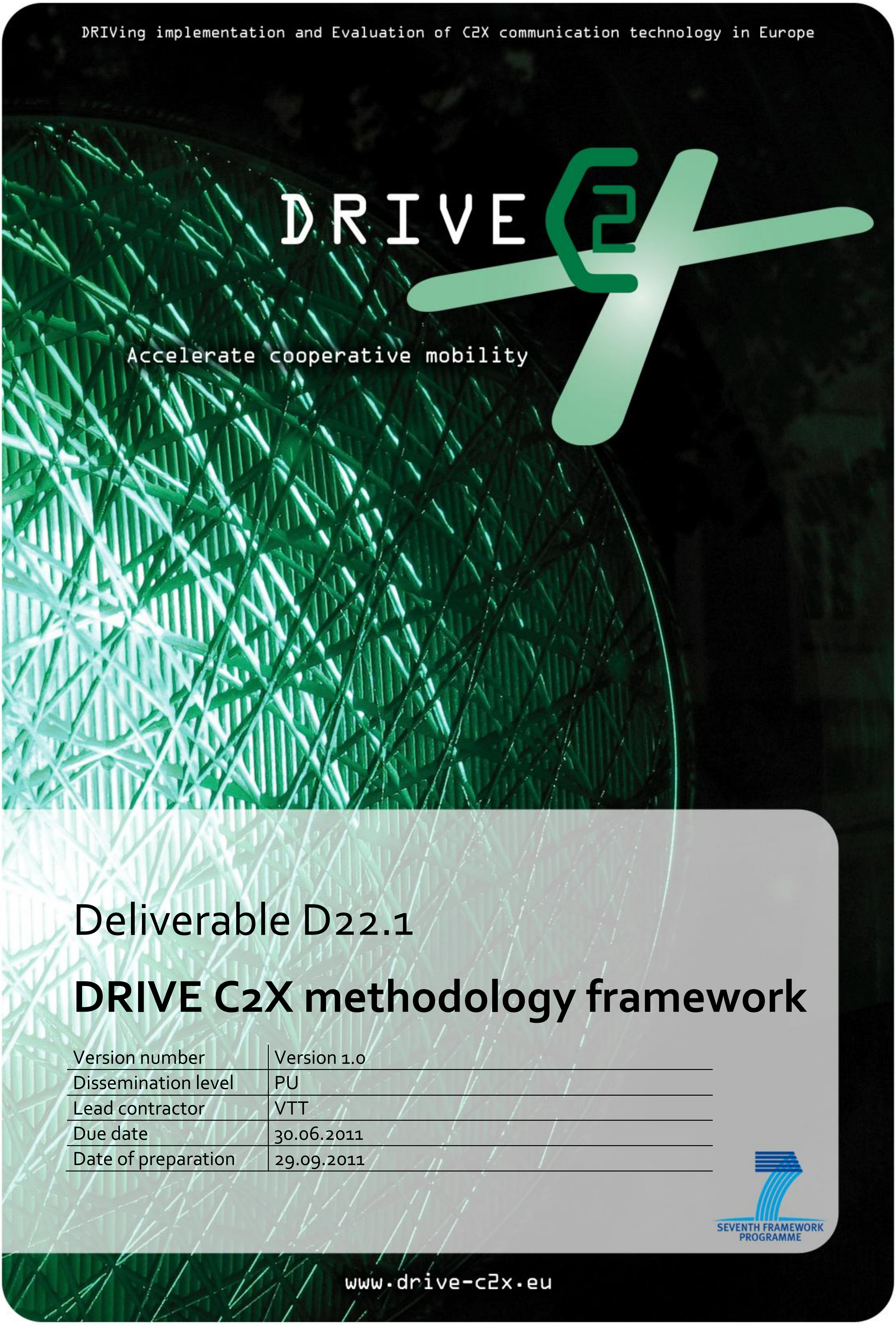

DRIVing implementation and Evaluation of C2X communication technology in Europe

DRIVE C2X

Accelerate cooperative mobility

Deliverable D22.1

DRIVE C2X methodology framework

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SEVENTH FRAMEWORK PROGRAMME

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Executive summary

This deliverable presents the DRIVE C2X methodology for testing and studying the impacts of a number of cooperative functions and services before their market introduction. The aim of cooperative driving applications is to support foresighted driving and early detection of hazards. This is realised by means of a communication-based system that extends the drivers' horizon and warns of potentially dangerous situations ahead. Consequently, the aim of these approaches is to provide drivers with the opportunity to adapt the vehicle speed and also increase headways between vehicles leading to a higher situational awareness of an unforeseen danger.

At present there is a general understanding of the benefits of cooperative systems, but so far they have been tried out in small scale experiments mostly on closed test tracks. Yet, there is no proof of these benefits with many communicating vehicles used by ordinary people in varying conditions on roads.

Communication systems and their components are now mature enough to be brought to large-scale field operational tests.

Most of the functions in this project are based on the PRE-DRIVE C2X project. It created a sound basis for Europe-wide field operational tests of vehicular communication technology. Together with the COMeSafety support action, PRE-DRIVE C2X has agreed on a system specification, which lays the basis for the ongoing standardisation activities in ETSI TC ITS. Based on this, the PRE-DRIVE C2X project developed state-of-the-art system prototypes to be tested in real life conditions and that can be replicated in sufficient numbers. These prototypes are close enough to future production systems to ensure that the results of the envisaged field tests are valid and contribute to the fast deployment of cooperative systems in Europe.

Furthermore, PRE-DRIVE C2X has validated the tools and methods necessary for testing and evaluation of cooperative systems in field operational tests.

DRIVE C2X identified four major objectives:

1. Create and harmonise a Europe-wide testing environment for cooperative systems,
2. Coordinate the tests carried out in parallel throughout the DRIVE C2X community,
3. Evaluate cooperative systems and
4. Promote cooperative driving.

This deliverable presents the DRIVE C2X overall methodology all the way from the selection of functions to impacts assessment of the road tests. Furthermore, the report is a public deliverable and consequently written in "a stand-alone" mode to provide a complete picture to the reader of the purpose of Field Operational Tests (FOT) and the testing procedures of DRIVE C2X in sufficient detail.

The first Chapter "Introduction" leads the reader to the rationale and context of this project and previous work which the current project is based on.

Chapter 2 "DRIVE C2X concept" first presents the objectives of the work in detail and moves on to the architecture of the DRIVE C2X system and then features the application areas. This part shows the project's connection to standards for cooperative communication technologies used and also the relation to the other FOTs.

Chapter 3 "Field Operational Tests overall concept and scope" features the requirements set for FOTs as well defines the basic concepts that have relevance to the project work. Furthermore, DRIVE C2X relation to major other FOTs is shown.

Chapter 4 "DRIVE C2X FOT methodology" makes the core of this report. Here, the whole methodology is described. It is noteworthy that since the whole methodology is written down practically five months after the project start, all details of all methods are not yet in place. This applies e.g. to the precise number of test vehicles, test sites, testing procedures and analysis methods. The upcoming functional tests early 2012 determine to a large extent the details of testing. However, the framework of the methodology can be presented already at this stage. The complete methodology will be presented at month 18 after the pilot tests have been completed.

Chapter 5 "Conclusions" presents the conclusions of the methodology to be applied to FOTs. It also shows the constraints of the testing. This applies to what can be concluded from the tests and how usable the results will be for the needs of various stakeholders of the project.

The origin of Field Operational Tests stems from the needs to assess the impacts of various road traffic safety measures on driver behaviour and safety. The first large-scale FOTs were carried out in the USA and the Nordic Countries in the late 1980's and the early 1990's. The topics of these tests ranged from assessing the impacts of new type of road markings, different types of tyres and ISA (Intelligent Speed Adaptation) and in-vehicle terminals on driver behaviour and risk taking. These pioneering activities also included extensive development of measurement methodology and methods.

The first attempt to realise cooperative systems in PROMETHEUS in the 1980's failed due to the unavailability of suitable communication technology. Serious research efforts in this area were started in Europe in the beginning of this century. Projects such as PReVENT-WILLWARN, Network on Wheels (NoW) and SAFESPOT have produced research prototypes, which showed that communication-based safety and efficiency applications are not only technically viable but may also provide considerable benefits. In order to guide this work and ensure that the projects follow the same technological direction, the COMeSafety Support Action was initiated by the members of the CAR2CAR Communication Consortium. COMeSafety did not only harmonise the activities, but pursued various projects dealing with C2X communication technology. The most significant achievement of this initiative was to provide a commonly agreed architecture description for a European cooperative driving system.

