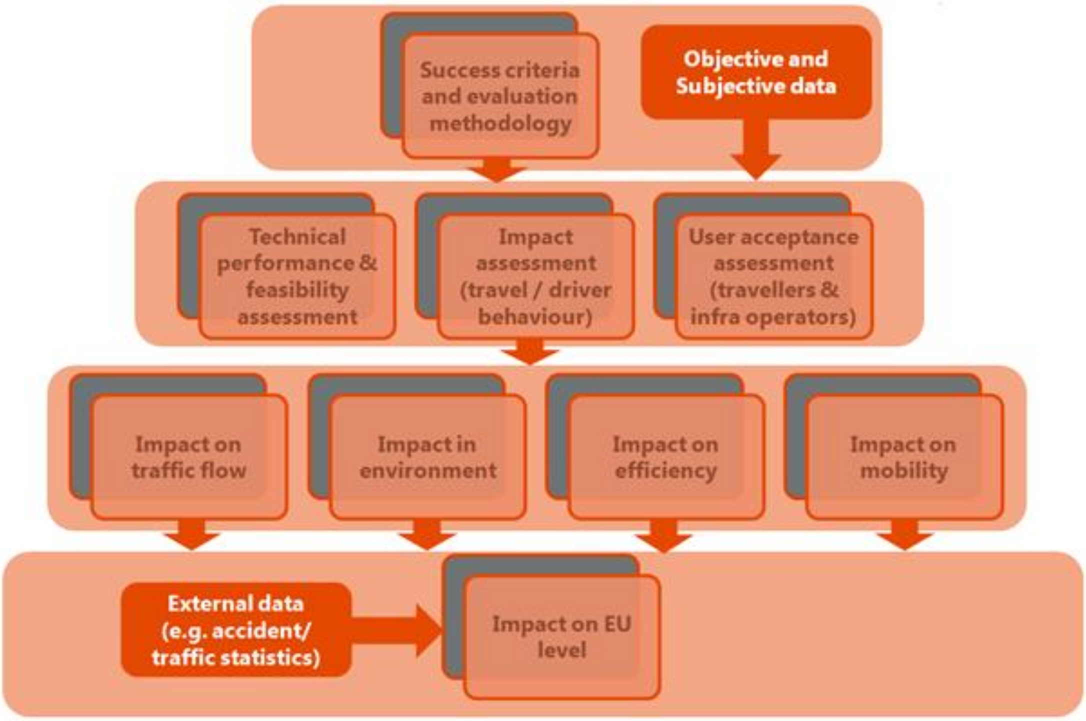


Figure 1.1: From the evaluation methodology to the impact on EU level.

Evaluation is a multidisciplinary activity combining several approaches and methodologies. The evaluation activities include the definition of objectives, hypotheses and success criteria in the beginning of the project. This is important to evaluate the actual performance and impact against the pre-defined criteria and thresholds. For this reason, the next chapter introduces a generic development model which shows how evaluation is fully integrated into development.

1.2 Evaluation as part of development

A development process model includes evaluation as a main activity of development. The basic idea behind this is to focus the development on the main requirements and prove in the evaluation that these requirements are actually met. This chapter provides a model that describes this approach and explains the approach followed in SP5 to first define high level research questions and then start a focused evaluation.

For a common understanding of the requirements definition and evaluation approach a model is needed that is understood by all researchers and developers. Whereas a remarkable variety of process models do exist for both system and human factors engineering, [7] introduced in the SAFEWAY2SCHOOL EU R&D project [8] the V-ISO model, which is a fusion of the V-model [10] and the DIN EN ISO 9241-210 [9] and allows to bring system engineering mindset together with human factors approaches. A short introduction is given on V-model and DIN EN ISO 9241-210 before the fusion of both in the form of the V-ISO model is introduced which guides the approach of this deliverable.

1.2.1 The V-Model:

Since the 1980s the V-model is a well-established and popular development method in the systems engineering sciences. There are many versions of the V-model which – depend on the specific application – utilized, so this description only covers the basic idea of the approach as it is displayed in the figure below.

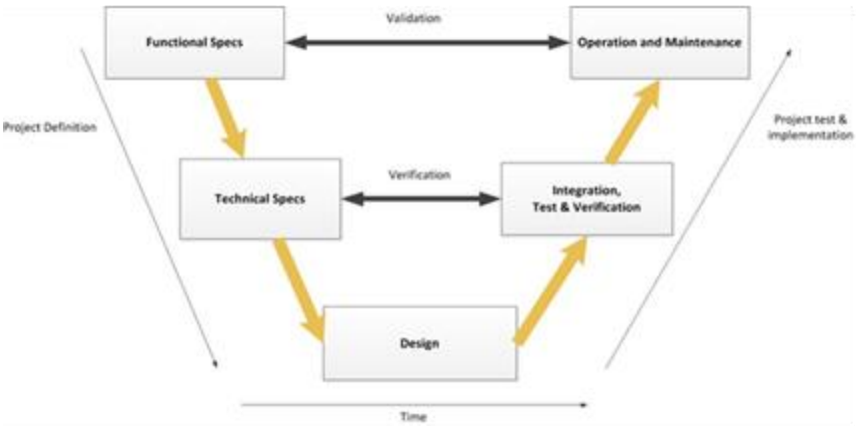


Figure 1.2: V-Model.

The V-model can be de divided in 2 branches that form a V. The left branch defines a line of action which generates requirements the system must meet. The V-model follows a chronological order. First the generic goals that the system should meet are defined. From these goals, specific functional requirements which are executed in the system are defined. Subsequently technical requirements are derived that fulfill the above defined functional requirements. After that, the product developing and design steps are derived from the technical requirements.

At the pivotal point of the V the specifications are implemented to a product. The right branch covers the validation of the system. Here, firstly the single components are tested to meet the technical requirements. If the component tests are successful, the complete system is validated against the functional requirements.

The whole process is strictly hierarchical and chronological so that every step must be carried out in the same order and that every subsequent step is built on the previous steps. This unveils both the strengths and weaknesses of the V-model. On the one hand, this model is easy to understand and enhances project monitoring: It is clear at which time which professional has to carry out which task.

On the other hand this has the disadvantage that a correction of the requirements on the left branch affects all following steps and cannot or may hardly be eliminated. Thus the V-model is to some extend inflexible and requires a lot of professionalism in its execution. For human factors specialists the V-Model is for this reason impractical since in their mindset of an iterative product development it is essential to update the requirements which may change when users getting aware of more and more elaborated prototypes. Human factors specialists prefer the EN ISO 9241-210 –Model.

1.2.2 The EN ISO 9241-210 -Model:

The standard DIN EN ISO 9241-210 provides guidance for an iterative human centered design process for interactive systems. A figure of the process can be seen below. According to ISO the process starts with an overall choice to make use of the process.

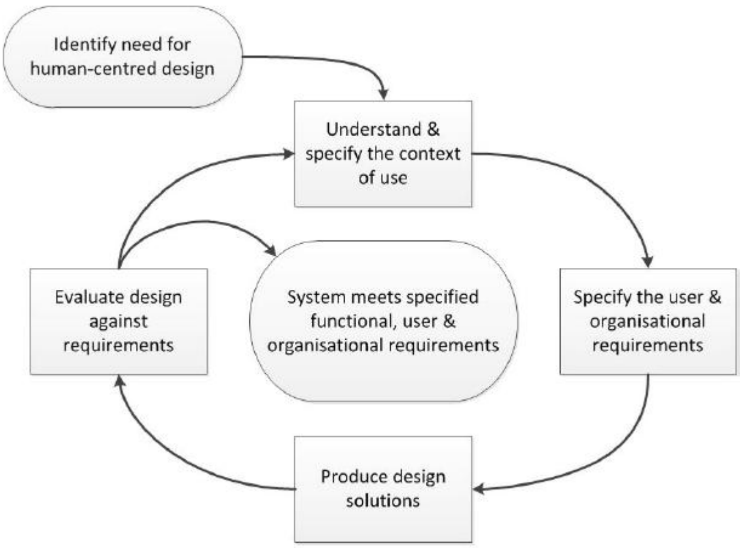


Figure 1.3: Process of the EN ISO 9241-210-Model.

Initially, the context of use is analysed and specified. Characteristics about the user, tasks, and the context, where the system will be used, are collected. This step can not only be applied to develop systems but also in order to improve existing systems.

In the next step, user and organizational requirements are derived.

Subsequently, a design solution which meets the requirements is developed. Here it is also possible to develop a prototype or mockup version which is iteratively tested and improved by repeating the models circle.

In the last step the finalised design is evaluated with previously postulated requirements. In case the system does not meet the requirements, it can either be improved - especially when there are only small derivations - or the whole process starts again from the first step and the specifications and requirements are adjusted until the developed system meets all requirements. According to Diederichs [7], it is quite common that two to four iterative cycles are undertaken to achieve a satisfactory version of the system.

The strengths of this model are its iterative approach that enables a high degree of flexibility to unforeseen conditions and its user orientation. However, it is hard to define and find a stop criterion, since everything can be questioned again and again in this model.

Another weakness of this model is that the dependencies between all development steps make it difficult to subdivide these steps to single work packages that can be executed separately and chronological by different teams; instead the complete development team is constantly involved in the process. The V-ISO model provides such an approach.

1.2.3 The V-ISO-Model:

The V-ISO model combines the advantages of both the V- and the ISO-model. It is described in detail by Diederichs [7]. Visualization is provided in figure 1.4 below.

The V-ISO model consists of two branches and connecting loops. The development starts on top of the left branch. High level objectives are defined for the system development. These objectives may still be vague and on a very high level but they contain the essence of what is expected from the system, or, in case of TEAM, they provide the main high level research questions that shall be investigated by developing and evaluating the TEAM applications. The high level research questions are typically derived from the expected impacts described in the project work plan and from expectations formulated by the funding organization. To serve as development guidance, they need to be agreed by the project's management group. The SP5 main scope is the definition of research questions and evaluation of research questions' results in the use cases.

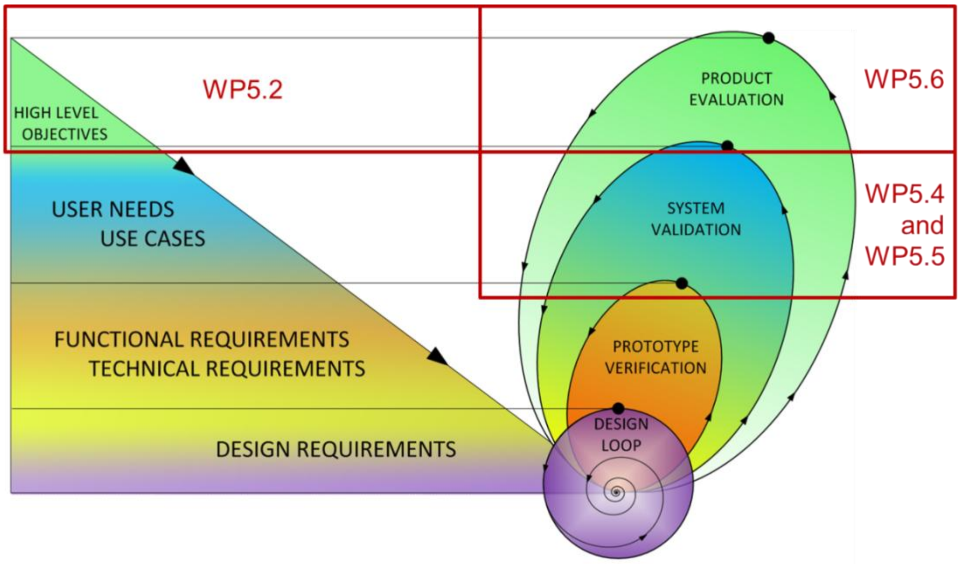


Figure 1.4: The V-ISO Model [7].

In the model the use cases and user needs that the system should cover should be collected in order to focus the developments on the most relevant use cases for not wasting resources. In TEAM the use cases have been selected together with the TEAM stakeholders in an online survey (SP6) and are already specified in D1.0, where this deliverable refers to.

Subsequently, technical requirements that are needed to achieve the objectives are derived. This work has been carried out in SP2, 3 and 4. In the last step of the left branch of the model the design requirements are defined. In TEAM this is a work carried out in SP3 and SP4.

On the right branch, the development of the product takes place, starting with a design loop enabling a user centered and iterative HMI development process. Especially SP4, but also SP3 include such steps in their developments.

When the design requirements are met or adjusted, based on the design testing results, the design loop is completed and analogous to the V-model. In the subsequent steps a prototype or individual system components can be checked against the technical requirements. This work is also part of the development SPs.

Within SP5 the system evaluation is carried out in use cases during the EuroEco Challenge. This is done in WP 5.4 and WP5.5. Here the research questions and hypothesis from this deliverable shall be tested. A final assessment of the TEAM applications and their fitting to the TEAM high level research questions concerning technical performance, user acceptance and impact will be part of WP5.6.

It is important to state that the evaluation in TEAM will be carried out with prototypes which may have limitations in terms of possible use cases and wide spread application. For this reason the users involved in testing shall be instructed to take into account either the limited functionality imagining a complete implementation or to judge only the specific function they have experienced regardless the possible limitations they may expect for the prototype. The WP5.6 analysis will consider these limitations when assessing the potentials for products.

2 Method for defining the TEAM high level research questions

The method followed to conclude the TEAM HLOs and Research Questions (RQs) is presented in this section. The HLO are transferred into fixed and agreed High Level research Questions which shall not be changed anymore. However the application specific RQs may be updated on the basis of the experience accumulated during the first analyses of the data from pilot tests and/or the Euro-EcoChallenge. The current status represents the knowledge available at the point of writing. Potential updates will be included in the reports that follow the Euro-EcoChallenge.

The deliverable also constitutes, as one of the major outcomes of WP5.2, the commonly agreed templates to collect and categorize the RQs in a final stage.

The following sub-chapters explain the work done on HLO, RQ and template definition and the results achieved.

2.1 High Level Objectives definition

The first step of the activities was the collection of TEAM high level objectives (HLO) and vision by analysing project planning and funding documents, discussions with project management and risk assessing for the TEAM applications. This work feeds (top down) the definition of research questions, study designs and evaluation tools for the TEAM Euro EcoChallenge.

The identified TEAM HLOs have then been used for the first big stakeholder web questionnaire, in which the High Level Research Questions were complemented, and finally selected.

In the following sections the sources which were used to define the HLOs are presented.

2.1.1 TEAM vision and rationale

Firstly, the TEAM vision and rational was analysed. This is specified very well to the point in the TEAM DoW to be:

TEAM envisions an integrated mobility system, where travellers, drivers, vehicles and the infrastructure construct a seamless and sustainable collaborative network. Collaboration is the key concept towards enhanced and environmentally aware mobility for all citizens, building on cooperative systems, reliable real-time data, and on active participation of all network actors.

2.1.2 TEAM main objectives

Secondly, the TEAM main objectives were analysed, as these are stated in the DoW. The core objective of TEAM is to:

Create an elastic and collaborative mobility management system; test, demonstrate, and evaluate its benefits in various environments.

TEAM responds to this main objective by moving from a concept of static to adaptive mobility by:

1. moving to a concept of elastic infrastructures and collaborative behaviour of travellers and drivers,
2. making infrastructures change pro-actively and in real-time based on user needs (and also vice versa) and by making mobility behaviour change based on the infrastructure demands,
3. making use of data-driven operations enabled by novel data aggregators, cloud computing and interaction between all nodes of the envisaged mobility network namely of the travellers, vehicles and infrastructure.

TEAM is built on benefits that will accrue in making the transition from static concept of mobility arising from the needs of individual road users only to a community-aware and adaptive concept of mobility using reliable real-time, system-wide data, capturing the needs and intentions of all travellers by monitoring interactions among all network actors including the travellers, vehicles and infrastructure operators. Community-awareness refers to actions making road users to follow collaborative strategies that benefit all road users as a group. Adaptive mobility refers to the ability of the road operator to capture the needs of all road users and respond to them, and vice versa to indicate its changing needs and goals towards road users, using bidirectional technologies. Furthermore, it emphasizes on the ability to respond to the changing needs and goals of drivers and travellers, creating a novel highly elastic road infrastructure.

A key enabler of this is the fact that today there is a widespread use of smart-phones and positioning technologies in traffic. Cooperative communication is taken firmly on the roadmap of many leading car manufacturers, suppliers and infrastructure companies. Field-operational testing like DRIVE C2X will mature the technology and the accompanying standards. Moreover, there is a growing awareness of the pressing need to address future mobility problems holistically by municipal, regulatory and standardization bodies. This makes it possible, for the first time within TEAM, to extensively and in a fully integrated way tackle, through distributed and eco-friendly collaborative optimizations, important problems with active, real-time participation from all interested stakeholders, such as car manufacturers, suppliers, telecommunication and road infrastructure operators, who coexist and operate in parallel, employing also available bi-directional communication technologies to interact with road users.

2.1.3 Technical objectives

Moreover, the technical objectives of TEAM were analysed. TEAM identifies the following six major technical objectives:

Table 2.1: Technical objectives.

Technical Objectives	Relevant SP
1. Define adaptive and elastic TEAM concept by specifying overall collaborative decision making and control algorithms.	**SP2 EMPOWER**
2. Create the technological building blocks for seamless and ubiquitous communication and computation on vehicles, smart phones and in the Cloud.	**SP2 EMPOWER**
3. Develop algorithms for real-time aggregation of road users' and operators' needs to find collaborative Pareto-improvements on the default autonomous decisions.	**SP3 FLEX**
4. Enable road users to perceive the individual and collective benefits and fill the need of adopting those improvements to achieve a clean, efficient, and safe mobility as a new life style on the move.	**SP4 DIALOGUE**
5. Quantify the technical performance and impacts on mobility, efficiency, and the environment, so as to address deployment issues for such services.	**SP5 EVALUATION**
6. Promote community-aware and adaptive mobility concept among all relevant professional stakeholder groups, thus supporting the exploitation of the TEAM results.	**SP6 SUPPORT**

2.1.4 Stakeholder survey

Next, the results of the first stakeholder survey of TEAM were analysed, which were implemented by an online survey. The expert ranking resulted to the selection of the TEAM applications and the survey itself provided valuable input to all TEAM sub-projects.

The analysis of the stakeholder survey resulted in the final selection of applications, which will be implemented within the TEAM project. A detailed review of the first stakeholder survey is provided in Section 2.3 of TEAM Deliverable 1.0 [11] and the list is provided in table 2.2 below.

Table 2.2: TEAM Applications.

SP	No.	Application full name	Abbreviated name
FLEX	1	Collaborative pro-active urban/inter-urban monitoring and ad-hoc control	CMC
	2	Collaborative co-modal route planning	COPLAN
	3	Co-modal coaching with support from virtual/avatar users	CCA
	4	Collaborative smart intersection for intelligent priorities	CSI
	5	Collaborative public transport optimization	CPTO
	6	Collaborative dynamic corridors	DC
DIALOGUE	7	Collaborative adaptive cruise control	C-ACC
	8	Collaborative eco-friendly parking	EFP
	9	Collaborative driving and merging	CDM
	10	Green, safe and collaborative driving serious game and community building	SG-CM
	11	Collaborative eco-friendly navigation	CONAV

The applications are specified in TEAM Deliverables 3.3.1 entitled "FLEX requirements and initial specifications" [12] and 4.3.1 entitled "Requirements of DIALOGUE components, enablers and applications" [13]. The initial specification of the TEAM applications feeds the formulation of the research questions and success criteria of TEAM.

Moreover, one particular focus of the web survey was the collection of additional research questions in the form of risks per application area. The survey results were analysed by each sub project and results of the analyses were included in TEAM Deliverable 1.0, titled "TEAM users, stakeholder and use cases" [11] in sections 3.5, 4.2 and 5.2 respectively.

Closely related to the formulation of the TEAM HLOs and high level research questions are the open comments provided by participants about the technical risks of the TEAM applications.

For example, for the DIALOGUE applications data management and processing raised concerns, especially for the heterogeneity of the collected data that may lead to comparability issues. Accuracy is often recalled as a key factor, seen as possibly tackling for most applications (e.g.

accuracy of parking detection for collaborative parking, of vehicle detection for driving and merging, etc.). When it comes to the business case some additional concerns were raised, namely:

- The actual interest for end users and therefore their willingness to pay for such applications
- The ownership of the application and therefore the ownership of related costs
- The attractiveness of the revenues generated

Moreover, from subjective answers, it becomes clear that end user acceptance is strongly connected with systems reliability, a clear interpretation of the systems' instructions (and therefore the discouragement of misbehaviours), and a generalised users' uptake that is of primary importance for the adoption of such technologies. Some of the concerns raised by stakeholders regard the over-confidence that users may put in the system, leading thus to safety issues.

Other relevant issues pointed out regard legal aspects (especially responsibility, liability, data security and privacy) and organizational aspects, especially the need of a considerable amount of equipped vehicles as a requirement for the applications to work properly.

These issues have been taken into account during the formulation of the high level research questions (top-down) but were mainly used during the definition of the way to measure the extent to which the TEAM applications reach the generic objectives of TEAM (bottom up), i.e. during the definition of the detailed research questions and success criteria.

2.2 High Level Research Questions

Following the analysis of the aforementioned sources, it was possible to define the HLOs and translate them into high level research questions (HL research questions). The intention of a pre-definition of such high level research questions is that the development of applications and the planning of the evaluation can be focused on exactly meeting the high level research questions and thus spending resources efficiently on reaching the high level objectives.

High level research questions were grouped into three main evaluation fields:

- The assessment of technical performance and technical feasibility of TEAM applications.
- The assessment of the potential for user acceptance, namely travellers and infrastructure operators.
- The assessment of the impacts on traffic flow, efficiency, safety, environmental issues, and mobility.

The high level research questions which shall be answered by the obtained evaluation results are presented hereafter.

The technical HL research questions shall determine if the TEAM applications can promote elasticity and collaboration.

TECHNICAL HL Research Questions:

4. Does the application support (in a first level) and achieve (in a second level) the dynamic adaptation of the infrastructure?
5. Does the user receive a dynamically adapted output from the application?
6. Does the application support the interaction of multiple and different types of users?

User acceptance HL research questions determine if the users accept elasticity and collaboration.

ACCEPTANCE HL Research Questions:

6. Does the user agree to be and is an active input to the application?
7. Does the user act according to the application output?
8. Is willingness to use high?
9. Is willingness to pay high?
10. Do the users consider usability/ user experience to be good/high?

The impacts HL research questions determine the impact that the TEAM applications have on mobility, efficiency and safety.

IMPACTS HL Research Questions:

8. Does the application have impact on individual behaviour (of users and stakeholders)? (comment: all the other impacts are actually mediated through changes in behaviour)
9. Does the application have (a positive) impact on traffic safety?
10. Does the application have (a positive) impact on traffic efficiency?
11. Does the application have (a positive) impact on environmental load of traffic?
12. Does the application have (a positive) impact on mobility?
13. Do users themselves see positive community effect of TEAM applications?
14. Which impact can be expected on future applications and use cases due to the new collaborative and social networking based TEAM approach?

When we answer the above HL research questions we figure out if the TEAM applications address the TEAM HLO.

The next chapter is devoted to the presentation of the TEAM research questions grouped and summarized in accordance to the TEAM areas of interest for the evaluation:

- The assessment of technical performance and technical feasibility of TEAM applications.
- The assessment of the potential for user acceptance, namely travellers and infrastructure operators.
- The assessment of the impacts on traffic flow, efficiency, environmental issues, and mobility.

3 Application specific research questions

The research questions (RQs) per TEAM evaluation area and application are presented in this section. First the technical research questions and success criteria are presented, followed by the user acceptance and concluding with the impact evaluation. The specific RQ guide the definition of hypothesis and also questions to the users.

All specific research questions are collected in an excel file which is also presented in the annexes of this deliverable. The application specific research questions are based on current state of knowledge and may be subject to changes and extension during the specific planning of test cases in the pilot sites. Since the research questions only represent current state of knowledge the annex tables are not completely filled in all cells. The annex remains as a living document and will be updated during specification of test cases. A final version will be available when results analysis starts in WP5.5 and WP5.6.

Also hypothesis are not yet specified and the respective cells in the annex are currently empty. It will be important to specify the hypothesis but this is only possible when the specific test planning is conducted and the limitation of technical performance and test sites are fully known.

Indicators, measurements and tools to be applied are important information in the annex tables. As for the research questions updates may be included when the specific test cases are planned. So far all foreseeable details are included in the tables and are taken into account in the chapter number 4 “evaluation approaches and study designs” and chapter number 5 “evaluation tools”.

3.1 Technical research questions

For the formulation of the technical research questions a combination of top-down bottom-up approaches were deployed. This included the following steps:

1. Cover all aspects of the technical high level research questions (top down)
2. Formulate more detailed research questions and hypothesis based on the initial functions specifications
3. Select the research questions according to importance (justified by current literature, experts perception and the strength of contribution to the technical evaluation)
4. The feasibility of answering the associated hypotheses, limited by a knowledge of the data to be collected (bottom up)
5. The open comments provided by participants of the stakeholder survey about the technical risks of the TEAM applications (bottom up)

The template used to define the RQs and success criteria for the evaluation of impacts is presented in the next section, while an example of the CPTO application follows. The filled templates for all applications are presented in the Annex of this deliverable and represent the detailed results achieved in WP5.2 concerning the definition of research questions, study designs and evaluation tools.

3.1.1 Template presentation

The columns of the template are presented hereafter, followed by the template itself, so as the reader acquires a full picture of the template used.

Template contents:

- Research questions: Research questions were written in a question format. Two levels of research questions can be distinguished; the first level represents the technical high level research questions, while the second level provides detailed research questions that allow deriving specific hypotheses.
- Hypotheses: A Hypothesis is "a specific statement linking a cause to an effect and based on a mechanism linking the two. It is applied to one or more functions and can be tested with statistical means by analysing specific performance indicators in specific scenarios. A hypothesis is expected to predict the direction of the expected change." Here all hypotheses are posed on travel and driver behaviour. Hypotheses are written in sentence format. They include the measure in which the impact will be measured, the direction of impact (increase vs. decrease), the conditions in which the impact is supposed to happen and a reason why an impact is expected. There may be several hypotheses for a single

research question. The process of formulating hypotheses translates the general research questions into more specific and statistically testable hypotheses.

- Indicators: Indicator is determined for each hypothesis. Performance indicators are qualitative or quantitative measurements, agreed on beforehand, expressed as a percentage, index, rate or value, which is monitored at regular or irregular intervals and can be compared with one or more criteria.
- Measurements: Measurement defines how the indicator is measured. A measure does not have a "denominator". Therefore it is not in itself comparable to other instances of the same measure or to external criteria. The measure itself, however, can very well be a fraction (like speed). Several performance indicators can use the same measures as input, and the same measures can be derived from different types of sensors.
- Relevancy: Cells to mark the relevancy of each hypothesis for each impact area (travel and driver behaviour, safety, efficiency, environment, and mobility) so as to summarize the importance of the hypotheses with respect to the HL research question and specific for each application.

The actual template is presented in a tabular format hereafter.

Table 3.1: Template for the definition of Technical RQs and success criteria.

RQ level 1 (high level research question)	RQ level 2	Hypotheses	Indicators	Measurements / Tools	Relevant for CMC	Relevant for COPLAN	Relevant for CCA	…	Relevant for App. X
L1-RQ1	L2-RQ1.1	H1.1.1…	…	…					
…	…	…							
…	…	…							
L1-RQn.j	L2-RQn.j.x	Hn.j.x.y							

3.1.2 Example Application

Table 3.2: Hypothesis, indicators, measurements and tools to analyse the technical performance and feasibility of the CPTO-application on users' interaction.

Hypotheses	Indicator	Measurement / Tools
Multiple travellers interact among themselves	Mobile device data logs	Mobile device data logs / Data logging tool / Data analysis tool
The operator interacts with travellers	Provision of information to the travellers	Log travellers' mobile device events (information from operator) / Observation on real time bus schedule and events
The operator interacts with bus drivers	Bus route modification	Bus route Schedule log and events

Hypotheses, indicators and measurements to analyse the performance of CPTO-application on users interaction, which is relevant to the third technical HL research question "Does the application support the interaction of multiple and different types of users?", which is further detailed into the research question "Does the application promote the collaborative behaviour of users (operator, travellers and driver)?"

3.2 User acceptance research questions and success criteria

For the formulation of the user acceptance research questions a combination of top-down bottom-up approaches was deployed. This included the following steps:

1. Cover all aspects of the acceptance high level research questions (top down)
2. Formulate more detailed research questions and hypothesis based on the initial functions specifications
3. Select the research questions according to importance (justified by current literature, experts perception and the strength of contribution to the acceptance evaluation)
4. The feasibility of answering the associated hypotheses, limited by a knowledge of the data to be collected (bottom up)
5. The open comments provided by participants of the stakeholder survey about the acceptance risks of the TEAM applications (bottom up)

The template used to define the RQs and success criteria for the evaluation of user acceptance is presented in the next section, while an example for the C-ACC application follows. The filled templates for all applications are presented in the Annex.

3.2.1 Template presentation

The contents of the template are presented hereafter, followed by the template itself, so as the reader acquires a full picture of the template used in order to define the impact assessment RQs and research criteria.

Template contents:

- Research questions: Research questions were written in a question format. Two levels of research questions can be distinguished; the first level represents the technical high level research questions, while the second level provides detailed research questions that allow deriving specific hypothesis.
- Hypotheses: A Hypothesis is "a specific statement linking a cause to an effect and based on a mechanism linking the two. It is applied to one or more functions and can be tested with statistical means by analysing specific performance indicators in specific scenarios. A hypothesis is expected to predict the direction of the expected change." Here all hypotheses are posed on travel and driver behaviour. Hypotheses are written in sentence format. They include the measure in which the impact will be measured, the direction of impact (increase vs. decrease), the conditions in which the impact is supposed to happen and a reason why an impact is expected. There may be several hypotheses for a single research question. The process of formulating hypotheses translates the general research questions into more specific and statistically testable hypotheses.
- Indicators: Indicator is determined for each hypothesis. Performance indicators are qualitative or quantitative measurements, agreed on beforehand, expressed as a percentage, index, rate or value, which is monitored at regular or irregular intervals and can be compared with one or more criteria.
- Measurements: Measurement defines how the indicator is measured. A measure does not have a "denominator". Therefore it is not in itself comparable to other instances of the same measure or to external criteria. The measure itself, however, can very well be a fraction (like speed). Several performance indicators can use the same measures as input, and the same measures can be derived from different types of sensors.
- Relevancy: Cells to mark the relevancy of each hypothesis for each impact area (travel and driver behaviour, safety, efficiency, environment, and mobility) so as to summarize the importance of the hypotheses with respect to the HL research question and specific for each application.

The actual template is presented in a tabular format hereafter.

Table 3.3: Template for the definition of Acceptance RQs and success criteria.

RQ level 1 (high level research question)	RQ level 2	Hypotheses	Indicators	Measurements	Relevant for CMC	Relevant for COPLAN	Relevant for CCA	…	Relevant for App. X
L1-RQ1	L2-RQ1.1	H1.1.1…	…	…					
…	…	…							
…	…	…							
L1-RQn.j	L2-RQn.j.x	Hn.j.x.y							

3.2.2 Example Application

Table 3.4: Hypothesis, indicators, measurements and tools to analyse the user acceptance of C-ACC application.

Hypothesis	Indicator	Measurement
Drivers agree that their location, speed, direction and acceleration are communicated to other vehicles.	Drivers accept that vehicle dynamics are shared through V2V communication	CAN data log / GPS data log / Accelerometer data log /Questionnaire / Scales / Behaviour analysis / Use history logger
Drivers agree that their location, speed, direction and acceleration are communicated to the infrastructure.	Drivers accept that vehicle dynamics are available through V2I communication	CAN data log / GPS data log / Accelerometer data log / Questionnaire / Scales / Behaviour analysis / Use history logger

Hypotheses, indicators and measurements to analyse the impacts of C-ACC-application which is relevant to the first acceptance related HL research question "Does the user agree to be and is an active input to the application?", which is further detailed into the research question "Do drivers accept that their location, direction, speed and acceleration is transmitted to the application?".

3.3 Impact evaluation research questions and success criteria

For the formulation of the impact research hypotheses a combination of top-down bottom-up approaches was deployed. This included the following steps:

1. Cover different aspects of travel and driver behaviour (top – down)

2. Mediate impacts by changes in travel and driver behaviour
3. Creation of a theoretical structure for all impact areas
4. Copy the hypotheses from behaviour to other impact areas
5. Select relevant hypotheses and complement wording for each function (bottom – up)

The template used to define the RQs and success criteria for the evaluation of impacts is presented in the next section, while an example for the COPLAN application follows. The filled templates for all applications are presented in Annex 3.

3.3.1 Template presentation

The contents of the template are presented hereafter, followed by the template itself, so as the reader acquires a full picture of the template used in order to define the impact assessment RQs and research criteria.

Template contents:

- Research questions: Research questions were posed on travel and driver behaviour and grouped. Research questions were written in a question format. Three levels of research questions can be distinguished; the first level directly addresses the impact high level research questions, the second level provides the area of interest (e.g. mode choice) and the third provides the formulated research question.
- Hypotheses: A Hypothesis is "a specific statement linking a cause to an effect and based on a mechanism linking the two. It is applied to one or more functions and can be tested with statistical means by analysing specific performance indicators in specific scenarios. A hypothesis is expected to predict the direction of the expected change." Here all hypotheses are posed on travel and driver behaviour. Hypotheses are written in sentence format. They include the measure in which the impact will be measured, the direction of impact (increase vs. decrease), the conditions in which the impact is supposed to happen and a reason why an impact is expected. There may be several hypotheses for a single research question. The process of formulating hypotheses translates the general research questions into more specific and statistically testable hypotheses.
- Indicators: Indicator is determined for each hypothesis. Performance indicators are qualitative or quantitative measurements, agreed on beforehand, expressed as a percentage, index, rate or value, which is monitored at regular or irregular intervals and can be compared with one or more criteria.
- Measurements: Measurement defines how the indicator is measured. A measure does not have a "denominator". Therefore it is not in itself comparable to other instances of the same

measure or to external criteria. The measure itself, however, can very well be a fraction (like speed). Several performance indicators can use the same measures as input, and the same measures can be derived from different types of sensors.

- Relevancy: Cells to mark the relevancy of each hypothesis for each impact area (travel and driver behaviour, safety, efficiency, environment, and mobility) so as to summarize the importance of the hypotheses.

The actual template is presented in a tabular format hereafter.

Table 3.5: Template for the definition of Impact RQs and success criteria.

RQ level 1 (high level research questions)	RQ level 2	RQ level 3	Hypotheses	Indicators	Measurements / Tools	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
HL- RQ1	L1-RQ1.1	L2-RQ1.1.1	H1.1.1.1 …						
HL-RQ2	…	…	…						
…	…	…	…						
HL-RQn	L1-RQn.j	L2-RQn.j.x	Hn.j.x.y						

One excel file was used for each of the TEAM applications, including the research questions for all impact areas under investigation in TEAM (travel and driver behaviour, safety, efficiency, environment, and mobility).

3.3.2 Example Application

The impact of COPLAN-application (Collaborative Co-Modal Route Planning) was analysed by analysing the potential changes in user behaviour. The HL research questions: "Is there a change in the use of modes?" and "Is there a change in use of multimodal travelling?" were further analysed into detailed hypotheses (table below). In addition, the preliminary methodologies to gather the information and the indicators were listed for each hypothesis.

Table 3.6: Hypothesis, indicators and measurements to analyse the impacts of COPLAN-application into the mode choice.

Hypothesis	Indicator	Measurement / Tools
There is an increase in the use of public transport for commuting because COPLAN supports multimodal travelling, and may hence encourage people to use public transit for at least part of their trip (instead of their own car for the whole trip)	Increased use of public transport per commuting journey	Behaviour measures, subjective impression measures / Questionnaire / Scales / Interview / Behaviour Monitoring Methods / Travel Diary Templates / Use history logging tools / Use history analysis tools
There is an decrease in the use of car for commuting because COPLAN supports multimodal travelling	Increased use of car per commuting journey	Behaviour measures, subjective impression measures / Questionnaire / Scales / Interview / Behaviour Monitoring Methods / Travel Diary Templates / Use history logging tools / Use history analysis tools
There is an increase in the use of bicycle or walking for commuting because COPLAN supports multimodal travelling	Increased use of bicycle or walking per commuting journey	Behaviour measures, subjective impression measures / Questionnaire / Scales / Interview / Behaviour Monitoring Methods / Travel Diary Templates / Use history logging tools / Use history analysis tools
There is an increase in the use of public transport for other journeys than commuting because COPLAN supports multimodal travelling	Increased use of public transport per non-commuting journey	Behaviour measures, subjective impression measures / Questionnaire / Scales / Interview / Behaviour Monitoring Methods / Travel Diary Templates / Use history logging tools / Use history analysis tools

4 Evaluation approaches and study design

4.1 Overview of the evaluation areas and study designs

Technical performance of the TEAM-applications will be evaluated with respect to coverage, correctness, reliability and real-time performance, but also topics such as security and privacy will be addressed, investigating risks and mitigation measures. The technical performance is investigated and stepwise enhanced during the adaptation and integration procedures in the pilot sites, starting from the primary test site. Final technical evaluation is carried during the Euro-EcoChallenge, monitoring the technical performance of the components and applications and comparing the results to the technical success criteria.

User reactions and acceptance of collaborative systems will be studied, as well as users' willingness to participate in the new collaborative transport system in general, including their willingness to use the systems, pay for the systems, act as an input for the systems and follow the instructions given by the systems and hence change their travelling and driving behaviour. The results will be interpreted in terms of future potential to deploy collaborative systems. One important target of SP5 will be to provide evidence of the additional value of a wide system deployment for different parties, and also highlight the opportunities and potential shortcomings.

Impact assessment will be heavily built on the state of the art, utilising the most recent findings in the on-going large field operational tests (TeleFOT, DRIVE C2X) with comparable applications and environments. The methods, including tools, question lists and instructions to evaluate the impacts, to be utilized for impact evaluation have been mainly developed in previous related projects. The actual impact assessment will mainly be based on simulation models which are fed by realistic data collected in earlier studies and complemented based on the needs by e.g. expert interviews, stakeholder workshops, user surveys, user behaviour statistics and travelling data, and later validated with the selected data and findings of Euro-EcoChallenge. This approach enables cost-efficient TEAM impact evaluation.

4.2 General guidelines to be followed in the evaluation

TEAM will follow the detailed FESTA guidelines on ethical issues as well as the experience gained by partners in other national, European, and international projects involving on-road experiments of ICT mobility services.

The TEAM evaluation will be carried out with prototypical applications with limitations in terms of possible use cases and wide spread application. For this reason the users involved in any testing shall be instructed to take into account the limited functionality. As an example: Users' feedback on collaborative parking in terms of acceptance and impact perspectives will vary if it will be usable in a couple of city areas or in the whole city. For this reason the questions to the test participants shall be either formulated in a way asking for support in order to enhance further development of the application or in order to assess possible impact of the application by instructing the participants to imagine and project the experienced function to work in a wider context and without any possible technical limitations.

In addition, as presented more detailed in more extensive FOT evaluation plans and deliverables (e.g. FESTA-guidelines, TeleFOT, eImpact, DriveC2X), the following general aspects always need to be taken into account when evaluating the impact of any system, even in small scale studies:

- What is the baseline?
    - User (driver/traveller) behaviour and hence related impacts of the system need to be compared to the behaviour without the system. The difference between the “with the system” and “without the system” is the impact.
    - When the final set of applications and use cases per test site is available, the “baseline” for each application will be set. In many cases it will be simply “without the system”. This is applicable specifically with the newest concepts such as serious gaming and driving and merging. With the systems closer to the already available systems, such as collaborative navigation, ACC and co-modal planning, the baseline can also be the already available system in the market, especially if users do have experience of those existing systems.
    - The baseline always needs to be clearly selected before the data is collected. If needed, the baseline will also be indicated to the user (subjective measures, such as questionnaires and interviews).
    - The actual measures and the selection of “between subjects” or “within-subjects” test setups are presented more detailed in the FOT test descriptions.
- How to select the participants?
    - When measuring the impacts of a system in driving behaviour, it would be optimal to use various types of drivers, e.g. more and less experienced drivers, younger and elderly drivers, and even drivers with and without experience of ITS in general. This holds true especially for the large scale FOT’s, and naturalistic driving experiences.
    - If measuring smaller set of impacts (to feed in the simulation models, as in TEAM), it is acceptable to use also more special type of drivers, such as professional drivers. Especially when the newest systems and company policies of using the test vehicles only allow the use of e.g. employees. It just needs to be

carefully reported what kind of drivers have been used – and also if the impacts are expected to be the same for generic users.

- However, when measuring the user acceptance, willingness to use and willingness to pay for the systems, it is very important to have "normal" users, i.e. drivers and travellers as subjects. Even if the generic public is not allowed to drive the actual test vehicles, user acceptance can be evaluated with the help of e.g. scenarios, use case illustrations etc. as presented more detailed in IR 5.2.3
- The number of participants per test site is also important. It is clear that in TEAM it is not feasible to get a representative sample of driving population in each country (normally representative sample would require e.g. 1000 drivers per country). However, to be able to make some kind of numerical analysis and comparisons on one hand between the applications/use cases and on the other hand between the different user groups the following is desirable:
    - to test each application/use case at least in two test sites (if not with the test drivers, at least with the help of scenarios/use case illustrations and related subjective measures)
    - to have at least 100 users per application/use case in total – not all using the application, but at least participating in the subjective data collection (questionnaires, interviews). This would be easiest to realize through public events in each test site during the Euro-EcoChallenge.
- When analysing the impacts, the data from the actual users (trying the system themselves) will be kept separate from the data from the more SP-type (Stated Preference, collected with the help of scenarios, use case illustrations etc.) data.

The actual detailed guidelines for the evaluation for each test site will be provided when the test setup for each site is available (applications and use cases to be tested in each site, test route, test vehicle, test drivers, and other public events planned).

4.3 Technical evaluation

4.3.1 Study design of the technical evaluation

Two main objectives of the technical evaluation are: (1) to verify that the TEAM applications and functions meet the selected technical requirements and (2) to gain detailed insights into the TEAM applications technical performance. Technical evaluation will be based on scenarios / data from Euro-EcoChallenge. The final set of applications and more specifically, use cases per test sites is not yet finally decided, and the planning continues. However, the detailed technical research questions for each application have been selected.

Detailed technical evaluation plan will contain all necessary technical data that should be logged during the Euro-EcoChallenge. Further, guidance for conducting the test will be prepared such that the experimental data will carry statistical meaning. During the Euro-EcoChallenge, data will be logged and preliminary checks will be conducted to ensure good quality of the collected data. After the Euro-EcoChallenge, the data will be processed and technical performance evaluation for the data will be conducted to verify that the system developed in TEAM is able to meet the requirements. The technical performance evaluation will also provide further insights into how to improve the TEAM components towards commercial products.

Based on the experiences from earlier projects (e.g. DRIVE C2X) the detailed technical evaluation plan, and hence evaluation can include the following aspects:

- communication tests; V2V, V2I, I2V – also number of communicating units; scalability test
- requirements for the testing equipment; hardware, software, location/positioning
- test metrics: content of a data package, organization and content of the log file,
- test procedure: number of required repetitions for each test, how to send the data (e.g. how often, distance between communication units if relevant), speed of the vehicles
- data collection: detailed test procedures for each test site (including the selected applications and use cases implemented in each test site). The data collected in each test site should be comparable (e.g. collected with the same pre-defined procedures) to make sure the results can be generalized to pan-European level.

4.3.2 Focus of the technical evaluation for each TEAM application

Technical evaluation will be based on the data collected from the scenarios demonstrated in the Euro-EcoChallenge. In addition to the general aspects of technical evaluation, for each application, the following specific aspects will be also covered in the technical evaluation:

Collaborative ACC (CACC)

Description/Objectives: The assumption is that vehicles shall communicate with other vehicles and infrastructure and share position and speed information. This information can be used to extend the foresight range of ACC Systems (Adaptive Cruise Control), allowing appropriate reaction to adapt vehicle longitudinal speed and ultimately improve traffic flow. Addressing TEAM innovation points "Group-centric acceleration and deceleration", "Elimination of string instability"," Estimating traffic density in real-time based on in-vehicle estimation", "safe and green driving speeds", "Using map", "data Green MMI". C-ACC shall:

- increase the dynamics on the roads and lead to a more stable traffic flow with decreased accelerations and decelerations (improve highway platooning)
- decrease traffic jams and adapt vehicles speed in order to, as fast as possible, get back to an uncongested situation; adapt vehicle speed to optimize emission traffic throughput adapt vehicle speed to current weather conditions promoting safety
- act as a ACC safety margin assistant, which detects potentially dangerous traffic hindrance situations before their location is reached

Inputs: speed and positional information of the ego vehicle; traffic data per road segment from the cloud server; information from other users

Measures: brake and acceleration behaviour comparisons of vehicles using the CACC system, versus vehicles that are not; time taken to complete a journey, and the quantity of fuel consumed, when using the CACC system, versus when not

Collaborative Eco-Friendly Parking (EFP)

Description/Objectives: Collaborative parking application offers real time information of location of free parking spaces either in the surrounding of the navigator destination or in the most probable destination (based on driving storyboard). Via manual trigger or autonomous parking/leaving detection the vehicle sends relevant data when entering /leaving a parking slot so that the cloud-based application can constantly monitor the availability of free parking slots. This application's objective will enable connected vehicles to access real time information about parking availabilities along the destination. The vehicles are connected to a cloud service which informs individual road users (vehicle drivers and other device equipped users) with data about available parking spots. The application includes the following features:

- Detection of the parking searching context
- Open slot sensing
- Free parking markets

The application will include a system which manages the knowledge about the free parking spaces and the allocation of parking spaces to users in search for such places. Relevant statistics will also be possible, to guarantee an acceptable quality of service, e.g. filtering information about free slots (or, in general, individually preferred routes, such as safe routes where few accidents happen, non-complex crossings etc.).

Inputs: desired destination; real-time information about parking availability

Measures: time taken to find a park when using the system, versus when not using the system; probability of the system informing the driver of a free parking spot, and the driver then arriving to find that a park, in reality, is not available

Collaborative Driving and Merging (CDM)

Description/Objectives: The application addresses the challenges in the collaboration among the vehicles to increase safety and improve energy efficiency. It refers to situations where two or more vehicles need to interact among them and/or with the road infrastructure to solve specific driving situations. The most representative use case is lane change or lane merging; other relevant situations include roundabout driving, emergency braking or hazardous situation in front, intersection start and stop including vehicle-infrastructure collaboration, highway entrance or exit and speed limit adaptation. The application is implemented by the vehicle/driver and the TEAM backend. This application provides 1) action for the driver or vehicle and 2) support to the driver/vehicle for decision making.

Inputs: vehicular information (e.g. speed, position) of the ego and other travelling vehicles; information from central infrastructure

Measures: vehicular reaction time to the advice given by the system, and whether increased safety and energy efficiency was achieved (e.g. adapted braking and accelerating behaviour when the system was in use, versus when it was not)

Green, safe and collaborative driving serious game and community building (SG-CM)

Description/Objectives: This application intends to promote and favour appropriate driver behaviour, with a particular attention to collaborative applications that are being developed in TEAM. The SG-CB application consists of a gamified social network environment where drivers and passengers can share their information and improve their use of collaborative TEAM applications (and also 3rd parties, in an open and scalable perspective), in a pleasant and compelling way and featuring a map-based user interface. Given this support to a good use of the other TEAM applications, SG-CB may be thought of as a "meta-application", a user-centred user-interaction based layer aimed at incentivising the use of every connected TEAM application. The application includes also a serious game (SG) that exploits vehicle data in order to create a challenge so that drivers are motivated to collaboratively reach high levels of green driving and low levels of traffic in their zones (typically a city or a city area).

Inputs: real-time vehicle information e.g. from the CAN bus; data communicated from the other TEAM applications

Measures: accuracy of the performance feedback given to the driver

Collaborative eco-friendly Navigation (CONAV)

Description/Objectives: This application is a turn-by-turn navigation application running on Smartphones and on a vehicle-integrated platform. It does routing and navigation for vehicles considering individual user's needs and community (system-centric) needs. This application provides the interface to the user while he is driving and makes turn-by-turn instructions. It monitors the user behaviour especially looking at his preferences and triggers new route calculations (in case they behave both differently from the instructions or if traffic conditions have changed). In comparison to today's navigation systems, it provides route recommendations, which are optimized based on multifold needs (environment, traffic load balancing, robustness, queuing at gas stations, balanced pollution levels, safety). The application will consider real-time traffic information provided by the infrastructure.

Inputs: individual user preferences and constraints; needs of other drivers; other traffic data

Measures: trip information and comparisons (e.g. travel time, distance, fuel consumption, noise)

Collaborative pro-active/inter-urban monitoring and ad-hoc control (CMC)

Description/Objectives: Collaborative pro-active urban/inter-urban monitoring and ad-hoc control (CMC) TEAM equipped vehicles monitor urban roads and recognize incidents or special events (i.e. road closures, work zones, public large-scale events) while driving, provide real-time information to the TMC, which validates the reliability of this information and optimizes the traffic efficiency. Such innovative paradigm is based both on the information that comes from the vehicle side as a monitoring sensor and proactive traffic management centre through a V2I communication and information from other data sources (e.g. crowd sourcing, mobile devices tracking) and existing legacy monitoring system. All the data collected are mashed up and processed in order to obtain reliable traffic forecasts regarding the status of the network in the short and mid-term to define estimated LOS, travel time, saturation ratio and forecasted utilisation of the arcs of the road network. This application will also support other TEAM application providing dynamic real-time information to coordinate collaborative traffic control, in order to reduce congestion, fuel consumption and consequently emissions level (see TEAM webpage).

Inputs: information exchange between the Vehicle-API as a monitoring sensor and the proactive TMC through V2I communication; data from crowd sourcing, mobile devices, data providers, public authorities, etc.

Measures: whether accurate and reliable network status forecast is achieved

Collaborative co-modal route planning (COPLAN)

Description/Objectives: COPLAN provides collaborative co-modal route planning services considering: 1) statistical information for specific geo-locations, 2) real-time evaluation and computation of predicted / forecasted traffic development, 3) evaluation of location-specific and distributed routing data from all vehicles involved in the system in order to enable truly collaborative route planning by involving user decisions through a feedback information facility. To this end, COPLAN is enabled through a global system view by aggregating and fusing information of TEAM infrastructure (FLEX) applications, such as CMC and CPTO. COPLAN has a high environmental impact, thanks to the inclusion of environmentally friendly transportation modes such as public transportation, bikes, car-sharing services, walk, etc. COPLAN also involves user preferences in its optimization engine allowing prioritized transportation modes, differentiated vehicle priorities, desired time of arrival, and maximal overall travel cost, among others. COPLAN has built-in routed and existing traffic tracking features, in order to enable its real-time predictive and interpolative traffic evolution engine. In this way, traffic behaviour is available on a real-time basis with much greater accuracy than that available today on TMC enabled navigation systems. COPLAN is available to all TEAM and non-TEAM applications that might require global routing services beyond the capabilities offered by user-level navigation devices.

Inputs: data from other TEAM applications, e.g. pollution sensor data, traffic density, information from third parties relevant to real-time and future road incidents; data from other sources, e.g. public safety answering points, municipality services, road operators, historical traffic related data; user-centric information, e.g. origin and destination, departure time, preferences.

Measures: route and/or transportation mode comparisons, e.g. cost savings, fuel consumption, travel time, waiting time, emissions.

Co-modal coaching support from virtual/avatar users (CCA)

Description/Objectives: This is a co-modal application with post trip cost/benefit analysis functionalities, made through a comparison of the behaviours of the real user and the "virtual" avatar user. The proposed idea does not aim on vague pre-trip forecasts but reliable and exact post-trip information about a user's realized trip alternatives. These concern the same pair of origin-destination including monitoring and displaying their true costs, travel times and CO2 emissions based on real-time knowledge about occurred traffic jams or delays in public and private transport. The idea in here is to understand the users' mobility patterns and provide co-modal real-time route recommendations that integrate environmental footprint costs on post planned journey, offering travellers the opportunity to choose the most environmentally friendly alternative of mode for their journey. A comparison will be made through real time monitoring of the individual route of a user and the encountered trip alternatives of an avatar travelling by optimal transport modes from the same origin to the same destination at mostly the same time. Such cost-benefit analysis can create good understanding on a user in taking decisions about a real mobility options on his next trips. The integration of this application with collaborative and social aspects of TEAM will further increase its end-user impact.

Inputs: real-time monitoring of a user's individual route; real-time knowledge of occurred traffic jams, delays in public transport, etc.

Measures: post-trip cost/benefit analyses concerning costs, travel times, CO_2 emissions, etc.

Collaborative smart intersection for intelligent priorities (CSI)

Description/Objectives: This is an integrated application for intersections. One of the main objectives is to optimize public transport, giving priority to buses. Priority techniques can generate improvements in service regularity, which usually means alignment with nominal time-tables and headways. The priorities can also be considered based on the vehicle type (e.g. truck, bus, tram, car, motorcycle, pedestrians, cyclists etc.) and on other factors (truck with dangerous goods, ambulance, disabled person wanting to cross the street, etc.).This application also includes communication and synchronization of multiple traffic lights in a region to optimize traffic flow. The vehicles will send their intended destination to the current intersection and that one will communicate with the next ones to help regulate the traffic flow, based on the number of vehicles that will follow in each direction. The vehicles will receive a speed recommendation in order to get to the next traffic light in green. Additionally, the application includes start and stop functionality based on information that comes from smart and pro-active RSUs (i.e. how long do they have to turn off the engine, when to turn on the engine, duration of the red light phase, when the lights will be green, position in a queue etc.)

Inputs: information exchange from smartphones, Vehicle-APIs, TMCs and road-side units.

Measures: whether priority is given correctly and updated dynamically depending on current traffic conditions; whether communication and synchronization of multiple traffic lights in a region occurs seamlessly; whether speed recommendations and smart start-stop and braking recommendations can be achieved by the vehicle.

Collaborative public transport optimization (CPTO)

Description/Objectives: The goal of this application is to highlight the flexibility of the transport infrastructure serving dynamically the needs and demands of the cities and the citizens. It mainly focuses on buses, but it can be extended to other means of transport, as well. By exploiting information from the TEAM users, such as their position, destination and preferences, together with information about the road traffic and bus line characteristics, the public transport operator dynamically adapts the timetables and the routes in order to achieve specific targets. These include optimisation of the overall network efficiency, reduced CO_2 emissions, minimisation of operator cost from low demand lines and in general increase of the network efficiency.

Inputs: traveller information, e.g. position, destination, departure time, selected bus route; traffic information, e.g. current road situation; public transport timetables.

Measures: achievability of dynamic updates while en-route.

Dynamic collaborative corridors (DC)

Description/Objectives: The main objective of this application is to establish corridors for heavy vehicles, being trucks or buses, in a dynamic way. Certain lanes could be reserved for certain vehicles during a certain period. For example, a bus lane could be assigned in the city centre only for buses during the period of peak in traffic, in order to prioritize public transportation schedule. Another example is to have lanes dedicated to distribution vehicles during the early morning to deliver goods in an efficient way. As a last example, inter-urban roads could have dynamic dedicated lanes only for heavy trucks.

Inputs: vehicular information, e.g. size, weight, emissions, noise; traffic conditions and current priorities; local regulations.

Measures: ability of the inference engine to appropriately designate corridors to drivers; ability of the system to adapt to real-time conditions.

4.4 User acceptance evaluation

4.4.1 Objective of the user acceptance evaluation

The main objectives of user acceptance evaluation are to study adequate Human-Machine Interfaces, user acceptance and stakeholder opinions about TEAM functions. The evaluation will be specifically targeting at acceptance of collaborative aspects of TEAM applications. The high level research questions were hence selected as follows:

1. Does the user agree to be (or is already) an active input to the application?
2. Does the user act according to the application output?
3. Is willingness to use high?
4. Is willingness to pay high?
5. Do the users consider usability/ user experience to be good/high?

These selected high level research questions are very much aligned with the respective research hypotheses proposed in DRIVE C2X user acceptance evaluation (Figure 4.1)

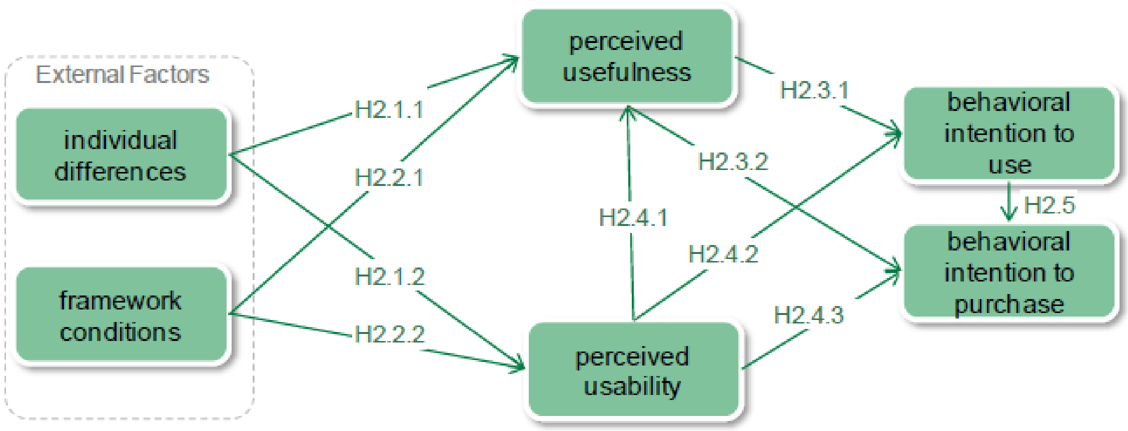


Figure 4.1: Example of research hypotheses of adapted technology acceptance model (DRIVE C2X).

TEAM user acceptance evaluation will be conducted mainly in parallel with Euro-EcoChallenge by expert assessments, workshops, focus groups, interviews, and individual and collaborative behaviour monitoring, and possibly traffic data analysis, if feasible. User acceptance evaluation will be based on one hand on the data collected from the actual users of the systems, but on the other hand during the public events related to Euro-EcoChallenge with help of scenarios and illustrated use cases (when trying of a system is not feasible), as explained in the impact evaluation.

4.4.2 Towards more detailed research questions and methodologies in user acceptance evaluation

Regardless of the application, the following detailed research questions may be relevant when measuring the user acceptance.

1) Do users (travellers and drivers) accept that their location and planned route is transmitted to the application?
2) To what extent have the applications been switched on? Are the applications been switched on more or less over time?
3) Do travellers change their routes according to the guidance given by the system? Is the "guidance acceptance" changing over time?
4) Does the number of users (travellers) that prefer the re-scheduled routes increase over time?)
5) Does the number of users (operators) that reschedule routes according to the system output increase over time?
6) Does the number of users (drivers) that change routes as suggested increase over time?
7) Do users state that they will use the system? (before trying it)
8) Is user acceptance influenced by perceived application ease of use? ... by perceived usefulness of application? ... by perceived trust in application?
9) Does the design of the application user interface affect user’s acceptance?
10) Is user acceptance influenced by perceived privacy and confidentiality offered by the application?
11) Is user acceptance influenced by the user's willingness to pay for the application?
12) Are the users willing to pay for the application? Is willingness to pay influenced by the perceived usefulness? Is willingness to pay influenced by users' (travellers/operators/bus drivers) perceived additional mobile data charges?

4.4.3 Focus of the user acceptance evaluation for each TEAM application

Collaborative ACC (CACC)

Description/Objectives related to the user acceptance assessment: The assumption is that vehicles shall communicate with other vehicles and infrastructure and share position and speed information, and adapt the speed accordingly when the application is activated.

Main related user acceptance aspects: Since the main impacts of C-ACC are expected in the tactical level, i.e. adapting vehicle speed and headway, the user acceptance is mainly related to the actual usage of the system, and hence passing the location and speed information to the other C-ACC users. In addition to the willingness to use the system, willingness to pay for

Study designs: Driving behaviour (and hence acceptance of the system) can be best measured by logging vehicle data such as speed, accelerations/decelerations, and headway to the vehicle in front. Also, logging the system usage (system activated/in-active) gives also an indication of the user acceptance. In addition, most of the user acceptance related research questions can be best answered by subjective measures, such as questionnaires.

Collaborative Eco-Friendly Parking (EFP)

Description/Objectives related to the user acceptance assessment: Collaborative parking application offers real time information of location of free parking spaces either in the surrounding of the navigator destination or in the most probable destination. The application will include a system which manages the knowledge about the free parking spaces and the allocation of parking spaces to users in search for such places.

Main related user acceptance aspects: The main expected user acceptance impacts are mainly the usage of the system (system on / off), if the users allow them to be located and if the users are accepting the guidance provided by the system.

Study designs: The main methods to assess user acceptance are subjective measures such as questionnaires, and interviews. In addition, some data could also be logged from the vehicles including the suggested parking slot/route and the one the user selected, but this requires using the application longer time and in real context, not only driving a short test drive.

Collaborative Driving and Merging (CDM)

Description/Objectives related to the user acceptance assessment: The application addresses the challenges in the collaboration among the vehicles to increase safety and improve energy efficiency. It refers to situations where two or more vehicles need to interact among them and/or with the road infrastructure to solve specific driving situations. The most representative use case is lane change or lane merging; other relevant situations include roundabout driving, emergency braking or hazardous situation in front, intersection start and stop including vehicle-infrastructure collaboration, highway entrance or exit and speed limit adaptation. This application provides either direct action advice for the driver or support to the driver for decision making.

Main related user acceptance aspects: Since the main impacts of CDM are expected in tactical level, i.e. driving behaviour such as speed, headway, accepted time gaps, and focus of attention, user acceptance evaluation should focus on the drivers' willingness to use the system (system on/off) and also the acceptance of the given instructions of the system. It is also important to find out if the willingness to use (and accept the systems' instructions or accept the system to take over the control) is changing over time. This may, however, not be possible in short term use.

Study designs: Users willingness to use the system and willingness to accept the instructions of the system could be measured by logging the vehicle and the application data (including the information of the given instruction/drivers reaction to it). In addition, subjective measures, such as interviews and questionnaires can be used. It is important, that if the user cannot try the system him/herself, the demonstration of the system (especially if intervening) needs to cover most important aspects of the system.

Green, safe and collaborative driving serious game and community building (SG-CM)

Description/Objectives related to the user acceptance: This application intends to promote and favour appropriate driver behaviour, with a particular attention to collaborative applications that are being developed in TEAM. The SG-CB application consists of a gamified social network environment where drivers and passengers can share their information and improve their use of collaborative TEAM applications, in a pleasant and compelling way and featuring a map-based user interface. The application includes also a serious game (SG) that exploits vehicle data in order to create a challenge so that drivers are motivated to collaboratively reach high levels of green driving and low levels of traffic in their zones (typically a city or a city area).

Main related user acceptance aspects: Since the main expected impacts of SG-CM applications are in the strategic level, i.e. mode choice and route choice, the main user acceptance measures should also concentrate into the willingness to use the system, and willingness to change travelling behaviour according to the feedback/suggestions from the system.

Study designs: Subjective measures, such as travel diaries and questionnaires are expected to be the main methods to evaluate the user acceptance of SG-CM-application.

Collaborative eco-friendly Navigation (CONAV)

Description/Objectives related to the user acceptance: This application is a turn-by-turn navigation application running on Smartphones and on a vehicle-integrated platform. It performs routing and navigation for vehicles considering individual user's needs and community (system-centric) needs. This application provides the interface to the user while he is driving and makes turn-by-turn instructions. It monitors the user behaviour especially looking at his preferences and triggers new route calculations (in case they both behave differently from the instructions or if traffic conditions have changed). Different to today's navigation systems, it provides route recommendations, which are optimized based on multifold needs (environment, traffic load balancing, robustness, queuing at gas stations, balanced pollution levels, safety). The application will consider real-time traffic information provided by the infrastructure.

Main related user acceptance aspects: User acceptance evaluation of CONAV is mainly concentrated into users' willingness to use the system (system on/off) as well as their willingness to change their behaviour according to the instructions given by the system. It would be also very interesting to see if the acceptance is changing over time. In case of only short time usage, this is challenging.

Study designs: Main methods to collect data of the user acceptance of CONAV are both subjective: travel diaries and questionnaires and objective: mainly logging the routes suggested by the system and the routes used by the driver.

Collaborative pro-active/inter-urban monitoring and ad-hoc control (CMC)

Description/Objectives related to the user acceptance: Collaborative pro-active urban/inter-urban monitoring and ad-hoc control (CMC) TEAM equipped vehicles monitor urban roads and recognize incidents or special events (i.e. road closures, work zones, public large-scale events) while driving, provide real-time information to the TMC, which validates the reliability of this information and optimizes the traffic efficiency. This application will also support other TEAM application providing dynamic real-time information to coordinate collaborative traffic control, in order to reduce congestion, fuel consumption and consequently emissions level. (TEAM webpage)

Main related user acceptance aspects: User acceptance of CMC is mainly users' willingness to have their location to be recorded and passed to the traffic management and/or other TEAM applications.

Study designs: mainly logging the system usage (system on/off).

Collaborative co-modal route planning (COPLAN)

Description/Objectives related to the user acceptance: COPLAN provides collaborative co-modal route planning services. COPLAN has a high environmental impact potential, thanks to the inclusion of environmentally friendly transportation modes, such as public transportation, bikes, car-sharing services, walk, etc. COPLAN also involves user preferences in its optimization engine allowing prioritized transportation modes, differentiated vehicle priorities, desired time of arrival, and maximal overall travel cost, among others.

Main related user acceptance aspects: Since the main impacts of COPLAN are expected in strategic level; mode choice, including multimodal travelling, the main user acceptance aspects are related to the users' willingness to use the system and also willingness to change their behaviour accordingly (follow the instructions given by the system).

Study designs: user acceptance can be measured mainly by subjective methods, such as travel diaries and questionnaires.

Co-modal coaching support from virtual/avatar users (CCA)

Description/Objectives related to the user acceptance: This is a co-modal application with post trip cost/benefit analysis functionalities, made through a comparison of the behaviours of the real user and the "virtual" avatar user. The idea is to understand the users' mobility patterns and provide co-modal real-time route recommendations that integrate environmental footprint costs on post planned journey, offering travellers the opportunity to choose the most environmentally friendly alternative of mode for their journey.

Main related user acceptance aspects: since most of the expected impacts of CCA are in strategic level – having impact on mode, and route choice as well as timing of the trip, the user acceptance aspects are mainly in the willingness to use the system – and also (in longer term) willingness to change the behaviour accordingly.

Study designs: user acceptance can be evaluated mainly by subjective measures such as travel diaries and questionnaires.

Collaborative smart intersection for intelligent priorities (CSI)

Description/Objectives related to the user acceptance: This is an integrated application for intersections. One of the main objectives is to optimize public transport, giving priority to buses. The priorities can also be considered based on the vehicle type (e.g. truck, bus, tram, car, motorcycle, pedestrians, cyclists etc.) and on other factors (truck with dangerous goods, ambulance, disabled person wanting to cross the street, etc.). The vehicles will receive a speed recommendation in order to get to the next traffic light in green. Additionally, the application includes start and stop functionality based on information that comes from smart and pro-active RSUs.

Main related user acceptance aspects: Since the main expected impacts of CSI-application are in tactical level, i.e. driving behaviour due to optimized traffic lights and hence traffic flow, user acceptance evaluation is mainly concentrated into users' willingness to use the system as well as willingness to change their behaviour according to the instructions given by the system.

Study designs: vehicle data and system usage data logging would be the best way to measure usage of the system, and hence user acceptance. In addition, user acceptance can be also somewhat measured by subjective measures such as questionnaires and travel diaries.

Collaborative public transport optimization (CPTO)

Description/Objectives related to the user acceptance: The goal of this application is to highlight the flexibility of the transport infrastructure serving dynamically the needs and demand of the cities and the citizens. The public transport operator dynamically adapts the timetables and the routes in order to achieve specific targets. These include optimisation of the overall network efficiency, reduced CO2 emissions, minimisation of operator cost from low demand lines and in general increase of the network efficiency.

Main related user acceptance aspects: Since the main impacts in individual level are in strategic level, i.e. users' mode choice, the main user acceptance aspects are in the willingness to use the system and willingness to change the behaviour according to the instructions/guidance given by the system.

Study designs: the main methods to gather information on the user acceptance of CPTO are subjective: travel diaries and questionnaires.

Dynamic collaborative corridors (DC)

Description/Objectives related to the user acceptance: The main objective of this application is to establish corridors for heavy vehicles, being trucks or buses, in a dynamic way. Certain lanes could be reserved for certain vehicles during a certain period. For example, a bus lane could be assigned in the city centre only for buses during the period of peak in traffic, in order to prioritize public transportation schedule. Another example is to have lanes dedicated to distribution vehicles during the early morning to deliver goods in an efficient way. As a last example, inter-urban roads could have dynamic dedicated lanes only for heavy trucks.

Main related user acceptance aspects: the main user acceptance aspects are users' willingness to use the system as well as users' willingness to act according the instructions/guidance given by the system.

Study designs: user acceptance of Dynamic Corridors can be partly collected by subjective measures, such as travel diaries and questionnaires. It would, however, be good to also log the usage of the system, instructions and guidance given by the system, and the actual selected routes of the vehicle.

4.5 Impact evaluation

4.5.1 Objective of the impact evaluation

The main objective of the impact evaluation is to study the impacts of TEAM functions on mobility, traffic flow, efficiency and environment. In addition, the impacts on traffic safety are of interest, although not as a main topic as covered already in many previous FOTs, such as DRIVE C2X, TeleFOT.

All the impacts are mediated through changes in behaviour, mostly either driving behaviour or travelling behaviour. In order to assess the impacts of the TEAM applications behavioural data needs to be collected in some extend. The following chapters describe typical study designs on how to collect such data in a suitable way for impact assessment. Up scaling of available data is also used in order to assess the impacts in e.g. EC level.

4.5.2 Towards methodologies in impact evaluation

An overview of the state of the art of the impacts of newest cooperative systems will be made to start with. In this review, special attention will be paid to the results of the ongoing and finished EU-wide large scale FOTs on cooperative ITS, such as DRIVE C2X and TeleFOT. Hence, the impact assessment will be strongly built on this existing knowledge, since no large scale FOTs are to be conducted in TEAM.

More specifically, carefully selected sub sets of the exact measures used in the earlier FOTs will be applied to scale up the impacts of TEAM applications with the most recent existing knowledge. Consequently, limited and carefully selected data sets – such as small scale user data and expert assessments – are to be collected during Euro-EcoChallenge, and will be efficiently utilized in impact assessment, including the simulation models (see figure below). Detailed knowledge of the ongoing FOT measures by TEAM partners enables this approach. In TEAM a remarkable challenge will be to evaluate the impact of new collaborative systems, i.e. solutions involving the new role of the end users; transforming from the service user to the active information generator and supplier. (TEAM DoW, 2014)

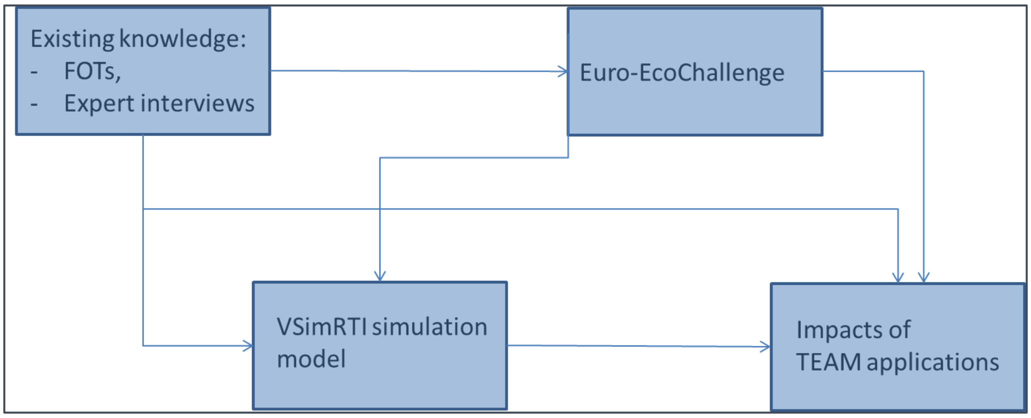


Figure 4.2: TEAM impact evaluation phases and main methodology.

To complete the impact assessment data from the earlier studies, the TEAM application impacts on **efficiency and environment** will be mainly assessed with help of simulation models. A central tool for the impact assessment is the VSimRTI simulation environment (see chapter on tools below).

The **safety and mobility** impact evaluation will be strongly build on existing data, existing scaling up tools, such as ERIC-tool (European Risk Calculation tool) developed in DRIVE C2X to scale up the safety impacts, and the selected user behaviour data collected during the Euro-EcoChallenge. All other impacts are mediated through changes in behaviour (see figure below). All three categories or hierarchical levels of driver decision making and behaviour: strategic decisions, tactical decisions and operational decisions (Michon, 1985) are to be taken into account when relevant. In many TEAM applications, the main focus lays on the strategic level, especially when the application support travelling with various modes, but also when the application supports in route selection.

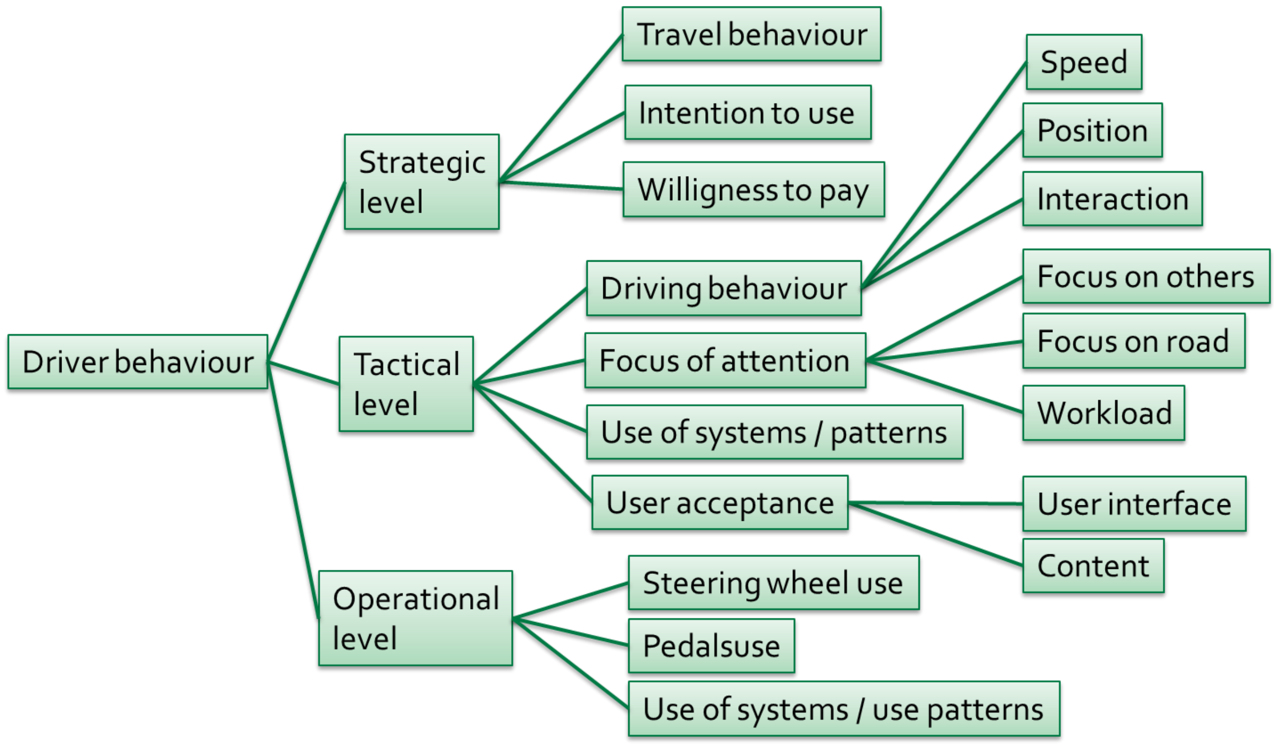


Figure 4.3: Impacts are mediated through changes in driver, or traveller behaviour (DRIVE C2X).

Since TEAM is not conducting any long term naturalistic experiments, the behavioural changes of individual users will be mainly collected by using subjective measures, i.e. users (drivers and travellers) reporting themselves how they have (or would be willing) to change their behaviour due to implementation of various TEAM applications and use cases in their own travelling context. When possible, the FESTA methodology will be utilized, but not anyhow in the extent it is utilized in real Field Operational Tests.

Several study designs can be applied to collect the data on TEAM application impacts on traveller behaviour and hence safety, efficiency, mobility, and environment. Subjective data can be collected by methods such as travel diaries, interviews, questionnaires, expert assessment and workshops.