PRE-DRIVE C2X followed the COMeSafety architecture description, refined it and realised a system prototype based on it. So, PRE-DRIVE C2X advanced COMeSafety work beyond the status of a pure research system and being robust enough to sustain a year-long field operational trial. In order to show the performance of this system, PRE-DRIVE C2X also analyzed various applications of vehicular communication technology developed in the numerous research projects concerning effectiveness and suitability for a Europe-wide roll-out. Furthermore, a cooperative systems prototype was realised.

The task of DRIVE C2X is not only to show that the function selection done by PRE-DRIVE C2X is valid from an European point of view, but that the cooperative systems prototype developed by PRE-DRIVE C2X based on the COMeSafety architecture description is functioning as expected and ready for roll out in European member states.

For the data collection, DRIVE C2X is following a two-pronged approach. First, DRIVE C2X is aggregating the data that is generated by the national FOTs during normal national operations. These data provide the basis for the assessments carried out in DRIVE C2X, but naturally it can only give a rough indication of the impacts cooperative systems will have. These data will be assessed for validity, and where possible the results will be scaled up for whole Europe. In parallel, DRIVE C2X will conduct tests on DRIVE C2X specific functions, which have been selected aiming at maximum effectiveness and are expected to yield equal benefit to all member states. By doing this, it is ensured that at the end of DRIVE C2X a number of verified applications of cooperative system technology have been tested and impacts proven and quantified. These are accompanied by applications whose benefits in given European member states have been shown. This gives system developers the possibility to design a common system taking into account the particularities of the European member state in which a given vehicle is serving most of its life.

The DRIVE C2X system enhances the system architecture that was developed in the predecessor project PRE-DRIVE C2X. The system consists of software and hardware components and relies on the enhanced reference specification. Furthermore, the system includes vehicles as well as road-side communication equipment and backend communication infrastructure. The DRIVE C2X system uses state-of-the-art technology for cooperative systems and complies with current communication standards.

More precisely, there is a need to have enough properly organised large-scale Field Operational Tests in European conditions to provide reliable and unbiased insight into:

- Usability of the systems, effects on and benefits to ordinary users, the society and stakeholders.
- Long-term user acceptance and willingness to pay for such systems and different functions.
- Long-term impacts of assistance functions on driver behaviour and "behaviour compensation",, the over-reliance on assistance functions and the possibly following decreased vigilance.
- Technical performance of the systems and services in real-life long enduring large-scale use.
- Real-life performance of different business models for operation and provision of intelligent vehicle safety systems and services.

Methodologically, FOTs can be realised in a number of ways. Several DRIVE C2X partners participated in the 1st Call FOT *FESTA* that put a lot of effort on the methodological issues of later large-scale FOTs such as the work proposed here.

The consortium envisions two major approaches that are needed in any given serious FOT approach:

1. Tests in daily traffic with sophisticated measurement methods but with less controlled conditions, e.g. non-experimental driving to accumulate data and have an insight of long-term impacts.

2. Tests in closed-circuits or on roads with little traffic in well controlled conditions to get deeper in the behavioural dynamics of drivers and to establish causal relationships.

DRIVE C2X has two technology areas. They are car-to-car communication (C2C) and car-to-infrastructure communication (C2I). Both technology areas are subject to road tests in this project. Nine functions were selected for the full impact assessment. These are:

Traffic safety-related functions:

1. *Road works warning*: vehicles approaching road works are warned in due course before they reach the road works zone. The function is applicable both to stationary road works and moving road works found typically on motorways.

2. *Traffic jam ahead warning*: the driver is warned when approaching the end of a traffic jam to avoid running into the last vehicle in the queue.

3. *Car breakdown warning*: approaching vehicles are warned before reaching a broken down vehicle to avoid running into that vehicle or endangering people in the vicinity.

4. *Weather warning*: information about bad weather conditions ahead is communicated to oncoming vehicles to avoid entering areas with adverse weather conditions at excessive speed.

5. *Emergency electronic brake light*: in case of a hard braking manoeuvre following vehicles are warned to avoid rear end collisions and backing up.
6. *Approaching emergency vehicle warning*: approaching emergency vehicles warn surrounding drivers about their presence to ensure that they can proceed quickly even in very heavy traffic.
7. *Post crash warning*: in the event of an accident oncoming vehicles are warned to ensure that drivers slow down and do not run into the vehicles involved in the accident .

Traffic efficiency related functions:

1. *In-vehicle signage & regulatory and contextual speed limit*: traffic sign information such as “ban on passing” is communicated to the vehicles and indicated in the instrument cluster or the head unit. Information on fixed and variable speed limits as well as the recommended optimal speed is communicated to the vehicles and indicated in the instrument cluster or the head unit. This application does in particular address variable message signs.
2. *Green-light optimal speed advisory*: signal phases of traffic lights are communicated to vehicles in order to inform the drivers about the optimal speed to pass traffic lights at green.

Functions pre-validation was carried out to anticipate the need for vehicles and observations for the actual road tests. Functions cannot all be tested in the same way but need a different approach. In this, pre-validations provide valuable information.

Comprehensive knowledge of impacts of DRIVE C2X functions will be provided on different levels, ranging from individual user behaviour to the transport system and society level in Europe. The specific impacts in target areas (safety, environment, efficiency, mobility) are based on changes in driver behaviour. Therefore, the measures focus on driving and travelling behaviour. For each impact area, the most effective measures compatible with the indicators and criteria will be applied. Furthermore, the target area specific impact estimates create the basis for regional and Europe-wide impact estimates.

The methodology for impact assessment is based on the FESTA methodology and follows directly from the evaluation framework developed in WP42. The methodology is first tested in the piloting phase, before applying it to all functions in the project.

It is necessary to scale up impacts to the level at which stakeholders can make decisions. Even large FOTs with thousands of vehicles only represent a tiny percentage of the traffic exposure and of the traffic composition at any given time. The extrapolation of the results at the test site level to higher levels requires both methodological development as well as a coupling with computer models with high-quality data sources.

This deliverable presents the methodology for the road tests as it stands about five months since project start. So far all the functions to be tested have been selected, and pre-validation was carried out to provide input for the actual test planning. Furthermore, the process from the DRIVE c2x system level to functions, target scenarios and test scenarios was identified. Also the technical test plan was created. What still needs to be done in setting up the complete methodology is to define all the research questions, hypotheses and performance indicators. After that, the actual test design process can start. The tested functions need different designs, and this process has just started. This deliverable will be updated after the piloting phase has been completed. The complete DRIVE C2X methodology will be presented after the pilot tests have been completed and all iterations to the testing methodology have been done.

The greatest challenge in creating the methodology is to harmonise the test sites in terms of test design, testing procedure overall and HMI across test sites. All these have an impact on the final results. Finally, long-term testing needs also to be planned and agreed throughout the testing community. Even though we are entering large-scale field trials, the results from these tests are still indicative due to the lack of sufficient penetration of cooperative vehicles and needed interaction. However, the results combined with the systematic collection of user experiences and opinions will yield a picture that warrants taking decisions on the continuation of cooperative driving systems.

1 Introduction

1.1 Structure of the deliverable

This deliverable presents the DRIVE C2X overall methodology all the way from the selection of functions to the impact assessment of the road tests. The report is a public deliverable and consequently written in a "stand-alone" mode. The aim is to provide a complete picture to the reader of the purpose of Field Operational Tests (FOTs) and the testing procedures of DRIVE C2X in sufficient detail to be able to assess the work to be carried out later.

Chapter "1 Introduction" provides the rationale and context of this project and the preceding work it based on.

Chapter 2 "DRIVE C2X concept" presents the objectives of the work in detail, the architecture of the DRIVE C2X system and finally the technology areas. This part shows how the project relates to standards for cooperative communication technologies used and to the other FOTs.

Chapter 3 "Field Operational Tests overall concept and scope" details the requirements set for FOTs and defines the basic concepts relevant to the project work. Furthermore, DRIVE C2X relation to major other FOTs are shown.

Chapter 4 "DRIVE C2X FOT methodology" makes the core of this report. Here, the whole methodology is described. It is noteworthy that while the whole methodology is written down practically only five months after the project start, all the details of the methods are not yet in place. This applies e.g. to the precise number of test vehicles, test sites, testing procedures and analysis methods. The upcoming piloting phase early 2012 determines to a large extent the details of testing. However, the framework of the methodology can be presented already at this stage. So, some of the items concerning the methodology are still subject to revision and change depending on the results of the pilot tests and test sites arrangements.

Chapter 5 "Conclusions" presents the conclusions of the methodology to be applies to FOTs. It also shows the constraints of the testing. This applies to what can be concluded from the tests and how usable the results will be for the needs of various stakeholders of the project.

There are still a number of details open concerning various methods needed to set up a complete testing system for numerous functions listed later in this paper.

This applies to precise test design and methods needed to be tailored for different functions. It is obvious that same testing procedures cannot be applied to all the functions, since they are very different. Furthermore, only after the pilot tests have been carried out, the design of testing procedures can be completed and the methodology finalised.

Consequently, this deliverable will be updated after the testing process is detailed and agreed on. The second version of the methodology framework is expected to be submitted one and a half years after the project start.

1.2 Cooperative driving systems

The idea of cooperative driving originates from the concept of automated highway, where the vehicle is receiving input signals from the road environment – either from a road surface or roadside. The first documented ideas of an automated highway were presented in 1960 by General Motors, where a car's front wheels were automatically positioned by responding to signals picked up by tuned coils mounted on the front of the car [9].

Today, the aim of cooperative driving applications is to support foresighted driving and early detection of hazards. This is realised by means of a communication-based system that extends the drivers' horizon and warns of potentially dangerous situations ahead. Consequently, the aim of these approaches is to provide drivers with the opportunity to decrease the vehicle speed early on and also to increase headways between vehicles, leading to a higher situational awareness of an unforeseen hazard.

At present there is a general understanding of the benefits of cooperative systems, but so far they have been tried out only in small scale experiments mostly on closed test tracks. Validation of these benefits with many communicating vehicles used by ordinary drivers in varying conditions on roads is still missing, but communication systems and their components are now mature enough to be used in large-scale field operational tests.

In addition, several technical issues call for large-scale testing. For instance, the performance of cooperative systems needs to be validated in situations where many vehicles communicate simultaneously, for example at intersections or in congested traffic. Methods for channel usage and congestion control have been developed and simulated but the functioning has not been proved in real traffic, yet.

Hence, there is now a need for large-scale comprehensive field operational tests on cooperative systems and to quantify their impacts. This is also important for the various stakeholders planning investments in cooperative driving technology and future production systems. Moreover, there are still a number of technical issues which can only be tested in real driving conditions.

Several national field operational tests and programmes with vehicular communication technology are currently under preparation. The most extensive one is the German simTD programme (Sichere Intelligente Mobilität – Testfeld Deutschland). Road authorities and the German automotive industry are cooperating to equip more than 300 kilometres of a road network including motorways, lower category roads, streets and more than 100 vehicles. simTD is expected to increase the understanding of the operation of cooperative systems. However, the national activities limit the scope to specific local needs such as SCORE@F (French Field Operational Test for cooperative systems) in France or Test Site Sweden in Southern Sweden. The testing methodologies, technologies and functions selected for these tests are not necessarily compatible. Consequently, the results of different national studies would not be comparable either. Furthermore, separate testing would slow down the market introduction of interoperable systems and their functionality across borders.

For these reasons there is a need for a Europe-wide integrated approach to large-scale user tests of cooperative systems. This can be realised by bringing together various ongoing national activities and ensuring the compatibility of emerging systems with the architecture defined and specified at a European-level by COMeSafety and PRE-DRIVE C2X projects [4,22]. The purpose of the proposed DRIVE C2X activity is not to set up new national test sites but to connect the selected national test sites into a large European testing platform.

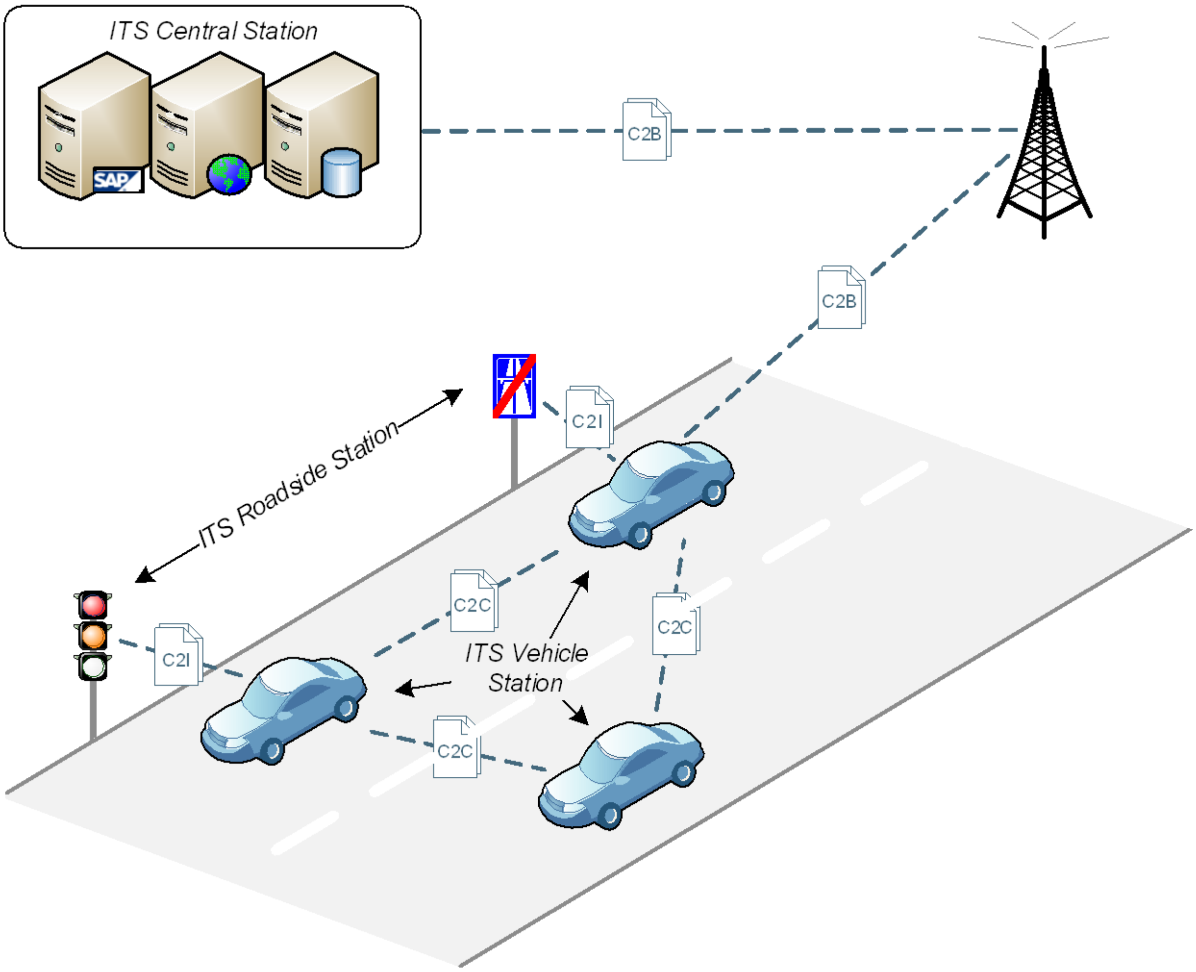


Figure 1: Idea of cooperative communication.

To prepare the future, the PRE-DRIVE C2X project has created a sound basis for Europe-wide field operational tests of vehicular communication technology. Together with the COMeSafety support action, PRE-DRIVE C2X has agreed on a system specification, which lays the basis for the ongoing standardisation activities in ETSI TC ITS. Based on this, the PRE-DRIVE C2X project developed state-of-the-art system prototypes to be tested in real traffic which can also be replicated in sufficient numbers. These prototypes are close enough to future production systems to ensure that the results of the envisaged field tests are valid and contribute to the fast deployment of cooperative systems in Europe.

Furthermore, PRE-DRIVE C2X has validated the tools and methods necessary for testing and evaluation of cooperative systems in field operational tests. Particularly, the integrated simulation toolset will allow the assessment of all aspects of vehicular communication technology. Also, test management tools have been developed to answer the complexity of parallel testing on different European test sites with a large number of test vehicles and infrastructure equipment and to handle the large amount of collected data.