Objective data can be collected by e.g. travel time measures, logging routes used and routes suggested by the system, driving behaviour related measures (logging vehicle data). To study the impacts, test persons for the pilot sites will be recruited to use the functions in a real context when possible. In practice, several types of user data will be collected from small scale behaviour monitoring to subjective user data.

Based on the detailed research question, and related hypothesis, the actual impact evaluation data collection is done before, during and after any kind of experience the user got with the application. The experience can be from lightest to the most extensive experience, depending on the deployment of the system in each site:

- A description of the system
- A demonstration of the system, e.g. real prototype
- Testing the system in pre-selected task/route
- Get the system for permanent use over a certain period

Nonetheless, it is important to get the data with or without the system in order to be able to identify what are the real impacts of the system as described in chapter 4.2.

Especially in safety impact assessment, it is important that the impacts are considered not only to the user of a system, but in the larger scale, taking into account all nine impact mechanisms of ITS introduced by Kulmala 19] are to be taken into consideration when traffic safety effects for ITS are studied. The list of mechanisms is as follows:

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

Mechanisms 1 to 5 [19] deal with crash risk. The related measures are: Speed, Proximity, Position, Interaction, Use of signals, Driver condition, Attention. The following assumptions were made:

- Safety increases as speed decreases (the so-called power model (Nilsson 2004) which describes the relationship between relative mean speed effects and injury accidents)
- Safety increases as standard deviation of speed decreases
- Safety increases as number of jerks decreases
- Safety increases as speed violations decrease
- Safety increases as following very close decreases
- Safety increases as lateral position is more stable
- Safety increases as vulnerable road users are taken into consideration
- Safety increases as signals are used correctly
- Safety increases as driver condition is not deteriorated
- Safety increases as focus of attention is allocated correctly.

Mechanisms 6, 7 and 8 are related to exposure. Accordingly, the related research questions are (1) Time spent on road (2) Mode chosen for the journey (3) Timing of the journey, and (4) Road type used. Time spent on the road has quite linear relationship with safety; traffic safety decreases when mileage increases [20]. Choice of transport mode has relevance as, for a given mileage, public transport is safer than driving private cars [20]. Timing of journey affects traffic safety, because driving during peak hours and night time is more dangerous than driving in different times [20]. There are differences in crash risk between different road types showing lower risk in high class roads [20]. Consequently safety increases as proportion of motorway driving increases, and safety increases as proportion of urban driving decreases.

Finally the mechanism 9 deals with crash consequences. First, it was assumed that the consequences would be more severe as speed increase (fatality equation). In addition, vehicle type has relevance as bigger and heavier vehicles are safer in crash.

4.5.3 Focus of the impact evaluation for each TEAM application

As stated earlier, impact evaluation will be based on:

- existing data from the earlier FOTs, such as TeleFOT and DRIVE C2X,
- traffic simulation (especially impacts on efficiency and environment)

- the data collected from the selected scenarios (to be selected when the implementation proceeds) demonstrated in the Euro-EcoChallenge.

For each application, the detailed research questions are presented in IR 5.2.1, and based on the expected behavioural changes, the main focus of the impact evaluation for each application is:

Collaborative ACC (CACC)

Description/Objectives related to the impact assessment: The assumption is that vehicles shall communicate with other vehicles and infrastructure and share position and speed information.
C-ACC shall:

- increase the dynamics on the roads and lead to a more stable traffic flow with decreased accelerations and decelerations (improve highway platooning)
- decrease traffic jams and adapt vehicles speed in order to, soonest possible, get back to an uncongested situation; adapt vehicle speed to optimize emission traffic throughput adapt vehicle speed to current weather conditions promoting safety
- act as a ACC safety margin assistant, which detects potentially dangerous traffic hindrance situations before their location is reached

Main expected impacts for an individual driver: The main impacts are expected in the tactical level, i.e. actual driving behaviour such as speed selection, acceleration, deceleration and headway. In addition, CACC is expected to have impact on workload and focus on attention.

Study designs: Driving behaviour can be best measured by logging vehicle data such as speed, accelerations/decelerations, and headway to the vehicle in front. In addition, some indications of the impacts can be collected by subjective measures, such as questionnaires, e.g. workload-scales.

Collaborative Eco-Friendly Parking (EFP)

Description/Objectives related to the impact assessment: Collaborative parking application offers real time information of location of free parking spaces either in the surrounding of the navigator destination or in the most probable destination. The application will include a system which manages the knowledge about the free parking spaces and the allocation of parking spaces to users in search for such places. Relevant statistics will also be possible, to guarantee an acceptable quality of service, e.g. filtering information about free slots (or in general individually preferred environments, such as safe routes where few accidents happen, non-complex crossings etc.).

Main expected impacts: The main expected impacts on the individual behaviour are in strategic level, i.e. mode choice, time allocated to the trip, and route choice. In addition, in tactical level, the EFP is expected to mainly reduce stress and hence increase comfort. In network level the impacts of efficiency and environment can be bi-fold: on one hand, the application reduces unnecessary search (and related driving around) of the parking slots, and hence have positive effect. If, on the other hand, the application has impact on mode choice, increasing the use of cars, then the impact can also be negative, increasing the driven mileage by personal vehicles, and hence increasing the emissions, and having negative impact on efficiency.

Main methodology: The main methods to measure impacts of EFP are subjective measures such as questionnaires, interviews and travel diaries. Of course, some data could also be logged from the vehicles, but this requires using the application longer time and in real context, not only driving a short test drive. In addition, the special attention should be paid on the control data (i.e. driving without the system).

Collaborative Driving and Merging (CDM)

Description/Objectives related to the impact assessment: The application addresses the challenges in the collaboration among the vehicles to increase safety and improve energy efficiency. It refers to situations where two or more vehicles need to interact among them and/or with the road infrastructure to solve specific driving situations. The most representative use case is lane change or lane merging; other relevant situations include roundabout driving, emergency braking or hazardous situation in front, intersection start and stop including vehicle-infrastructure collaboration, highway entrance or exit and speed limit adaptation. This application provides direct action recommendations for the driver and supports the driver in decision making.

Main expected impacts: The main impacts of CDM are expected in tactical level, i.e. driving behaviour such as speed, headway, accepted time gaps, and focus of attention. CDM is also expected to reduce stress and increase comfort. It may also have some impact on strategic level, if it, due to increased comfort, effect on the mode choice – and increase driven mileage by personal vehicles.

Study designs: Impacts on driving behaviour should be mainly measured by logging vehicle data. Special attention should be paid at control/base line data (and locations to collect it), making sure the impact measured is the impact of the system in action, not the impact related to the other factors. In addition, the impacts on comfort, stress and mode choice can be measured by subjective methods such as questionnaires and interviews.

Green, safe and collaborative driving serious game and community building (SG-CM)

Description/Objectives related to the impact assessment: This application intends to promote and favour appropriate driver behaviour, with a particular attention to collaborative applications that are being developed in TEAM. The SG-CB application consists of a gamified social network environment where drivers and passengers can share their information and improve their use of collaborative TEAM applications in a pleasant and compelling way and featuring a map-based user interface. The application includes also a serious game (SG) that exploits vehicle data in order to create a challenge so that drivers are motivated to collaboratively reach high levels of green driving and low levels of traffic in their zones (typically a city or a city area).

Main expected impacts: The main expected impacts of SG-CM applications are on the strategic level, i.e. mode choice and route choice. In addition, the application is expected to have an impact on speed selection (tactical level). Some changes in the focus of attention, and related distraction may be expected, and needs to be minimised through careful user interface design and system interaction.

Study designs: Subjective measures, such as travel diaries and questionnaires are expected to be the main methods to evaluate the impacts of SG-CM-application.

Collaborative eco-friendly Navigation (CONAV)

Description/Objectives related to the impact assessment: This application is a turn-by-turn navigation application running on Smartphones and on a vehicle-integrated platform. It does routing and navigation for vehicles considering individual user's needs and community (system-centric) needs. This application provides the interface to the user while he is driving and makes turn-by-turn instructions. It monitors the user behaviour especially looking at his preferences and triggers new route calculations (in case they both behave differently from the instructions or if traffic conditions have changed). Different to today's navigation systems, it provides route recommendations, which are optimized based on multifold needs (environment, traffic load balancing, robustness, queuing at gas stations, balanced pollution levels, safety). The application will consider real-time traffic information provided by the infrastructure.

Main expected impacts: The main impacts of CONAV are expected to be in strategic level, i.e. choice of route, timing of travel and time allocated for the travel. On one hand, CONAV could even have an (indirect) impact on mode choice, in case of overall congestion in the road network (reducing the travel by car in this case). On the other hand, CONAV can also increase the use of one's own car, due to dynamically adapted (and less congested) routes. In tactical level, CONAV is expected to have an impact on speed (because of avoiding the congestion), and reducing stress and increasing comfort. In network level, CONAV is expected mainly to increase efficiency and decrease environmental effects.

Study designs: Main methods to collect data of the effects of CONAV are both subjective: travel diaries and questionnaires and objective: mainly logging the routes.

Collaborative pro-active/inter-urban monitoring and ad-hoc control (CMC)

Description/Objectives related to the impact assessment: Collaborative pro-active urban/inter-urban monitoring and ad-hoc control (CMC) TEAM equipped vehicles monitor urban roads and recognize incidents or special events (i.e. road closures, work zones, public large-scale events) while driving, provide real-time information to the TMC, which validates the reliability of this information and optimizes the traffic efficiency. This application will also support other TEAM application providing dynamic real-time information to coordinate collaborative traffic control, in order to reduce congestion, fuel consumption and consequently emissions level. (TEAM webpage)

Main expected impacts: The expected impacts of CMC are indirect – through other TEAM applications. The better data of the traffic in the network is expected to improve the traffic management and control measures, and hence have overall positive impact on especially efficiency, environment and also safety.

Study designs: no specific methodology to measure the impact of CMC only. The impacts are mediated through other TEAM application impacts!

Collaborative co-modal route planning (COPLAN)

Description/Objectives related to the impact assessment: COPLAN provides collaborative co-modal route planning services. COPLAN has a high environmental impact, thanks to the inclusion of environmentally friendly transportation modes, such as public transportation, bikes, car-sharing services, walk, etc. COPLAN also involves user preferences in its optimization engine allowing prioritized transportation modes, differentiated vehicle priorities, desired time of arrival, and maximal overall travel cost, among others.

Main expected impacts: The main impacts of COPLAN are expected in strategic level; mode choice, including multimodal travelling, as being the most obvious one. In addition, COPLAN may have an effect on tactical level, mainly by decreasing uncertainty and increasing comfort. If used when driving, the careful HMI design is a key to avoid distraction.

Study designs: the strategic level impacts can be measured mainly by subjective methods such as travel diaries and questionnaires.

Co-modal coaching support from virtual/avatar users (CCA)

Description/Objectives related to the impact assessment: This is a co-modal application with post trip cost/benefit analysis functionalities, made through a comparison of the behaviours of the real user and the "virtual" avatar user. The idea in here is to understand the users' mobility patterns and provide co-modal real-time route recommendations that integrate environmental footprint costs on post planned journey, offering travellers the opportunity to choose the most environmentally friendly alternative of mode for their journey. The integration of this application with collaborative and social aspects of TEAM will further increase its end-user impact.

Main expected impact: the expected impact of CCA is mostly on a strategic level – having impact on mode, and route choice as well as timing of the trip.

Study designs: impact can be evaluated mainly by subjective measures such as travel diaries and questionnaires.

Collaborative smart intersection for intelligent priorities (CSI)

Description/Objectives related to the impact assessment: This is an integrated application for intersections. One of the main objectives is to optimize public transport, giving priority to buses. The priorities can also be considered based on the vehicle type (e.g. truck, bus, tram, car, motorcycle, pedestrians, cyclists etc.) and on other factors (truck with dangerous goods, ambulance, disabled person wanting to cross the street, etc.). The vehicles will receive a speed recommendation in order to get to the next traffic light in green. Additionally, the application includes start and stop functionality based on information that comes from smart and pro-active RSUs.

Main expected impacts: The main expected impacts of CSI-application are in tactical level, i.e. driving behaviour due to optimized traffic lights and hence traffic flow. A few impacts can also be expected in strategic level, depending on the priorities (may have potential getting user to change from car to bus if faster). The HMI of the application is crucial, in case some related information is provided to the driver visually, to avoid distraction.

Study designs: vehicle data logging would be the best way to measure impacts of the system in individual vehicle level. A careful planning of control data collection is needed. Possible impacts in strategic level can be measured by subjective measures such as questionnaires and travel diaries.

Collaborative public transport optimization (CPTO)

Description/Objectives related to the impact assessment: The goal of this application is to highlight the flexibility of the transport infrastructure serving dynamically the needs and demand of the cities and the citizens. The public transport operator dynamically adapts the timetables and the routes in order to achieve specific targets. These include optimisation of the overall network efficiency, reduced CO_2 emissions, minimisation of operator cost from low demand lines and in general increase of the network efficiency.

Main expected impacts: The main impacts in individual level are in strategic level. If the public transport is providing more flexible choices than before, this may have impact on the mode choice.

In addition, in tactical level stress and uncertainty may decrease and at the same time comfort of travel increase.

Study designs: the main methods to gather information on the impacts of CPTO are subjective: travel diaries and questionnaires.

Dynamic collaborative corridors (DC)

Description/Objectives related to the impact assessment: The main objective of this application is to establish corridors for heavy vehicles, being trucks or buses, in a dynamic way. Certain lanes could be reserved for certain vehicles during a certain period. For example, a bus lane could be assigned in the city centre only for buses during the period of peak in traffic, in order to prioritize public transportation schedule. Another example is to have lanes dedicated to distribution vehicles during the early morning to deliver goods in an efficient way. As a last example, inter-urban roads could have dynamic dedicated lanes only for heavy trucks.

Main expected impacts: the main impacts for user are in strategic level: mode choice, route choice, and timing of the trip. In addition, for e.g. truck (and other prioritize vehicle drivers) impacts are also expected in tactical level, such as speed, and also increasing comfort, and decreasing stress.

Study designs: for individual traveller the main method to collect the impact data are subjective: travel diaries, questionnaires. For the drivers of prioritizes vehicles, also logging vehicle data would give valuable information of the impacts of dynamic corridors and related priorities. Special attention needs to be paid at collecting control (base line) data.

5 Evaluation Tools

The evaluation of the TEAM applications is carried out with approved measuring tools and where needed with new tools. The TEAM evaluation tools support the evaluation with respect to the following three areas:

- Technical evaluation
- User acceptance evaluation and
- Impact evaluation.

Each evaluation type may employ different evaluation tools which are described in separate chapters below. The identification of tools to be used in TEAM was carried out by two complementary approaches.

First, the application leaders and test site leaders were asked to indicate which tools they plan to apply in the evaluation of their applications. This approach assures the inclusion of approved and TEAM specific evaluation tools.

For the collection of the needed evaluation tools the same tables were used as for the research question identification, which is described above. In order to provide the specific answers of the application developing experts and to allow later updates the tables provide a common framework for reporting the needed tools. The individual tables per application are available in the annex of this document. For the identification of tools the columns "measurements" and "tools" are important. Measurements indicate the need for certain data and tools and provide the material used to collect this data. Specifically tailored tools for special evaluation purposes are included in this step. Table 5.1 below contains a consolidated list of the tools that have been mentioned by the application leaders. The consolidation compromises the tools to categories and clusters the variety of labels used by different professions in the TEAM team into one common language. However, the specific names remain in the tables in the annex. The tool categories, reported in the table below, also form the chapters of the following sections of this report where the tools are described on a more specific level.

Table 5.1: Consolidated list of tools to be used in TEAM Evaluation.

Technical Tools	User Acceptance Tools	Impact Analysis Tools
Data Logging Tools	Questionnaires	Questionnaires
Data Analysis Tool	Scales	Scales
Data Synchronization tools	Interview	Interview
	Behaviour Monitoring Methods	Behaviour Monitoring Methods
	Use history logging tools	Travel Diary Templates
	Use history analysis tools	Use history logging tools
		Use history analysis tools
		Data Logging Tools
		Data Analysis Tool
		Traffic simulator tools
		Driving simulator tools

In a second step, dedicated experts for each evaluation field (technical, acceptance, impact) where involved in order to review and specify the mentioned tools and add evaluation tools that have not been mentioned but are typically used. Especially the approved evaluation tools from following projects have been reviewed and included in the tool box:

- AIDE
- FESTA
- SAFESPOT
- GoodRoute
- TeleFOT
- Drive Car2X
- InteractIVe

The outcome of the twofold approach is a list and description of approve and TEAM specific evaluation tools which shall be used in the TEAM evaluation. They are presented in the chapters below and will provide all needed data to assess the success of the TEAM applications in the three areas of technical, user acceptance and impact evaluation.

5.1 Tools for instructions for participants and for experimenters

All evaluation tests shall be carried out in reliable and repeatable conditions. The involvement of human test participants requires special attention on this matter since there is a high variability that human testers bring into the results of repeated tests. Typical countermeasures are to select a wide and heterogenic subset of test participants, randomize the order of testing for the participants and provide standardized instructions and evaluation tools to the test participants. This assures that no biasing or uncontrolled variance is introduced by the evaluation tools to the results.

The basic tool for all evaluation approaches are also standardized instructions and a checklist for the experimenter. They are highly recommended for the specific reasons described below.

5.1.1 Instructions for test participants

One relevant disturbance effect is caused by instructions. Great importance must be given to instructions given to participants involved in empirical experiments. In fact, the way in which instructions are prepared, could influence collected answers.

Written instructions avoid the disturbance effect due to the experimenter, contrarily to oral instructions. The voice tone may transmit unconsciously relevant information about the experimenter's opinion. As a consequence it is recommended to use written instruction, whenever this is possible. These written instructions must be written in a simple way, using simple words and phrases and, moreover, the instruction must make explicit the possibility to ask to experimenter for further clarifications.

Another important issue to be given to the participants in a written form is the introduction to the research, in which there are information about who is the experimenter, what the purpose of the research is and what the results are going to be used for. One must be careful to avoid putting information in the introduction that may bias the participant in any way.

Information given by the participants and data collected will be treated only for statistical purpose and in an anonymous way. Last but not least, it is important to underline that there will not be any evaluation about participants´ ideas and performance during the experiments. As the thinking aloud may be a very important aspect in order to collect precious information about usability and, in general, system acceptance, it should be considered to write in the instruction that participants should think aloud, telling all information that come to their minds.

Written instruction about the system functionality is another important part to consider. In particular, to measure the very first impact of the system only general information about devices shall be given.

In particular:

- what type of devices are present (i.e. navigator, frontal collision warning, etc);

- which functions are linked to different devices (i.e. *"with the navigator system you can insert a destination, …"*

Since reading a comprehensive manual is very tiring for participants, it is important to develop a manual with few written instructions. Following the indication of the manual, the experimenter should demonstrate the system showing the different functions in order to maximize the attention of participants.

Participants shall be informed explicitly that the test is a "test of the system and NOT a test of the person". Also, an informed consent is mandatory for all tests, including information about possible risks, data storage/data privacy and video/photo data, etc.

5.1.2 Instructions for experimenters

During the experiments, the unavoidable interaction between experimenter and participant is surely different from an interaction that happens in everyday life. The experimenter presence and role can't be indifferent for the participant. The fact of being observed can induce participants to behave in a different way with respect to their normal life. And these changes could modify the experiment results. During the interaction, the disturbance effects can come from information that the experimenter communicates involuntarily through their individual characteristics: physical aspect, personality, momentary emotional state. Moreover, the experimenter can induce systematic mistakes with their behaviour. The experimenter's expectations can induce some observation, data registration and interpretation mistakes.

In order to avoid negative effects due to the experimenter presence, written presentations and an experimenter who does not know research objectives and hypotheses (double blind method) can help.

Additionally, the experimenter has to carry out all experimental preparations and procedures in a standardized way and always in the same order. It has been proven very helpful to prepare a list with all actions to be performed by the experimenter for each test participant. This list can be very detailed and clustered in groups of action so that the experimenter can check each necessary step during the experiment. This avoids mistakes by the experimenter and helps to detect unintended behaviour by the experimenter instantly.

5.2 Technical Performance measurement tools

This chapter proposes the tools for the assessment of technical performance and technical feasibility of TEAM applications. The proposed tools allow all measurements required by the application leaders which have been specified in the tables provided in the annex of this document. The tools enable the evaluation of the technical performance with respect to the technical high level objectives specified in chapter 1.

The following list of evaluation tools is sorted by equipment type and further lists the measures that can be taken from using the equipment. Those measures fulfil the requirements collected in the tables in the annex.

According to the consolidated table of evaluation tools above the following tool categories are further specified for the TEAM application evaluation:

5.2.1 Data logging and data analysis tools

Data logging tools are used to collect technical data. Most logging tools provide analysis tools for their data. The logging and analysis allow analysis about data correctness, data reliability, latency and performance, as well as robustness under different weather or use case conditions.

5.2.1.1 High Accuracy GPS Data Loggers

Description: High Accuracy GPS Data Loggers record the driven route in an internal storage and have the advantages of high level accuracy and test repeatability. Possible fields of application for these devices are especially those, in which position and speed data is required. Focusing on communication between different vehicles and infrastructure Collaborative ACC (C-ACC), for instance, requires devices such as High Accuracy GPS Data Loggers to share position and speed information. The interpretation of these data can be used for appropriate reaction regarding the traffic situation to improve traffic flow. Another use case in the TEAM evaluation of High Accuracy GPS Data Loggers will be Collaborative Eco-Friendly Parking (EFP). In order to offer real time information of location of free parking spaces either in the surrounding of the navigator or in the most probable destination the application requires information about the driver´s position. Recorded routes from the past can help predicting the driver´s likely destination and provide proper parking lots in advance. Collaborative driving and merging (CDM) requires precise positioning and hence the application of High Accuracy GPS Data Loggers to prove the technical performance of the system.

With today´s GPS Data Loggers the data can be shown live (using a USB serial connection) and be logged to compact flash cards for easy transfer to PC. Included specific software enables to show real time graphs of speed against time, setup slip angle data and calculate antenna locations like the VBOX3i – Dual Antenna (VB3iSL) (http://www.velocitybox.co.uk/index.php/en/products/gps-data-loggers.

The High Accuracy GPS Data Loggers require the following input and provide the below listed measures for evaluation.

Data Input:

- Real time information about position and speed
- Data Input units are the same as measurement units below

Measurements:

- True heading
- Slip angle
- Pitch/roll angle
- Yaw rate
- Lateral velocity
- Longitudinal velocity

5.2.1.2 OBDII Diagnostic Connector, Scan Tools and Adaptors

Description: Various tools are available that plug into the OBDII connector to access the on-board diagnostic functions by communicating and retrieving information from the car´s computer. The transmission is carried out wirelessly to any end device like smartphones or PC. Adaptors also allow connecting high performance aftermarket sensors such as wideband air/fuel ratio, exhausting gas temperature, vacuum/boost, air intake temperature, fluid pressure and fluid temperature and viewing on Android mobile devices. Such a solution is desired for TEAM applications where vehicles do not support certain sensors or the car´s computer does not report them. They also have an important role as reference data collectors. TEAM applications such as Collaborative Active Crouse Control (C-ACC) or Collaborative Smart Intersections (CSI) rely on the measures of this evaluation tool in order to allow evaluation of emissions and generally technical performance.

The different tools range from simple, generic consumer level tools to sophisticated OEM dealership tools to vehicle telematics devices like the Kiwi Bluetooth from PLX Devices (http://www.plxdevices.com).

Measurements (example PIDs, some implemented at the manufacturers' discretion):

- 0 – 100kph time
- 100 – 0kph time
- Absolute throttle position
- Accelerator pedal position
- Air-fuel ratio
- Ambient air temperature
- Average trip speed
- Barometric pressure
- Catalyst temperature
- CO_2
- Distance to empty (estimated)
- Engine coolant temperature
- Engine load
- Engine oil temperature
- Engine RPM
- EVAP system vapour pressure

- Exhaust gas temperature
- Fuel flow rate
- Fuel level
- Fuel pressure
- Fuel trims
- Horsepower
- Intake air temperature
- Intake manifold temperature
- Kilometres per litre
- Litres per 100 kilometres
- Mass air flow rate
- Motor RPM
- Motor torque
- O_2 sensor equivalence ratio
- Speed
- Torque
- Transmission temperature

5.2.1.3 Vehicle Detection Sensors

Description: Traffic detection is a fundamental component of the planning and operation of local roads and highways. There is a wide range of sensor technologies available for vehicle detector (e.g. video image processors; infrared detectors; ultrasonic detectors; microwave/millimetre wave radar; passive acoustic detector arrays; piezoelectric; photoelectric; spread-spectrum wideband radar; inductive loop detectors; magnetic detectors; acceleration detectors; wireless detection sensors.)

Primary applications for vehicle detection sensors are traffic flow monitoring and signal control. The sensors can measure volume, speed, occupancy, presence, headway, gap, direction of travel, and vehicle length. They can support traffic monitoring stations on freeways and arterials or traffic signal control applications including stop bar and advance detection at intersections, as well as ramp management at freeway entrances.

For nearly 50 years, the primary technology used to detect vehicles has been the inductive loop detector. Although simple, inductive loop detectors are somewhat expensive to install. They require a nearby source of electrical power, which adds to the cost of installation. They can also be expensive to maintain, as they suffer from various forms of deterioration caused by the mechanical stress of freeze/thaw cycles and vibrations, as well as oxidation. The development of wireless vehicle sensors reduces the disadvantages caused by inductive loop detectors. The wireless nature provides added flexibility in complicated configurations such as split roadways, flyovers, bridges, or when detection is required at long distances from the traffic signal controller. The relatively low cost and ease of installation also hold the potential for additional applications such as work zone management and traffic monitoring of secondary roadways.

Measurements:

- Speed
- Occupancy
- Headway
- Gap
- Direction of travel
- Count
- Presence
- Vehicle classification

5.2.1.4 Ready-To-Go Adaptive Cruise Control Test Systems

Description: To test some applications like Collaborative Active Crouse Control (C-ACC), different driving manoeuvres with two vehicles must be performed. There are testing tools (e.g. CAPS-ACC by DEWETRON) that allow synchronised measurements from both vehicles which requires a universal and multifunctional measurement system for each vehicle.

The synchronisation includes analogue data (e.g. voltage, acceleration, strain, etc.), CAN, GPS and video data. The advantage of a Ready-to-go Adaptive Cruise Control measurement system like CAPS-ACC lies within comparable and reproducible tests. Data such as vehicle distance, speed, heading is recorded fully synchronized together with CAN Bus and video data. There is also a possibility for online checking of the measurement data quality with visualization of the relative position and the heading of both vehicles. Automated reports can be generated for predefined manoeuvres.

For further Information check
http://www.dewetron.com/de/anwendungen/automobilmesstechnik/fahrerassistenz-systeme/adaptive-geschwindig-keitsregelung/

Measurements:

- GPS and gyro-based measurements
- Relative speed, distance, acceleration

5.2.2 Data synchronization tools

Logging of various data implies the urgent need of having all data synchronized and stored in a common data base. In TEAM the following tool chain consisting of the TEAM testing unit, the TEAM logging station, and the TEAM log data store is used for this:

TEAM Testing Unit

The TEAM Testing Unit (TU) is an OSGi-Bundle deployed on all relevant ITS stations (VIS, RIS, CIS). The concept foresees also an application on the PIS. It runs in the same OSGi environment as all the other TEAM bundles. The TU provides interfaces to the other bundles such that they log all kinds of data. The TU is capable to serialize the log data in CSV-files on the hard drive of the ITS station. Besides it could be configured in a way that log data (or a subset of it) is send via some IP connection to a central entity, e.g. in order to monitor the pilot or ECO-Challenge execution in real-time.

TEAM Logging Station

The TEAM Logging Station (LS) is an optional tool that could be used if the pilot sites have many VIS deployed and log a huge amount of data. The LS is used when log data from ITS stations is transmitted to some central entity (we assume to have a broadband connection here) using USB sticks. The USB sticks are configured in a way that they support data privacy and integrity. The LS will be used to acquire the data from USB sticks and forward it to the final TEAM log data store.

TEAM Log data store

The TEAM log data store (LDS) is the central repository for log files. It will be hosted by FOKUS and will provide performing access to all logged data to all relevant partners.

5.3 User Acceptance measurement tools

User acceptance is a construct that is defined as the willingness to use a system or product. Related constructs to user acceptance are usability or user experience which is known to enhance the probability of user acceptance. Systems or products which are supposed to be used as a secondary task (e.g. while driving) require further that users do not get more distracted than appropriate in the primary task.

Tools for User Acceptance measurements and its related concepts can be categorized in

- Behaviour analysis and
- Self assessment tools (interviews, questionnaires and scales)

The annex of this document provides an extensive description and user guide of useful user acceptance tools. Further tools can be found in the literature. Technical descriptions and instructions on how to apply specific tools can be found e.g. in Stanton et al. (2006).

5.3.1 Behaviour monitoring tools

Behaviour analysis can be used for user acceptance as soon as a prototype is available that allows interaction. Typically, a user is involved in the interaction and is monitored while using the application. This can happen by data logging and application of the same tools used for technical evaluation or by an observer. This observation can be done either directly or via cameras. Observation allows qualitative and quantitative evaluation. A qualitative assessment can be done by a description of the user's activities while a quantitative assessment requires that certain behaviour has been identified beforehand and the observer registers if this behaviour occurs.

Supportive tools which can be used for behaviour analysis are eyetracking devices or automated gesture and posture analysis.

A typical question to answer related to behaviour analysis is if the application is used at all or under which circumstances it is used. It is also possible to measure if a user chooses the new application over an alternative to comply a task.

Well established behaviour observation tools also allow the evaluation of sleepiness (TUBS – TU Berlin Schläfrigkeitsskala, KSS - Karolinska Sleepiness Scale) [14], distraction (BABS – Beobachterbasierte Ablenkungsskala [15, 16], or driver's intention BP-BOS (Behaviour Prediction with Behaviour Observation Scales)[17].

5.3.2 Use history logging and analysis tools

Modern digital systems usually log and store a large number of data related to their usage. A specific description of tools that shall be used in the TEAM project is provided in the chapter on technical evaluation tools. However, the data collected with such tools also provide valuable information for user acceptance evaluation.

Typical data that provide information on user acceptance are:

- Number of users who used the system
- Number of times system was used
- Duration of system usage
- Functions that have been used, or not used
- In which situations was the system switched off by the user?

5.3.3 Self Assessment Tools: questionnaires, scales, interviews

In order to achieve valid results in the self-assessment, it is important to pay attention to the following aspects:

- all the systems need to be described to the users using the commonly understandable terminology

- formulation of the questions need to be neutral, i.e. not to indicate what are the expectations of the researcher
- one impact area should be measured with multiple questions, if feasible, to avoid so called "socially desirable responses"
- in all the questions it needs to be absolutely clear if the user needs to compare the situations "with the system" to the situations "without the system"
- user needs to be reminded of the context of use (and context of impact evaluation) often
- commonly accepted scales, e.g. Likert-scales, need to be used when possible.

5.3.3.1 Questionnaires

Questionnaires collect subjective data and hypothetical decisions in a self assessment of the test participant. They are especially useful for large numbers of participants. Questionnaires for user acceptance assessment usually include questions with respect to:

- Demographic and person data
- Willingness to use and willingness to pay
- Specific questions about the application in order to answer specific hypotheses

Acceptance can be assessed very well by a simple question that should be asked to all participants after experiencing a system.

"Would you keep the system on/active all the time or inactivate it in certain situations?"

If the answer is "I would inactivate it…" the following question should be asked additionally:

"When?" and *"Why?"*

5.3.3.2 Scales

In contrast to questionnaires, scales measure well described concepts with a set of standardized numbers and sequence of questions and provide an analysis method to calculate a final value as a result. Typically, Likert Scales and Semantinc Differentials are applied.

In order to assess user acceptance a well-established set of scales has been developed. The following scales are described in the annex with instructions on how to use and analyse the results:

- User Acceptance Scale (UAS) --> see annex
- System Usability Scale (SUS) --> see annex
- User Experience Questionnaire AttraktDiff2 --> see annex

- Workload scale NASA TLX. --> see annex

5.3.3.3 Interviews

Interviews are especially useful when the assessment criteria are not clear. Open interviews provide topics rather than specific questions and avoid biasing the answers of the test participants. The answers will be more specific if a detailed view of the application can be provided.

Typical questions for an open interview that shall assess user acceptance are

- What do you think about XY?
- Describe how you would use this?
- Did you understand the information? What did you understand?
- What did you appreciate most about the system?
- What did you appreciate the least of the system?
- How can the information given be optimized in your opinion?
- How is your behaviour influenced by having the system activated?
- Do you have further comments about the presentation of information (HMI)?

On the other hand, the more structured an interview is prepared the easier is it to structure the responses and even turn them into categories and finally quantification. Semi structured interviews provide specific questions but allow as much time as needed for the answer and will not bias the answer by any means.

Typical questions for a semi-structured interview are:

- What do you like about X?
- What do you dislike about X?
- How did you perceive the timing of the information or warning?
- Did the information distract from the event? Why? / How?
- Did the information help to manage the event? Why? / How?

Fully structured interviews provide questions that already define the answer’s format. Such questions do not differ much from questions in questionnaires.

5.4 Impact assessment tools

According to chapter 4, impact evaluation is carried out with two kinds of data. On one hand, objective data is collected from test scenarios. The tools for collecting such data are the same like the tools used for technical evaluation and are described in the respective chapter above.

On the other hand, impact evaluation is carried out based on subjective data collected with the same tools used for user acceptance evaluation; however a specific focus will be in the questionnaires and interviews on impact related questions.

5.4.1 Scaling up tools

Scaling up tools, such as ERiC-tool (European Risk Calculation tool) http://www.drive-c2x.eu/tl_files/publications/Final%20event/03_Field%20Trials%20Methodolody_Pirkko%20Raema.pdf that have proven well results in the Drive Car2X project shall also be used in TEAM. Additional simulation tools are applied to produce data that cannot be collected on test tracks or by subjective assessments. Scaling up tools are used to upscale available small scale data and to estimate impacts in case of higher application rates.

5.4.1 Simulation tools

In TEAM project the main simulation tool is actually a toolbox which integrates all available simulation tools. The VSimRTI simulation environment (Figure below) is a simulation framework that overcomes the limitations of hitherto existing V2X simulation systems. It uses a concept that allows to couple arbitrary simulation systems providing a remote control interface. Hence, the most relevant simulators can be integrated for the microscopic simulation of vehicle traffic, the analysis of environmental effects and emissions, the modelling of wireless communication including V2X, and the execution of applications implemented in vehicles. VSimRTI facilitates up-to-date solutions even if the currently combined single simulators become obsolete and have to be replaced. With this framework and integrated simulators, TEAM project is able to assess all TEAM applications under various penetration rate assumptions in various aspects related to environmental impacts and impacts on traffic flow.

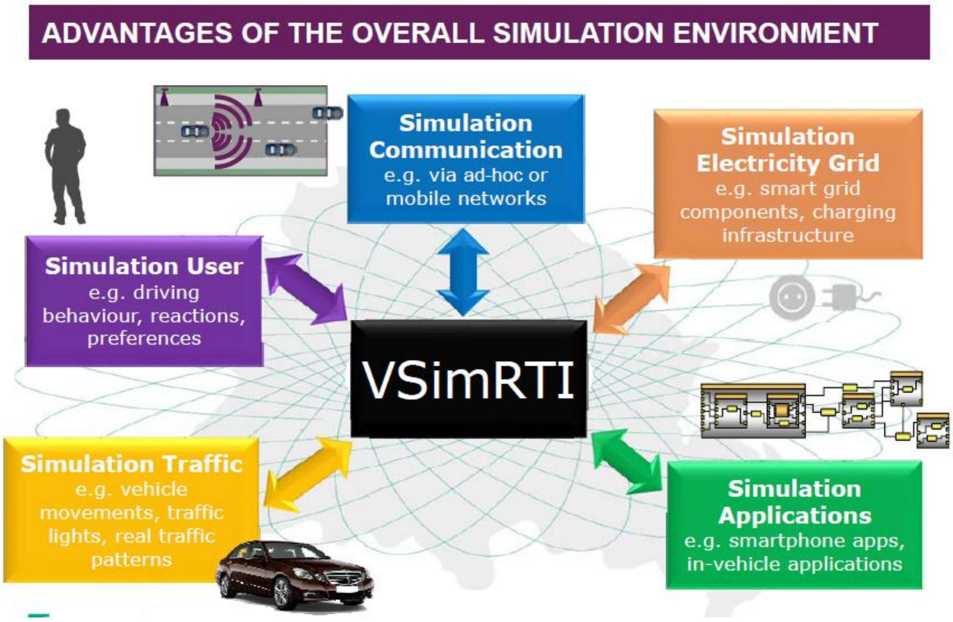


Figure 5.1: Overall advantages of VSimRTI-simulation tool (VSimRTI presentation, 2014).

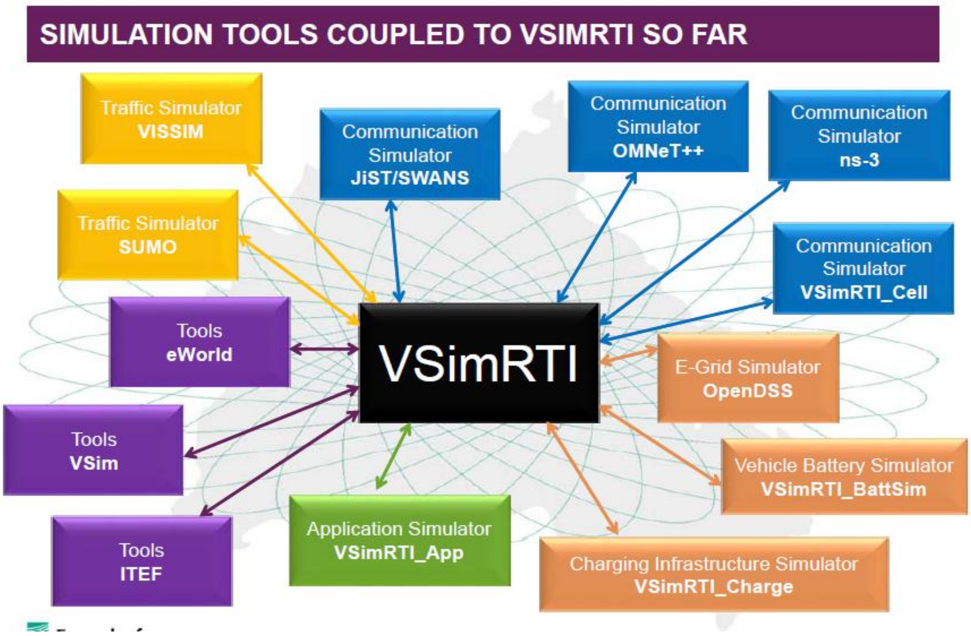


Figure 5.2: Simulation tools coupled with VSimRTI up today (VSimRTI presentation, 2014).