PRE-DRIVE C2X also investigated potential implementation strategies for cooperative systems technology and came up with realistic business models for vehicle equipment and infrastructure operation. The envisaged field operational tests will also be used to validate these business models and verify the implementation strategies.

The main expected application areas are as follows:

- Traffic information exchange between vehicles and background systems (just as aftermarket and nomadic devices do today),

- Early hazard warning system,
- Driver support in merging traffic and
- Platoon driving.

Furthermore, in even a more distant future are cooperative systems for multiple vehicles such as is the case with intersection scenarios. First studies also in this area have been conducted.

Cooperative driving concept in Europe was first promoted and addressed in the EUREKA project of the EC PROMETHEUS Programme (1987-1994). In this, the activities focused first on bi-directional roadside-vehicle communication to be followed by first vehicle-to-vehicle communication studies. Since then, the focus of the European automotive industry has shifted to stand-alone vehicle safety systems such as ESP, launched by Bosch in 1995, and later different ADAS applications initiated by Adaptive Cruise Control (ACC) in 2000. Meanwhile in USA and Japan the activities on cooperative driving continued. Not until a few years ago, after realising the need for earlier driver support than ADAS can provide, OEMs and suppliers "rediscovered" the cooperative driving concept that is also reflected in the later of Calls 6 FP and today, in the 7 FP Calls.

In Japan, a broad range of cooperative systems have been tested – even though our information of them in Europe is scant. For instance operative platooning has been demonstrated.

Recently, a number of vehicle-to-vehicle communications research projects have been carried out or are underway in Europe, Japan and the USA. So far, prototype applications such as the recently demonstrated PReVENT sub-project WILLWARN (Wireless Local Danger Warning) and INTERSAFE prototype systems exist but are not yet providing mature solutions for commercial use [21].

1.3 PRE-DRIVE C2X

PRE-DRIVE C2X was the predecessor project of DRIVE C2X, preparing the DRIVE C2X large-scale field trial with vehicular communication technology by developing the methods and tools needed to conduct a field operational trial with cooperative systems and realising a prototype for a common European C2X communication system based on the emerging ETSI TC ITS standards. The project started in July 2008 and concluded in September 2010, with over 25 partners contributing to its success.

1.3.1 Objectives

PRE-DRIVE 2X had the following objectives:

Based on a common European architecture description for a vehicle-to-x communication system prepared by COMeSafety a detailed system specification was to be prepared and realised as a functionally verified prototype robust enough to be used in future field operational tests.

The second objective of PRE-DRIVE C2X was to develop and implement an integrated simulation toolset for cooperative systems, which enables a holistic estimation of the expected benefits in terms of safety, efficiency and environment. The toolset should be applied in order to validate it and to get a first impression on the likely impacts of cooperative systems. Furthermore, tools and methods for economic evaluation of C2X communication technology had to be developed to accompany the integrated simulation toolset. Also these tools and methods had to be validated through an initial application using input data for Germany.

Finally, extensive dissemination activities had to be conducted in order to promote the idea of cooperative driving and to better involve road operators and public authorities in the development and deployment of cooperative systems technologies. This included the participation in European standardisation activities such as ETSI TC ITS and in working groups of the Car 2 Car Communication Consortium.

1.3.2 Achievements

PRE-DRIVE C2X produced a number of significant results which were either carried over directly to DRIVE C2X or provided the basis for the work in this project. The major achievements of PRE-DRIVE C2X are described below.

1. System architecture, system specification

The description of the architecture for a common European communication system originally drafted by the COMeSafety support action was transferred into a detailed system specification in PRE-DRIVE C2X, and was made available to ETSI TC ITS as input for standardisation of cooperative systems and to related projects such as simTD in order to foster interoperability.

2. Tools and methods for impact assessment

PRE-DRIVE C2X developed and applied a dedicated set of simulation tools which allows the holistic evaluation of the complete interacting system of vehicle traffic, communication and application. It serves to evaluate systems under development and thus supports the development process by providing a chance to test the system in its current stage under realistic conditions. This holds for the development of both the application and the communication systems including hardware and software. Furthermore, this tool-set provides input for socio-economic and business economic evaluations of cooperative systems and makes a scaling-up of the benefits to EU level possible. By doing this, the simulation tool-set developed in PRE-DRIVE C2X is unique. Before PRE-DRIVE C2X, there was no integrated and sufficiently detailed simulation model for cooperative systems development.

3. System prototype

In order to provide a working prototype of the common European architecture for a vehicular communication system based on the COMeSafety definition first the necessary hard- and software components as well as the testing, management and monitoring tools needed for system development have been identified. Functional prototypes of these components were realised and functionally verified on a suitable test bench. After they had successfully passed this functional verification all components were replicated in sufficient numbers to set up a small scale test site and to equip a small vehicle fleet for the demonstration and testing of the PRE-DRIVE C2X vehicular communication system. Particular care was taken that all systems and components developed were robust enough to support the field operational trial envisaged after PRE-DRIVE C2X.

4. Tools and methods for field operational testing

Based on a comprehensive survey of national and international projects dealing with vehicular communication technology PRE-DRIVE C2X has identified appropriate functions of vehicular communication and selected the most promising for the pilot testing and demonstration. Based on these functions the requirements for testing architecture, test management and test site selection were derived and test metrics and procedures were developed and implemented.

5. System demonstration and preliminary impact assessment

In order to prove the proper functioning of the system prototype and to validate the evaluation methodologies developed in PRE-DRIVE C2X a first assessment was conducted, applying the tools and methods developed in PRE-DRIVE C2X. It helped to identify methodological gaps as well as technical deficits and avoided time consuming bug-fixing. Also, this assessment, that was accompanied by an application of the simulation tool set developed in the project gave a first impression of the system benefits that can be expected – one particular outcome was a reliable cost/benefit estimation accompanied by the description of viable business models – and delivered valuable data for the design of the test sites to be set up in DRIVE C2X. The assessment was combined with a system demonstration for interested parties in order to promote the common European communication architecture and the planned field trial.

6. Dissemination

The key scope of the dissemination activities in PRE-DRIVE C2X was to open the framework of cooperation to all relevant stakeholders and key partners in Europe to facilitate future market introduction with a high penetration rate as well as future planning of extensive field operational tests on cooperative systems. This major aim was achieved via the organization of joint workshops, the dissemination of project activities to the whole ICT community, and the identification of a path to market introduction. A particular result was the close collaboration with the EasyWay consortium representing the road operators of the 27 European member states which will be further intensified in DRIVE C2X.

Dissemination activities in PRE-DRVE C2X were also undertaken to provide specific input to the related standardisation bodies and to continuously exchange relevant information with all ongoing projects and other communities in the world. This was achieved through active contribution to the ongoing ETSI TC ITS activities by PRE-DRIVE C2X members and participation to the Joint EU/US Task Force for harmonisation of cooperative systems.

1.3.3 Open questions

By prototyping a common European system for cooperative driving and developing the necessary tools and methods for field trial operation and impact assessment, PRE-DRIVE C2X has paved the way for large-scale field trials of vehicular communication technology based on the European COMeSafety architecture for a vehicle-to-x communication system. The field trials on European level are a key step to move from mere technological developments towards deployment and are therefore the main objective within DRIVE C2X. They are needed to quantitatively assess the impact of cooperative systems on traffic safety and efficiency and on the environment, to identify for each European member state the functions with the most benefit and to verify the proper functioning of the technology under real life conditions with a large number of communicating vehicles.

Europe-wide interoperability is another issue that requires field operational trials in various European countries to be investigated properly. Interoperability must be ensured for all vehicle brands, for all road operators and traffic control centres and for all service providers across Europe. It is a major task of DRIVE C2X to ensure this interoperability by technical and non-technical means such as testing on different test sites or contributing to the ongoing standardization and harmonisation activities.

An important prerequisite for successful implementation of cooperative systems on European roads is the commitment of all relevant stakeholders. PRE-DRIVE C2X made a major step forward here by establishing collaboration with the EasyWay project, which represents the road operators of the 27 European member states. DRIVE C2X will intensify this collaboration by setting up a task force with EasyWay with the aim to agree on concrete actions to push implementation forward. Furthermore, a joint implementation plan of all industry partners, together with authorities and road operators, still needs to be developed.

1.4 Field Operational Tests

The origin of Field Operational Tests stems from the need to assess the impact of various road traffic safety measures on driver behaviour and safety – as actually is the case to a large extent with the DRIVE C2X approach too. The first large-scale FOTs were carried out in the USA and the Nordic Countries in the late 1980's and the early 1990's. The topics of these tests ranged from assessing the impact of new types of road markings, different types of tyres and ISA (Intelligent Speed Adaptation) and in-vehicle terminals on driver behaviour and risk taking. These pioneering activities included also extensive development of measurement methodology and methods.

Perhaps the most sophisticated approach was the introduction of unobtrusive (non-invasive) instrumented vehicles in the 1990's [15, 16, 19]. These vehicles looked just like ordinary cars but had all the measuring instruments and cameras hidden to minimize the bias caused by the visible equipment and experiment. The subjects were performing the tests alone, and a cover task was given to them to conceal the original purpose of the tests – to be later revealed to them. Even the determination of precise lateral positioning of the vehicle (off-line) was possible at that time. In later versions the data collected was transferred wirelessly to the experiment leader.

By means of dedicated approaches long-term impacts of various measures on behaviour were studied. These tests were at best about 1,5 years in duration. Overall, the known number of such long-term tests is small

Development of ICT functions and systems for mobility and transport such as intelligent vehicle safety systems have been largely driven by technology interest and possibilities. Recent pilots and demonstrations have concentrated on assessing the technical performance and user acceptance of the system either as prototypes or preliminary versions or service in a small scale. There is still a great demand for facts on the short- and especially long-term impacts of the systems on travel and traffic behaviour, the related transport system effects on safety, flow, efficiency and environment, and the overall social and business impacts of the services and systems in a large-scale deployment. In addition, all stakeholders want to know with sufficient reliability the long-term acceptance and willingness-to-pay for the systems by ordinary users.

Field Operational Tests are now recognized as the most powerful method to provide these facts as in FOTs a large number of participants use the systems and services in their daily lives in real driving conditions. In addition to the evaluation of effects, benefits and costs, FOTs are very useful in verifying the technical performance of the systems in large-scale deployments and in guiding the development of driver assistance functions.

As mentioned above, FOTs have been used quite long in the USA to evaluate the technical performance and user acceptance but recently also the effects of various intelligent vehicle safety systems. These FOTs have dealt e.g. with collision avoidance systems, technologies for hazardous material transport, Intelligent Cruise Control and tracking the behaviour of the drivers in daily driving situations. In Japan before entering the overseas market, the vehicle manufacturers often utilise the home market as a gigantic FOT for the early evaluation of new systems such as collision warning, drowsiness monitoring, and vehicle to infrastructure communication based services. In Australia tests with the SafeCar (with Intelligent Speed Adaptation, Following Distance Warning, Seatbelt Reminder and Reverse Collision Warning) were carried out for the period of one year.

Large-scale testing of intelligent vehicle systems with ordinary drivers in traffic has been rare in Europe so far. The most noteworthy of these tests have dealt with speed alert and adaptation systems, where the largest tests were carried out in Sweden with 5 000 vehicles and over 10 000 drivers. The other tests with speed alert and adaptation systems in the UK, the Netherlands, France, Finland and Belgium were much smaller with clearly less than hundred drivers and vehicles each. The recent Dutch FOT on Adaptive Cruise Control and Lane Departure Warning included only 20 vehicles. All of aforementioned large-scale tests have focused on the ADAS-type functions.

Hence, there is a need to have enough large-scale and properly organised Field Operation Tests in European conditions to provide reliable and unbiased insight into:

- Systems' usability, impacts on and benefits to ordinary users, the society and stakeholders,
- Long-term user acceptance and willingness to pay for such systems and different functions,
- Long-term impacts of assistance functions on driver behaviour and often so called behaviour compensation e.g. over-reliance on assistance functions and the possibly following decreased vigilance,
- Technical performance of the systems and services in real-life long enduring large-scale use,
- Real-life performance of different business models for operation and provision of intelligent vehicle safety systems and services.

Methodologically, FOTs can be realised in a number of ways. The consortium participated in the 1st Call FOT Support Action *FESTA* that developed a methodology for later large-scale FOTs such as the work being carried out here.

Without going into details here, the DRIVE C2X consortium envisions two major approaches that are needed in any given serious FOT approach:

1. Tests in daily traffic with sophisticated measurement methods but *with less controlled* conditions e.g. non-experimental driving to accumulate data and have an insight of long-term impacts.
2. Tests in closed-circuits or on roads with little traffic in *well controlled* conditions to get deeper in the behavioural dynamics of drivers and to establish causal relationships.

These approaches are interrelated so that data from less controlled daily driving may raise issues that need closer examination.

2 DRIVE C2X concept

2.1 Objectives

DRIVE C2X defined four major objectives that are detailed below. The objectives can be directly linked to the work in the four of the five subprojects.

1. Create and harmonise a Europe-wide testing environment for cooperative systems
    a. *Create and activate a Europe-wide DRIVE C2X test community* for carrying out extensive meaningful and complementary field tests on cooperative systems. This work actually started already at the proposal phase in order to commit partner test sites to a common testing methodology and have a testing system in place to start implementing the testing methodology in the beginning of the project. As much as this is an activity to realise Europe-wide tests, this effort aims also at creating Europe-wide commitment to new driver assistance technology promoting foresighted driving and travel.
    b. *Harmonise the selected test sites* in terms of compliance with the needs for a field operational test on cooperative systems at a European level. The work builds on PRE-DRIVE C2X and other previous and on-going supporting projects. Necessary functional and technical extensions need to be implemented to ensure that all selected test sites are at a same functional level and that their systems are compatible.
    c. *Define and agree on a common testing methodology and implement it across all test sites.* The work that needs to be done will not be started from a clear sheet of paper but is making use of PRE-DRIVE C2X and its predecessors' work, the guidelines developed in FESTA the on-going Integrated Projects euroFOT and TeleFOT. This procedure enables the comparison of the results of the same functions across test sites. The main task in this part is to bind a set of field testing methods into a common methodology adopted throughout the testing community.

These objectives above are being met in SP2 – FOT framework.

2. Coordinate the tests carried out in parallel throughout the DRIVE C2X community
    a. *Create a formal, commonly agreed coordination procedure* to ensure effective running of tests across the large European DRIVE C2X community. Since this project has a special character of being both a coordinating and methodological activity, it is vital that national test sites and the actual project make a coherent whole where all relevant aspects of testing are agreed together and ensured that the common methodology will be observed.
    b. *Implement the adopted common methodology* to investigate different impacts of cooperative systems in variable traffic conditions and study the robustness and technical functionality of the system. The methodology needs to fulfil the following main requirements for testing:
        - Ensure the statistical validity in terms of two major issues: (i) the measures selected need to be accurate and describe the phenomenon intended to be measured such as using parameters enabling us to make precise statements for example on safety (ii) the measures selected must be reliable and mainly quantifiable so that repeated measurements in constant conditions yield the same results.

- Apply robust quasi-experimental design in order to mitigate the effects of random fluctuation on results, a major one of them being behaviour changing over time rather than being the system impact. One of the main requirements of tests is to reveal long-term impacts of cooperative systems.
- Use a common method in subject recruitment and apply a sampling technique making possible a generalization of the results to the population at large.
- Carry out long-term testing to ensure that the impacts evaluated are free from short-term confounding effects.
- Respect the rules of research ethics by treating the subjects, handling the subject information and data with discreet and ensure the security of data capture and storage.

c. *Investigate functions common to all test sites as well as site-specific functions*. European aspects need to be implemented into the test sites, which today address national requirements only. Particular focus will be on European interoperability showing that cooperative functions work across European borders and devices. In addition, investigation is needed in functions enabling faster deployment or a combination of functions responding to specific traffic scenarios and / or increases the potential for commercialization.

d. *Involve users strongly in the evaluation of cooperative systems in addition to serving as subjects in road tests only*. Cooperatives systems development is still in the phase where user feedback for enhancing the systems is crucial. This will be taken into account by involving users outside actual road tests to assess the functioning and HMI aspects of cooperative systems. Eventually, user responses determine the fate of cooperative systems.

These objectives above are being met in SP3 – FOT operations.