5.4.2 Driving simulation tools

Driving simulator is an important tool for driving behaviour studies. It offers a safe and replicable virtual driving environment where it is possible to create scenarios that are ethically, logistically and monetarily impossible to carry out in real environment. There are some commonly recognized reasons why simulation is used in driving performance or behaviour studies. First, repeatability provides the researcher with the ability to study the phenomena numerous times, which in the real world would be hard to accomplish. Second, safety plays a critical role when studying, for example, unexpected driving conditions or driving under the influence of alcohol. Third, tracking of the most operations of the driver becomes possible in a simulator, and fourth, a simulator enables the use of versatile research equipment, thus providing a comprehensive recording of multivariate data for detailed analysis. Simulation studies can be conducted on large and small scales and simulation data can be upscaled in order to estimate the impact of new applications that may be introduced to a larger set of road users.

6 Conclusions

The deliverable achieved a framework for the final evaluation of the TEAM applications. As pointed out in chapter 1 “Introduction”, every evaluation starts with the definition of high level research questions.

This deliverable reports in chapter 2 “a Method for defining the TEAM research questions” the process how those high level research questions have been defined and concludes with overall 15 high level research questions clustered in three categories: technical evaluation, user acceptance evaluation and impact evaluation. Those 15 high level research questions have been agreed with the project management and are supposed to be final and may not be changed anymore. They serve the project management to disseminate the overall results of the project and guide the final evaluation of all applications.

Based on the high level research questions an intensive process of collecting application specific detailed research questions has been started which is described in chapter 3 “Application specific research questions”. Those research questions are defined according to the current state of knowledge and are summarized in the annexes of the deliverable as well as in excel sheets. They are subject to possible changes in case application testing plans change. However changes shall be reported and commented since the research questions are the main guide for evaluation planning and results analysis.

Chapter 4 “valuation approaches and study design” is dedicated to providing common guidance and specific ideas how to carry out the evaluation in general and specifically for each application. The study design plans are on the one hand generic enough to be relevant for every application and reflecting the current state of knowledge with respect to the planning at test sites and application developments.

Chapter 5 “Evaluation tools” reports which tools are currently planned to be used in the evaluation of the TEAM applications. This information is taken from the information provided by the application leaders in the annex tables of this deliverable. Furthermore the chapter provides a description for each tool to be applied. Tool descriptions are clustered in the evaluation fields: technical evaluation, user acceptance evaluation and impact evaluation.

The high level research questions specified in this deliverable will serve, together with the framework tables for research questions, hypothesis, measurements and tools, for the specification of the test cases and evaluations to be carried out in the Euro Eco Challenge and furthermore will be used to carry out and focus the results analysis on the most important aspects. This aspect is a very important result of the deliverable since now the tests can be planned in a way that the important research questions can be tackled and the results will be useful for an overall evaluation and interpretation of the TEAM achievements. Research questions, study designs and tools are specified in a preliminary but very helpful approach for the tests to be carried out and by following this approach in the end of the evaluation a large set of results will be available that can be attributed directly to the high level research questions. This will allow a big overall picture for researchers, politicians and the European citizens.

List of abbreviations and acronyms

Abbreviation	Meaning
C2x	Car to Car and Car to Infrastructure or other entities
C-ACC	Collaborative adaptive cruise control
CCA	Co-modal coaching with support from virtual/avatar users
CDM	Collaborative driving and merging
CMC	Collaborative pro-active urban/inter-urban monitoring and ad-hoc control
CONAV	Collaborative eco-friendly navigation
COPLAN	Collaborative co-modal route planning
CPTO	Collaborative public transport optimization
CSI	Collaborative smart intersection for intelligent priorities
D	Deliverable
DC	Collaborative dynamic corridors
DoW	Description of Work
EC	European Commission
EFP	Collaborative eco-friendly parking
EU	European Union
EU	European Union
H	Hypothesis
HL	High Level (e.g. HL RQ is the abbreviation of High Level Research Questions)
HL RQ	High Level Research Question
HLO	High Level Objectives
HMI	Human Machine Interface
IR	Internal Report

Abbreviation	Meaning
OBU	On board unit
Req	Requirement
RQ	Research Question
SG-CM	Green, safe and collaborative driving serious game and community building
SoA	State of the Art
SP	Sub Project
TEAM	Tomorrow's Elastic Adaptive Mobility
UA	User Acceptance
WP	Work package

References

1. TEAM (2014). TEAM-project webpage: http://www.collaborative-team.eu
2. Penttinen, M., Diederichs, F., Pagle, K., Portouli, E., Rämä, P., Impact evaluation methodology for collaborative transport applications. Accepted for publication in proceedings of 21st World Congress on ITS 2014, in Detroit, Michigan
3. FESTA (2012). http://wiki.fot-net.eu/index.php?title=FESTA_handbook
4. Rämä, P., Innamaa, S., Brignolo, R. (2012). Creating research hypotheses and defining measurements. In proceedings of 19th World Congress on ITS, Vienna, Austria. ERTICO (ITS Europe)
5. Franzén, S., Karlsson, I.C.M., Paglé, K., Morris, A., Testing and Evaluation Strategy II, TeleFOT Project Deliverable, available online at http://ec.europa.eu/information_society/apps/projects/logos/7/224067/080/deliverables/001_TeleFOTD222TestingandEvaluationStrategyII130222.pdf
6. Fakler. O., Willemsen. D., Diederichs. F. (2011) Method for harmonized evaluation, of large lets of vehicle based and roadside based applications. In proceedings of 8th European Congress on ITS 2011, Lyon, France. ERTICO (ITS Europe).
7. Diederichs, Frederik; Fried, Felix (2012): Universal methodology for iterative user centered HMI development and testing. In: *Procedia* 48, S. 1164–1173.
8. www.safeway2school-eu.org, 2009-2012.
9. ISO 13407 (1999): Human-centred design processes for interactive systems, replaced by ISO 9241-210 (2010), Ergonomics of human-system interaction -- Part 210: Human-centred design for interactive systems.
10. v-model: Systems Engineering for Intelligent Transportation Systems. US Dept. of Transportation, p. 10. URL: http://ops.fhwa.dot.gov/publications/seitsguide/seguide.pdf. [10.11.2010].
11. TEAM Deliverable 1.0 “TEAM users, stakeholders and use cases”
12. TEAM Deliverable 3.4.1 “FLEX platform, applications and enablers design”
13. TEAM Deliverable 4.3.1 “Requirements of DIALOGUE components, enablers and applications”

14. Hagenmeyer, L. Development of a multimodal, universal human-machine-interface for hypovigilance-management-systems. Jost-Jetter Verlag (2007). IPA-IAO Forschung und Praxis, 462. ISBN: 3-939890-17-0

15. Ganzhorn, Melanie; Diederichs, Frederik; Höfer, Manuel (2013): Eine bewerterbasierte Ablenkungsskala (BABS) zur objektiven Beurteilung von Unaufmerksamkeit. In: Der Fahrer im 21. Jahrhundert. Düsseldorf: VDI-Verlag, S. 133–146.

16. Ganzhorn, Melanie; Diederichs, Frederik; Widlroither, Harald (2013): A holistic approach for measuring driver distraction and inattention. In: 3rd International Conference on Driver Distraction and Inattention, DDI 2013. Presentations & Reviewed Papers. Online resource. Gothenburg, S. 15.

17. Diederichs, F. & Pöhler, G. (2014). Driving Maneuver Prediction Based on Driver Behaviour Observation. In: Proceedings of the 5th International Conference on Applied Human Factors and Ergonomics (AHFE). Kraków, Poland.

18. Kulmala R., Leviäkangas P., Sihvola N., Rämä P., Francics J., Hardman E., Ball S., Smith B., McCrae I., Barlow T. & Stevens A. (2008). CODIA Deliverable 5: Final Study Report. CODIA Co-Operative systems Deployment Impact Assessment. Submitted to European Commission DG-INFSO

19. Kulmala (2010). Ex-ante assessment of the safety effects of intelligent transport systems. Accident Analysis and Prevention 42 (2010), p. 1359 -1369.

20. Elvik R., Høye A., Vaa T. and Sørensen M. (2009). The handbook of road safety measures. Second edition. Bingley, U.K.: Emerald Group Publishing Limited.

7 Annexes

Annex 1 Technical Research Questions, Measurements and Tools

The following tables present the research questions and success criteria relevant for the technical evaluation of all TEAM applications.

Table 7.1: Technical Research Questions and Success Criteria for CMC.

HL RQs		RQs		Hs		Indicators	Measurements/ Tools
1	Does the application support (in a first level) and achieve it (in a second level) the dynamic adaptation of the infrastructure?	1.1	Is demand data available and accurate? Does the data cover the whole network area?	-	-		
		1.2	Is traffic data available and accurate? Does the data cover the whole network area?	-	-		
		1.3	Is air quality data available and accurate? Does the data cover the whole network area?				air quality index for the area: (good, satisfactory, fair, poor, very poor)
		1.4	Is the incident data available and accurate? Does it cover the whole area?				traffic mgmt / network operator

HL RQs	RQs		Hs		Indicators	Measurements/ Tools
	1.5	Is the data/information of special events available and accurate? Does the data cover the whole network area?	-	-		traffic mgmt / network operator
	1.6	Are the forecasts for the traffic available and accurate? Do the forecasts cover the whole network area?	-	-		traffic mgmt / network operator
	1.7	Is communication seamless and ubiquitous?	-	-		
	1.8	To what extent are the calculated data accurate?				
	1.9	Do the calculated data fulfil the real-time requirements?				timestamps (delta_t < 60s)
	1.10	Are the source data available in sufficient quality when needed?				
	1.11	Which penetration rates are needed?				
	1.12	Is system integration achieved in sufficient quality?				
	1.13	How can the initial installation cost for RSU be reduced?				
	1.14	How can the initial installation cost for OBU be reduced?				

HL RQs		RQs		Hs		Indicators	Measurements/ Tools
2	Does the user receive a dynamically adapted output from the application?	2.1	Does the traveller receive a dynamically adapted travel plan (schedule, route) before the trip?	-	-		HMI / CIS logs
		2.2	Does the driver receive a dynamically adapted travel plan (including schedule/estimated arrival time and route) during the trip?	-	-		HMI / CIS logs
3	Does the application support the interaction of multiple and different types of users?	3.1	Does the application promote the collaborative behaviour of users (operator, driver)	3.1.1	Multiple drivers interact among themselves		questionnaire / HMI logs
				3.1.2	The operator interacts with drivers		HMI / CIS logs
		3.2	Do the application algorithms allow the collaborative decision making	-	-		logging when collaborative methods used
		3.3	Are users decisions collaboratively improved through real time guidance?	-	-		questionnaire / diaries
		3.4	How can the requirements of many different stakeholder (e.g. different parking lot operators) be included?				

Table 7.2: Technical Research Questions and Success Criteria for COPLAN.

HL RQs		RQs		Hs		Indicators	Measurements/ Tools
1	Does the application support (in a first level) and achieve it (in a second level) the dynamic adaptation of the infrastructure?	1.1	Is demand data available and accurate? Does the data cover the whole network area?	-	-	Demand data availability. Availability depends on network coverage. Accuracy refers both to the terminal/application itself (e.g. location determination) and the correct storage/retrieval to/from the database.)	Extensive coverage related measurements (RSSI/RSRP, RSSNR, RSRQ, CQI). Verification of the correct storage/retrieval of the demand data to/from the DB.
		1.2	Is traffic data available and accurate? Does the data cover the whole network area?	-	-	Traffic data availability. Availability depends on network coverage. Accuracy refers both to the terminal/application itself (e.g. location determination) and the correct storage/retrieval to/from the database.	Extensive coverage related measurements (RSSI/RSRP, RSSNR, RSRQ, CQI). Verification of the correct storage/retrieval of the traffic data to/from the DB.
		1.3	Is air quality data available and accurate? Does the data cover the whole network area?			The correct retrieval of air quality data from the external provider.	Verify the correct retrieval of air quality data from the external provider.
		1.4	Are routes dynamically rescheduled?	-	-	Dynamic route rescheduling. (Change(s) of initial route in real	Monitoring the actual route in real time.

HL RQs	RQs		Hs		Indicators	Measurements/ Tools
					time.)	
	1.5	Is total travel time reduced?	-	-	Route time reduction (Comparison of the travel time with and without using the application).	Total travel time with and without using the application. Verify the time reduction.
	1.6	Is total waiting time reduced?	-	-	Waiting time reduction. (Comparison of the travel time with and without using the application).	Total waiting time with and without using the application. Verify the time reduction.
	1.7	Is communication seamless and ubiquitous?	-	-	Ubiquity in communications (Depends on network availability and access technology interoperability, as well as on proper application operation, e.g. bug free).	Extensive coverage related measurements (RSSI/RSRP, RSSNR, RSRQ, CQI) and repetitive app usage.
	1.8	Is traffic data sent in real time (or near real time)?	1.7.1	Traffic data is sent in real time	Time required for the transfer of data.	Time difference between departure and arrival/storage time of data.
			1.7.2	Traffic data is sent with a small delay of up to 3 minutes (near real time)	Time required for the transfer of data.	Time difference between departure and arrival/storage time of data.

HL RQs	RQs		Hs		Indicators	Measurements/ Tools
			1.7.3	Traffic data is sent with a considerable delay (more than 3 minutes)	Time required for the transfer of data.	Time difference between departure and arrival/storage time of data.
	1.9	Is traffic data integrity and reliability achieved?	1.8.1	Traffic data integrity is achieved	Received traffic data availability. Concerning access/core mobile network data integrity is supported inherently.	Verify that the received traffic data is correct. Verify that the data has been processed/presented as expected. Concerning the access/core mobile network no measurement required.
			1.8.2	Traffic data reliability is achieved	Received traffic data availability. Concerning access/core mobile network data reliability is supported inherently.	Verify that the received traffic data is correct. Verify that the data has been processed/presented as expected. Concerning the access/core mobile network no measurement required.

HL RQs	RQs		Hs		Indicators	Measurements/ Tools
			1.8.3	Traffic data integrity is partially achieved	Received traffic data availability. Concerning access/core mobile network data integrity is supported inherently.	Verify whether the received traffic data is correct. Verify whether the data has been processed/presented as expected. Concerning the access/core mobile network no measurement required.
			1.8.4	Traffic data reliability is partially achieved	Received traffic data availability. Concerning access/core mobile network data reliability is supported inherently.	Verify whether the received traffic data is correct. Verify whether the data has been processed/presented as expected. Concerning the access/core mobile network no measurement required.
	1.10	Does the application ensure user info privacy?	1.9.1	The application ensures user info privacy	No indication required. Concerning access/core mobile network data security is supported inherently.	Verify that at application installation time the application requests only the necessary permissions to access personal data and that the personal data is not forwarded to 3rd party servers .

HL RQs	RQs		Hs		Indicators	Measurements/ Tools
						Concerning the access/core mobile network data no measurement required.
			1.9.2	The application offers limited user info privacy		
			1.9.3	The application does not offer user info privacy		
	1.11	Does the application use a secure communications channel for the transmission of data?	1.10.1	The application uses a secure communications channel for the transmission of data.	No indicator required. Access/core mobile network support security inherently.	No measurement required. Access/core mobile network support security inherently.
			1.10.2	The application does not use a secure communications channel for the transmission of data.	No indicator required. Access/core mobile network support security inherently.	No measurement required. Access/core mobile network support security inherently.
	1.12	Is the application updated on a regular basis at no expense for the user?	1.11.1	The application is updated on a regular basis	Updated information appears on terminal screen.	Verify that the application is updated with the latest changes (e.g. route rescheduling).
			1.11.2	The application is updated, but not on a regular basis	Updated information appears more often (or delayed) than expected on terminal screen.	Time interval between information updates with the latest changes (e.g. route rescheduling).

HL RQs		RQs		Hs		Indicators	Measurements/ Tools
2	Does the user receive a dynamically adapted output from the application?	2.1	Does the traveller receive a dynamically adapted travel plan (including schedule, route and modes) before the trip?	-	-	Adapted travel plan (change(s) of initial travel plan in real time) received within seconds by the traveller, upon some kind of rescheduling before the trip.	Make rescheduling of an initial route (e.g. change of schedule, route and/or modes) before the trip and verify that the traveller receives the adapted travel plan within seconds.
		2.2	Does the traveller receive a dynamically adapted travel plan (including schedule, route and modes) during the trip?	-	-	Adapted travel plan (change(s) of initial travel plan in real time) received by the traveller within seconds, upon some kind of rescheduling during the trip.	Make rescheduling of an initial route (e.g. change of schedule, route and/or modes) during the trip and verify that the traveller receives the adapted travel plan in near real-time.
		2.3	Does the driver receive a dynamically adapted travel plan (including schedule, route and modes) during the trip?	-	-	Adapted travel plan (change(s) of initial travel plan in real time) received by the driver, upon some kind of rescheduling during the trip.	Make rescheduling of an initial route (e.g. change of schedule, route and/or modes) during the trip and verify that the driver receives the adapted travel plan in near real-time.

HL RQs	RQs		Hs		Indicators	Measurements/ Tools
	2.4	Does the application suggest alternative routes for travellers?	2.4.1	The application suggests alternative routes for travellers.	Availability/Suggestion of alternative routes.	Verify that the application suggests alternative routes for travellers.
			2.4.2	The application does not suggest alternative routes for travellers.	Unavailability of alternative route suggestion	Verify that the application suggests only one route for travellers.
	2.5	Does the application suggest the seat availability to the traveller?	2.5.1	The application suggests the bus seat availability to the traveller.	Bus seat availability suggestion	Verify that the application suggests the bus seat availability to the traveller.
			2.5.2	The application does not suggest the bus seat availability to the traveller.	Unavailability of bus seat suggestion	Verify that the application doesn't suggest any bus seat to the traveller.
	2.6	Do the application algorithms allow the user to optimise a route based on certain criteria (cost, time, etc.)	2.6.1	The application algorithms allow the user to optimise a route based on certain criteria (cost, time, etc.)	Route optimisation suggestion in terms of cost, time, etc.	Verify that the application suggests route(s) based on certain user preferences.
			2.6.2	The application algorithms do not allow the user to optimise a route based on certain criteria (cost, time, etc.)	Incapability of the application to offer optimized route(s) based on user preferences.	Verify that the application does not "calculate" the optimum route based on user preferences.

HL RQs		RQs		Hs		Indicators	Measurements/ Tools
3	Does the application support the interaction of multiple and different types of users?	3.1	Does the application promote the collaborative behaviour of users (operator, travellers and driver)	3.1.1	Multiple users interact among themselves	Multiple user interaction	Verify that the application allows multiple users (operator, travellers, drivers) to interact among themselves (e.g. have access to pool information, send/receive information about schedules, routes, modes, etc.)
				3.1.2	The operator interacts with travellers	Interaction between travellers and operator	Verify that the application allows the operator to interact with travellers exchanging information about schedules, routes, modes, etc.)
		3.2	Do the application algorithms allow the collaborative decision making?	-	-	Suggestion including information derived by multiple users.	Contribution of various information by users (operator, travellers, driver) and verify that the decision making considers all of it.

HL RQs	RQs		Hs		Indicators	Measurements/ Tools
	3.3	Does the application interface allow the interaction of multiple and different types of users?	3.3.1	The application interface allows the interaction of multiple and different types of users.	Successful interaction of multiple types of users (operator, travellers, drivers).	Verify that multiple and different types of users are able to interact (e.g. exchange information on schedules, routes, modes, etc.)
			3.3.2	The application interface does not allow the interaction of multiple and different types of users.	Incapability of successful interaction of multiple types of users (operator, travellers, drivers).	Verify that multiple and different types of users are not able to interact (e.g. exchange information on schedules, routs, modes, etc.)
	3.4	Is the interaction of multiple and different types of users increasing over time?	3.4.1	The interaction of multiple and different types of users is increasing over time.	Increase in number of multiple users who interact.	Measure the number of users who interact over time.
			3.4.2	The interaction of multiple and different types of users is decreasing over time.	Reduction of the number of multiple users who interact.	Measure the number of users who interact over time.
	3.5	Does the application offer information from 3rd parties (e.g. municipalities)?	3.5.1	The application offers information from 3rd parties (e.g. municipalities).	Retrieval and distribution of 3rd party info.	Verify that information from an external source (e.g. weather data) is received, processed and disseminated properly.
			3.5.2	The application does not offer information from 3rd	3rd party info unavailability to users.	Verify that information from an external source (e.g. weather data) is

HL RQs	RQs		Hs		Indicators	Measurements/ Tools
				parties (e.g. municipalities).		received, but is not available to the users.
	3.6	Are users decisions collaboratively improved through real time aggregation of needs?	-	-	User decision improvement	Measure the number of satisfied users?

Table 7.3: Technical Research Questions and Success Criteria for CCA.

HL RQs		RQs		Hs	Indicators	Measurements/Tools
1	Does the application support (in a first level) and achieve it (in a second level) the dynamic adaptation of the infrastructure?	1.1	Are routes dynamically rescheduled?		The application supports dynamic adaptation of the infrastructure but this is reflected in trip alternatives shown to the driver.	Dynamic adaptation would be reflected in the showing of alternative routes, and information about them, to the driver.
		1.2	Is total route time reduced?		The application supports dynamic adaptation of the infrastructure but this is reflected in trip alternatives shown to the driver.	Time taken to complete routes.
		1.3	Is total waiting time in traffic reduced?		The application supports dynamic adaptation of the infrastructure but this is reflected in trip alternatives shown to the driver.	Time taken to complete trips.
		1.4	Is it necessary that communication is seamless and ubiquitous?		The application supports dynamic adaptation of the infrastructure but this is reflected in trip alternatives shown to the driver.	Does the alternative trip information presented to the driver reflect reality? (No, if communication is not adequate.)
	-	1.5	Are users decisions collaboratively improved through real time aggregation of needs?		The application supports dynamic adaptation of the infrastructure but this is reflected in trip alternatives shown to the driver.	Collaborative behaviour is not the primary focus of the application.
		1.6	Is real-time traffic information necessary (rather than off-		The application supports dynamic adaptation of the infrastructure but	Does the alternative trip information

HL RQs	RQs		Hs	Indicators	Measurements/Tools
		line)?		this is reflected in trip alternatives shown to the driver.	presented to the driver reflect reality? (Offline data doesn't inform of current traffic jams, etc.)
	1.7	Is the integration of many (very different) data necessary and to what extent is it achieved?		The application supports dynamic adaptation of the infrastructure but this is reflected in trip alternatives shown to the driver.	Less integration of available data (e.g. public transport options; current traffic jams) results in information on alternative routes presented to the driver being limited.
	1.8	To what extent are the calculated data accurate?		The application supports dynamic adaptation of the infrastructure but this is reflected in trip alternatives shown to the driver.	(Unsure how to measure.)
	1.9	Do the calculated data fulfill the real-time requirements?		The application supports dynamic adaptation of the infrastructure but this is reflected in trip alternatives shown to the driver.	Total time to complete trips; noise, gas or particulate matter pollution output from trips; etc.
	1.10	Are the source data available when needed?		The application supports dynamic adaptation of the infrastructure but this is reflected in trip alternatives shown to the driver.	Data logs.

HL RQs		RQs		Hs		Indicators	Measurements/Tools
		1.11	Which penetration rates are needed?			The application supports dynamic adaptation of the infrastructure but this is reflected in trip alternatives shown to the driver.	N/A
	-	1.12	Is system integration achieved in sufficient quality?			The application supports dynamic adaptation of the infrastructure but this is reflected in trip alternatives shown to the driver.	Upload to smartphone, etc.
2	Does the user receive a dynamically adapted output from the application?	2.1	Does the traveller receive a dynamically adapted route?	-	-	Depends on the availability of up-to-date infrastructure-related information (e.g. lane rule switching and the resultant traffic changes in dynamic corridors).	Dynamic adaptation would be reflected in the showing of alternative routes, and information about them, to the driver.
		2.2	To what extent is the avatar behaviour similar to real user behaviour?	-	-	The output is based on exact post-trip information about realised trip alternatives.	(Should be exact.)
3	Does the application support the interaction of multiple and different types of users?	3.1	Does the application promote the collaborative behaviour of users (operator, travellers and driver)	3.1.1	Multiple travellers interact among themselves	Collaborative behaviour is not the primary focus of the application.	N/A
				3.1.2	The operator interacts with travellers	Collaborative behaviour is not the primary focus of the application.	N/A
				3.1.3	The operator interacts with bus drivers	Collaborative behaviour is not the primary focus of the application.	N/A
		3.2	How can the requirements of			Different stakeholders to ensure	N/A

HL RQs		RQs		Hs	Indicators	Measurements/Tools
			many different stakeholders (e.g. different parking lot operators) be included?		that up-to-date information about their service is obtainable by the application.	
4	Does the application perform offline tasks?	4.1	Are there offline tasks to perform a priori?		N/A	N/A
		4.2	Are there offline tasks to perform post travel?		Compute times to complete alternative trips; pollution output; etc.	Provide comparisons to the driver.

Table 7.4: Technical Research Questions and Success Criteria for CSI.

HL RQs		RQs		Hs		Indicators	Measurements/Tools
1	Does the application support (in a first level) and achieve it (in a second level) the dynamic adaptation of the infrastructure?	1.1	Is demand data available and accurate? From how many locations?	-	-	Demand data availability in many locations. Availability depends on network coverage. Accuracy refers both to the terminal/application itself (e.g. location determination) and the correct storage/retrieval to/from the database.	Extensive coverage related measurements (RSSI/RSRP, RSSNR, RSRQ, CQI) in various locations. Verification of the correct storage/retrieval of the demand data to/from the DB.
		1.2	Is traffic data available and accurate? From how many locations?	-	-	Traffic data availability. Availability depends on network coverage. Accuracy refers both to the terminal/application itself (e.g. location determination) and the correct storage/retrieval to/from the database.	Extensive coverage related measurements (RSSI/RSRP, RSSNR, RSRQ, CQI) in many locations. Verification of the correct storage/retrieval of the demand data to/from the DB.
		1.3	Are routes dynamically rescheduled?	-	-	Dynamic route rescheduling. (Change(s) of initial route in real time.)	Monitoring the actual route in real time.
		1.4	Is total route time reduced?	-	-	Route time reduction. (Comparison of the travel time with and without using	Route time (min) calculations and comparison with and

HL RQs	RQs		Hs		Indicators	Measurements/Tools
					the application).	without the application.
	1.5	Is total waiting time reduced?	-	-	Waiting time reduction. (Comparison of the waiting time with and without using the application).	Waiting time (min) calculations and comparison with and without the application.
	1.6	Is communication seamless and ubiquitous?	-	-	Ubiquity in communications. Depends on network availability and access technology interoperability, as well as on proper application operation (e.g. bug free).	Extensive coverage related measurements (RSSI/RSRP, RSSNR, RSRQ, CQI) and repeatitive app usage.
	1.7	Are users decisions collaboratively improved through real time aggregation of needs?	-	-	User decision improvement	Measure the number of satisfied users?
	1.8	Is traffic data sent in real time (or near real time)?	1.8.1	Traffic data is sent in real time	Time required for the transfer of data.	Time difference between departure and arrival/storage time of data.
			1.8.2	Traffic data is sent with a small delay of up to 3 minutes (near real time)	Time required for the transfer of data.	Time difference between departure and arrival/storage time of data.

HL RQs	RQs		Hs		Indicators	Measurements/Tools
			1.8.3	Traffic data is sent with a considerable delay (more than 3 minutes)	Time required for the transfer of data.	Time difference between departure and arrival/storage time of data.
	1.9	Is traffic data integrity and reliability achieved?	1.9.1	Traffic data integrity is achieved	Received traffic data availability. Concerning access/core mobile network data integrity is supported inherently.	Verify that the received traffic data is correct. Verify that the data has been processed / presented as expected. Concerning the access/core mobile network no measurement required.
			1.9.2	Traffic data reliability is achieved	Received traffic data availability. Concerning access/core mobile network data reliability is supported inherently.	Verify that the received traffic data is correct. Verify that the data has been processed / presented as expected. Concerning the access/core mobile network no measurement required.

HL RQs	RQs	Hs		Indicators	Measurements/Tools
		1.9.3	Traffic data integrity is partially achieved	Received traffic data availability. Concerning access/core mobile network data integrity is supported inherently.	Verify whether the received traffic data is correct. Verify whether the data has been processed / presented as expected. Concerning the access/core mobile network no measurement required.
		1.9.4	Traffic data reliability is partially achieved	Received traffic data availability. Concerning access/core mobile network data reliability is supported inherently.	Verify whether the received traffic data is correct. Verify whether the data has been processed / presented as expected. Concerning the access/core mobile network no measurement required.

HL RQs	RQs		Hs		Indicators	Measurements/Tools
	1.10	Does the application ensure user info privacy?	1.10.1	The application ensures user info privacy	No indication required. Concerning access/core mobile network data security is supported inherently.	Verify that at application installation time the application requests only the necessary permissions to access personal data and that the personal data is not forwarded to 3rd party servers . Concerning the access/core mobile network data no measurement required.
			1.10.2	The application offers limited user info privacy		
			1.10.3	The application does not offer user info privacy		
	1.11	Does the application use a secure communications channel for the transmission of data?	1.11.1	The application uses a secure communications channel for the transmission of data.	No indicator required. Access/core mobile network support security inherently.	No measurement required. Access/core mobile network support security inherently.

HL RQs	RQs		Hs		Indicators	Measurements/Tools
			1.11.2	The application does not use a secure communications channel for the transmission of data.	No indicator required. Access/core mobile network support security inherently.	No measurement required. Access/core mobile network support security inherently.
	1.12	Is the application updated on a regular basis at no expense for the user?	1.12.1	The application is updated on a regular basis	Updated information appears on terminal screen.	Verify that the application is updated with the latest changes (e.g. route rescheduling). It is important that this is done within seconds.
			1.12.2	The application is updated, but not on a regular basis	Updated information appears more often (or delayed) than expected on terminal screen.	Verify that the application is updated with the latest changes (e.g. route rescheduling). It is important that this is done within seconds.
	1.14	To what extent are the calculated data accurate?			Accuracy refers both to the terminal/application itself (e.g. location determination) and the correct storage/retrieval to/from the database).	Verification of the correct calculations of data with many iterations of requests or other information provided by a user (traveller, operator,

HL RQs	RQs		Hs	Indicators	Measurements/Tools
					driver).
	1.15	Do the calculated data fulfil the real-time requirements?		Transmission time of calculated data in the order of seconds.	Time required for data calculations after a request or an information provided by a user (traveller, operator, driver).
	1.16	Are the source data available when needed?		Source data availability.	Verify that source data are available when needed (extensive user requests regarding routes, schedules, traffic info, their preferences, etc.).
	1.17	How can the initial installation cost for RSU be reduced?			

HL RQs		RQs		Hs		Indicators	Measurements/Tools
2	Does the user receive a dynamically adapted output from the application?	2.1	Does the traveller receive a dynamically adapted schedule?	-		Adapted schedule (change(s) of initial schedule in real time) received by the traveller, upon rescheduling.	Make rescheduling of an initial route (e.g. change of schedule) before or during the trip and verify that the traveller/driver receives the adapted travel plan in near real-time.
		2.2	Does the bus driver receive a dynamically adapted schedule?	-		Adapted schedule (change(s) of initial schedule in real time) received by the driver, upon rescheduling.	Make rescheduling of an initial route (e.g. change of schedule) before or during the trip and verify that the driver receives the adapted travel plan in near real-time.
		2.3	Does the operator receive suggestions for dynamically adapted scheduling selected routes?	-		Availability of suggestions towards the operator.	Verify that the operator receives suggestions when scheduling changes occur for selected routes.
		2.4	Does the application suggest alternative routes / buses for travellers?	2.4.1	The application suggests alternative routes / buses for travellers.	Availability of alternative routes / buses suggestions.	Verify that the application suggests alternative routes / buses for travellers for the same request.

HL RQs	RQs		Hs		Indicators	Measurements/Tools
			2.4.2	The application does not suggest alternative routes / buses for travellers.	Unavailability of alternative route / bus suggestion.	Verify that the application suggests only one route / bus for travellers for a specific request.
	2.5	Does the application suggest the bus seat availability to the traveller?	2.5.1	The application suggests the bus seat availability to the traveller.	Bus seat availability suggestion	Verify that the application suggests the bus seat availability to the traveller.
			2.5.2	The application does not suggest the bus seat availability to the traveller.	No bus seat availability suggestion	Verify that the application doesn't suggest the bus seat availability to the traveller.
	2.6	Do the application algorithms allow the user to optimise a route based on certain criteria (cost, time, etc.)	2.6.1	The application algorithms allow the user to optimise a route based on certain criteria (cost, time, etc.)	Availability of route optimisation suggestion in terms of cost, time, etc.	Verify that the application suggests route(s) based on certain user preferences.
			2.6.2	The application algorithms do not allow the user to optimise a route based on certain criteria (cost, time, etc.)	Incapability of the application to offer optimized route(s) based on user preferences.	Verify that the application does not "calculate" the optimum route based on user preferences.

HL RQs		RQs		Hs		Indicators	Measurements/Tools
3	Does the application support the interaction of multiple and different types of users?	3.1	Does the application promote the collaborative behaviour of users (operator, travellers and driver)	3.1.1	Multiple travellers interact among themselves	Multiple user interaction	Verify that the application allows multiple users (operator, travellers, drivers) to interact among themselves (e.g. have access to pool information, send/receive information about schedules, routes, etc.)
				3.1.2	The operator interacts with travellers	Interaction between travellers and operator	Verify that the application allows the operator to interact with travellers exchanging information about schedules, routes, etc.)
				3.1.3	The operator interacts with bus drivers	Interaction between operator and bus drivers	Verify that the application allows the operator to interact with bus drivers exchanging information about schedules, routes, traffic, etc.)

HL RQs	RQs		Hs		Indicators	Measurements/Tools
	3.2	Do the application algorithms allow the collaborative decision making?	-		Suggestion including information derived by multiple users.	Contribution of various information by users (operator, travellers, driver) and verify that the decision making considers all of it.
	3.3	Does the application interface allow the interaction of multiple and different types of users?	3.3.1	The application interface allows the interaction of multiple and different types of users.	Successful interaction of multiple types of users (operator, travellers, drivers).	Verify that multiple and different types of users are able to interact (e.g. exchange information on schedules, routes, traffic, etc.)
			3.3.2	The application interface does not allow the interaction of multiple and different types of users.	Incapability of successful interaction of multiple types of users (operator, travellers, drivers).	Verify that multiple and different types of users are not able to interact (e.g. exchange information on schedules, routes, traffic, etc.)
	3.4	Is the interaction of multiple and different types of users increasing over time?	3.4.1	The interaction of multiple and different types of users is increasing over time.	Increase in number of multiple users who interact.	Measure the number of users who interact over time.
			3.4.2	The interaction of multiple and different types of	Reduction of the number of multiple users who interact.	Measure the number of users who interact over time.

HL RQs	RQs		Hs		Indicators	Measurements/Tools
				users is decreasing over time.		
	3.5	Does the application offer information from 3rd parties (e.g. municipalities)?	3.5.1	The application offers information from 3rd parties (e.g. municipalities).	Retrieval and distribution of 3rd party info.	Verify that information from an external source (e.g. weather data) is received, processed and disseminated properly.
			3.5.2	The application does not offer information from 3rd parties (e.g. municipalities).	3rd party info unavailability to users	Verify that information from an external source (e.g. weather data) is received, but is not available to the users.

Table 7.5: Technical Research Questions and Success Criteria for CPTO.

	HL RQs		RQs		Hs	Indicators	Measurements/Tools
1	Does the application support (in a first level) and achieve it (in a second level) the dynamic adaptation of the infrastructure?	1.1	Is demand data available and accurate? From how many locations?	-	-	Demand data availability in many locations. Availability depends on network coverage. Accuracy refers both to the terminal/application itself (e.g. location determination) and the correct storage/retrieval to/from the database.	Extensive coverage related measurements (RSSI/RSRP, RSSNR, RSRQ, CQI) in various locations. Verification of the correct storage/retrieval of the demand data to/from the DB.

HL RQs		RQs		Hs	Indicators	Measurements/Tools
	1.2	Is traffic data available and accurate? From how many locations?	-	-	Traffic data availability. Availability depends on network coverage. Accuracy refers both to the terminal/application itself (e.g. location determination) and the correct storage/retrieval to/from the database.	Extensive coverage related measurements (RSSI/RSRP, RSSNR, RSRQ, CQI) in many locations. Verification of the correct storage/retrieval of the demand data to/from the DB.
	1.3	Are routes dynamically rescheduled?	-	-	Dynamic route rescheduling. (Change(s) of initial route in real time.)	Monitoring the actual route in real time.
	1.4	Is total route time reduced?	-	-	Route time reduction. (Comparison of the travel time with and without using the application).	Route time (min) calculations and comparison with and without the application.
	1.5	Is total waiting time reduced?	-	-	Waiting time reduction. (Comparison of the waiting time with and without using the application).	Waiting time (min) calculations and comparison with and without the application.
	1.6	Is communication seamless and ubiquitous?	-	-	Ubiquity in communications. Depends on network availability and access technology interoperability, as well as on proper application	Extensive coverage related measurements (RSSI/RSRP, RSSNR, RSRQ, CQI) and repeatitive app usage.

HL RQs		RQs		Hs	Indicators	Measurements/Tools
					operation (e.g. bug free).	
	1.7	Are users decisions collaboratively improved through real time aggregation of needs?	-	-	User decision improvement	Measure the number of satisfied users?
	1.8	Is traffic data sent in real time (or near real time)?	1.8.1	Traffic data is sent in real time	Time required for the transfer of data.	Time difference between departure and arrival/storage time of data.
			1.8.2	Traffic data is sent with a small delay of up to 3 minutes (near real time)	Time required for the transfer of data.	Time difference between departure and arrival/storage time of data.
			1.8.3	Traffic data is sent with a considerable delay (more than 3 minutes)	Time required for the transfer of data.	Time difference between departure and arrival/storage time of data.
	1.9	Is traffic data integrity and reliability achieved?	1.9.1	Traffic data integrity is achieved	Received traffic data availability. Concerning access/core mobile network data integrity is supported inherently.	Verify that the received traffic data is correct. Verify that the data has been processed/presented as expected. Concerning the access/core mobile network no

HL RQs	RQs		Hs	Indicators	Measurements/Tools
					measurement required.
		1.9.2	Traffic data reliability is achieved	Received traffic data availability. Concerning access/core mobile network data reliability is supported inherently.	Verify that the received traffic data is correct. Verify that the data has been processed/presented as expected. Concerning the access/core mobile network no measurement required.
		1.9.3	Traffic data integrity is partially achieved	Received traffic data availability. Concerning access/core mobile network data integrity is supported inherently.	Verify whether the received traffic data is correct. Verify whether the data has been processed/presented as expected. Concerning the access/core mobile network no measurement required.