3. Evaluate cooperative systems

a. *Study phenomena ranging from driver reactions to societal impact*. These comprise:

- User preferences and reactions, HMI included,
- Driving behaviour in terms of system usage and safe behaviour,
- Safety impacts,
- Impacts on traffic flow,
- Impacts on environment,
- Socio-economic projections and
- Deployment potential.

b. *Carry out technical tests* to show the cooperative systems functioning and acquire feedback for further development. These tests include:

- Tests on systems robustness and ability to withdraw harsh conditions in terms of weather and traffic volumes,
- Systems functioning across borders,
- The usefulness and acceptance of different applications in different European countries,
- Identification of the necessary functional and system extensions for national field operational tests to achieve a common European system based on COMeSafety architecture, Study the functionality of different system components,
- Comparison of the same functions across all test sites.

c. *Draw conclusions and make recommendations for further development and deployment of cooperative systems for users*. This activity is done after all test results are available and it culminates the whole DRIVE C2X work. Here, the first comprehensive assessment on the potential of cooperative systems is made.

These objectives above are being met in SP4 – FOT evaluation.

4. Promote cooperative driving

a. *Disseminate and promote cooperative driving and its potential benefits*. Cooperative systems are still to the driving public largely 'terra incognita'. This sets a special challenge to the project promotion. We have available effective mechanisms – tested over the years in numerous other projects – to reach conventional target groups, especially medium level users like road operators, industry, service operators and other professionals in the field. However, reaching the general public needs special measures and more efforts than hitherto has been made. Here social media will be used in different ways, since people 'meet' and socialise and get acquainted with new phenomena more and more often in Internet. Furthermore, those most actively engaged in social media forums, are future users of cooperative systems.

b. *Develop effective procedures of enhancing awareness and take-up of cooperative systems* among the public. This objective relates to the promotion of cooperative systems by increasing public awareness of the potential cooperative systems offer in vehicle environment. The use of personal navigators, smart phones and other comparable devices as in-vehicle terminals are today creating good grounds for wider promotion of truly cooperative vehicle-integrated systems. For this reason, also the cooperation with TeleFOT on the impacts of aftermarket and nomadic devices is seen very useful for the DRIVE C2X, since similar type of services and functions are currently being tested therein.

c. *Study the deployment potential and create a road-map for the introduction of cooperative systems.* This objective includes studies on the business models of cooperative functions and services. It also means opening up for new players in the market and investigating in joint ventures across sectors. It is possible that the real break-through of cooperative systems may happen in ways not easy to fully anticipate yet. For this reason the approach should be wide and broadminded including also cooperative entertainment systems and the potential of "open innovation" platform activities to accelerate the progress of cooperative driving functions.

d. *Promote integration and collaboration in cooperative system initiatives in Europe and overseas* such as INTELLIDRIVE™ in the U.S.A., and SMARTWAY, DSSS, and ASV4 in Japan. The DRIVE C2X consortium is also planning to cooperate closely with other FP7 projects such as FOTsis dealing with cooperative systems technology. To minimise time and costs and to maximise the output, the DRIVE C2X consortium is actively seeking cooperation and proposing to share test sites, equipment and tools and to collaborate whenever possible.

e. *Improve and validate a testing methodology for cooperative systems for upcoming European field tests after DRIVE C2X*. Until now, cooperative systems have not been extensively tested anywhere. The creation of testing methodology – as stated earlier – is not starting from a scratch but applying good established principles of experimental field testing to new technical-behavioural context and documenting them systematically for later and parallel use. The principles and guidelines developed in FESTA, ongoing European FOTs and earlier field experiment by partners in course of over 20 years will be used where applicable.

The number of aftermarket navigators and smart phones is increasing exponentially today. So, the functions and services these devices provide is reaching an ever increasing mass of users. Platforms and possibilities for new cooperative functions exist now. For this reason also, the time for wide awareness activities is from now on. This ideal opportunity will be fully used in the project dissemination mechanism set up in a dedicated sub-project (SP5 – Cooperative driving promotion).

2.2 Context of DRIVE C2X

Cooperative systems are not new. The first attempt to realise cooperative systems in PROMETHEUS in the 1980's failed due to the unavailability of suitable communication technology. Serious research efforts in this area were started in Europe in the beginning of this century.

A number of field trials with cooperative systems are currently under preparation or already ongoing in various European member states such as simTD in Germany, SCORE@F in France or SAFER in Sweden. These field trials all have the same objectives: prove that vehicle-centric communication is working under real life conditions and find out what benefits cooperative systems may bring about. However, the understanding of what a field trial is varies considerably between the test sites as do the test sites themselves and the systems and applications tested. Also, these field trials are focusing on national particularities only and do not consider European aspects.

National field operational trials may provide results having even some validity for Europe. But it is difficult to transfer the results of national FOTs directly to all Europe due to the differences in European traffic systems such as different vehicle populations, different traffic regulations and different traffic culture. This is why there is a need to carry out testing making use of a harmonised methodology and agreed common functions across Europe. DRIVE C2X responds to this challenge. Instead of setting up field trials in selected European member states on its own, DRIVE C2X makes use of the already existing national filed trials as far as possible. This is done by updating the technologies used for these field trials when necessary with the aim to have a common technological platform based on the COMeSafety architecture and implementing common applications based on the PRE-DRIVE C2X functions where needed..

Projects such as PReVENT-WILLWARN, Network on Wheels (NoW) [7] and SAFESPOT [13] have produced research prototypes, which showed that communication-based safety and efficiency applications are not only technically viable but may also provide considerable benefits. In order to guide this work and ensure that the projects follow the same technological direction, the COMeSafety Support Action was initiated by the members of the CAR2CAR Communication Consortium. COMeSafety did not only harmonise the activities, but pursued various projects dealing with C2X communication technology [22]. The most significant achievement was to provide a commonly agreed architecture description for a European cooperative driving system.

The task of DRIVE C2X is not only to show that the function selection done by PRE-DRIVE C2X is valid from an European point of view, but that the cooperative systems prototype developed by PRE-DRIVE C2X based on the COMeSafety architecture description is functioning as expected and ready for roll out in European member states. Figure 2 below describes the relationship between the various projects and consortia that has led to the DRIVE C2X proposal via the project PRE-DRIVE C2X.

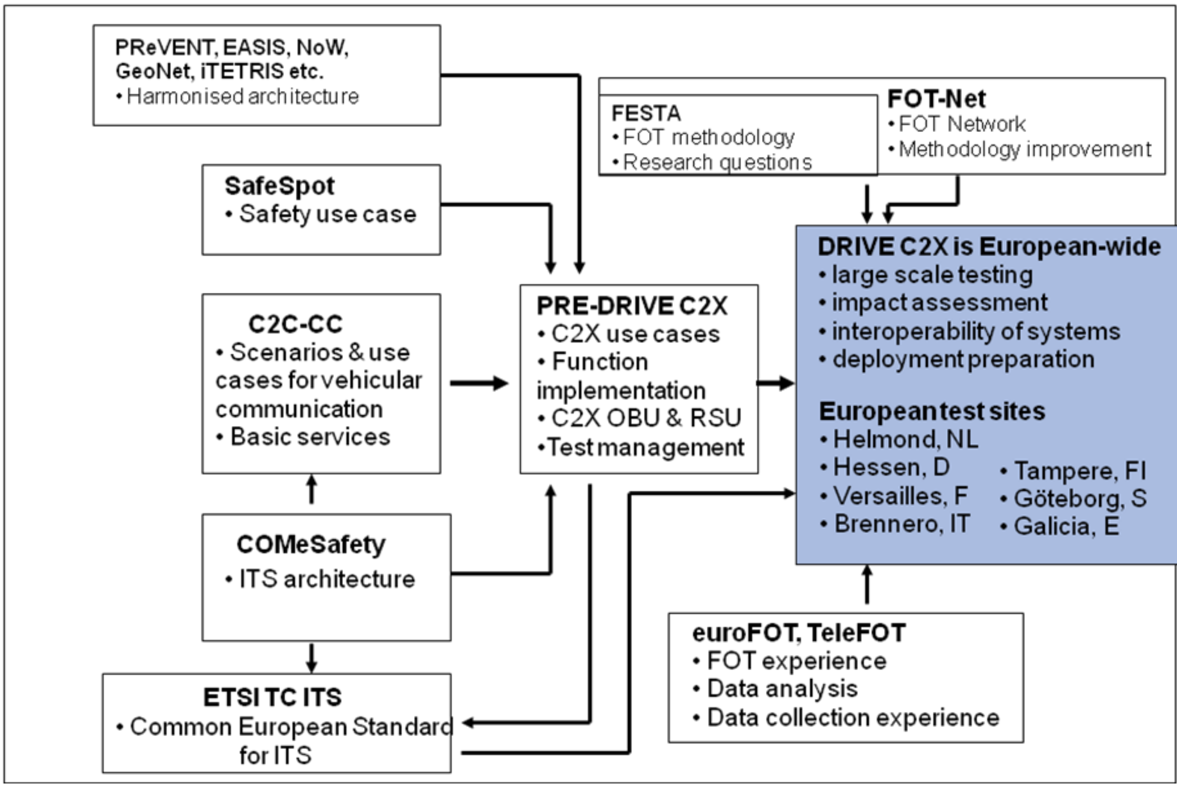


Figure 2: DRIVE C2X in the cooperative traffic activities context (Spain is an associated test site).

For data collection DRIVE C2X is following a two-pronged approach. First, DRIVE C2X is aggregating the data generated by the national FOTs during normal operation on national level. These data make the basis for the assessments carried out in DRIVE C2X but can only give a rough indication of the impacts cooperative systems will have on a European level. These data will be assessed for validity on European level and where possible the results will be scaled up for whole Europe. In parallel DRIVE C2X will conduct dedicated tests on DRIVE C2X specific functions, which have been selected with a view on maximum effectiveness on European level and are expected to give equal benefit in all European member states. By doing this, it is guaranteed that at the end of DRIVE C2X, a number of verified European applications of cooperative system technology are tested and impacts proven and quantified. These are accompanied by applications whose benefits in different European member states have been shown. This provides system developers with the possibility to design a common European system taking into account the particularities of the European member states, in which an existing vehicle is running most of its life.

The assessment to be conducted in DRIVE C2X will follow the guidelines set up by FESTA and is built on the experience gathered in already running FOTs with participation of DRIVE C2X partners such as euroFOT and TeleFOT. DRIVE C2X will make use of the networking possibilities provided by FOT-Net. This ensures that for system evaluation and impact assessment only well proven methods are applied that guarantee the Europe-wide validity of the results and their acceptance by stakeholders affected. The latter is of particular importance because implementation of cooperative systems requires considerable investments from the major stakeholder groups such as OEMs, infrastructure operators or authorities. These will make the necessary investments only if on the one hand it can be expected that their investment pays back in terms of money and other benefits in a reasonable timeframe, and on the other hand they can be sure that the systems installed can remain in operation for a long time and are not made redundant by new developments after a short time, as is the case with consumer electronics.

This is guaranteed by the fact that DRIVE C2X systems and applications are developed along the standards for European ITS systems that are currently under preparation by ETSI TC ITS based, among others, on the results of PRE-DRIVE C2X.

By building on the results of the projects in the field of vehicular communication that have been successfully completed and application of methodologies for test and evaluation, which are proven and accepted, DRIVE C2X prepares the way for successful introduction of cooperative systems in all European markets. The technology used is mature enough for series production. Consequently, the results of the field operational testing can really be used as basis for an implementation decision and the methodologies applied have been developed jointly by European industry and research institutes. This ensures that the results of DRIVE C2X are accepted by all parties involved, industry, road operators and authorities. They can all make their implementation decision on the same basis.

2.3 System architecture

The DRIVE C2X system is based on sub-systems as defined by the COMeSafety communications architecture [42][43], i.e. comprised of vehicle, roadside, personal and central subsystems (Figure 3). It is in line with the communications architecture standard published in ETSI EN 302 665 [44]. The DRIVE C2X project refines and enhances the system architecture that was developed by the PRE-DRIVE C2X project.

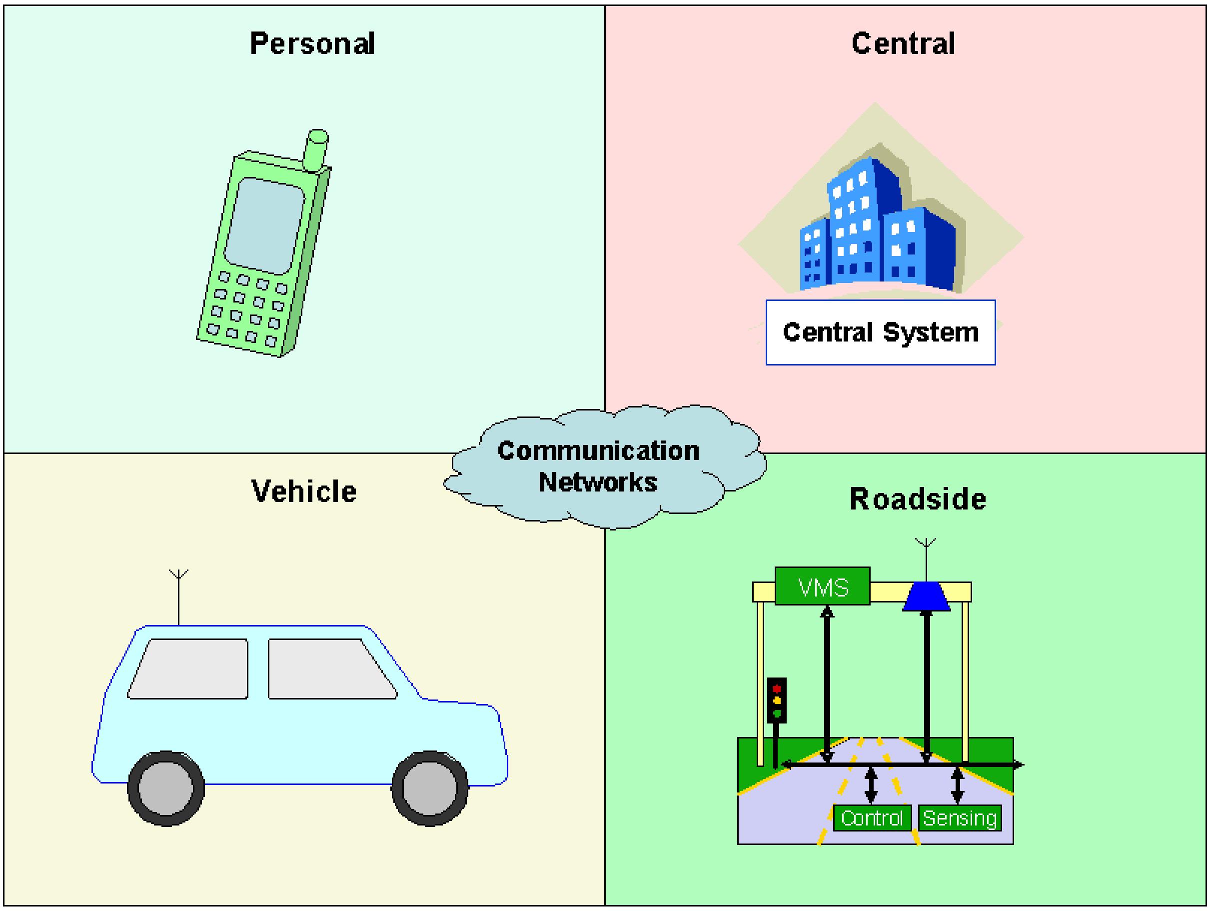


Figure 3: Sub-systems of the ITS Station Architecture following the COMeSafety communications architecture and ETSI EN 302 665 communications architecture

The DRIVE C2X system architecture makes use of the ITS Station concept and realises Vehicle ITS Stations (VIS), Roadside ITS Stations (RIS) and Central ITS Stations (CIS) as backend systems (Figure

4). To these core components, the DRIVE C2X projects adds test-specific components Test Management Center and Test Driver Communication Units.