HL RQs		RQs		Hs	Indicators	Measurements/Tools
			1.9.4	Traffic data reliability is partially achieved	Received traffic data availability. Concerning access/core mobile network data reliability is supported inherently.	Verify whether the received traffic data is correct. Verify whether the data has been processed/presented as expected. Concerning the access/core mobile network no measurement required.
	1.10	Does the application ensure user info privacy?	1.10.1	The application ensures user info privacy	No indication required. Concerning access/core mobile network data security is supported inherently.	Verify that at application installation time the application requests only the necessary permissions to access personal data and that the personal data is not forwarded to 3rd party servers . Concerning the access/core mobile network data no measurement required.
			1.10.2	The application offers limited		

HL RQs	RQs		Hs		Indicators	Measurements/Tools
				user info privacy		
			1.10.3	The application does not offer user info privacy		
	1.11	Does the application use a secure communications channel for the transmission of data?	1.11.1	The application uses a secure communications channel for the transmission of data.	No indicator required. Access/core mobile network support security inherently.	No measurement required. Access/core mobile network support security inherently.
			1.11.2	The application does not use a secure communications channel for the transmission of data.	No indicator required. Access/core mobile network support security inherently.	No measurement required. Access/core mobile network support security inherently.
	1.12	Is the application updated on a regular basis at no expense for the user?	1.12.1	The application is updated on a regular basis	Updated information appears on terminal screen.	Verify that the application is updated with the latest changes (e.g. route rescheduling). It is important that this is done within seconds.
			1.12.2	The application is updated, but not on a regular basis	Updated information appears more often (or delayed) than expected on terminal screen.	Verify that the application is updated with the latest changes (e.g. route rescheduling). It is important that this is done within seconds.

HL RQs			RQs	Hs	Indicators	Measurements/Tools
		1.14	To what extent are the calculated data accurate?		Accuracy refers both to the terminal/application itself (e.g. location determination) and the correct storage/retrieval to/from the database).	Verification of the correct calculations of data with many iterations of requests or other information provided by a user (traveller, operator, driver).
		1.15	Do the calculated data fulfill the real-time requirements?		Transmission time of calculated data in the order of seconds.	Time required for data calculations after a request or an information provided by a user (traveller, operator, driver).
		1.16	Are the source data available when needed?		Source data availability.	Verify that source data are available when needed (extensive user requests regarding routes, schedules, traffic info, their preferences, etc.).
		1.17	How can the initial installation cost for RSU be reduced?			
2	Does the user receive a dynamically adapted output	2.1	Does the traveller receive a dynamically adapted schedule?	-	Adapted schedule (change(s) of initial schedule in real time) received by the traveller,	Make rescheduling of an initial route (e.g. change of schedule) before or during the

HL RQs		RQs		Hs	Indicators	Measurements/Tools
from the application?					upon rescheduling.	trip and verify that the traveller/driver receives the adapted travel plan in near real-time.
	2.2	Does the traveller receive a dynamically adapted schedule? (Repetition)	-			
	2.3	Does the bus driver receive a dynamically adapted schedule?	-		Adapted schedule (change(s) of initial schedule in real time) received by the driver, upon rescheduling.	Make rescheduling of an initial route (e.g. change of schedule) before or during the trip and verify that the driver receives the adapted travel plan in near real-time.
	2.4	Does the operator receive suggestions for dynamically adapted scheduling selected routes?	-		Availability of suggestions towards the operator.	Verify that the operator receives suggestions when scheduling changes occur for selected routes.
	2.5	Does the application suggest alternative routes / buses for travellers?	2.5.1	The application suggests alternative routes / buses for travellers.	Availability of alternative routes / buses suggestions.	Verify that the application suggests alternative routes / buses for travellers for the same request.

HL RQs		RQs		Hs	Indicators	Measurements/Tools
			2.5.2	The application does not suggest alternative routes / buses for travellers.	Unavailability of alternative route / bus suggestion.	Verify that the application suggests only one route / bus for travellers for a specific request.
	2.6	Does the application suggest the bus seat availability to the traveller?	2.6.1	The application suggests the bus seat availability to the traveller.	Bus seat availability suggestion	Verify that the application suggests the bus seat availability to the traveller.
			2.6.2	The application does not suggest the bus seat availability to the traveller.	No bus seat availability suggestion	Verify that the application doesn't suggest the bus seat availability to the traveller.
	2.7	Do the application algorithms allow the user to optimise a route based on certain criteria (cost, time, etc.)	2.7.1	The application algorithms allow the user to optimise a route based on certain criteria (cost, time, etc.)	Availabilityof route optimisation suggestion in terms of cost, time, etc.	Verify that the application suggests route(s) based on certain user preferences.
			2.7.2	The application algorithms do not allow the user to optimise a route based on certain criteria (cost, time, etc.)	Incapability of the application to offer optimized route(s) based on user preferences.	Verify that the application does not "calculate" the optimum route based on user preferences.

	HL RQs		RQs		Hs	Indicators	Measurements/Tools
3	Does the application support the interaction of multiple and different types of users?	3.1	Does the application promote the collaborative behaviour of users (operator, travellers and driver)	3.1.1	Multiple travellers interact among themselves	Multiple user interaction	Verify that the application allows multiple users (operator, travellers, drivers) to interact among themselves (e.g. have access to pool information, send/receive information about schedules, routes, etc.)
				3.1.2	The operator interacts with travellers	Interaction between travellers and operator	Verify that the application allows the operator to interact with travellers exchanging information about schedules, routes, etc.)
				3.1.3	The operator interacts with bus drivers	Interaction between operator and bus drivers	Verify that the application allows the operator to interact with bus drivers exchanging information about schedules, routes, traffic,etc.)

HL RQs		RQs		Hs	Indicators	Measurements/Tools
	3.2	Do the application algorithms allow the collaborative decision making?	-		Suggestion including information derived by multiple users.	Contribution of various information by users (operator, travellers, driver) and verify that the decision making considers all of it.
	3.3	Does the application interface allow the interaction of multiple and different types of users?	3.3.1	The application interface allows the interaction of multiple and different types of users.	Successful interaction of multiple types of users (operator, travellers, drivers).	Verify that multiple and different types of users are able to interact (e.g. exchange information on schedules, routes, traffic, etc.)
			3.3.2	The application interface does not allow the interaction of multiple and different types of users.	Incapability of successful interaction of multiple types of users (operator, travellers, drivers).	Verify that multiple and different types of users are not able to interact (e.g. exchange information on schedules, routes, traffic, etc.)
	3.4	Is the interaction of multiple and different types of users increasing over time?	3.4.1	The interaction of multiple and different types of users is increasing over time.	Increase in number of multiple users who interact.	Measure the number of users who interact over time.
			3.4.2	The interaction of multiple and different types of users is decreasing over time.	Reduction of the number of multiple users who interact.	Measure the number of users who interact over time.

HL RQs		RQs		Hs	Indicators	Measurements/Tools
	1.x	Does the application offer information from 3rd parties (e.g. municipalities)?	3.5.1	The application offers information from 3rd parties (e.g. municipalities).	Retrieval and distribution of 3rd party info.	Verify that information from an external source (e.g. weather data) is received, processed and disseminated properly.
			3.5.2	The application does not offer information from 3rd parties (e.g. municipalities).	3rd party info unavailability to users	Verify that information from an external source (e.g. weather data) is received, but is not available to the users.
	3.5	How can the requirements of many different stakeholder (e.g. different parking lot operators) be included?			Not a technical CPTO RQ	
	3.6	How can non-TEAM member be included or how do they threaten the application?			Not a technical CPTO RQ	
	3.7	How are disadvantages of this application mitigated?			Not a technical CPTO RQ	

Table 7.6: Technical Research Questions and Success Criteria for DC.

	HL RQs		RQs	Hs	Indicators	Measurements/Tools
1	Does the application support (in a first level) and achieve it (in a second level) the dynamic adaptation of the infrastructure?	1.1	Is demand data available and accurate? From how many locations?		Traffic flow and composition (e.g. private cars, trucks, buses, emergency vehicles, motor bikes).	Historical records; live traffic monitoring.
		1.2	Is traffic data available and accurate? From how many locations?		Traffic flow and composition (e.g. private cars, trucks, buses, emergency vehicles, motor bikes).	Historical records; live traffic monitoring.
		1.3	Are routes dynamically rescheduled?		Alternative routes are not an objective of the application.	N/A
		1.4	Is total route time reduced?		Alternative routes are not an objective of the application.	N/A
		1.5	Is total waiting time in traffic reduced?		Dynamic corridors should reduce waiting time for emergency vehicles, for example.	Total trip time.
		1.6	Is it necessary that communication is seamless and ubiquitous?		Drivers require good communication regarding lane regulations.	Ability of drivers to know of and follow current lane regulations.

HL RQs		RQs		Hs	Indicators	Measurements/Tools
		1.7	Is total waiting time for public transport reduced?		Total trip time.	Total trip time.
		1.8	Is real-time traffic information necessary (rather than off-line)?		Knowledge of current traffic flow and composition is desired.	Do lane regulation rules make sense at the present time? E.g. do they result in an emergency vehicle taking less time to complete travel down a highway?
		1.9	Does the infrastructure allow for adaptation?		Lane regulation rules should result in the dynamic adaption of the infrastructure.	Lane regulation rule output.
		1.10	To what extent are the calculated data accurate?		Observance of the adapted traffic behaviour.	Total trip time; noise output; etc.
		1.11	Which penetration rates are needed?		The objective is for all vehicles travelling on the road to obey the lane regulations.	Observe vehicle disobedience.
		1.12	How can the initial installation cost for RSU be reduced?		Financial cost.	Cost comparisons.
2	Does the user receive a dynamically adapted output from the	2.1	Does the traveller receive a dynamically adapted schedule?		Drivers should have up-to-date knowledge of the lane regulations.	Driver obedience.

	HL RQs		RQs		Hs	Indicators	Measurements/Tools
	application?						
		2.2	Does the traveller receive a dynamically adapted route?			Alternative routes are not an objective of the application.	N/A
		2.3	Does the bus/truck driver receive a dynamically adapted schedule?			Drivers should have up-to-date knowledge of the lane regulations.	Driver obedience.
		2.4	Does the bus/truck driver receive a dynamically adapted route?			Alternative routes are not an objective of the application.	N/A
		2.5	Does the traveller receive recommendations (besides schedule/route) to adapt to local regulations (speed, safety, emissions, noise)?			Drivers should have up-to-date knowledge of the lane regulations.	Driver obedience.
		2.6	Does the operator receive suggestions for dynamically adapted scheduling selected routes?			Alternative routes are not an objective of the application.	N/A
3	Does the application support the interaction of multiple and different types of users?	3.1	Does the application promote the collaborative behaviour of users (operator, travellers and driver)	3.1.1	Multiple travellers interact among themselves	The application doesn't primarily support collaboration between drivers.	N/A
				3.1.2	The operator interacts with travellers	Drivers should have up-to-date knowledge of the lane regulations.	Driver obedience.

HL RQs		RQs		Hs		Indicators	Measurements/Tools
				3.1.3	The operator interacts with bus drivers	Drivers should have up-to-date knowledge of the lane regulations.	Driver obedience.
		3.2	Do the application algorithms allow the collaborative decision making			Do the lane regulations make sense?	Effective traffic management.
		3.3	Are users decisions collaboratively improved through real time aggregation of needs?			The objective is for all vehicles travelling on the road to obey the lane regulations.	N/A
		3.4	What are system misuse mitigation strategies?			The objective is for all vehicles travelling on the road to obey the lane regulations.	Driver obedience.
4	Does the application perform offline tasks?	4.1	Are there offline tasks to perform a priori?			Historical records.	Gather data; data analysis.
		4.2	Are there offline tasks to perform post travel?			Update traffic records.	Database entry.

Table 7.7: Technical Research Questions and Success Criteria for C-ACC.

	HL RQs		RQs		Hs	Indicators	Measurements/ Tools
1	Does the application support (in a first level) and achieve it (in a second level) the dynamic adaptation of the infrastructure?	1.1	Do traffic lights adapt according to the suggestion of the application to create traffic flow optimised on emissions and throughput?	-	-	Traffic lights phase change	Log file (RSU)
		1.2	Is the pollution level in a certain area not exceeding a certain level by dynamically adapting the longtitudinal speed of the vehicles?			Emissions, travelling time change through time and penetration rate	Before/after comparison through simulation
		1.3	Are emissions and travelling times reduced by adjusting traffic lights and ACC speed?			Emissions, travelling time change through time and penetration rate	Before/after comparison through simulation
		1.4	Are vehicle consumption and emissions reduced by dynamically adapting the longtitudinal speed of the vehicles?			Emissions, consumption change through time and penetration rate	Before/after comparison through simulation
		1.5	Are vehicle consumption and emissions reduced by dynamically adapting the C-ACC according to the road infrastructure topology (approaching intersection,			Emissions, travelling times, consumption change through time and penetration rate	Before/after comparison through simulation

	HL RQs		RQs	Hs		Indicators	Measurements/ Tools
			highway ramps, hilltops, sags, long curves, speed limit zones etc)?				
		1.6	Are vehicle consumption and emissions reduced by dynamically adapting the C-ACC according to the available traffic data (when approaching a traffic jam)?	-	-	Emissions, consumption change through time and penetration rate	Before/after comparison through simulation
2	Does the user receive a dynamically adapted output from the application?	2.1	Is the vehicle speed and distance value provided to the user dynamically adapted?	-	-	Suggested vehicle speed and distance	Vehicle dynamics log file (CAN Bus)
		2.2	Is the traffic lights switching time advice provided to the user dynamically adapted?	-	-	Traffic lights switching time (over time)	Traffic light phase log file (RSU)
		2.3	Is traffic flow improved in traffic congestion or traffic hindrance situations by dynamically adapting the ACC based on local (ego vehicle) and non local (V2X) information?	-		Traffic flow, traffic congestion, traffic hindarance situations evolution (at different penetration levels)	Before/after comparison through simulation
		2.4	Is traffic flow improved in traffic congestion or traffic hindrance situations by			Traffic flow, traffic congestion, traffic hindarance situations evolution (at different	Before/after comparison through simulation

	HL RQs		RQs	Hs		Indicators	Measurements/ Tools
			adapting the ACC speed and distance parameters based on local information (vehicles ahead, road slope)?			penetration levels)	
		2.5	Is the vehicle longtitudinal speed value dynamically overriden according to the application suggested values?			Vehicle (longtitudinal) speed change on spot (during the event)	Vehicle dynamics log (CAN bus)
3	Does the application support the interaction of multiple and different types of users?	3.1	Do multiple users interact for extending the foresight range of the ACC systems?	-	-	t.b.d	t.b.d.
		3.2	Do multiple drivers interact so as to allow appropriate reaction to adapt vehicle longitudinal speed?	-	-	t.b.d.	t.b.d.
		3.3	Do multiple drivers interact so as to improve traffic flow?	-	-	t.b.d.	t.b.d.

Table 7.8: Technical Research Questions and Success Criteria for EFP.

HL RQs		RQs		Hs	Indicators	Measurements /Tools
1	Does the application decrease the time for searching a parking slot?	1.1	Does the application reduce time for searching a parking slot?	-	-	
		1.2	Is traffic flow improved in in traffic congestion due to the fact that less driving is needed to search for a parking slot?	-		
		1.3	Are vehicle consumption and emissions reduced by reducing driving time to look for a parking slot?			
		1.4	Is the pollution level in a certain area not exceeding a certain level by reduced timing to search for parking?			
2	Does the user receive a dynamically adapted output from the application?	2.1	Is the vehicle receiving parking slot availability that is dynamically adapted?	-	-	
3	Does the application support the interaction of multiple drivers?	3.1	Do multiple drivers interact for parking search?	-	-	

Table 7.9: Technical Research Questions and Success Criteria for CDM.

	HL RQs		RQs		Hs	Indicators	Measurements /Tools
1	Does the application support (in a first level) and achieve it (in a second level) the dynamic adaptation of the infrastructure?	1.1	Are dynamic road restrictions accurately registered in central traffic informational systems?	-		Country and locally specific	
		1.2	Is emergency notification issued by the vehicle (in case of Emergency slowdown and stop) accurately sent to the traffic centre and other authorities?	-	-	CAM msg sent from emergency vehicle. Traffic center and authorities are not involved in this use case.	
		1.3	Are speed limits accurately adapted to dynamic restrictions?	-	-	Unclear question, which speed limit and which dynamic restriction?	
		1.4	Is a free way achieved for priority vehicles passing?	-	-	Covered by CDM application functionality	
		1.5	To what extent are the calculated data correct?				
		1.6	To what extent are the calculated data accurate?				
		1.7	Do the calculated data fulfill the real-time requirements?			This is requested for the application to work.	
		1.8	Which penetration rates are needed?			High penetration rate is preferred. Exact	

	HL RQs		RQs		Hs	Indicators	Measurements /Tools
						numbers is hard to figure out. This uestion is common for C-ITS in general.	
		1.9	Is the estimation of dynamic traffic situations good enough?			If the penetration rate is too low the estimation of dynamic traffic situation will suffer.	
		1.10	How can the initial installation cost for RSU be reduced?			Ongoing work within the Amsterdam group to sort this out.	
		1.11	How can the initial installation cost for OBU be reduced?			Ongoing work within the C2C to sort this out.	
		1.12	How is centralised or decentralised management organized and maintained?			N/A for CDM	
2	Does the user receive a dynamically adapted output from the application?	2.1	Is the road restriction output provided to the user dynamically adapted?	-	-	No road restriction in CDM	
		2.2	Is the lane change advice provided to the user dynamically adapted?	-	-	Yes	
		2.3	Is the roundabout driving advice provided to the user dynamically adapted?	-	-	CRF is doing this work	
		2.4	Is the emergency breaking advice	-	-	No EB in CDM. The	

HL RQs		RQs		Hs	Indicators	Measurements /Tools
		provided to the user dynamically adapted?			vehicles have this functionality but out of scope for TEAM project.	
	2.5	Is the emergency slowdown and stop advice provided to the user dynamically adapted?	-	-	Not in CDM	
	2.6	Is the intersection optimisation advice provided to the user dynamically adapted?	-	-	Yes, for GLOSA	
	2.7	Is the speed limit adaptation advice provided to the user dynamically adapted?	-	-	Yes, for GLOSA. No for Speed advice. There is no infrastructure component to provide temporary speed limit information	
	2.8	Is the highway entrance/exit advice provided to the user dynamically adapted?	-	-	This is part of the lane advice functionality.	
	2.9	Is the custom clearance advice provided to the user dynamically adapted?	-	-	Not for CDM	
	2.10	Is the lane advice provided to the user dynamically adapted?			Must be dynamic adapted for the CDM function. Same as 2.2?	
	2.11	Is the overtaking advice provided to			Not in CDM, demands	

	HL RQs		RQs		Hs	Indicators	Measurements /Tools
			the user dynamically adapted?			100% penetration to be safe.	
		2.12	Is driver intention estimation needed and is it good enough?			Yes, ICCS should solve this.	
3	Does the application support the interaction of multiple and different types of users?	3.1	Do multiple drivers interact for a lane change manoeuvre?	-	-	Yes	
		3.2	Do multiple drivers interact for entering / leaving a roundabout ?	-	-	Yes	
		3.3	Do multiple drivers interact with the vehicle in emergency so as to create a safety shield around it?	-	-	No	
		3.4	Do multiple drivers interact for a highway entrance / exit manoeuvre?	-	-	Yes	
		3.5	Do multiple drivers interact so as to provide a free way for priority vehicles passing?	-	-	Yes, indirectly via lane change	
		3.6	Do multiple drivers interact for an overtaking manoeuvre?	-	-	N/A	

Table 7.10:: Technical Research Questions and Success Criteria for SG-CM.

HL RQs		RQs		Hs		Indicators	Measurements /Tools
1	Does the application support (in a first level) and achieve it (in a second level) the dynamic adaptation of the infrastructure?	1.1	Is demand data available and accurate? From how many locations?	1.1.1	Demand data is available and sufficiently accurate.	t.b.d.	t.b.d.
		1.2	Is traffic data available and accurate? From how many locations?	1.1.2	From how many locations is demand data received?	counting	locations
		1.3	Is the integration of many (very different) data necessary and to what extent is it achieved?				
2	Does the user receive a dynamically adapted output from the application?	2.1	Does the traveller / driver receive a dynamically adapted schedule?		is information dynamically updated?	Dynamic updates	Ratio of adapted outputs.
3	Does the application support the interaction of multiple and different types of users?	3.1	Does the application promote the collaborative behaviour of users (operator, travellers and driver)	3.1.1	Multiple travellers interact among themselves	contacts	number of contacts between travellers
		3.2	Is the detection of misuse and cheating possible?				

HL RQs	RQs		Hs	Indicators	Measurements /Tools
	3.3	How can the requirements of many different stakeholders (e.g. different parking lot operators) be included?			
	3.4	How is access to privacy data organized and secured?			
	3.5	What are system misuse mitigation strategies?			

Table 7.11: Technical Research Questions and Success Criteria for CONAV.

HL RQs		RQs		Hs		Indicators	Measurements /Tools
1	Does the application support (in a first level) and achieve it (in a second level) the dynamic adaptation of the infrastructure?	1.1	Is demand data available and accurate? From how many locations?	-	-		not required for assessment; it is assumption that the data is available to run the application
		1.2	Is traffic data available and accurate? From how many locations?	-	-		not required for assessment; it is assumption that the data is available to run the application
		1.3	Are routes dynamically recalculated?	-	-		comparison of calculated routes and number of times of calculations
		1.4	Is total route time reduced?	-	-		only by simulations
		1.5	Are total km travelled reduced?	-	-		only by simulations
		1.6	Is communication seamless and ubiquitous?	-	-		assessment of availability of routing engine
		1.7	Are users decisions collaboratively improved through real time aggregation of needs?				only by simulations

HL RQs	RQs	Hs	Indicators	Measurements /Tools
	1.8 Is fuel consumption reduced?			only by simulations
	1.9 Does route calculation incorporate vehicle information?			comparison of calculated routes with different vehicles
	1.10 Does stochastic routing incorporate real time events? (2nd stage)	-	-	only by simulations
	1.11 Does route calculation takes into account individual preferences?			comparison of calculated routes with different individual preferences
	1.12 Is traffic congestion actually reduced?			only by simulations
	1.13 Are response times compliant to guidelines?			
	1.14 Is traffic noise actually reduced?			only by simulations
	1.15 Is traffic pollution actually reduced?			only by simulations
	1.16 Is the integration of many (very different) data necessary and to what extent is it achieved?			
	1.17 Do the calculated data fulfil the real-time requirements?			time elapsed between route request and route result

HL RQs		RQs		Hs		Indicators	Measurements /Tools
		1.18	Are the source data available in sufficient quality when needed?				test site and data specific
		1.19	Which penetration rates are needed?				only by simulations
		1.20	To what extent is data security achieved?				number of attacks successfully run
		1.21	To what extent are the calculated data reliable?				only by simulations
2	Does the user receive a dynamically adapted output from the application?	2.1	Does the driver receive a dynamically adapted route?	-	-		comparison of routes and measurement of update rate of routes
		2.2	Does the operator receive suggestions for dynamically adapted routing?	-	-		
		2.3	Does the application output meet the HMI requirements for good user experience?	-	-		counting trips without using CONAV during trip/measuring eco points from SG/CB

HL RQs		RQs		Hs	Indicators	Measurements /Tools
3	Does the application support the interaction of multiple and different types of users?	3.1	Does the application promote the collaborative behaviour of users (operators and drivers)	3.1.1		measurement of earned and spent coins
		3.2	Do the application algorithms allow the collaborative decision making	3.1.2		counting trips without using CONAV during trip/measuring eco points from SG/CB
		3.3	How can the requirements of many different stakeholders (e.g. different parking lot operators) be included?	3.1.3		not measureable; part of implemented algorithm

Annex 2 User Acceptance Research Questions, Measurements and Tools

The following tables present the research questions and success criteria relevant for the evaluation of user acceptance for all TEAM applications. Note that the numbering is not sequential, following the research questions selection phase, as explained above.

Table 7.12: User Acceptance Research Questions and Success Criteria for CMC.

HL RQs		RQs		Hs		Indicators	Measurements /Tools
1	Does the user agree to be and is an active input to the application?	1.1	Do users (drivers) accept that their location and planned route is transmitted to the application? (CMC)	1.1.1	Users accept that their location is transmitted to the application.		questionnaire, travel diary interview, or data logging
				1.1.3	Users accept that their planned destination is transmitted to the application.		questionnaire, travel diary interview, or data logging
		1.2	To what extent have the applications been switched on CMC?	-	-		questionnaire, travel diary interview, or data logging
		1.3	Are the applications switched on more or less over time? CMC	1.3.1	Application "switched-on" time increases with the longer experience	usage over time	questionnaire, travel diary interview, or data logging
2	Does the user act according to the	2.1	Do drivers change their routes according to the guidance given by the	2.1.1	Drivers follow the instructions provided by the system		questionnaire, travel diary or data logging

HL RQs		RQs		Hs		Indicators	Measurements /Tools
	application output?		system?				
		2.2	Is the "guidance acceptance" changing over time?	2.2.1	Drivers follow the instructions provided by the system better with longer experience		questionnaire, travel diary or data logging
3	Does the user accept and trust the application?	3.1	Do drivers state that they will use the system? (before trying it)	3.1.1	Drivers are interested in the system and agrees to use it		interviews, questionnaire
		3.2	Is user acceptance influenced by perceived application ease of use?	3.2.1	User acceptance increases after trying the system.		interviews, questionnaire after trying the system
		3.3	Is user acceptance influenced by perceived usefulness of application?	3.3.1	User acceptance increases after longer period of use if the driver considers it to be useful		interviews, questionnaire after trying the system
		3.4	Is user acceptance influenced by perceived trust in application?	3.4.1	User acceptance increases after longer period of use IF the drivers trusts the application		interviews, questionnaire after trying the system
		3.5	Does the design of the application user interface affect user's acceptance?	3.5.1			interviews after trying the system
4	Is the user	4.1	Are the users willing to		Drivers are ready to pay for the		interviews, questionnaire

HL RQs		RQs		Hs		Indicators	Measurements /Tools
	willing to pay for the application?		pay for the application	4.1.1	application (buying the application/device)		
				4.1.2	'Drivers are ready to pay for the application (a monthly fee)		interviews, questionnaire
		4.2	Is willingness to pay influenced by the perceived usefulness?	4.2.1	Drivers who consider the application to be useful are more willing to pay for it than drivers who perceive it less useful		interviews, questionnaire
5	Usability	5.1	Is the application functionality useful and usable?	-	-	Learnability, Efficiency, Memorability, Errors, Satisfaction	questionnaire / monitoring data

Table 7.13: User Acceptance Research Questions and Success Criteria for COPLAN.

HL RQs		RQs		Hs		Indicators	Measurements /Tools
1	Does the user agree to be and is an active input to the application?	1.1	Do users (travellers and drivers) accept that their location and planned route is transmitted to the application?	1.1.1	Users accept that their location is transmitted to the application.		interviews, logging of the system usage
				1.1.2	Users accept that their route is transmitted to the application.		interviews, logging of the system usage
				1.1.3	Users accept that their planned destination is transmitted to the application.		interviews, logging of the system usage
		1.2	To what extent have the applications been switched on?	-	-		logging the system/application usage
		1.3	Are the applications been switched on more or less over time?	1.3.1	Application "switched-on" time increases with the longer experience		logging the system/application usage
2	Does the user act according to the application output?	2.1	Do travellers change their routes according to the guidance given by the system?	2.1.1	Drivers follow the instructions provided by the system		logging the system, travel diaries, interviews
				2.1.2	Travellers follow the route instructions provided by the system		logging the system, travel diaries, interviews
				2.1.3	The use of public transportation		logging the

HL RQs	RQs		Hs		Indicators	Measurements /Tools
				increases due to mode change (from private cars to public transportation)		system, travel diaries, interviews
	2.2	Is the "guidance acceptance" changing over time?	2.2.1	Drivers follow the instructions provided by the system better with longer experience	this is very important to see if the acceptance is changing over time, when the novelty effect is gone	logging the system, travel diaries, interviews
			2.2.2	Travellers follow the route instructions provided by the system	this is very important to see if the acceptance is changing over time, when the novelty effect is gone	logging the system, travel diaries, interviews
	2.3	Does the number of users (travellers) that prefer the re-scheduled routes increase over time?)	2.3.1	The number of users (travellers) that prefer the re-scheduled routes increases over time.	this is very important to see if the acceptance is changing over time, when the novelty effect is gone	logging the system, travel diaries, interviews

HL RQs	RQs		Hs		Indicators	Measurements /Tools
			2.3.2	The number of users (travellers) that prefer the re-scheduled routes decreases over time.	this is very important to see if the acceptance is changing over time, when the novelty effect is gone	logging the system, travel diaries, interviews
	2.4	Does the number of users (operators) that reschedule routes according to the system output increase over time?	2.4.1	The number of users (operators) that reschedule routes according to the system output increases over time	this is very important to see if the acceptance is changing over time, when the novelty effect is gone	logging the system, travel diaries, interviews
			2.4.2	The number of users (operators) that reschedule routes according to the system output decreases over time	this is very important to see if the acceptance is changing over time, when the novelty effect is gone	logging the system, travel diaries, interviews
	2.5	Does the number of users (drivers) that change routes as suggested increase over time?	2.5.1	The number of users (drivers) that change routes as suggested increases over time.	this is very important to see if the	logging the system, travel diaries, interviews

HL RQs		RQs		Hs		Indicators	Measurements /Tools
						acceptance is changing over time, when the novelty effect is gone	
				2.6.2	The number of users (drivers) that change routes as suggested decreases over time.	this is very important to see if the acceptance is changing over time, when the novelty effect is gone	logging the system, travel diaries, interviews
3	Does the user accept and trust the application?	3.1	Do users state that they will use the system? (before trying it)	3.1.1	Drivers are interested in the system and agrees to use it		interviews, questionnaires
				3.1.2	Travellers are interested in the system and agrees to use it		interviews, questionnaires
		3.2	Is user acceptance influenced by perceived application ease of use?	3.2.1	User acceptance increases after trying the system.		interviews, questionnaires
		3.3	Is user acceptance influenced by perceived usefulness of application?	3.3.1	User acceptance increases after longer period of use if the driver considers it to be useful		interviews, questionnaires
		3.4	Is user acceptance influenced by perceived trust in application?	3.4.1	User acceptance increases after longer period of use IF the users trusts the application		interviews, questionnaires

HL RQs		RQs		Hs		Indicators	Measurements /Tools
		3.5	Does the design of the application user interface affect user's acceptance?	3.5.1	User acceptance is better for the systems with better HMI		interviews, questionnaires
		3.6	Is user acceptance influenced by perceived privacy and confidentiality offered by the application?	3.6.1	User acceptance is influenced by perceived privacy and confidentiality offered by the application.		interviews, questionnaires
				3.6.2	User acceptance is not influenced by perceived privacy and confidentiality offered by the application.		interviews, questionnaires
		3.7	Is user acceptance influenced by the user's willingness to pay for the application? (Collaborative public transport optimization - CPTO)	3.7.1	User acceptance is influenced by the user's willingness to pay for the application.		interviews, questionnaires
				3.7.2	User acceptance is not influenced by the user's willingness to pay for the application.		interviews, questionnaires
4	Is the user willing to pay for the application?	4.1	Are the users willing to pay for the application	4.1.1	Users are ready to pay for the application (buying the application/device)		interviews, questionnaires
				4.1.2	Users are ready to pay for the application (a monthly fee)		interviews, questionnaires
		4.2	Is willingness to pay influenced by the perceived usefulness?	4.2.1	Users who consider the application to be useful are more willing to pay for it than drivers who perceive it		interviews, questionnaires

HL RQs		RQs		Hs		Indicators	Measurements /Tools
					less useful		
		4.3	Is willingness to pay influenced by users' (travellers/operators/bus drivers) perceived additional mobile data charges?	4.3.1	Willingness to pay is influenced by users' (travellers/operators/drivers) perceived additional mobile data charges.		interviews, questionnaires
				4.3.2	Willingness to pay is not influenced by users' (travellers/operators/drivers) perceived additional mobile data charges.		interviews, questionnaires
5	Usability	5.1	Is the application functionality useful and usable?	-	-	Learnability, Efficiency, Memorability, Errors, Satisfaction	questionnaire / monitoring data

Table 7.14: User Acceptance Research Questions and Success Criteria for CCA.

HL RQs		RQs		Hs		Indicators	Measurements /Tools
1	Does the user agree to be and is an active input to the application?	1.1	Do travellers accept that their location and planned route is transmitted to the application?	1.1.1	Users accept that their location is transmitted to the application.	It is required for the app. to be able to compare the driver's route taken to alternative routes.	questionnaire
		1.2	Does the user have to manually input data and/or set preferences?			The driver may want the app. to ignore a certain mode of transport, e.g. trains, when doing it's comparison of alternative routes to the driver's route.	questionnaire
2	Does the user acts according to the application output?	2.1	Should travellers prefer the re-scheduled routes?			The app. may actually show that the drivers' route was optimal.	questionnaire
3	Willingness to use	3.1	Do travellers/operators/bus drivers state that they will use the system?			The driver informs the app. he/she is ready to use the system.	questionnaire
		3.2	Is user acceptance influenced by perceived application ease of use?			The app. should be easy to use.	questionnaire
		3.3	Is user acceptance influenced by perceived usefulness of application?			The app. should highlight the potential benefits of considering other routes/modes of transport to the driver,	questionnaire

HL RQs		RQs		Hs	Indicators	Measurements /Tools
					e.g. less fuel usage and thus a cost saving.	
		3,4	Is user acceptance influenced by perceived trust in application?		The alternative routes should reflect reality and really be available to the driver, i.e. accurate real-time data is needed by the app.	questionnaire
		3,5	Does the design of the application user interface affect user's acceptance?		UI is high priority in that the app. reflects information highly personal/applicable to the particular driver.	questionnaire
		3,6	Do the users have to accept that a historical record of their travel information is kept?		Current records are more important however historical records are useful.	questionnaire
4	Willingness to pay	4.1	Do the users (travellers/operators/bus drivers) desire to have the application?		This is an optional app. and so there is a need to create desire for drivers to want it.	questionnaire
		4.2	Is willingness to pay influenced by users' (travellers/operators/bus drivers) perceived affordability?		Price of the app. should not exceed cost benefits of alternative routes that the driver receives.	questionnaire
		4.3	Is willingness to pay influenced by		Only applicable if try-	questionnaire

HL RQs		RQs		Hs		Indicators	Measurements /Tools
			success of previous experience with application?			before-you-buy is available.	
5	Usability	5.1	Is the application functionality useful and usable?	-	-	Learnability, Efficiency, Memorability, Errors, Satisfaction	questionnaire / monitoring data

Table 7.15 User Acceptance Research Questions and Success Criteria for CSI.

HL RQs		RQs		Hs		Indicators	Measurements /Tools
1	Does the user agree to be and is an active input to the application?	1.1	Do travellers accept that their location and planned route is transmitted to the application?	1.1.1	Drivers accept that their location and planned route is transmitted.	Hypothetical agreement in questionnaire	Questionnaire, Data Log on Application on/off
2	Does the user acts according to the application output?	2.1	Do traffic participants who are not preferred accept that they have disadvantages?	-	-	Hypothetical agreement in questionnaire	Questionnaire
		2.3	Do drivers of preferred vehicles accept being preferred?	-	-	Hypothetical agreement in questionnaire	Questionnaire or driving simulator
		2.4	Do drivers of preferred vehicle feel that they profit from the preference?	-	-	Hypothetical agreement in questionnaire	Questionnaire or driving simulator
3	Willingness to use	3.1	Do travellers/operators/bus drivers state that they will use the system?	-	-	What advantages / disadvantages do travellers / operators / drivers expect from this application	Questionnaire, Interview
4	Willingness to pay	4.1	Are users interested in paying for preferences?	-	-	How much money are users willing to pay per saved minute	Questionnaire, Interview
		4.2	Are users interested in earning money by giving preferences?	-	-	How much money would users expect to receive in case they lose one minute of time	Questionnaire, Interview

HL RQs		RQs		Hs		Indicators	Measurements /Tools
5	Usability	5.1	Is the system sufficiently transparent?	5.1.1	Users understand the reasons for system decisions.	Hypothetical agreement in questionnaire	Questionnaire
		5.2	Is the application functionality useful and usable?	-	-	Learnability, Efficiency, Memorability, Errors, Satisfaction	Questionnaire / monitoring data

Table 7.16: User Acceptance Research Questions and Success Criteria for CPTO.

HL RQs		RQs		Hs		Indicators	Measurements/Tools
1	Does the user agree to be and is an active input to the application?	1.1	Do users (travellers) accept that their location and planned route is transmitted to the application? (Collaborative public transport optimization - CPTO)	1.1.1	Users accept that their location is transmitted to the application.	this is relevant to the collaborative concept of the TEAM applications	questionnaire
				1.1.2	Users don't accept that their location is transmitted to the application.	this is relevant to the collaborative concept of the TEAM applications	questionnaire
				1.1.3	Users accept that their planned route is transmitted to the application.	this is relevant to the collaborative concept of the TEAM applications	questionnaire
				1.1.4	Users don't accept that their planned route is transmitted to the application.	this is relevant to the collaborative concept of the TEAM applications	questionnaire
				1.1.5	Users partially accept that their location is transmitted to the	this is relevant to the	questionnaire

HL RQs		RQs		Hs		Indicators	Measurements/Tools
					application (ability to choose whether this info will be transmitted or not).	collaborative concept of the TEAM applications	
				1.1.6	Users partially accept that their planned route is transmitted to the application (ability to choose whether this info will be transmitted or not).	this is relevant to the collaborative concept of the TEAM applications	questionnaire
		1.2	To what extent have the applications been used (before, during, after journeys)? (Collaborative public transport optimization - CPTO)	-	-	this is relevant to usage	questionnaire or log file on application on/off
		1.3	Are the applications been used more or less over time? (Collaborative public transport optimization - CPTO)	-	-	this is relevant to usage	questionnaire or log file on application on/off
2	Does the user acts according to the application output?	2.1	Do users (travellers) prefer the re-scheduled routes? (Collaborative public transport optimization - CPTO)	-	-	this is relevant to the collaborative concept of the TEAM applications	questionnaire
		2.2	Do users (operators) reschedule routes according to the system output? (Collaborative public	-	-	this is relevant to the collaborative	questionnaire

HL RQs	RQs		Hs		Indicators	Measurements/Tools
		transport optimization - CPTO)			concept of the TEAM applications	
	2.3	Do users (bus drivers) change routes as suggested? (Collaborative public transport optimization - CPTO)	-	-	this is relevant to the collaborative concept of the TEAM applications	questionnaire
	2.4	Does the number of users (travellers) that prefer the re-scheduled routes increase over time? (Collaborative public transport optimization - CPTO)	2.4.1	The number of users (travellers) that prefer the re-scheduled routes increases over time.	this is relevant to the collaborative concept of the TEAM applications	questionnaire
			2.4.2	The number of users (travellers) that prefer the re-scheduled routes decreases over time.	this is relevant to the collaborative concept of the TEAM applications	questionnaire
	2.5	Does the number of users (operators) that reschedule routes according to the system output increase over time? (Collaborative public transport optimization - CPTO)	2.5.1	The number of users (operators) that reschedule routes according to the system output increases over time	this is relevant to the collaborative concept of the TEAM applications	questionnaire

HL RQs		RQs		Hs		Indicators	Measurements/Tools
				2.5.2	The number of users (operators) that reschedule routes according to the system output decreases over time	this is relevant to the collaborative concept of the TEAM applications	questionnaire
		2.6	Does the number of users (bus drivers) that change routes as suggested increase over time? (Collaborative public transport optimization - CPTO)	2.6.1	The number of users (bus drivers) that change routes as suggested increases over time.	this is relevant to the collaborative concept of the TEAM applications	questionnaire
				2.6.2	The number of users (bus drivers) that change routes as suggested decreases over time.	this is relevant to the collaborative concept of the TEAM applications	questionnaire
3	Does the user accept and trust the application?	3.1	Do users (travellers/operators/bus drivers) state that they will use the system? (Collaborative public transport optimization - CPTO)	-	-	user acceptance	questionnaire, application on/off
		3.2	Is user acceptance influenced by perceived application ease of use? (Collaborative public transport optimization - CPTO)	-	-	user acceptance	questionnaire
		3.3	Is user acceptance influenced by	-	-	user acceptance	questionnaire

HL RQs	RQs		Hs		Indicators	Measurements/Tools
		perceived usefulness of application? (Collaborative public transport optimization - CPTO)				
	3.4	Is user acceptance influenced by perceived trust in application? (Collaborative public transport optimization - CPTO)	-	-	user acceptance	questionnaire
	3.5	Does the design of the application user interface affect user's acceptance? (Collaborative public transport optimization - CPTO)	-		user acceptance	questionnaire
	3.6	Is user acceptance influenced by perceived privacy and confidentiality offered by the application? (Collaborative public transport optimization - CPTO)	3.6.1	User acceptance is influenced by perceived privacy and confidentiality offered by the application.	user acceptance	questionnaire
			3.6.2	User acceptance is not influenced by perceived privacy and confidentiality offered by the application.	user acceptance	questionnaire
	3.7	Is user acceptance influenced by the user's willingness to pay for the application? (Collaborative public transport optimization - CPTO)	3.7.1	User acceptance is influenced by the user's willingness to pay for the application.	user acceptance	questionnaire
			3.7.2	User acceptance is not influenced by the user's willingness to pay for the application.	user acceptance	questionnaire

HL RQs		RQs		Hs		Indicators	Measurements/Tools
4	Is the user willing to pay for the application?	4.1	Do the users (travellers/operators/bus drivers) desire to have the application? (Collaborative public transport optimization - CPTO)	-	-	willingness to have/to pay	questionnaire
		4.2	Is willingness to pay influenced by users' (travellers/operators/bus drivers) perceived affordability? (Collaborative public transport optimization - CPTO)	-	-	willingness to have/to pay	questionnaire
		4.3	Is willingness to pay influenced by users' (travellers/operators/bus drivers) perceived additional mobile data charges? (Collaborative public transport optimization - CPTO)	4.3.1	Willingness to pay is influenced by users' (travellers/operators/bus drivers) perceived additional mobile data charges.	willingness to have/to pay	questionnaire
				4.3.2	Willingness to pay is not influenced by users' (travellers/operators/bus drivers) perceived additional mobile data charges.	willingness to have/to pay	questionnaire
5	Usability	5.1	Is the application functionality useful and usable?	-	-	Learnability, Efficiency, Memorability, Errors, Satisfaction	questionnaire / monitoring data

Table 7.17 : User Acceptance Research Questions and Success Criteria for DC.

HL RQs		RQs		Hs	Indicators	Measurements/ Tools
1	Does the user agree to be and is an active input to the application?					
2	Does the user acts according to the application output?	2.1	Should travellers prefer the re-scheduled routes?			
		2.2	Is it compulsory for users to change their actions (e.g. lanes)?			
3	Willingness to use	3.1	Do travellers/operators/bus drivers state that they will use the system?			
		3.2	Is user acceptance influenced by perceived application ease of use?			
		3.3	Is user acceptance influenced by perceived usefulness of application?			
		3,4	Is user acceptance influenced by perceived trust in application?			
		3,5	Does the design of the application user interface affect user's acceptance?			
4	Willingness to pay	4.1	Do the users (travellers/operators/bus drivers) desire to have the application?			
		4.2	Is willingness to pay influenced by users' (travellers/operators/bus drivers) perceived affordability?			

		4.3	Is willingness to pay influenced by success of previous experience with application?			
		4,4	Is the application compulsory (e.g. for a stretch of road)?			
5	Usability	5.1	Is the application functionality useful and usable?	-	-	Learnability, Efficiency, Memorability, Errors, Satisfaction

Table 7.18: User Acceptance Research Questions and Success Criteria for C-ACC.

	HL RQs		RQs		Hs	Indicators	Measurements/Tools
1	Does the user agree to be and is an active input to the application?	1.1	Do drivers accept that their location, direction, speed and acceleration is transmitted to the application?	1.1.1	Drivers agree that their location, speed, direction and acceleration are communicated to other vehicles.		questionnaire
				1.1.2	Drivers agree that their location, speed, direction and acceleration are communicated to the infrastructure.		questionnaire
		1.2	Do drivers accept that their desired speed is communicated to the application?	-	-		questionnaire
		1.3	Do drivers accept that their emission, noise and eco information are communicated to the application?	-	-		questionnaire
		1.4	Do drivers accept that their driving profile is monitored by the application?	-	-		questionnaire
		1.5	Do traffic operators accept that traffic data per road segment (traffic density estimation, information on road events, queuing location) are communicated to the application?	-	-		questionnaire

	HL RQs		RQs		Hs	Indicators	Measurements/Tools
		1.6	Do traffic operators accept that overall emissions and current pollution level per road segment are communicated to the application?	-	-		questionnaire
2	Does the user acts according to the application output?	2.1	Do drivers (of basic ACC equipped vehicles) follow the suggested speed advice (and accelerate/decelerate accordingly)?	-	-		questionnaire (to capture perception) and log file
		2.2	Do operators accept switching traffic lights switching times according to the green light optimizing cruise control functionality?	-	-		questionnaire (to capture perception) and log file
3	Willingness to use	3.1	Do users state that they will use the system?	3.1.1	Drivers state that they will use the system.		questionnaire
				3.1.2	Operators state that they will use the system.		questionnaire
4	Willingness to pay	4.1	Do users state that they would pay for the system?	4.1.1	Drivers state that they would pay for the system.		questionnaire
				4.1.2	Operators state that they would pay for the system.		questionnaire
5	Usability	5.1	Is the application functionality useful for the users?	5.1.1	The application functionality is useful for the drivers.	Learnability, Efficiency, Memorability , Errors,	questionnaire

HL RQs	RQs		Hs	Indicators	Measurements/Tools
				Satisfaction	
		5.1.2	the application functionality is useful for the operators.	Learnability, Efficiency, Memorability, Errors, Satisfaction	questionnaire

Table 7.19: User Acceptance Research Questions and Success Criteria for EFP.

HL RQs		RQs		Hs		Indicators	Measurements /Tools
1	Does the user agree to be and is an active input to the application?	1.1	Do drivers accept that their location, direction, speed and acceleration is transmitted to the application?	1.1.1	Drivers agree that their location is communicated to other vehicles.		Questionnaire
				1.1.2	Drivers agree that their location is communicated to the infrastructure.		Questionnaire
		1.2	Do traffic operators accept that traffic data per road segment (traffic density estimation, information on road events, queuing location) are communicated to the application?	1.2.1	Traffic operators accept that traffic data per road segment (traffic density estimation, information on road events, queuing location) are communicated to the application		Questionnaire
2	Does the user acts according to the application output?	2.1	Do drivers (looking for parking) follow the suggested parking advice?	-	-		Questionnaire/ monitoring data
		2.2	Can operators collect aggregated data on parking availability (either free or not) in the public areas?	-	-		questionnaire
3	Willingness to use	3.1	Do users state that they will use the system?	3.1.1	Drivers state that they will use the system.		questionnaire
				3.1.2	Operators state that they will use the system.		questionnaire

HL RQs		RQs		Hs		Indicators	Measurements /Tools
4	Willingness to pay	4.1	Do users state that they would pay for the system?	4.1.1	Drivers state that they would pay for the system.		questionnaire
				4.1.2	Operators state that they would pay for the system.		questionnaire
5	Usability	5.1	Is the application functionality useful for the users?	5.1.1	The application functionality is useful for the drivers.	Learnability, Efficiency, Memorability, Errors, Satisfaction	questionnaire / monitoring data
				5.1.2	The application functionality is useful for the operators.	Learnability, Efficiency, Memorability, Errors, Satisfaction	questionnaire

Table 7.20: User Acceptance Research Questions and Success Criteria for CDM.

	HL RQs		RQs		Hs	Indicators	Measurements /Tools
1	Does the user agree to be and is an active input to the application?	1.1	Do drivers accept that their location and speed is transmitted to the application?	-	-		questionnaire
		1.2	Do drivers accept that their driving behaviour (speed, acceleration, lateral position, location, etc.…) is monitored by the application?	-	-		questionnaire
		1.3	Do drivers accept that their vigilance state is monitored by the application?	-	-		questionnaire
2	Does the user acts according to the application output?	2.1	Do drivers select the suggested rerouting in case of road restriction?	-	-		questionnaire (to capture perception) and log file
		2.2	Do drivers select the suggested manoeuvre in case of lane change?	2.2.1	The ego-driver follows the suggestion given by the system		questionnaire (to capture perception) and log file
				2.2.2	The other drivers follow the suggestion given by the system and give way to the ego-vehicle		questionnaire (to capture perception) and log file
		2.3	Do drivers select the suggested	2.3.1	The ego-driver follows the suggestion given by the		questionnaire (to capture

HL RQs		RQs		Hs	Indicators	Measurements /Tools
		manoeuvre in case of roundabout?		system		perception) and log file
			2.3.2	The other drivers follow the suggestion given by the system and give way to the ego-vehicle		questionnaire (to capture perception) and log file
	2.4	Do drivers select the suggestions of the braking application?				questionnaire (to capture perception) and log file
	2.5	Do drivers accept that the vehicle performs an automated emergency stop in case of their low vigilance?	-	-		questionnaire (to capture perception) and log file
	2.6	Do drivers follow the suggestions of the intersection optimization function ?	2.6.1	The driver follow the suggestion of the intersection optimisation function to cross in green		questionnaire (to capture perception) and log file
			2.6.2	The driver follow the suggestion of the intersection optimisation function to brake in an eco-friendly way		questionnaire (to capture perception) and log file
	2.7	Do drivers conform to the adapted speed limits?				questionnaire (to capture perception) and log file

	HL RQs		RQs		Hs	Indicators	Measurements /Tools
		2.8	Do drivers follow the manoeuvring suggestions in case of highway entrance or exit?	2.8.1	The ego-driver follows the suggestion given by the system		questionnaire (to capture perception) and log file
				2.8.2	The other drivers follow the suggestion given by the system and give way to the ego-vehicle		questionnaire (to capture perception) and log file
		2.9	Do drivers accept the suggested custom clearance in case of ambulances, fire trucks, and police cars passing?				questionnaire (to capture perception) and log file
		2.10	Do drivers select the suggested lane advice?				questionnaire (to capture perception) and log file
		2.11	Do drivers select the suggested overtaking advice?	-			questionnaire (to capture perception) and log file
3	Willingness to use	3.1	Do drivers / traffic centre operators state that they will use the system?	-	-	user acceptance	questionnaire
		3.2	Do drivers state that they will use the system?	-	-	user acceptance	questionnaire
4	Willingness to pay	4.1	Do drivers / traffic centre operators	-	-	willingness to	questionnaire

	HL RQs		RQs		Hs	Indicators	Measurements /Tools
			state that they would pay for the system?			have/to pay	
5	Usability	5.1	Is the road restriction functionality usable by drivers / traffic centres operators?	-	-	Learnability, Efficiency, Memorability, Errors, Satisfaction	questionnaire
5	Usability	5.1	Is the merging functionality useful and usable?	-	-	Learnability, Efficiency, Memorability, Errors, Satisfaction	questionnaire / monitoring data

Table 7.21: User Acceptance Research Questions and Success Criteria for SG-CM.

HL RQs		RQs		Hs		Indicators	Measurements/Tools
1	Does the user agree to be and is an active input to the application?	1.1	Do users (travellers) accept that their location and planned route is transmitted to the application?	1.1.1	Users accept that their location is transmitted to the application.		questionnaire
				1.1.2	Users accept that their planned route is transmitted to the application.		questionnaire
		1.2	Do users use similar applications?	-	-		questionnaire
2	Does the user acts according to the application output?	2.1		-	-		
3	Does the user accept and trust the application?	3.1	Do users (travellers/operators/bus drivers) state that they will use the system?	-	-		questionnaire
		3.2	Is user acceptance influenced by perceived application ease of use? (Collaborative public transport optimization - CPTO)	-	-		questionnaire, scale
		3.3	Is user acceptance influenced by perceived usefulness of application?	-	-		questionnaire, scale
		3.4	Is user acceptance influenced by perceived joy of use of the application?				questionnaire, scale
		3.4	Is user acceptance influenced by perceived trust in application?	-	-		questionnaire, scale

HL RQs		RQs		Hs		Indicators	Measurements/Tools
4	Is the user willing to pay for the application?	4.1	Do the users (travellers/operators/bus drivers) desire to have the application?	-	-		questionnaire
5	Usability	5.1	Is the application functionality useful and usable?	-	-	Learnability, Efficiency, Memorability, Errors, Satisfaction	questionnaire / monitoring data

Table 7.22: User Acceptance Research Questions and Success Criteria for CONAV.

	HL RQs		RQs		Hs	Indicators	Measurements /Tools
1	Does the user agree to be and is an active input to the application?	1.1	Do drivers accept that their location and planned route is transmitted to the application?	1.1.1			questionnaire, application usage
		1.2	Is the user aware of what the collaboration concept implies? (e.g. the more information he provides, the better it works)	1.2.1			questionnaire
		1.3	Is personal data entry, even if not compulsory, completed?	1.3.1			questionnaire, data log
2	Does the user acts according to the application output?	2.1	Do drivers follow the navigation directions?	2.1.1		This is a key objective for the application	questionnaire, data log
		2.2	Does route length affect driver's following the application output?	2.2.1			questionnaire, travel diary, interview
		2.3	Does route familiarity affect driver's following the application output?	2.3.1			questionnaire, travel diary, interview
		2.4	Does the system's use affect habitual routing?				questionnaire, travel diary, interview
3	Willingness to use	3.1	Do drivers state that they will use the	3.1.1			questionnaire,

	HL RQs		RQs	Hs	Indicators	Measurements /Tools
			system?			travel diary, interview
		3.2	Do traffic conditions affect driver's willingness to use the system?	3.2.1		questionnaire, travel diary, interview
		3.3	Do drivers trust that the system will improve their travel efficiency?	3.3.1	If they don't or do to a limited extent, they won't probably use it	questionnaire
4	Willingness to pay	4.1	Would driver pay for the system?	4.1.1	willingness to pay	questionnaire
		4.2	How much would he be willing to pay?	4.2.1	willingness to pay	questionnaire
		4.3	At which conditions would he be willing to pay? (only if having individual advantages...)	4.3.1	willingness to have	questionnaire
5	Usability	5.1	Does the usage affect driver's workload?	...	workload	questionnaire
		5.2	Does the system affect users driving efficiency?			questionnaire
		5.3	Do users correctly perceive interpret system's instructions?			questionnaire
		5.4	Is the system easy to use?			questionnaire
		5.5	Does the design of the application user			questionnaire

HL RQs		RQs	Hs	Indicators	Measurements /Tools
		interface affect user's acceptance?			
	5.6	Is the system perceived as easy to use?			questionnaire
	5.7	Does the system affect user effectiveness?			questionnaire
	5.8	Are users satisfied with the system?		We need to know if users see a value in what the system delivers	questionnaire
	5.9	Are they aware of the system status?			questionnaire

Annex 3 Impact Research Questions, Measurements and Tools

The following tables present the research questions and success criteria relevant for the evaluation of impacts for all TEAM applications. Note that the numbering is not sequential, following the research questions selection phase, as explained above.

Table 7.23: Impact Research Questions and Success Criteria for CMC.

RQ level 1	RQ level 2	RQ level 3[1]		Hypotheses		Indicators	Measurements / Tools	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
1. Travel behaviour	1.1 Number of journeys	1.1.1	Is the number of journeys undertaken affected? (n)	1.1.1.1	-			X	X	X	X
	1.2 Travel mode	1.2.1	Is there a change in mode of travel? (n)	1.2.1.1	There is an increase/decrease in the use of public transport for commuting because…	Use of public transport per commuting journey	Questionnaire / travel diary	X		X	X
				1.2.1.2	There is an increase/decrease in the use of car for commuting because…	Use of car per commuting journey	Questionnaire / travel diary / key on and vehicle movement GPS, GPS logging		X	X	X

[1] n = applies only for naturalistic driving setup

RQ level 1	RQ level 2	RQ level 3[1]		Hypotheses		Indicators	Measurements / Tools	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
				1.2.1.3	There is an increase/decrease in the use of bicycle or walking for commuting because…	Use of bicycle or walking per commuting journey	Questionnaire / travel diary			X	X
				1.2.1.4	There is an increase/decrease in the use of public transport for other journeys than commuting because…	Use of public transport per non-commuting journey	Questionnaire / travel diary	X		X	X
				1.2.1.5	There is an increase/decrease in the use of car for other journeys than commuting because…	Use of car per non-commuting journey	Questionnaire / travel diary / key on and vehicle movement GPS, GPS logging		X	X	X
				1.2.1.6	There is an increase/decrease in the use of bicycle or walking for other journeys than commuting because…	Use of bicycle or walking per non-commuting journey	Questionnaire / travel diary			X	X
		1.2.2	Is there a change in	1.2.2.1	There is an increase/decrease in	Use of public transport / car /	Questionnaire			X	X

RQ level 1	RQ level 2	RQ level 3[1]		Hypotheses		Indicators	Measurements / Tools	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
			multimodal travel? (n)		multimodal travel because…	bicycle per journey					
	1.3 Length/ duration	1.3.1	Are durations of comparable/repeated journeys affected?	1.3.1.1	Journeys times of daily commuting or regular journeys increase/decrease because…	Travel time per distance, commuting or regular journeys	Journey time in hours/minutes	X	X		X
		1.3.2	Are lengths of comparable/repeated journeys affected?	1.3.1.2	Lengths of journeys (daily commute/regular journeys) increase/decrease because…	Journey length in distance, commuting or regular journeys	Journey length in km/metres	X	X	X	X
	1.4 Time budget/ timing	1.4.1	Is there a change in time allocated to travel? (n)	1.4.1.1	Time allocated to travel increases/decreases because…	Time allocated to travel per journey	Questionnaire / travel diary / key on and vehicle movement GPS, GPS logging		X		X
		1.4.2	Is there a change in starting time of journey? (n)	1.4.2.1	Starting time of commuting is shifted earlier/later because…	Starting time of commuting journey	Questionnaire / travel diary / key on and vehicle movement GPS, GPS logging	X	X	X	X

RQ level 1	RQ level 2	RQ level 3[1]		Hypotheses		Indicators	Measurements / Tools	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
				1.4.2.2	Starting time of journeys other than commuting is shifted earlier/later because…	Starting time of non-commuting journey	Questionnaire / travel diary / key on and vehicle movement GPS, GPS logging	X	X	X	X
	1.5 Route	1.5.1	Is there a change in route choice? (n)	1.5.1.1	Route used for commuting changes because…	Route	Map matching, tracks on digital map / questionnaire		X	X	X
				1.5.1.2	Route used for other frequently used routes than commuting changes because…	Route	Map matching, tracks on digital map / questionnaire		X	X	X
		1.5.2	Is the travel on different road types affected? (n)	1.5.2.1	There is an increase/decrease in motorway travel because…	Shares of km per road type	Map matching, tracks on digital map / questionnaire	X	X	X	X
				1.5.2.2	There is an increase/decrease in rural road travel because…	Shares of km per road type	Map matching, tracks on digital map / questionnaire		X	X	X

RQ level 1	RQ level 2	RQ level 3[1]		Hypotheses		Indicators	Measurements / Tools	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
				1.5.2.3	There is an increase/decrease in urban road travel because…	Shares of km per road type	Map matching, tracks on digital map / questionnaire	X	X	X	X
		1.5.3	Is travelling in residential areas affected?	1.5.3.1	There is an increase/decrease in travelling in residential areas because…	Shares of km per road environment (rural, urban, residential area)	Map matching, tracks on digital map / questionnaire	X	X	X	X
4 Driving behaviour	4.1 Speed	4.1.1	Is speed affected?	4.1.1.1	There is an increase/decrease in mean speed because…	Mean speed of the vehicle	Speed in km/h, 1 Hz	X	X		
				4.1.1.2	There is an increase/decrease in standard deviation of speed because…	Standard deviation of vehicle speed	Speed in km/h, 1 Hz	X	X		
				4.1.1.3	There is an increase/decrease in maximum speed because…	Maximum speed recorded over event/scenario	Speed in km/h, 1 Hz	X	X		
				4.1.1.6	There is an increase/decrease in	Median speed	Speed in km/h, 1 Hz	X	X		

RQ level 1	RQ level 2	RQ level 3[1]	Hypotheses	Indicators	Measurements / Tools	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
			median speed because…						
		4.1.1.8	There is a change in the vehicle speed patterns which affects emissions and fuel consumption because…	Registered speed patterns in relevant areas	Speed in km/h, 1 Hz	X	X	X	
	4.1.2 Is acceleration affected?	4.1.2.1	-				X	X	
	4.1.3 Is very sudden / heavy acceleration affected?	4.1.3.1	-			X	X	X	
	4.1.4 Are speed violations affected?	4.1.4.1	-			X			
	4.1.5 Is braking affected?	4.1.5.1	There is an increase/decrease in max brake force because…	Maximum brake force	Brake force	X	X		

RQ level 1	RQ level 2	RQ level 3[1]		Hypotheses		Indicators	Measurements / Tools	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
				4.1.5.2	There is an increase/decrease in the number of times the brake force exceeds X per time or distance or another appropriate variable because...	the number of times the brake force exceeds X per time or distance or another appropriate variable	Brake force		X		
	4.2 Position	4.2.1	Is proximity to other vehicles affected?	4.2.1.1	-			X	X		
		4.2.2	Is number of lane changes affected?	4.2.2.1	There is an increase/decrease in the number of lane changes because...	Number of lane changes / 10 km	current lane	X	X		
	4.3 Interaction with other road users	4.3.1	Is giving way for pedestrians and cyclists affected?	4.3.1.1	-			X			
		4.3.2	Is the use of emergency lights affected?	4.3.2.1	-			X			

RQ level 1	RQ level 2	RQ level 3[1]		Hypotheses		Indicators	Measurements / Tools	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
		4.3.3	Is use of turn signals affected?	4.3.3.1	-			X			
	4.4 Workload	4.4.1	Is workload affected?	4.4.1.1	There is an increase/decrease in workload because…	questionnaire/ Peripheral Detection Task (PDT) / SRR	Steering reversal rate	X			
		4.4.2	Is fatigue affected?	4.4.2.1	-			X			
5 Focus of attention	5.1 Focus on road	5.1.1.	Is the duration 'eyes off road' affected?	5.1.1.1	-			X			
		5.1.2	Is frequency 'eyes off road' affected?	5.1.2.1	-			X			
	5.2 Focus on other road users	5.2.1	Is focus of attention to pedestrians and cyclists affected?	5.2.1.1	-			X			
		5.2.2	Is focus of attention to	5.2.2.1	-						

RQ level 1	RQ level 2	RQ level 3[1]	Hypotheses	Indicators	Measurements / Tools	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
		other vehicles affected?							
		5.2.3 Is relevant information missed (road signs)?	5.2.3.1 -			X			
	5.3 Focus on device	5.3.1 Is the driver distracted by the system?	5.3.1.1 -			X			
			5.3.1.2 -			X			
6 User acceptance	6.1 User experience	6.1.1 Does the function improve the comfort?	6.1.1.1 -						X
		6.1.4 Does the function reduce the stress of the driver?	6.1.4.1 Stress increases/decreases because…		questionnaire	X			
		6.5.3 What is the trust in the system?	6.5.3.1 -						
7	7.1 Steering	7.1.1 Is there change in the steering	7.1.1.1 -			X			

RQ level 1	RQ level 2	RQ level 3[1]	Hypotheses	Indicators	Measurements / Tools	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
	wheel	wheel frequency?							
		7.1.2 Is there change in steering wheel amplitude?	7.1.2.1 -			X			
		7.2.5 Is there change in the clutch frequency?	7.2.5.1 Clutch frequency increases/decreases because…	Clutch frequency				X	
	7.3 Fuel consumption / Emissions	7.3.1 Is fuel consumption affected?	7.3.1.1 Fuel consumption increases/decreases because…	Fuel consumption / 100 km	Fuel consumption litres / 100 km			X	
		7.3.2 Pollutant emissions (NOx, PM, HC) increase/decrease because…	7.3.2.1 The emission increases/decreases because…	TBD				X	

Table 7.24: Impact Research Questions and Success Criteria for COPLAN.

RQ level 1	RQ level 2	RQ level 3[2]		Hypotheses		Indicators	Measurements /Tools	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
1 Travel behaviour	1.1 Number of journeys	1.1.1	Is the number of journeys undertaken affected? (n)	1.1.1.1	Number of journeys undertaken increases in total because with COPLAN it is easier to optimize one's travel to find the fastest mode (and route)	Total number of journeys / day	Questionnaire / travel diary / key on and vehicle movement GPS, GPS logging	X	X	X	X
				1.1.1.3	Number of other journeys than commuting increases because with COPLAN it is easier to optimize one's travel to find the fastest mode (and route)	Number of journeys other than commuting / day	Questionnaire / travel diary / key on and vehicle movement GPS, GPS logging		X	X	X
	1.2 Travel mode	1.2.1	Is there a	1.2.1.1	There is an	Use of public	Questionnaire /	X		X	X

[2] n = applies only for naturalistic driving setup

RQ level 1	RQ level 2	RQ level 3[2]	Hypotheses	Indicators	Measurements /Tools	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
		change in mode of travel? (n)	increase in the use of public transport for commuting because COPLAN supports multimodal travelling, and may hence encourage people to use public transit for at least part of their trip (instead of their own car for the whole trip)	transport per commuting journey	travel diary				
			1.2.1.2 There is an decrease in the use of car for commuting because COPLAN supports multimodal travelling	Use of car per commuting journey	Questionnaire / travel diary / key on and vehicle movement GPS, GPS logging		X	X	X

RQ level 1	RQ level 2	RQ level 3[2]	Hypotheses		Indicators	Measurements /Tools	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
			1.2.1.3	There is an increase in the use of bicycle or walking for commuting because COPLAN supports multimodal travelling	Use of bicycle or walking per commuting journey	Questionnaire / travel diary			X	X
			1.2.1.4	There is an increase in the use of public transport for other journeys than commuting because COPLAN supports multimodal travelling	Use of public transport per non-commuting journey	Questionnaire / travel diary	X		X	X
			1.2.1.5	There is an decrease in the use of car for other journeys than commuting	Use of car per non-commuting journey	Questionnaire / travel diary / key on and vehicle movement GPS,		X	X	X

RQ level 1	RQ level 2	RQ level 3[2]	Hypotheses	Indicators	Measurements /Tools	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
			because COPLAN supports multimodal travelling		GPS logging				
			1.2.1.6 There is an increase in the use of bicycle or walking for other journeys than commuting because COPLAN supports multimodal travelling	Use of bicycle or walking per non-commuting journey	Questionnaire / travel diary			X	X
		1.2.2 Is there a change in multimodal travel? (n)	1.2.2.1 There is an increase in multimodal travel because COPLAN supports it	Use of public transport / car / bicycle per journey	Questionnaire			X	X
	1.3 Length/ duration	1.3.1 Are durations of comparable/repeated journeys	1.3.1.1 Journey times of daily commuting or regular journeys decrease because COPLAN	Travel time per distance, commuting or regular journeys	Journey time in hours/minutes	X	X		X

RQ level 1	RQ level 2	RQ level 3[2]		Hypotheses		Indicators	Measurements /Tools	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
			affected?		helps to select the fastest mode/multimodal trip and route						
		1.3.2	Are lengths of comparable/repeated journeys affected?	1.3.1.2	Lengths of journeys (daily commute/regular journeys) may increase because COPLAN routes the users to optimize the traffic - and hence may guide them into longer, but less congested route	Journey length in distance, commuting or regular journeys	Journey length in km/metres	X	X	X	X
	1.4 Time budget/ timing	1.4.1	Is there a change in time allocated to travel? (n)	1.4.1.1	Time allocated to travel decreases because COPLAN helps to optimize the travelling	Time allocated to travel per journey	Questionnaire / travel diary / key on and vehicle movement GPS, GPS logging		X		X
		1.4.2	Is there a	1.4.2.1	Starting time of	Starting time of	Questionnaire /	X	X	X	X

RQ level 1	RQ level 2	RQ level 3[2]		Hypotheses		Indicators	Measurements /Tools	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
			change in starting time of journey? (n)		commuting may be shifted earlier/later because COPLAN helps to select the optimal mode/route	commuting journey	travel diary / key on and vehicle movement GPS, GPS logging				
				1.4.2.2	Starting time of journey other than commuting may be shifted earlier/later because COPLAN helps to select the optimal mode/route	Starting time of non-commuting journey	Questionnaire / travel diary / key on and vehicle movement GPS, GPS logging	X	X	X	X
	1.5 Route	1.5.1	Is there a change in route choice? (n)	1.5.1.1	Route used for commuting changes because COPLAN helps to select the optimal (less congested etc.) route	Route	Map matching, tracks on digital map / questionnaire		X	X	X
				1.5.1.2	Route used for	Route	Map matching,		X	X	X

RQ level 1	RQ level 2	RQ level 3[2]		Hypotheses		Indicators	Measurements /Tools	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
					other frequently used routes than commuting changes because COPLAN helps to select the optimal (less congested etc.) route		tracks on digital map / questionnaire				
		1.5.2	Is the travel on different road types affected? (n)	1.5.2.1	There may be an increase or decrease in motorway travel because COPLAN supports drivers and travellers to select the least congested routes. In case motorways are congested, then the use of those decreases	Shares of km per road type	Map matching, tracks on digital map / questionnaire	X	X	X	X
				1.5.2.2	There is an increase in rural	Shares of km per road type	Map matching, tracks on digital		X	X	X

RQ level 1	RQ level 2	RQ level 3[2]		Hypotheses		Indicators	Measurements /Tools	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
					road travel because COPLAN supports drivers and travellers in selecting the least congested routes		map / questionnaire				
				1.5.2.3	There is an decrease in urban road travel because COPLAN helps the drivers and travellers in selecting the least congested routes and modes	Shares of km per road type	Map matching, tracks on digital map / questionnaire	X	X	X	X
		1.5.3	Is travelling in residential areas affected?	1.5.3.1				X	X	X	X
2 Intention to use	2.2 Use patterns	2.2.1	In which circumstances does the driver intend to use the system?	2.2.1.1							

RQ level 1	RQ level 2	RQ level 3[2]		Hypotheses		Indicators	Measurements /Tools	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
4 Driving behaviour	4.1 Speed	4.1.1	Is speed affected?	4.1.1.1	There is an increase in mean speed because COPLAN helps drivers to select less congested routes and supports multimodal travelling	Mean speed of the vehicle	Speed in km/h, 1 Hz	X	X		
				4.1.1.2	There is a decrease in standard deviation of speed because traffic flow gets smoother when the number of cars decreases (when people travel by public/multimodal)	Standard deviation of vehicle speed	Speed in km/h, 1 Hz	X	X		
				4.1.1.8	There is a change	Registered	Speed in km/h,	X	X	X	

RQ level 1	RQ level 2	RQ level 3[2]	Hypotheses	Indicators	Measurements /Tools	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
			in the vehicle speed patterns which affects emissions and fuel consumption because traffic flow gets smoother (less congested)	speed patterns in relevant areas	1 Hz				
	4.4 Workload	4.4.1 Is workload affected?	4.4.1.1 There is a decrease in workload because COPLAN makes travelling smoother and well informed	questionnaire/ Peripheral Detection Task (PDT) / SRR	Steering reversal rate	X			
		4.4.2 Is fatigue affected?	4.4.2.1 There is an decrease in fatigue because COPLAN helps to avoid congestion	eye movements/questionnaire	video	X			
6 User acceptance	6.1 User experience	6.1.1 Does the function improve the	6.1.1.1 Comfort increases because COPLAN helps to avoid		questionnaire				X

RQ level 1	RQ level 2	RQ level 3[2]		Hypotheses		Indicators	Measurements /Tools	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
			comfort?		congestion						
		6.1.2		6.1.2.1	Uncertainty increases because COPLAN keeps the travellers/drivers informed		questionnaire				X
		6.1.3		6.1.3.1	Feeling of safety improves because COPLAN keeps the drivers and travellers informed		questionnaire				X
		6.1.4	Does the function reduce the stress of the driver?	6.1.4.1	Stress decreases because COPLAN keeps the drivers and travellers informed and helps to avoid congestion		questionnaire	X			
		6.1.5	How does the driver assess to benefit of the	6.1.5.1							

RQ level 1	RQ level 2	RQ level 3[2]		Hypotheses		Indicators	Measurements /Tools	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
			system?								
	6.5 Acceptance of system	6.5.2	Is the system reliable?	6.5.2.1	-						
7	7.3 Fuel consumption / Emissions	7.3.1	Is fuel consumption affected?	7.3.1.1	Fuel consumption decreases because traffic is less congested	Fuel consumption / 100 km	Fuel consumption litres / 100 km			X	
		7.3.2	Pollutant emissions (NOx, PM, HC) increase/decre ase because...	7.3.2.1	The emissions decreases because traffic is less congested	TBD				X	

Table 7.25: Impact Research Questions and Success Criteria for CCA.

RQ level 1	RQ level 2	RQ level 3		Hypotheses		Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
1 Travel behaviour	1.2 Travel mode	1.2.1	Is there a change in mode of travel? (n)	1.2.1.1	There is an increase in the use of public transport for commuting because most of the time it has lower CO2 emissions than private cars	Use of public transport per commuting journey	Questionnaire / travel diary	X		X	X
				1.2.1.2	There is an decrease in the use of car for commuting because most of the time private cars have higher CO2 emissions per person km than public transport or non-motorized modes	Use of car per commuting journey	Questionnaire / travel diary / key on and vehicle movement GPS, GPS logging		X	X	X
				1.2.1.3	There is an increase in the use of bicycle or walking for commuting because those are practically zero emissions modes, and also improve the fluency	Use of bicycle or walking per commuting journey	Questionnaire / travel diary			X	X

RQ level 1	RQ level 2	RQ level 3		Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
				of traffic (by "taking a car away" from the traffic flow)						
			1.2.1.4	There is an increase in the use of public transport for other journeys than commuting because most of the time it has lower CO2 emissions than private cars	Use of public transport per non-commuting journey	Questionnaire / travel diary	X		X	X
			1.2.1.5	There is an decrease in the use of car for other journeys than commuting because most of the time private cars have higher CO2 emissions per person km than public transport or non-motorized modes	Use of car per non-commuting journey	Questionnaire / travel diary / key on and vehicle movement GPS, GPS logging		X	X	X

RQ level 1	RQ level 2		RQ level 3		Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
				1.2.1.6	There is an increase in the use of bicycle or walking for other journeys than commuting because those are practically zero emissions modes, and also improve the fluency of traffic (by "taking a car away" from the traffic flow)	Use of bicycle or walking per non-commuting journey	Questionnaire / travel diary			X	X
		1.2.2	Is there a change in multimodal travel? (n)	1.2.2.1	There is an increase in multimodal travel because non-motorized and public transit have lower emissions than cars	Use of public transport / car / bicycle per journey	Questionnaire			X	X
	1.3 Length/ duration	1.3.1	Are durations of comparable/repeated journeys affected?	1.3.1.1	Journeys times of daily commuting or regular journeys increase/decrease because... This can be either way. Travel time is one part of the optimization, but the	Travel time per distance, commuting or regular journeys	Journey time in hours/minutes	X	X		X

RQ level 1	RQ level 2		RQ level 3		Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
					total impact depends on the importance of travel time versus CO2 emissions in the comparison with the avatar						
		1.3.2	Are lengths of comparable/repeated journeys affected?	1.3.1.2	Lengths of journeys (daily commute/regular journeys) increase/decrease because... This can be either way. Travel time (may correlate with the route length) is one part of the optimization, but the total impact depends on the importance of travel time versus CO2 emissions in the comparison with the avatar	Journey length in distance, commuting or regular journeys	Journey length in km/metres	X	X	X	X
	1.4 Time budget/ timing	1.4.1	Is there a change in time allocated to	1.4.1.1					X		X

RQ level 1	RQ level 2	RQ level 3		Hypotheses		Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
			travel? (n)								
	1.5 Route	1.5.1	Is there a change in route choice? (n)	1.5.1.1	Route used for commuting changes because the usage of the transport system is optimized	Route	Map matching, tracks on digital map / questionnaire		X	X	X
				1.5.1.2	Route used for other frequently used routes than commuting changes because usage of the transport system is optimized	Route	Map matching, tracks on digital map / questionnaire		X	X	X
		1.5.2	Is the travel on different road types affected? (n)	1.5.2.1	There is an increase/decrease in motorway travel because...Again this can be either way: decrease if the motorways are very congested, if not, then may increase (travel time savings)	Shares of km per road type	Map matching, tracks on digital map / questionnaire	X	X	X	X

RQ level 1	RQ level 2	RQ level 3		Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
			1.5.2.2	There is an increase/decrease in rural road travel because... Again this can be either way: increase if the rural roads are less congested than e.g. motorways and city streets (travel time savings)	Shares of km per road type	Map matching, tracks on digital map / questionnaire		X	X	X
			1.5.2.3	There is an increase/decrease in urban road travel because. As with previous ones: this depends on the current situation in the network, and also availability of different modes. Also: depends on the optimization algorithms (travel time versus CO2 emissions)	Shares of km per road type	Map matching, tracks on digital map / questionnaire	X	X	X	X

RQ level 1	RQ level 2		RQ level 3		Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
		1.5.3	Is travelling in residential areas affected?	1.5.3.1	There is an increase/decrease in travelling in residential areas because...As with previous ones: this depends on the current situation in the network, and also availability of different modes. Also: depends on the optimization algorithms (travel time versus CO2 emissions)	Shares of km per road environment (rural, urban, residential area)	Map matching, tracks on digital map / questionnaire	X	X	X	X
2 Intention to use	2.1 Frequency of use	2.1.1	How often does the driver plan to use the system?	2.1.1.1							
4 Driving behaviour	4.3 Interaction with other road users	4.3.3	Is use of turn signals affected?	4.3.3.1				X			
6 User acceptance	6.1 User experience	6.1.4	Does the function reduce the stress of the driver?	6.1.4.1	Stress decreases because travelling is optimized (by learning in the long run - not for the first travel though)		questionnaire	X			

RQ level 1	RQ level 2	RQ level 3			Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
7	7.3 Fuel consumption / Emissions	7.3.1	Is fuel consumption affected?	7.3.1.1	Fuel consumption decreases because usage of less congested routes and less consuming modes (public and non-motorized) are encouraged	Fuel consumption / 100 km	Fuel consumption litres / 100 km			X	
		7.3.2	Pollutant emissions (NOx, PM, HC) increase/decrease because...	7.3.2.1	The emissions decreases because usage of less polluting modes (and routes) are encouraged	TBD				X	

Table 7.26: Impact Research Questions and Success Criteria for CSI.

RQ level 1	RQ level 2		RQ level 3		Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
1 Travel behaviour	1.1 Number of journeys	1.1.1	Is the number of journeys undertaken affected? (n)								
	1.3 Length/ duration	1.3.1	Are durations of comparable/repeated journeys affected?	1.3.1.1	Journeys times of daily commuting or regular journeys decrease because of the smart optimization	Travel time per distance, commuting or regular journeys	Journey time in hours/minutes	X	X		X
		1.3.2	Are lengths of comparable/repeated journeys affected?								
	1.4 Time budget/ timing	1.4.1	Is there a change in time allocated to travel? (n)								
	1.5 Route	1.5.1	Is there a change in route choice? (n)	1.5.1.1	Route used for commuting changes because driver/traveller wants to use the routes in which the application works	Route	Map matching, tracks on digital map / questionnaire		X	X	X

RQ level 1	RQ level 2	RQ level 3		Hypotheses		Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
					(and minimizes stops etc)						
				1.5.1.2	Route used for other frequently used routes than commuting changes because driver/traveller wants to use the routes in which the application works (and minimizes stops etc)	Route	Map matching, tracks on digital map / questionnaire		X	X	X
		1.5.2	Is the travel on different road types affected? (n)								
4 Driving behaviour	4.1 Speed	4.1.1	Is speed affected?	4.1.1.1	There is an increase in mean speed because usage of the network is optimized	Mean speed of the vehicle	Speed in km/h, 1 Hz	X	X		

RQ level 1	RQ level 2	RQ level 3	Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
			4.1.1.2 There is an decrease in standard deviation of speed because usage of the network is optimised and e.g. number of stops is decreased	Standard deviation of vehicle speed	Speed in km/h, 1 Hz	X	X		
			S						
			4.1.1.8 There is a change in the vehicle speed patterns which affects emissions and fuel consumption because at least the number of stops are minimized	Registered speed patterns in relevant areas	Speed in km/h, 1 Hz	X	X	X	
	4.1.2 Is acceleration affected?		4.1.2.1 There is an increase/decrease in peak level of longitudinal or lateral acceleration achieved during a	maximum longitudinal and lateral acceleratio n	Longitudinal and lateral acceleration		X	X	

RQ level 1	RQ level 2	RQ level 3	Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
			scenario because…						
		4.1.3 Is very sudden / heavy acceleration affected?	4.1.3.1 There is an decrease in peak level of change of longitudinal or lateral acceleration because application optimizes the traffic flow (not that many sudden braking/acceleration s for the traffic lights)	Maximum change of longitudinal and lateral acceleratio ns above 3 m/s2, m/s^3	Change of longitudinal and lateral acceleration, 1 Hz	X	X	X	
		4.1.4 Are speed violations affected?							
	4.3 Interaction with other road users	4.3.2 Is the use of emergency lights affected?							
	4.4 Workload	4.4.1 Is workload affected?	4.4.1.1 There is an decrease in workload because application gives the	questionnai re/ Peripheral Detection	Steering reversal rate	X			

RQ level 1	RQ level 2	RQ level 3			Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
					recommendations for "smooth driving"	Task (PDT) / SRR					
5 Focus of attention	5.1 Focus on road	5.1.1.	Is the duration 'eyes off road' affected?	5.1.1.1	There is an increase in the duration 'eyes off road' because every extra display in the car have a risk to increase the "eyes off the road" time	eye movements	video	X			
		5.1.2	Is frequency 'eyes off road' affected?	5.1.2.1	There is an increase in the frequency of 'eyes off road' because of the potential new display and hence visual "distraction"	eye movements	video	X			
	5.2 Focus on other road users	5.2.1	Is focus of attention to pedestrians and cyclists affected?								
6 User acceptance	6.1 User experience	6.1.1	Does the function improve the comfort?	6.1.1.1	Comfort increases because application gives the		questionnaire				X

RQ level 1	RQ level 2	RQ level 3			Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
					recommendations for smooth driving						
		6.1.2									
		6.1.4	Does the function reduce the stress of the driver?	6.1.4.1	Stress decreases because application gives the recommendations for smooth driving		questionnaire	X			
		6.1.5	How does the driver assess to benefit of the system?								
7	7.2 Pedals	7.2.1	Is there change in the accelerator pedal frequency?	7.2.1.1	Accelerator pedal frequency decreases because application encourages smooth driving (and avoiding stopping in the traffic lights)	Accelerator pedal frequency					
		7.2.3	Is there change in the brake pedal frequency?	7.2.3.1	Brake pedal frequency decreases because application encourages smooth driving	Brake pedal frequency					

RQ level 1	RQ level 2		RQ level 3		Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
		7.2.5	Is there change in the clutch frequency?	7.2.5.1	Clutch frequency decreases because application encourages smooth driving	Clutch frequency				X	
	7.3 Fuel consumption / Emissions	7.3.1	Is fuel consumption affected?	7.3.1.1	Fuel consumption decreases because application reduces the number of stops in the traffic lights and also recommends to use the start-stop functionality	Fuel consumption / 100 km	Fuel consumption litres / 100 km			X	
		7.3.2	Pollutant emissions (NOx, PM, HC) increase/decrease because…	7.3.2.1	The emissions decreases because application reduces the number of stops in the traffic lights and also recommends to use the start-stop functionality	TBD				X	

Table 7.27: Impact Research Questions and Success Criteria for CPTO.

RQ level 1	RQ level 2	RQ level 3		Hypotheses		Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
1 Travel behaviour	1.1 Number of journeys	1.1.1	Is the number of journeys undertaken affected? (n)	1.1.1.1	Number of journeys undertaken increases in total because of the flexible bus service and because of the real-time information	Total number of journeys / day	Questionnaire / travel diary / key on and vehicle movement GPS, GPS logging	X	X	X	X
				1.1.1.3	Number of other journeys than commuting increases because of the flexible bus service and because of the real-time information	Number of journeys other than commutin g / day	Questionnaire / travel diary / key on and vehicle movement GPS, GPS logging		X	X	X
	1.2 Travel mode	1.2.1	Is there a change in mode of travel? (n)	1.2.1.1	There is an increase in the use of public transport for commuting because of the flexible bus service and because of the real-time information	Use of public transport per commutin g journey	Questionnaire / travel diary	X		X	X

RQ level 1	RQ level 2	RQ level 3		Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
			1.2.1.2	There is an decrease in the use of car for commuting because of the flexible bus service and because of the real-time information	Use of car per commuting journey	Questionnaire / travel diary / key on and vehicle movement GPS, GPS logging		X	X	X
			1.2.1.4	There is an increase in the use of public transport for other journeys than commuting because of the flexible bus service and because of the real-time information	Use of public transport per non-commuting journey	Questionnaire / travel diary	X		X	X
			1.2.1.5	There is an increase/decrease in the use of car for other journeys than commuting because...	Use of car per non-commuting journey	Questionnaire / travel diary / key on and vehicle movement GPS, GPS logging		X	X	X
	1.2.2	Is there a change in	1.2.2.1	There is an increase in multimodal travel	Use of public	Questionnaire			X	X

RQ level 1	RQ level 2		RQ level 3		Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
			multimodal travel? (n)		because of the flexible bus service and because of the real-time information	transport / car / bicycle per journey					
	1.3 Length/ duration	1.3.1	Are durations of comparable/repeated journeys affected?	1.3.1.1	Journeys times of daily commuting or regular journeys decrease because of the flexible bus service and because of the real-time information	Travel time per distance, commuting or regular journeys	Journey time in hours/minutes	X	X		X
	1.4 Time budget/ timing	1.4.1	Is there a change in time allocated to travel? (n)	1.4.1.1	Time allocated to travel decreases because of the flexible bus service and because of the real-time information	Time allocated to travel per journey	Questionnaire / travel diary / key on and vehicle movement GPS, GPS logging		X		X
		1.4.2	Is there a change in starting time of journey? (n)	1.4.2.1	Starting time of commuting is shifted earlier/later because of the flexible bus service and because of the real-time	Starting time of commuting journey	Questionnaire / travel diary / key on and vehicle movement GPS, GPS logging	X	X	X	X

RQ level 1	RQ level 2	RQ level 3			Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
					information						
				1.4.2.2	Starting time of journeys other than commuting is shifted earlier/later because of the flexible bus service and because of the real-time information	Starting time of non-commutin g journey	Questionnaire / travel diary / key on and vehicle movement GPS, GPS logging	X	X	X	X
	1.5 Route	1.5.1	Is there a change in route choice? (n)	1.5.1.1	Route used for commuting changes because of the flexible bus service and because of the real-time information	Route	Map matching, tracks on digital map / questionnaire		X	X	X
				1.5.1.2	Route used for other frequently used routes than commuting changes because of the flexible bus service and because of the real-time information	Route	Map matching, tracks on digital map / questionnaire		X	X	X
2 Intention to use	2.2 Use patterns	2.2.1	In which								

RQ level 1	RQ level 2	RQ level 3			Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
			circumstances does the driver intend to use the system?								
4 Driving behaviour	4.2 Position	4.2.1	Is proximity to other vehicles affected?								
6 User acceptance	6.1 User experience	6.1.1	Does the function improve the comfort?	6.1.1.1	Comfort increases because of the flexible bus service and because of the real-time information		questionnaire				X
		6.1.2		6.1.2.1	Uncertainty decreases because of the flexible bus service and because of the real-time information		questionnaire				X
		6.1.3		6.1.3.1	Feeling of safety improves because of the flexible bus service and because of the real-time information'		questionnaire				X

RQ level 1	RQ level 2		RQ level 3		Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
		6.1.4	Does the function reduce the stress of the driver?								
7	7.3 Fuel consumption / Emissions	7.3.1	Is fuel consumption affected?	7.3.1.1	Fuel consumption decreases in transport system level because of the flexible bus service and because of the real-time information - both increasing the usage of bus	Fuel consumpti on / 100 km	Fuel consumption litres / 100 km			**X**	
		7.3.2	Pollutant emissions (NOx, PM, HC) increase/decrea se because...	7.3.2.1	The emissions in transport system level decrease because of the flexible bus service and because of the real-time information - both increasing the usage of bus	TBD				**X**	

Table 7.28: Impact Research Questions and Success Criteria for DC.

RQ level 1	RQ level 2	RQ level 3		Hypotheses		Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
1 Travel behaviour	1.2 Travel mode	1.2.1	Is there a change in mode of travel? (n)	1.2.1.1	There is an increase in the use of public transport for commuting because travel times by public transport may improve due to new dynamic corridors	Use of public transport per commuting journey	Questionnaire / travel diary	X		X	X
				1.2.1.2	There is an decrease in the use of car for commuting because travel times by public transport may improve due to new dynamic corridors	Use of car per commuting journey	Questionnaire / travel diary / key on and vehicle movement GPS, GPS logging		X	X	X
				1.2.1.4	There is an increase in the use of public transport for other journeys than commuting because travel times by public transport may improve due to new dynamic	Use of public transport per non-commuting journey	Questionnaire / travel diary	X		X	X

RQ level 1	RQ level 2		RQ level 3		Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
					corridors						
				1.2.1.5	There is an decrease in the use of car for other journeys than commuting because travel times by public transport may improve due to new dynamic corridors	Use of car per non-commuting journey	Questionnaire / travel diary / key on and vehicle movement GPS, GPS logging		X	X	X
	1.3 Length/ duration	1.3.1	Are durations of comparable/repeated journeys affected?	1.3.1.1	Journeys times of daily commuting or regular journeys decrease because travel times by public transport may improve due to new dynamic corridors	Travel time per distance, commuting or regular journeys	Journey time in hours/minutes	X	X		X
	1.4 Time budget/ timing	1.4.1	Is there a change in time allocated to travel? (n)	1.4.1.1	Time allocated to travel decreases because travel times by public transport may improve due to new dynamic corridors	Time allocated to travel per journey	Questionnaire / travel diary / key on and vehicle movement GPS, GPS logging		X		X
		1.4.2	Is there a change in	1.4.2.1	Starting time of commuting is shifted	Starting time of commuting	Questionnaire / travel diary / key	X	X	X	X

RQ level 1	RQ level 2		RQ level 3		Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
			starting time of journey? (n)		earlier/later because travel times by public transport may improve due to new dynamic corridors	journey	on and vehicle movement GPS, GPS logging				
				1.4.2.2	Starting time of journeys other than commuting is shifted earlier/later because travel times by public transport may improve due to new dynamic corridors	Starting time of non-commuting journey	Questionnaire / travel diary / key on and vehicle movement GPS, GPS logging	X	X	X	X
	1.5 Route	1.5.1	Is there a change in route choice? (n)	1.5.1.1	Route used for commuting changes because travel times by public transport may improve due to new dynamic corridors - hence route is changed to utilize these corridors	Route	Map matching, tracks on digital map / questionnaire		X	X	X
				1.5.1.2	Route used for other frequently used routes	Route	Map matching, tracks on digital		X	X	X

RQ level 1	RQ level 2		RQ level 3		Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
					than commuting changes because travel times by public transport may improve due to new dynamic corridors - hence route is changed to utilize these corridors		map / questionnaire				
4 Driving behaviour	4.1 Speed	4.1.1	Is speed affected?	4.1.1.1	There is an increase in mean speed for prioritized vehicles because of the dynamic (priority) corridors	Mean speed of the vehicle	Speed in km/h, 1 Hz	X	X		
				4.1.1.2	There is an decrease in standard deviation of speed because of the dynamic (priority) corridors	Standard deviation of vehicle speed	Speed in km/h, 1 Hz	X	X		
				4.1.1.5	There is an increase/decrease in the 85th percentile speed because...	85th %ile speed	Speed in km/h, 1 Hz		X		

RQ level 1	RQ level 2		RQ level 3		Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
				4.1.1.6	There is an increase/decrease in median speed because...	Median speed	Speed in km/h, 1 Hz	X	X		
				4.1.1.8	There is a change in the vehicle speed patterns which affects emissions and fuel consumption because traffic flow is smoother on the dynamic corridors/lanes than on the other (congested) lanes	Registered speed patterns in relevant areas	Speed in km/h, 1 Hz	X	X	X	
		4.2.2	Is number of lane changes affected?	4.2.2.1	There is an decrease in the number of lane changes because heavy vehicles tend to stay in the dedicated priority lanes	Number of lane changes / 10 km	current lane	X	X		
		4.2.3	Is lateral positioning affected?								

RQ level 1	RQ level 2		RQ level 3		Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
	4.4 Workload	4.4.2	Is fatigue affected?	4.4.2.1	There is an decrease in fatigue because driving in the dedicated lanes is smoother	eye movements/questionnaire	video	X			
5 Focus of attention	5.1 Focus on road	5.1.1.	Is the duration 'eyes off road' affected?								
6 User acceptance	6.1 User experience	6.1.1	Does the function improve the comfort?	6.1.1.1	Comfort increases because driving in the dedicated lanes is smoother		questionnaire				X
		6.1.2		6.1.2.1	Uncertainty decreases because driving in the dedicated lanes is smoother		questionnaire				X
		6.1.3		6.1.3.1	Feeling of safety improves because driving in the dedicated lanes is smoother		questionnaire				X

RQ level 1	RQ level 2		RQ level 3		Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
		6.1.4	Does the function reduce the stress of the driver?	6.1.4.1	Stress decreases because driving in the dedicated lanes is smoother		questionnaire	**X**			
7	7.1 Steering wheel	7.1.1	Is there change in the steering wheel frequency?	7.1.1.1	Steering wheel frequency decreases because lane changes decrease and because driving in the dedicated lanes is smoother	Steering wheel frequency		**X**			
		7.1.2	Is there change in steering wheel amplitude?	7.1.2.1	Steering wheel amplitude decreases because lane changes decrease and because driving in the dedicated lanes is smoother	Steering wheel amplitude		**X**			
	7.2 Pedals	7.2.1	Is there change in the accelerator pedal frequency?								

RQ level 1	RQ level 2	RQ level 3	Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
		7.2.5 Is there change in the clutch frequency?	7.2.5.1 Clutch frequency decreases because driving in the dedicated lanes is smoother	Clutch frequency				X	
	7.3 Fuel consumption / Emissions	7.3.1 Is fuel consumption affected?	7.3.1.1 Fuel consumption decreases because driving in the dedicated lanes is smoother	Fuel consumption / 100 km	Fuel consumption litres / 100 km			X	
		7.3.2 Pollutant emissions (NOx, PM, HC) increase/decrease because...	7.3.2.1 The emissions decreases because driving in the dedicated lanes is smoother	TBD				X	

Table 7.29: Impact Research Questions and Success Criteria for C-ACC.

RQ level 1	RQ level 2	RQ level 3		Hypotheses		Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
1 Travel behaviour	1.1 Number of journeys	1.1.1	Is the number of journeys undertaken affected? (n)	1.1.1.1	Number of journeys undertaken increases in total because driving with C-ACC is smoother/easier	Total number of journeys / day	Questionnaire / travel diary / key on and vehicle movement GPS, GPS logging	X	X	X	X
	1.3 Length/ duration	1.3.1	Are durations of comparable/r epeated journeys affected?	1.3.1.1	Journeys times of daily commuting or regular journeys increase/decrease because of different route/start time choices due to existence of C-ACC	Travel time per distance, commuting or regular journeys	Journey time in hours/minutes (log file) OR travel diaries	X	X		X
		1.3.2	Are lengths of comparable/r epeated journeys affected?	1.3.1.2	Lengths of journeys (daily commute/regular journeys) increase/decrease because of different route choice due to existence of C-ACC	Journey length in distance, commuting or regular journeys	Journey length in km/metres (log file) OR travel diaries	X	X	X	X

RQ level 1	RQ level 2	RQ level 3		Hypotheses		Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
	1.4 Time budget/ timing	1.4.1	Is there a change in time allocated to travel? (n)	1.4.1.1	Time allocated to travel increases/decreases because of different route/start time choice due to existence of C-ACC	Time allocated to travel per journey	Questionnaire / travel diary / key on and vehicle movement GPS, GPS logging		X		X
		1.4.2	Is there a change in starting time of journey? (n)	1.4.2.1	Starting time of commuting is shifted earlier/later because driver wants to be able to utilize C-ACC when driving	Starting time of commuting journey	Questionnaire / travel diary / key on and vehicle movement GPS, GPS logging	X	X	X	X
				1.4.2.2	Starting time of journeys other than commuting is shifted earlier/later because driver wants to be able to utilize C-ACC when driving	Starting time of non-commuting journey	Questionnaire / travel diary / key on and vehicle movement GPS, GPS logging	X	X	X	X
	1.5 Route	1.5.1	Is there a change in route choice? (n)	1.5.1.1	Route used for commuting changes because driver wants to be able to utilize	Route	Map matching, tracks on digital map / questionnaire		X	X	X

RQ level 1	RQ level 2	RQ level 3		Hypotheses		Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
					C-ACC when driving						
				1.5.1.2	Route used for other frequently used routes than commuting changes because driver wants to be able to utilize C-ACC when driving	Route	Map matching, tracks on digital map / questionnaire		X	X	X
		1.5.2	Is the travel on different road types affected? (n)	1.5.2.1	There is an increase/decrease in motorway travel because driver wants to be able to utilize C-ACC when driving	Shares of km per road type	Map matching, tracks on digital map / questionnaire or travel diary (including map)	X	X	X	X
4 Driving behaviour	4.1 Speed	4.1.1	Is speed affected?	4.1.1.1	There is an increase in mean speed because traffic flow is smoother with C-ACC	Mean speed of the vehicle	Speed in km/h, 1 Hz (log file)	X	X		
				4.1.1.2	There is an decrease in standard deviation of speed because traffic flow is smoother with C-ACC	Standard deviation of vehicle speed	Speed in km/h, 1 Hz (log file)	X	X		

RQ level 1	RQ level 2	RQ level 3	Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
		4.1.1.3	There is an increase/decrease in maximum speed because traffic flow is smoother with C-ACC	Maximum speed recorded over event/scenario	Speed in km/h, 1 Hz (log file)	X	X		
		4.1.1.6	There is an increase in median speed because traffic flow is smoother with C-ACC	Median speed	Speed in km/h, 1 Hz (log file)	X	X		
		4.1.1.8	There is a change in the vehicle speed patterns which affects emissions and fuel consumption because traffic flow is smoother with C-ACC	Registered speed patterns in relevant areas	Speed in km/h, 1 Hz (log file)	X	X	X	
	4.1.2 Is acceleration affected?	4.1.2.1	There is an decrease in peak level of longitudinal or lateral acceleration achieved during a scenario because driving is smoother with C-ACC	maximum longitudinal and lateral acceleration	Longitudinal and lateral acceleration		X	X	

RQ level 1	RQ level 2		RQ level 3		Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
	4.1.3	Is very sudden / heavy acceleration affected?	4.1.3.1		There is an decrease in peak level of change of longitudinal or lateral acceleration because driving is smoother with C-ACC	Maximum change of longitudinal and lateral accelerations above 3 m/s2, m/s^3	Change of longitudinal and lateral acceleration, 1 Hz	X	X	X	
			4.1.4.2		There is an decrease in the number of times the speed limit was exceeded (count transitions from below speed limit to above speed limit) due to use of C-ACC	number of speed violations / 100 km	Speed in km/h, 1 Hz, map matching (log file)	X			
	4.1.5	Is braking affected?	4.1.5.1		There is an decrease in max brake force because traffic flow and hence driving is smoother with C-ACC	Maximum brake force	Brake force (log file)	X	X		
			4.1.5.2		There is an decrease in the number of times the brake force exceeds X per time or	the number of times the brake force exceeds X per time or	Brake force		X		

RQ level 1	RQ level 2		RQ level 3		Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
					distance or another appropriate variable because traffic flow and driving is smoother with C-ACC	distance or another appropriate variable					
	4.2 Position	4.2.1	Is proximity to other vehicles affected?	4.2.1.1	There is an decrease in the mean headway because of use of C-ACC	Time headway	Time headway		X		
				4.2.1.2	There is an decrease in the standard deviation of headway because of C-ACC	Standard deviation of headway	Time headway		X		
				4.2.1.3	There is an increase/decrease in the proportion of time headway local minima less than 1 s because of C-ACC (this is of course depending on the allowed minimum headway selection for C-ACC)	Proportion of time headway is less than 1s	Time headway		X		

RQ level 1	RQ level 2		RQ level 3		Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
				4.2.1.4	There is an increase/decrease in the probability of time headway less than 1 s during following because...(depending on the allowed minimum headway for C-ACC)	Proportion of time headway is less than 1s of the time headway is under 10 s	Time headway	X	X		
				4.2.1.5	There is an increase in the mean time-to-collision because C-ACC makes the traffic flow and driving smoother	Mean time-to-collision	Time-to-collision	X	X		
				4.2.1.6	There is an decrease in the proportion time-to-collision is less than 4 s because C-ACC makes traffic flow and driving smoother	Proportion of time time-to-collision is less than 4 s	Time-to-collision	X	X		
		4.2.2	Is number of	4.2.2.1	There is an decrease	Number of lane	current lane	X	X		

RQ level 1	RQ level 2		RQ level 3		Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
			lane changes affected?		in the number of lane changes because C-ACC makes traffic	changes / 10 km					
	4.4 Workload	4.4.1	Is workload affected?	4.4.1.1	There is an decrease in workload because C-ACC makes traffic flow and hence driving smoother	questionnaire/ Peripheral Detection Task (PDT) / SRR	Steering reversal rate	X			
		4.4.2	Is fatigue affected?	4.4.2.1	There is an decrease in fatigue because C-ACC makes driving smoother	eye movements/questionnaire	video	X			
5 Focus of attention	5.1 Focus on road	5.1.1.	Is the duration 'eyes off road' affected?	5.1.1.1	There is an increase in the duration 'eyes off road' because C-ACC makes driving smoother by taking care of the longitudinal control (and may give the driver impression, that he/she can pay less attention to the traffic ahead)	eye movements	video	X			

RQ level 1	RQ level 2	RQ level 3		Hypotheses		Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
		5.1.2	Is frequency 'eyes off road' affected?	5.1.2.1	There is an increase in the frequency of 'eyes off road' because C-ACC makes driving smoother by taking care of the longitudinal control (and may give the driver impression, that he/she can pay less attention to the traffic ahead)	eye movements	video	X			
	5.2 Focus on other road users	5.2.1	Is focus of attention to pedestrians and cyclists affected?	5.2.1.1	There is an increase in the focus of attention to pedestrians and cyclists because due to C-ACC driver does not need to pay as much attention to the cars ahead as without C-ACC	eye movements towards vulnerable road users	video	X			
		5.2.2	Is focus of attention to	5.2.2.1	There is an decrease in the focus of	eye movements towards other	video				

RQ level 1	RQ level 2		RQ level 3		Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
			other vehicles affected?		attention to other vehicles because C-ACC takes care of the headway to the car in front	vehicles					
		5.2.3	Is relevant information missed (road signs)?	5.2.3.1	There is an increase in number of times a road sign is missed because C-ACC may increase the eyes off the road time	questionnaire / video	video	X			
	5.3 Focus on device	5.3.1	Is the driver distracted by the system?	5.3.1.1	There is an increase/decrease in number of fixations because C-ACC may increase eyes off the road time	number of fixations	video	X			
				5.3.1.2	There is an increase in duration of fixations because C-ACC may increase eyes off the road time	duration of fixations	video	X			
6 User	6.1 User	6.1.1	Does the	6.1.1.1	Comfort increases		questionnaire				X

RQ level 1	RQ level 2		RQ level 3		Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
acceptance	experience		function improve the comfort?		because C-ACC makes traffic flow and driving smoother by taking care of the headway to the car(s) in front						
		6.1.2		6.1.2.1	Uncertainty decreases because C-ACC makes driving smoother by utilizing the information of the traffic situation in front		questionnaire				X
		6.1.3		6.1.3.1	Feeling of safety improves because C-ACC controls the headway and makes the driving smoother		questionnaire				X
		6.1.4	Does the function reduce the stress of the driver?	6.1.4.1	Stress decreases because C-ACC makes traffic flow and driving smoother		questionnaire	X			
		7.2.5	Is there	7.2.5.1	Clutch frequency	Clutch				X	

RQ level 1	RQ level 2		RQ level 3		Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
			change in the clutch frequency?		decreases because driving with C-ACC is smoother	frequency					
	7.3 Fuel consumption / Emissions	7.3.1	Is fuel consumption affected?	7.3.1.1	Fuel consumption decreases because driving with C-ACC is smoother	Fuel consumption / 100 km	Fuel consumption litres / 100 km			X	
		7.3.2	Pollutant emissions (NOx, PM, HC) increase/decrease because...	7.3.2.1	The emissions decrease because driving with C-ACC is smoother	emissions per 100 km	emissions AND CO2 correlates with fuel consumption, too			X	

Table 7.30: Impact Research Questions and Success Criteria for EFP.

RQ level 1	RQ level 2	RQ level 3	Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environmen	Relevant for Mobility
1 Travel behaviour	1.2 Travel mode	1.2.1 Is there a change in mode of travel? (n)	1.2.1.1 There is an decrease in the use of public transport for commuting because assured parking in destination makes it easier for one to drive there by car (exception: if supports multimodal travel, then could increase use of public transport for a certain part of the trip)	Use of public transport per commuting journey	Questionnaire / travel diary	X		X	X
			1.2.1.2 There is an increase in the use of car for commuting because assured parking in destination makes it easier for one to drive there by car (exception: if supports multimodal travel, then could increase use of public transport for a certain part of the trip)	Use of car per commuting journey	Questionnaire / travel diary / key on and vehicle movement GPS, GPS logging		X	X	X
			1.2.1.3 There is an decrease in the use of bicycle or walking for	Use of bicycle or	Questionnaire /			X	X

RQ level 1	RQ level 2	RQ level 3		Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environmen	Relevant for Mobility
				commuting because assured parking in destination makes it easier for one to drive there by car (exception: if supports multimodal travel, then could increase use of non-motorized modes for a certain part of the trip)	walking per commuting journey	travel diary				
			1.2.1.4	There is an decrease in the use of public transport for other journeys than commuting because assured parking in destination makes it easier for one to drive there by car (exception: if supports multimodal travel, then could increase use of public transport for a certain part of the trip)	Use of public transport per non-commuting journey	Questionnaire / travel diary	X		X	X
			1.2.1.5	There is an increase in the use of car for other journeys than commuting because assured parking in	Use of car per non-commuting journey	Questionnaire / travel diary / key on and vehicle		X	X	X

RQ level 1	RQ level 2		RQ level 3		Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environmen	Relevant for Mobility
					destination makes it easier for one to drive there by car (exception: if supports multimodal travel, then could increase use of public transport for a certain part of the trip)		movement GPS, GPS logging				
				1.2.1.6	There is an decrease in the use of bicycle or walking for other journeys than commuting because assured parking in destination makes it easier for one to drive there by car (exception: if supports multimodal travel, then could increase use of non-motorized modes for a certain part of the trip)	Use of bicycle or walking per non-commuting journey	Questionnaire / travel diary			X	X
		1.2.2	Is there a change in multimodal travel? (n)	1.2.2.1	There is an increase in multimodal travel because if the parking application supports multimodal travel. IF not, then application has the tendency to increase	Use of public transport / car / bicycle per journey	Questionnaire			X	X

RQ level 1	RQ level 2	RQ level 3			Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environmen	Relevant for Mobility
					the use of one's personal car due to assured parking in the destination						
	1.3 Length/ duration	1.3.1	Are durations of comparable/repeated journeys affected?	1.3.1.1	Journeys times of daily commuting or regular journeys decrease because one does not need to search for a parking slot in the destination	Travel time per distance, commuting or regular journeys	Journey time in hours/minutes	X	X		X
		1.3.2	Are lengths of comparable/repeated journeys affected?	1.3.1.2	Lengths of journeys (daily commute/regular journeys) decrease because one does not need to search for a parking lot in the destination	Journey length in distance, commuting or regular journeys	Journey length in km/metres	X	X	X	X
	1.4 Time budget/ timing	1.4.1	Is there a change in time allocated to travel? (n)	1.4.1.1	Time allocated to travel decreases because one does not need to reserve time to search for a parking lot in the destination	Time allocated to travel per journey	Questionnaire / travel diary / key on and vehicle movement GPS, GPS logging		X		X
		1.4.2	Is there a change in starting time	1.4.2.1	Starting time of commuting is shifted earlier/later because one does not need	Starting time of commuting	Questionnaire / travel diary / key on and	X	X	X	X

RQ level 1	RQ level 2	RQ level 3		Hypotheses		Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environmen	Relevant for Mobility
			of journey? (n)		to worry about the availability of a parking in the destination	journey	vehicle movement GPS, GPS logging				
				1.4.2.2	Starting time of journeys other than commuting is shifted earlier/later because one does not need to worry about the availability of a parking in the destination	Starting time of non-commuting journey	Questionnaire / travel diary / key on and vehicle movement GPS, GPS logging	X	X	X	X
6 User acceptance	6.1 User experience	6.1.1	Does the function improve the comfort?	6.1.1.1	Comfort increases because one does not need to worry about finding the parking in the destination		questionnaire				X
		6.1.2		6.1.2.1	Uncertainty decreases because one does not need to worry about finding the parking in the destination		questionnaire				X
		6.1.3		6.1.3.1	Feeling of safety improves because one does not need to worry about finding the parking in the destination		questionnaire				X
		6.1.4	Does the function	6.1.4.1	Stress decreases because one does not need to worry		questionnaire	X			

RQ level 1	RQ level 2	RQ level 3		Hypotheses		Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environmen	Relevant for Mobility
			reduce the stress of the driver?		about finding the parking in the destination						
	7.3 Fuel consumption / Emissions	7.3.1	Is fuel consumption affected?	7.3.1.1	Fuel consumption decreases because one does not need to drive around in search for a parking slot. Of course, IF the application increases the use of a personal car, then it (in total) increases fuel consumption!!!	Fuel consumptio n / 100 km	Fuel consumption litres / 100 km			X	
		7.3.2	Pollutant emissions (NOx, PM, HC) increase/decr ease because...	7.3.2.1	The emissions decreases because does not need to drive around in search for a parking slot. Of course, IF the application increases the use of a personal car, then it (in total) increases fuel consumption and hence emissions!!!	emissions per 100 km				X	

Table 7.31: Impact Research Questions and Success Criteria for CDM.

RQ level 1	RQ level 2	RQ level 3			Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
1 Travel behaviour	1.1 Number of journeys	1.1.1	Is the number of journeys undertaken affected? (n)	1.1.1.1	Number of journeys undertaken increases/decreases in total because driving with CDM is easier, and hence may get people to drive more that before even in adverse weather (bad visibility) conditions or in dense traffic	Total number of journeys / day	Questionnaire / travel diary / key on and vehicle movement GPS, GPS logging	X	X	X	X
	1.3 Length/ duration	1.3.1	Are durations of comparable/ repeated journeys affected?	1.3.1.1	Journeys times of daily commuting or regular journeys decrease because driving (and hence traffic flow) with CDM is smoother	Travel time per distance, commuting or regular journeys	Journey time in hours/minutes	X	X		X
		1.3.2	Are lengths of comparable/repeated journeys affected?	1.3.1.2	Lengths of journeys (daily commute/regular journeys) may increase because with CDM it is easier to merge/drive	Journey length in distance, commuting or regular journeys	Journey length in km/metres	X	X	X	X

RQ level 1	RQ level 2	RQ level 3			Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
					on the highways even in congestion, which may have impact on route choice (longer trips when using highways)						
	1.4 Time budget/ timing	1.4.1	Is there a change in time allocated to travel? (n)	1.4.1.1	Time allocated to travel decreases because driving and hence traffic flow is smoother with CDM	Time allocated to travel per journey	Questionnaire / travel diary / key on and vehicle movement GPS, GPS logging		X		X
		1.4.2	Is there a change in starting time of journey? (n)	1.4.2.1	Starting time of commuting is shifted earlier/later because driving with CDM is smoother, and it is easier to e.g. merge to the highways even in congestion	Starting time of commuting journey	Questionnaire / travel diary / key on and vehicle movement GPS, GPS logging	X	X	X	X
				1.4.2.2	Starting time of journeys other than commuting is shifted earlier/later because driving with CDM is	Starting time of non-commuting journey	Questionnaire / travel diary / key on and vehicle movement GPS, GPS logging	X	X	X	X

RQ level 1	RQ level 2	RQ level 3		Hypotheses		Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
					smoother, and it is easier to e.g. merge to the highways even in congestion						
	1.5 Route	1.5.1	Is there a change in route choice? (n)	1.5.1.1	Route used for commuting changes because CDM is smoother, and it is easier to e.g. merge to the highways even in congestion	Route	Map matching, tracks on digital map / questionnaire		X	X	X
				1.5.1.2	Route used for other frequently used routes than commuting changes because CDM is smoother, and it is easier to e.g. merge to the highways even in congestion	Route	Map matching, tracks on digital map / questionnaire		X	X	X
		1.5.2	Is the travel on different road types affected? (n)	1.5.2.1	There is an increase in motorway travel because CDM makes driving (merging etc) easier, even in	Shares of km per road type	Map matching, tracks on digital map / questionnaire	X	X	X	X

RQ level 1	RQ level 2	RQ level 3		Hypotheses		Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
					congestion						
4 Driving behaviour	4.1 Speed	4.1.1	Is speed affected?	4.1.1.1	There is an increase in mean speed because driving and traffic flow are smoother due to CDM	Mean speed of the vehicle	Speed in km/h, 1 Hz	**X**	**X**		
				4.1.1.2	There is an decrease in standard deviation of speed because CDM smoothens the traffic flow	Standard deviation of vehicle speed	Speed in km/h, 1 Hz	**X**	**X**		
				4.1.1.4	There is an increase in minimum speed because CDM makes driving and traffic flow smoother	Min speed recorded over event/scenario	Speed in km/h, 1 Hz		**X**		
				4.1.1.6	There is an increase in median speed because CDM makes driving and traffic flow smoother	Median speed	Speed in km/h, 1 Hz	**X**	**X**		

RQ level 1	RQ level 2		RQ level 3		Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
				4.1.1.7	There is an increase in spot speed because traffic flow and hence driving is smoother with CDM	Measured speed in a certain spot (defined location)	Speed in km/h, 1 Hz	X	X	X	
				4.1.1.8	There is a change in the vehicle speed patterns which affects emissions and fuel consumption because CDM makes driving smoother, i.e. less abrupt braking and accelerations	Registered speed patterns in relevant areas	Speed in km/h, 1 Hz	X	X	X	
		4.1.2	Is acceleration affected?	4.1.2.1	There is an decrease in peak level of longitudinal or lateral acceleration achieved during a scenario because CDM makes traffic flow and driving smoother	maximum longitudinal and lateral acceleration	Longitudinal and lateral acceleration		X	X	

RQ level 1	RQ level 2	RQ level 3	Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
		4.1.3 Is very sudden / heavy acceleration affected?	4.1.3.1 There is an decrease in peak level of change of longitudinal or lateral acceleration because CDM makes traffic flow and driving smoother	Maximum change of longitudinal and lateral accelerations above 3 m/s2, m/s^3	Change of longitudinal and lateral acceleration, 1 Hz	X	X	X	
		4.1.5 Is braking affected?	4.1.5.1 There is an decrease in max brake force because CDM makes traffic flow and hence driving smoother	Maximum brake force	Brake force	X	X		
			4.1.5.2 There is an decrease in the number of times the brake force exceeds X per time or distance or another appropriate variable because CDM makes traffic flow and hence driving smoother	the number of times the brake force exceeds X per time or distance or another appropriate variable	Brake force		X		

RQ level 1	RQ level 2	RQ level 3		Hypotheses		Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
		4.2.2	Is number of lane changes affected?	4.2.2.1	There may be either increase/decrease in the number of lane changes because it is easier to change lanes due to CDM (increasing the lane changes) but on the other hand: CDM makes traffic flow and driving smoother, and one may not need to change lanes that often (decreasing lane changes)	Number of lane changes / 10 km	current lane	X	X		
	4.3 Interaction with other road users	4.3.1	Is giving way for pedestrians and cyclists affected?	4.3.1.1	There is an increase in the number of occasions when the driver gives way for pedestrian per number when he could have given because CDM helps the interaction with other vehicles and hence driver can	Number of times when way is given for pedestrian, number of time pedestrian interacts with vehicle	Time To Collision (TTC) or Post Encroachment Time (PET) with vulnerable road users, speed of vehicle	X			

RQ level 1	RQ level 2		RQ level 3		Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
					concentrate more into the interaction with VRUs						
				4.3.1.2	There is an increase/decrease in the number of occasions when the driver gives way for cyclist per number when he could have given because CDM helps the interaction with other vehicles and hence driver can concentrate more into the interaction with VRUs	Number of times when way is given for cyclist, number of time cyclist interacts with vehicle	Time To Collision (TTC) or Post Encroachment Time (PET) with vulnerable road users, speed of vehicle	**X**			
	4.4 Workload	4.4.1	Is workload affected?	4.4.1.1	There is an decrease in workload because CDM makes driving and traffic flow smoother and makes it easier to interact with other vehicles in stressful situations	subjective workload	NASA TLX-workload questionnaire	**X**			

RQ level 1	RQ level 2	RQ level 3			Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
					such as merging						
		4.4.2	Is fatigue affected?	4.4.2.1	There is an decrease in fatigue because driving with CDM is easier	eye movements/questionnaire	video OR questionnaire	X			
	5.2 Focus on other road users	5.2.1	Is focus of attention to pedestrians and cyclists affected?	5.2.1.1	There is an increase in the focus of attention to pedestrians and cyclists because driver needs to pay less attention to the other vehicles when driving with CDM	eye movements towards vulnerable road users	video	X			
6 User acceptance	6.1 User experience	6.1.1	Does the function improve the comfort?	6.1.1.1	Comfort increases because CDM helps driver to interact with the other vehicles, especially in stressful situations such as merging		questionnaire				X
		6.1.2		6.1.2.1	Uncertainty decreases because driver knows		questionnaire				X

RQ level 1	RQ level 2		RQ level 3		Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
					that CDM helps him/her in the complicated interaction situations such as merging						
		6.1.3		6.1.3.1	Feeling of safety improves because CDM helps the driver to interact with the other vehicles in complicated situations such as merging		questionnaire				X
		6.1.4	Does the function reduce the stress of the driver?	6.1.4.1	Stress decreases because CDM helps the driver to interact with the other vehicles in complicated situations such as merging		questionnaire	X			
7	7.1 Steering wheel	7.1.1	Is there change in the steering wheel frequency?	7.1.1.1	Steering wheel frequency decreases because complicated situations, such as merging are easier	Steering wheel frequency		X			

RQ level 1	RQ level 2	RQ level 3	Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
			with help of CDM						
		7.1.2 Is there change in steering wheel amplitude?	7.1.2.1 Steering wheel amplitude decreases because complicated situations, such as merging are easier with help of CDM	Steering wheel amplitude		X			
		7.2.5 Is there change in the clutch frequency?	7.2.5.1 Clutch frequency decreases because traffic flow and hence driving is smoother with CDM	Clutch frequency				X	
	7.3 Fuel consumption Emissions	7.3.1 Is fuel consumption affected?	7.3.1.1 Fuel consumption decreases because traffic flow and hence driving is smoother with CDM	Fuel consumption / 100 km	Fuel consumption litres / 100 km			X	
		7.3.2 Pollutant emissions (NOx, PM, HC) increase/decrease because...	7.3.2.1 The emissions decreases because traffic flow and hence driving is smoother with CDM	emissions per 100 km (also related to fuel consumption)	emissions per 100 km			X	

Table 7.32: Impact Research Questions and Success Criteria for SG-CM.

RQ level 1	RQ level 2	RQ level 3		Hypotheses		Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
1 Travel behaviour	1.1 Number of journeys	1.1.1	Is the number of journeys undertaken affected? (n)	1.1.1.1	Number of journeys undertaken decreases in total because SG-CM promotes green travelling. IF the gaming takes into account total driven mileage, too, it is possible, that the driver decides to drive less if rewarded for that.	Total number of journeys / day	Questionnaire / travel diary / key on and vehicle movement GPS, GPS logging	X	X	X	X
				1.1.1.3	Number of other journeys than commuting decreases because green travelling. IF the gaming takes into account total driven mileage, too, it is possible, that the driver decides to drive less if rewarded for that.	Number of journeys other than commuting / day	Questionnaire / travel diary / key on and vehicle movement GPS, GPS logging		X	X	X
	1.2 Travel mode	1.2.1	Is there a change in mode of	1.2.1.1	There is an increase in the use of public transport for commuting IF the rewarding system takes	Use of public transport per commuting	Questionnaire / travel diary	X		X	X

RQ level 1	RQ level 2	RQ level 3		Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
		travel? (n)		into account the green travelling, not only driving behaviour!	journey					
			1.2.1.2	There is an decrease in the use of car for commuting IF the application rewarding system takes into account green travelling behaviour in total, not only green driving behaviour	Use of car per commuting journey	Questionnaire / travel diary / key on and vehicle movement GPS, GPS logging		X	X	X
			1.2.1.3	There is an increase in the use of bicycle or walking for commuting IF the application rewarding system takes into account green travelling in total, not only green driving behaviour	Use of bicycle or walking per commuting journey	Questionnaire / travel diary			X	X
			1.2.1.4	There is an increase in the use of public transport for other journeys than commuting IF the application rewarding	Use of public transport per non-commuting journey	Questionnaire / travel diary	X		X	X

RQ level 1	RQ level 2		RQ level 3		Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
					system takes into account green travelling in total, not only green driving behaviour						
				1.2.1.5	There is an decrease in the use of car for other journeys than commuting IF the application rewarding system takes into account green travelling in total, not only green driving behaviour	Use of car per non-commuting journey	Questionnaire / travel diary / key on and vehicle movement GPS, GPS logging		X	X	X
				1.2.1.6	There is an increase in the use of bicycle or walking for other journeys than commuting because IF the application rewarding system takes into account green travelling in total, not only green driving behaviour	Use of bicycle or walking per non-commuting journey	Questionnaire / travel diary			X	X
	1.2.2	Is there a change in multimodal		1.2.2.1	There is an increase in multimodal travel IF the application rewarding	Use of public transport / car / bicycle	Questionnaire			X	X

RQ level 1	RQ level 2		RQ level 3		Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
			travel? (n)		system takes into account green travelling in total, not only green driving behaviour	per journey					
	1.3 Length/ duration	1.3.1	Are durations of comparable/repeated journeys affected?	1.3.1.1	Journeys times of daily commuting or regular journeys decrease because gamin application encourages driver to drive outside most congested times	Travel time per distance, commuting or regular journeys	Journey time in hours/minutes	X	X		X
		1.3.2	Are lengths of comparable/repeated journeys affected?	1.3.1.2	Lengths of journeys (daily commute/regular journeys) increase because the application encourages driver to avoid most congested routes	Journey length in distance, commuting or regular journeys	Journey length in km/metres	X	X	X	X
		1.4.2	Is there a change in starting time of journey? (n)	1.4.2.1	Starting time of commuting is shifted earlier/later because gamin application encourages the driver to avoid most congested	Starting time of commuting journey	Questionnaire / travel diary / key on and vehicle movement GPS, GPS	X	X	X	X

RQ level 1	RQ level 2		RQ level 3		Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
					times		logging				
				1.4.2.2	Starting time of journeys other than commuting is shifted earlier/later because gaming application encourages drivers to avoid most congested times	Starting time of non-commuting journey	Questionnaire / travel diary / key on and vehicle movement GPS, GPS logging	X	X	X	X
	1.5 Route	1.5.1	Is there a change in route choice? (n)	1.5.1.1	Route used for commuting changes because gaming application encourages driver to avoid most congested routes	Route	Map matching, tracks on digital map / questionnaire		X	X	X
				1.5.1.2	Route used for other frequently used routes than commuting changes because gaming application encourages driver to avoid most congested routes	Route	Map matching, tracks on digital map / questionnaire		X	X	X
		1.5.2	Is the travel on different road types affected?	1.5.2.1	There is an increase/decrease in motorway travel because	Shares of km per road type	Map matching, tracks on digital map /	X	X	X	X

RQ level 1	RQ level 2	RQ level 3		Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
		(n)		gaming application encourages driver to avoid most congested routes, and to choose safest roads (the impact can be to either direction)		questionnaire				
			1.5.2.2	There is an increase/decrease in rural road travel because gaming application encourages driver to avoid most congested routes, and to choose safest roads (the impact can be to either direction)	Shares of km per road type	Map matching, tracks on digital map / questionnaire		X	X	X
			1.5.2.3	There is an decrease in urban road travel because gaming application encourages driver to avoid most congested routes, and to choose safest roads	Shares of km per road type	Map matching, tracks on digital map / questionnaire	X	X	X	X
	1.5.3	Is travelling in residential	1.5.3.1	There is an decrease in travelling in residential	Shares of km per road	Map matching, tracks on	X	X	X	X

RQ level 1	RQ level 2		RQ level 3		Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
			areas affected?		areas because gaming application encourages driver to avoid most congested routes, and to choose safest roads	environment (rural, urban, residential area)	digital map / questionnaire				
4 Driving behaviour	4.1 Speed	4.1.1	Is speed affected?	4.1.1.1	There is an increase/decrease in mean speed because on one hand driver tries to avoid congestion (mean speed can increase). On the other hand, he/she may also drive little slower to use less gas	Mean speed of the vehicle	Speed in km/h, 1 Hz	X	X		
				4.1.1.2	There is an decrease in standard deviation of speed because gaming application encourages driver to drive ecologically, i.e. to avoid unnecessary accelerations/deceleration s	Standard deviation of vehicle speed	Speed in km/h, 1 Hz	X	X		
				4.1.1.3	There is an decrease in	Maximum	Speed in km/h,	X	X		

RQ level 1	RQ level 2		RQ level 3		Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
					maximum speed because gaming application encourages driver to drive ecologically and safely	speed recorded over event/scenario	1 Hz				
				4.1.1.7	There is an increase/decrease in spot speed because application encourages the driver to drive safely and ecologically	Measured speed in a certain spot (defined location)	Speed in km/h, 1 Hz	x	x	x	
				4.1.1.8	There is a change in the vehicle speed patterns which affects emissions and fuel consumption because gaming application encourages into green driving	Registered speed patterns in relevant areas	Speed in km/h, 1 Hz	X	X	X	
		4.1.2	Is acceleration affected?	4.1.2.1	There is an decrease in peak level of longitudinal or lateral acceleration achieved during a scenario because gaming application encourages	maximum longitudinal and lateral acceleration	Longitudinal and lateral acceleration		X	X	

RQ level 1	RQ level 2	RQ level 3			Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
					into safe and green driving						
		4.1.3	Is very sudden / heavy acceleration affected?	4.1.3.1	There is an decrease in peak level of change of longitudinal or lateral acceleration because gaming application encourages the driver into green and safe driving	Maximum change of longitudinal and lateral accelerations above 3 m/s2, m/s^3	Change of longitudinal and lateral acceleration, 1 Hz	X	X	X	
		4.1.4	Are speed violations affected?	4.1.4.1	There is an decrease in percentage speed limit violations because gaming application takes the speed into account when assessing the safety of driving	time and/or distance (or proportion of) spend exceeding posted speed limit	Speed in km/h, 1 Hz, map matching	X			
	4.4 Workload	4.4.1	Is workload affected?	4.4.1.1	There is an increase in workload because driver may pay attention to the system - and considering how to gain points when driving	questionnair e		X			
5 Focus of attention	5.1 Focus on road	5.1.1.	Is the duration 'eyes off road'	5.1.1.1	There is an increase in the duration 'eyes off road'	eye movements	video	X			

RQ level 1	RQ level 2		RQ level 3		Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
			affected?		because of the extra display in the car						
		5.1.2	Is frequency 'eyes off road' affected?	5.1.2.1	There is an increase in the frequency of 'eyes off road' because of the extra display in the car	eye movements	video	X			
	5.2 Focus on other road users	5.2.1	Is focus of attention to pedestrians and cyclists affected?	5.2.1.1	There is an decrease in the focus of attention to pedestrians and cyclists because of the extra display in the car	eye movements towards vulnerable road users	video	X			
		5.2.3	Is relevant information missed (road signs)?	5.2.3.1	There is an increase in number of times a road sign is missed because driver may pay more attention to the in-vehicle display	questionnaire / video	video	X			
	5.3 Focus on device	5.3.1	Is the driver distracted by the system?	5.3.1.1	There is an increase/decrease in number of fixations because...	number of fixations	video	X			
				5.3.1.2							
6 User	6.1 User	6.1.4	Does the	6.1.4.1	Stress increases if the		questionnaire	X			

RQ level 1	RQ level 2		RQ level 3		Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
acceptance	experience		function reduce the stress of the driver?		driver needs to consider how to gain more points when driving						
	7.3 Fuel consumption / Emissions	7.3.1	Is fuel consumption affected?	7.3.1.1	Fuel consumption decreases because the application promotes green driving behaviour	Fuel consumption / 100 km	Fuel consumption litres / 100 km			X	
		7.3.2	Pollutant emissions (NOx, PM, HC) increase/decrease because...	7.3.2.1	The emissions decreases because application promotes green driving behaviour	CO2/100km				X	

Table 7.33: Impact Research Questions and Success Criteria for CONAV.

RQ level 1	RQ level 2	RQ level 3		Hypotheses		Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
1 Travel behaviour	1.1 Number of journeys	1.1.1	Is the number of journeys undertaken affected? (n)	1.1.1.1				X	X	X	X
	1.2 Travel mode	1.2.1	Is there a change in mode of travel? (n)	1.2.1.2	There is an increase in the use of car for commuting because CONAV helps the driver to avoid driving in congestion	Use of car per commuting journey	Questionnaire / travel diary / key on and vehicle movement GPS, GPS logging	X	X	X	X
				1.2.1.4	There is an decrease in the use of public transport for other journeys than commuting because CONAV helps the driver to avoid congestion	Use of public transport per non-commuting journey	Questionnaire / travel diary	X		X	X
				1.2.1.5	There is an increase in the use of car for other journeys than commuting because	Use of car per non-commuting journey	Questionnaire / travel diary / key on and vehicle		X	X	X

RQ level 1	RQ level 2	RQ level 3			Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environmen t	Relevant for Mobility
					CONAV helps the driver to avoid congestion		movement GPS, GPS logging				
		1.2.2	Is there a change in multimodal travel? (n)	1.2.2.1	There is an decrease in multimodal travel because CONAV only helps the driver (does not include other modes)	Use of public transport / car / bicycle per journey	Questionnaire			X	X
	1.3 Length/ duration	1.3.1	Are durations of comparable/repea ted journeys affected?	1.3.1.1	Journeys times of daily commuting or regular journeys decrease because CONAV helps the driver to avoid congestion	Travel time per distance, commuting or regular journeys	Journey time in hours/minutes	X	X		X
		1.3.2	Are lengths of comparable/repea ted journeys affected?	1.3.1.2	Lengths of journeys (daily commute/regular journeys) increase because CONAV helps the driver to avoid most congested routes by	Journey length in distance, commuting or regular journeys	Journey length in km/metres	X	X	X	X

RQ level 1	RQ level 2	RQ level 3			Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
					guiding him/her into routes that are less congested (and may be longer in km)						
	1.4 Time budget/ timing	1.4.1	Is there a change in time allocated to travel? (n)	1.4.1.1	Time allocated to travel decreases because CONAV helps the driver to avoid congestion	Time allocated to travel per journey	Questionnaire / travel diary / key on and vehicle movement GPS, GPS logging		X		X
		1.4.2	Is there a change in starting time of journey? (n)	1.4.2.1				X	X	X	X
				1.4.2.2				X	X	X	X
	1.5 Route	1.5.1	Is there a change in route choice? (n)	1.5.1.1	Route used for commuting changes because CONAV guides the driver into less congested routes	Route	Map matching, tracks on digital map / questionnaire		X	X	X
				1.5.1.2	Route used for other frequently used routes than commuting changes because CONAV guides the driver into	Route	Map matching, tracks on digital map / questionnaire		X	X	X

RQ level 1	RQ level 2	RQ level 3		Hypotheses		Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
					less congested routes						
		1.5.2	Is the travel on different road types affected? (n)	1.5.2.1				X	X	X	X
				1.5.2.2					X	X	X
				1.5.2.3				X	X	X	X
		1.5.3	Is travelling in residential areas affected?	1.5.3.1				X	X	X	X
4 Driving behaviour	4.1 Speed	4.1.1	Is speed affected?	4.1.1.1	There is an increase in mean speed because the user of CONAV is able to avoid the congestion	Mean speed of the vehicle	Speed in km/h, 1 Hz	X	X		
				4.1.1.2	There is an decrease in standard deviation of speed because driving is smoother when CONAV guides the users to the less congested routes	Standard deviation of vehicle speed	Speed in km/h, 1 Hz	X	X		
				4.1.1.3				X	X		
				4.1.1.4					X		

RQ level 1	RQ level 2	RQ level 3	Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environmen t	Relevant for Mobility
			4.1.1.5				X		
			4.1.1.6			X	X		
			4.1.1.7						
			4.1.1.8 There is a change in the vehicle speed patterns which affects emissions and fuel consumption because CONAV helps to choose less congested routes and hence smoothens driving	Registered speed patterns in relevant areas	Speed in km/h, 1 Hz	X	X	X	
		4.1.2 Is acceleration affected?	4.1.2.1				X	X	
		4.1.3 Is very sudden / heavy acceleration affected?	4.1.3.1			X	X	X	
		4.1.4 Are speed violations affected?	4.1.4.1			X			
			4.1.4.2			X			

RQ level 1	RQ level 2	RQ level 3	Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
		4.1.5 Is braking affected?	4.1.5.1			X	X		
			4.1.5.2				X		
	4.2 Position	4.2.1 Is proximity to other vehicles affected?	4.2.1.1				X		
			4.2.1.2				X		
			4.2.1.3				X		
			4.2.1.4			X	X		
			4.2.1.5			X	X		
			4.2.1.6			X	X		
		4.2.2 Is number of lane changes affected?	4.2.2.1			X	X		
	4.3 Interaction with other road users	4.3.1 Is giving way for pedestrians and cyclists affected?	4.3.1.1			X			
			4.3.1.2			X			
		4.3.2 Is the use of emergency lights effected?	4.3.2.1			X			
		4.3.3 Is use of turn signals affected?	4.3.3.1			X			
	4.4 Workload	4.4.1 Is workload affected?	4.4.1.1 There is an decrease in workload because	questionna ire/	Steering reversal rate	X			

RQ level 1	RQ level 2	RQ level 3		Hypotheses		Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
					CONAV helps the driver to choose less congested routes	Peripheral Detection Task (PDT) / SRR					
		4.4.2	Is fatigue affected?	4.4.2.1				X			
5 Focus of attention	5.1 Focus on road	5.1.1.	Is the duration 'eyes off road' affected?	5.1.1.1				X			
		5.1.2	Is frequency 'eyes off road' affected?	5.1.2.1				X			
	5.2 Focus on other road users	5.2.1	Is focus of attention to pedestrians and cyclists affected?	5.2.1.1				X			
		5.2.2	Is focus of attention to other vehicles affected?	5.2.2.1							
		5.2.3	Is relevant information missed (road signs)?	5.2.3.1				X			

RQ level 1	RQ level 2	RQ level 3		Hypotheses		Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environmen t	Relevant for Mobility
	5.3 Focus on device	5.3.1	Is the driver distracted by the system?	5.3.1.1				X			
				5.3.1.2				X			
6 User acceptance	6.1 User experience	6.1.1	Does the function improve the comfort?	6.1.1.1	Comfort increases because CONAV helps the driver to avoid the most congested routes		questionnaire				X
		6.1.2		6.1.2.1	Uncertainty decreases because CONAV helps the driver to avoid most congested routes and modifies the route based on dynamic information		questionnaire				X
		6.1.3		6.1.3.1							X
		6.1.4	Does the function reduce the stress of the driver?	6.1.4.1	Stress decreases because CONAV helps the driver to avoid most congested routes and modifies the route based on the		questionnaire	X			

RQ level 1	RQ level 2	RQ level 3			Hypotheses	Indicators	Measurements	Relevant for Safety	Relevant for Efficiency	Relevant for Environment	Relevant for Mobility
					dynamic information						
7	7.1 Steering wheel	7.1.1	Is there change in the steering wheel frequency?	7.1.1.1				**X**			
		7.1.2	Is there change in steering wheel amplitude?	7.1.2.1				**X**			
		7.2.5	Is there change in the clutch frequency?	7.2.5.1						**X**	
	7.3 Fuel consumption / Emissions	7.3.1	Is fuel consumption affected?	7.3.1.1	Fuel consumption decreases because CONAV guides the drivers into less congested routes	Fuel consumption / 100 km	Fuel consumption litres / 100 km			**X**	
		7.3.2	Pollutant emissions (NOx, PM, HC) increase/decrease because...	7.3.2.1	The emissions decreases because CONAV guides the drivers into less congested routes	TBD				**X**	

Annex 4 : Questionnaires and Scales

a. Testing acceptance

The user acceptance is a crucial requirement for any new system.

Definition of concept

Acceptance as defined for the User Acceptance Scale is a concept based on the perception on usefulness and satisfaction.

Proposed tool

Subjects are instructed to tick a box on each of the nine scales of the following questionnaire indicating the extent to which the stated attributes are applicable with respect to the system under evaluation.

User Acceptance Scale:

My judgements of the system are … (tick one box in every line)

1	Useful	☐☐☐☐☐	Useless
2	Pleasant	☐☐☐☐☐	Unpleasant
3	Bad	☐☐☐☐☐	Good
4	Nice	☐☐☐☐☐	Annoying
5	Effective	☐☐☐☐☐	Superfluous
6	Irritating	☐☐☐☐☐	Likeable
7	Assisting	☐☐☐☐☐	Worthless
8	Undesirable	☐☐☐☐☐	Desirable
9	Raising alertness	☐☐☐☐☐	Sleep-inducing

Figure 7.1: User acceptance scale.

Using the User Acceptance scale is easy:

- The test leader should describe the system to be evaluated in terms of '*what is your judgement about a system that would…?'* (short & clear explanation of the system functioning) and present the nine items (before-measurement).
- After experiences with the system under evaluation the nine items are presented again: '*What is your judgement about the system…(name)?', 'you just finished driving with…'* (after measurement).
- The results of those two judgements will be compared.

Reporting results

The results are reported with a specific description of the interaction of user and system within the study. The User Acceptance Scale results are calculated as follows:

Individual items should be coded from -2 to +2 from left to right, scores on items 3, 6, and 8 should be coded ranging from +2 to -2 (these items are mirrored).

- Reliability analysis should be performed between the before-measurement and after-measurement per item and per subject (use of Cronbach's "alpha"[3] is suggested). If reliability is sufficiently high (above 0.65), c the end scores are computed per subject for the two scales by averaging the scores on the uneven items 1, 3, 5, 7, and 9 for the usefulness score, and averaging scores on the even items 2, 4, 6, and 8 for the satisfying score.
- The usefulness scores can now be averaged over subjects to obtain an overall system practical evaluation. The same can be done with the satisfying scores.
- Difference-scores should be calculated per subject by subtracting the before-measurement score from the after-measurement score per scale. The difference scores show whether and in which direction subjects' opinion was altered as a result of experience with the system.

[3] *Cronbach's* α *is a reliability indicator and defined as*

$$\alpha = \frac{N}{N-1}\left(1 - \frac{\sum_{i=1}^{N}\sigma^2_{Y_i}}{\sigma^2_X}\right)$$

where N *is the number of items,* σ^2_X *is the variance of the observed total test scores, and* $\sigma^2_{Y_i}$ *is the variance of item i.*

b. User Experience Questionnaire: AttrakDiff2

Method of investigation:

AttrakDiff™ is an instrument for measuring the attractiveness of interactive products. With the help of pairs of opposite adjectives, users (or potential users) can indicate their perception of the product. These adjective-pairs make a collation of the evaluation dimensions possible.

The following product dimensions are evaluated:

Pragmatic Quality (PQ):

Describes the usability of a product and indicates how successfully users are in achieving their goals using the product.

Hedonic quality - Stimulation (HQ-S):

Mankind has an inherent need to develop and move forward. This dimension indicates to what extent the product can support those needs in terms of novel, interesting, and stimulating functions, contents, and interaction- and presentation-styles.

Hedonic Quality - Identity (HQ-I):

Indicates to what extent the product allows the user to identify with it.

Attractiveness (ATT):

Describes a global value of the product based on the quality perception.

For more detailed information refer to the website: http://www.attrakdiff.de/en/Home/

The results analysis should be done on the web site which is cost free for less than 20 subjects. For a simple analysis that can be performed in excel see the example below.

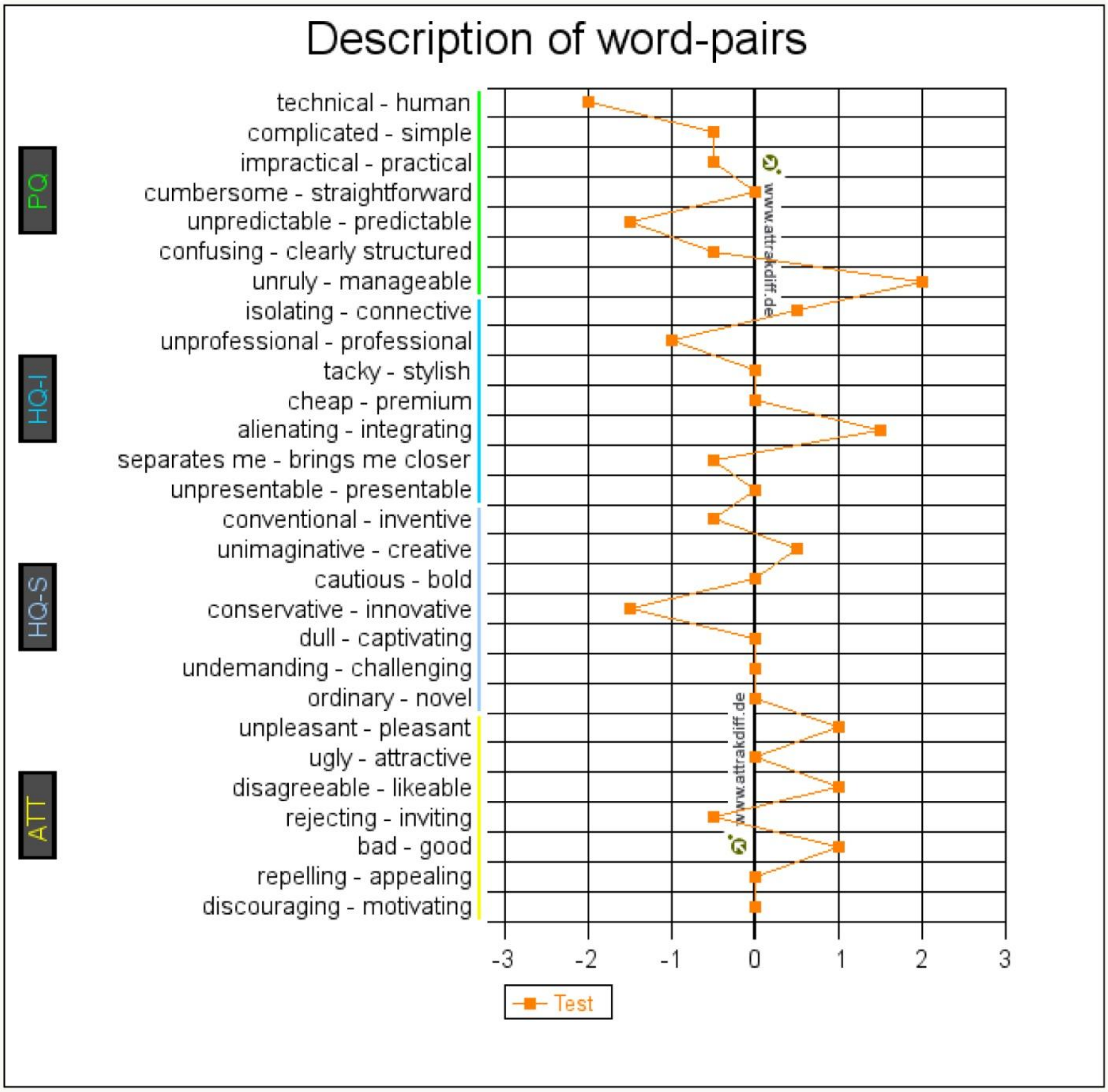
The AttrakDiff semantic differential:

human	◯	◯	◯	◯	◯	◯	◯	technical
isolating	◯	◯	◯	◯	◯	◯	◯	connective
pleasant	◯	◯	◯	◯	◯	◯	◯	unpleasant
inventive	◯	◯	◯	◯	◯	◯	◯	conventional
simple	◯	◯	◯	◯	◯	◯	◯	complicated
professional	◯	◯	◯	◯	◯	◯	◯	unprofessional
ugly	◯	◯	◯	◯	◯	◯	◯	attractive
practical	◯	◯	◯	◯	◯	◯	◯	impractical
likeable	◯	◯	◯	◯	◯	◯	◯	disagreeable
cumbersome	◯	◯	◯	◯	◯	◯	◯	straightforward
stylish	◯	◯	◯	◯	◯	◯	◯	tacky
predictable	◯	◯	◯	◯	◯	◯	◯	unpredictable
cheap	◯	◯	◯	◯	◯	◯	◯	premium
alienating	◯	◯	◯	◯	◯	◯	◯	integrating
brings me closer to people	◯	◯	◯	◯	◯	◯	◯	separates me from people
unpresentable	◯	◯	◯	◯	◯	◯	◯	presentable
rejecting	◯	◯	◯	◯	◯	◯	◯	inviting
unimaginative	◯	◯	◯	◯	◯	◯	◯	creative
good	◯	◯	◯	◯	◯	◯	◯	bad
confusing	◯	◯	◯	◯	◯	◯	◯	clearly structured
repelling	◯	◯	◯	◯	◯	◯	◯	appealing
bold	◯	◯	◯	◯	◯	◯	◯	cautious
innovative	◯	◯	◯	◯	◯	◯	◯	conservative
dull	◯	◯	◯	◯	◯	◯	◯	captivating
undemanding	◯	◯	◯	◯	◯	◯	◯	challenging

Figure 7.2: AttrakDiff scale for joy of use evaluation.

Example for a test result description of word-pairs

The mean values of the word pairs are presented here. Of particular interest are the extreme values. These show which characteristics are particularly critical or particularly well-resolved.



c. Testing usability

In order to test the usability of the applications and HMI it is recommended to use a standardized questionnaire. Usability tests should be seen also as a valid source for optimization of the product in following development cycles.

Definition of concept

Usability is defined as "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" (ISO 9241-11, 1998).

The terms effectiveness, efficiency and satisfaction are defined as follows:

Effectiveness: Accuracy and completeness with which users achieve specified goals

Efficiency: resources expended in relation to the accuracy and completeness with which users achieve goals.

Satisfaction: Freedom from discomfort and positive attitudes towards the use of the product.

Proposed tool

It is proposed to assess usability with the System Usability Scale (SUS) by Brooke (1996), which provides a reliable, low-cost tool that can be used for global assessments of systems' usability. For further reading Brooke (1996), Nielsen (1993), Stanton et al. (2005) and http://www.usabilitynet.org is recommended. The SUS is applied after a user has used a system, but before any discussion and debriefing. Subjects are asked to respond immediately, rather than thinking for long. The figure below presents the System Usability Scale.

	Strongly disagree				Strongly agree
1. I think that I would like to use this system frequently	1	2	3	4	5
2. I found the system unnecessarily complex	1	2	3	4	5
3. I thought the system was easy to use	1	2	3	4	5
4. I think that I would need the support of a technical person to be able to use this system	1	2	3	4	5
5. I found the various functions in this system were well integrated	1	2	3	4	5
6. I thought there was too much inconsistency in this system	1	2	3	4	5
7. I would imagine that most people would learn to use this system very quickly	1	2	3	4	5
8. I found the system very cumbersome to use	1	2	3	4	5
9. I felt very confident using the system	1	2	3	4	5
10. I needed to learn a lot of things before I could get going with this system	1	2	3	4	5

Figure 7.3: System usability scale (SUS).

Reporting results

The results are valid for the functions of a system that could be tested, so the exact interaction of the user should be specified in the reporting chapter.

In order to calculate the SUS score, following steps are necessary:

- Odd numbers in scale position (1, 3, 5, 7, 9): Score value minus 1 (e.g. Item 3 gets score 2; 2-1=1).
- Even number in scale position (2, 4, 6, 8, 10): 5 minus score value (e.g. Item 10 gets score 4: 5-4=1.
- The sum of the scores is multiplied by 2.5.
- The final figure derived represents the usability score between 0 (very low usability) and 100 (very high usability).

The SUS score provides a standardized value for comparison of different products or of the same product tested by different user groups or in different development stages. The SUS score will enable the SAFESPOT consortium to assess the general usability of each application, detect applications with low or high usability, enhance usability aspects if necessary and measure the effect by testing again with the SUS and finally compare the usability results of SAFESPOT applications with the results of applications developed in other or future projects. Heuristically it can be assumed that SUS scores above 70 are ok, while values below 60 should lead to a further optimization circle of the system.

d. Testing workload

A safety system should not increase the mental workload for drivers. It is proposed that for this reason the SMA is also evaluated regarding the mental workload.

Definition of concept

Definition of workload is difficult; however mental workload remains an important and practically relevant concept (Stanton et al. 2005). Workload can be assessed by using the NASA TLX and should be seen, according to this scale, as a composition of 6 sub concepts:

- Mental Demand
- Physical Demand
- Temporal Demand
- Performance
- Effort
- Frustration Level

Proposed tool

The NASA TLX is proposed to measure the workload of drivers. It is a widely spread technique and can be applied to many domains.

Name	Task	Date

Mental Demand — How mentally demanding was the task?

Very Low — Very High

Physical Demand — How physically demanding was the task?

Very Low — Very High

Temporal Demand — How hurried or rushed was the pace of the task?

Very Low — Very High

Performance — How successful were you in accomplishing what you were asked to do?

Perfect — Failure

Effort — How hard did you have to work to accomplish your level of performance?

Very Low — Very High

Frustration — How insecure, discouraged, irritated, stressed, and annoyed wereyou?

Very Low — Very High

Figure 7.4: NASA TLX scale for workload testing.

Procedural guidance for NASA TLX

The NASA TLX is an easy to use tool. A manual is also available for free. An "overview in few dots" is reported hereafter:

- The participants should get a short introduction on the questionnaire in order to understand the sub-scales meaning and to be able to answer quickly.
- The NASA TLX can be used during or after the test trial. It is however recommended for SAFESPOT to use it after the test since it can be intrusive to the task.
- It is proposed to use the NASA TLX in test trials with the SAFESPOT system activated and also in trials with the system deactivated in an equal situation. The results of the two trials for workload can be compared.
- After the test trial participants are asked first to weight the sub scales regarding most effect on their mental workload. This is done by presenting pair wise comparisons between the sub scales using the paper/pencil version for this comparison in Annex 9.2. The NASA TLX manual gives also specific instruction on how to perform this task.
- Then participants are asked to give a subjective rating for each sub scale between 0 (low) and 20 (high).

Reporting results

The calculation of the NASA TLX mental workload scale is done as follows:

- First the score of every sub scale is multiplied with the weighting (e.g. 0x11=0 or 6x15=90).
- Second all weighted results of all sub scales are added.
- Third the results are divided by 15 – a mental workload score between 0 and 100 is the result.

The results of the NASA TLX scores should be compared for the trials with the system versus the trials without the system. The mental workload should be approximately the same or lower when the system is activated.

References Annex 4

1. ISO 9241-11 (1998). Ergonomic requirements for office work with visual display terminals (VDTs) - Part 11 :Guidance on usability: http://www.idemployee.id.tue.nl/g.w.m.rauterberg/lecturenotes/ISO9241part11.pdf
2. Brooke, J. (1996) *SUS: a "quick and dirty" usability scale*. In P. W. Jordan, B. Thomas, B. A. Weerdmeester & A. L. McClelland (eds.) Usability Evaluation in Industry. London: Taylor and Francis.
3. Nielsen, Jakob: Usability Engineering. Academic Press, Boston 1993.
4. Stanton, N., Salmon, P.M.,Walker. G-H., Baber, C., and Jenkins, D.P., "Human Factors Methods", 2005
5. Usability Net: http://www.usabilitynet.org/tools/subjective.htm
6. NASA TLX is free for download at the following page: http://humansystems.arc.nasa.gov/groups/TLX/index.htmlNeville