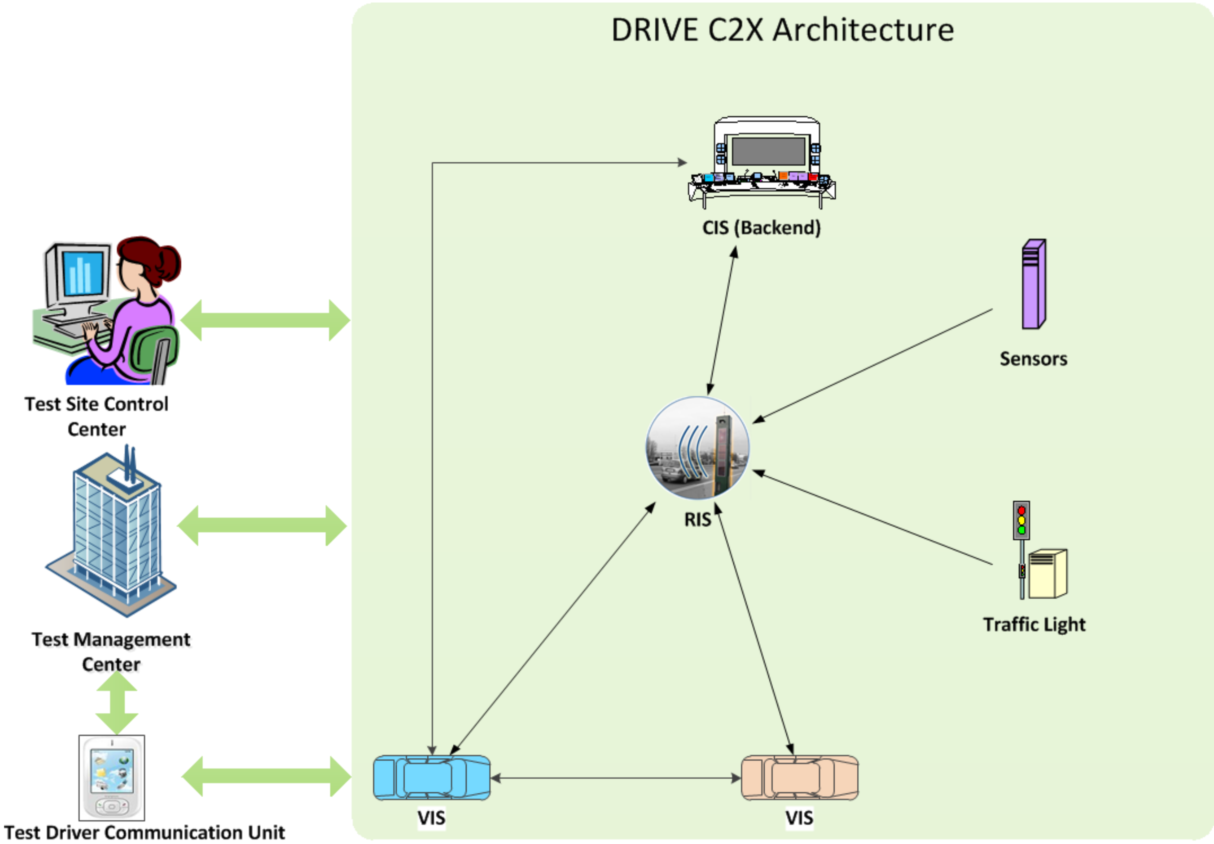


Figure 4: High-level system architecture

The DRIVE C2X system consists of several technology components made of software and hardware. These components rely on the system specification. The system uses state-of-the-art technology for cooperative systems and complies with standards developed in ETSI TC ITS. Figure 5 shows the technology components of the vehicle ITS station and Figure 6 those of roadside ITS station.

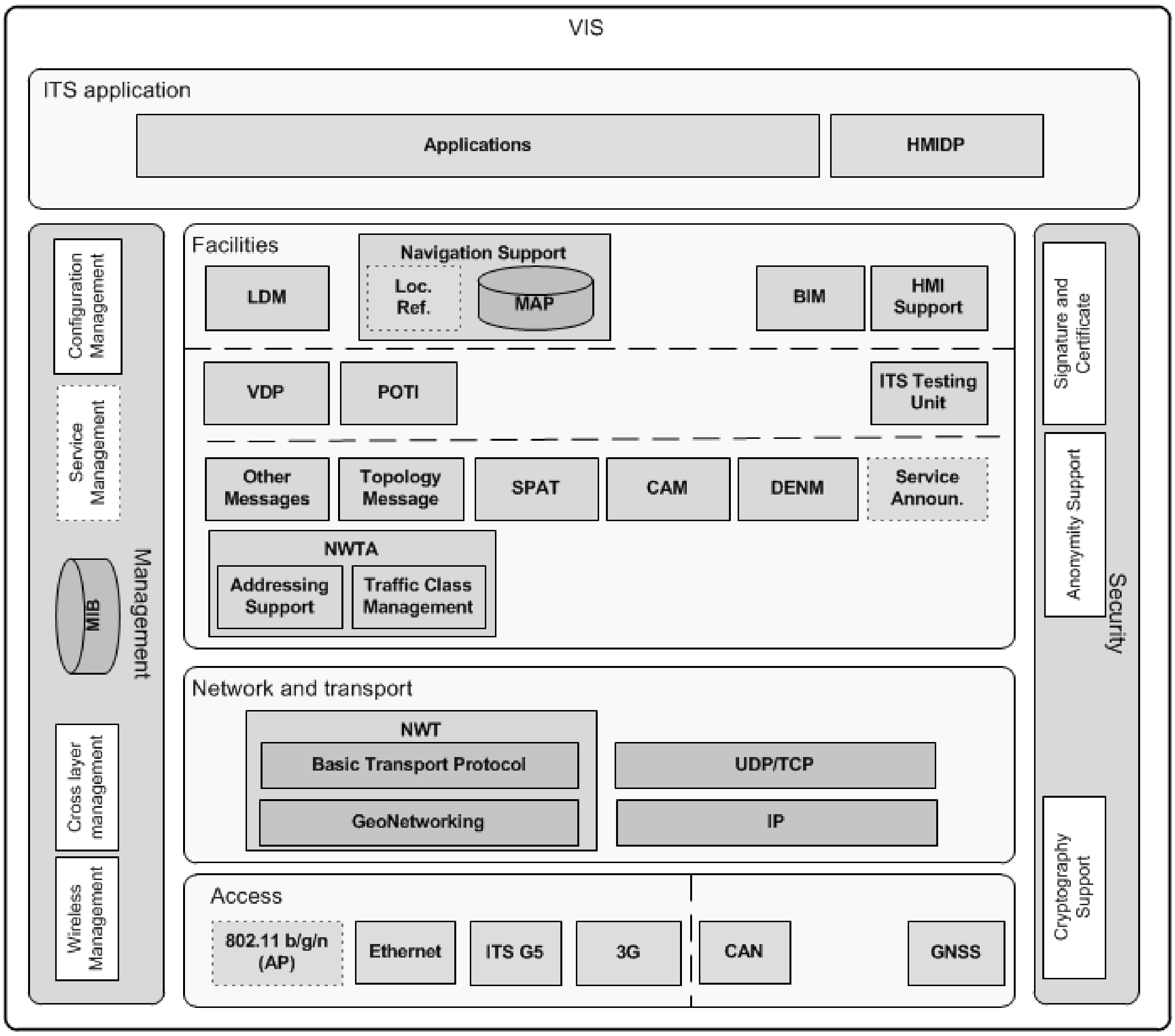


Figure 5: Technology components for the Vehicle ITS station (work in progress).

In Figure 5 the components at the bottom represent wireless access technologies, i.e., ITS-G5 based on IEEE 802.11p, 3G (UMTS) and Ethernet as well as IEEE 802.11b/g/n for access point functionality. Furthermore, it comprises different data sources, i.e., the vehicle data bus CAN and GNSS (GPS). Connected to the access technologies is the NWT (Network and Transport) component that provides networking and routing functionalities, such as GeoNetworking and IPv6 with their related transport protocols. On top of the NWT component, a set of "facilities" provide application support for messaging – CAM (Cooperative Awareness Messages) and DENM (Decentralized Environmental Notification Messages), for safety and traffic efficiency applications, and the so called BIM (Backend Integration Module) for business-related functions. Other components are for storing of contextual information in an ITS station's surrounding, i.e., the Local Dynamic Map (LDM) and facilitate the decoupling of the HMI from the applications (HMI Support). In addition, components such as the 'Location referencing' (LocRef) provide interfaces to use digital maps. All the facility components make use of OSGi, same as applications and management components do. Finally, security components mainly cover cryptographic protection and identity management including privacy functions.

Figure 6 depicts the components of the Roadside ITS station. Many components equal those in the Vehicle ITS station, but being specifically configured. Others are dedicated to Roadside ITS stations, such as the 'Sensor Roadside equipment'.

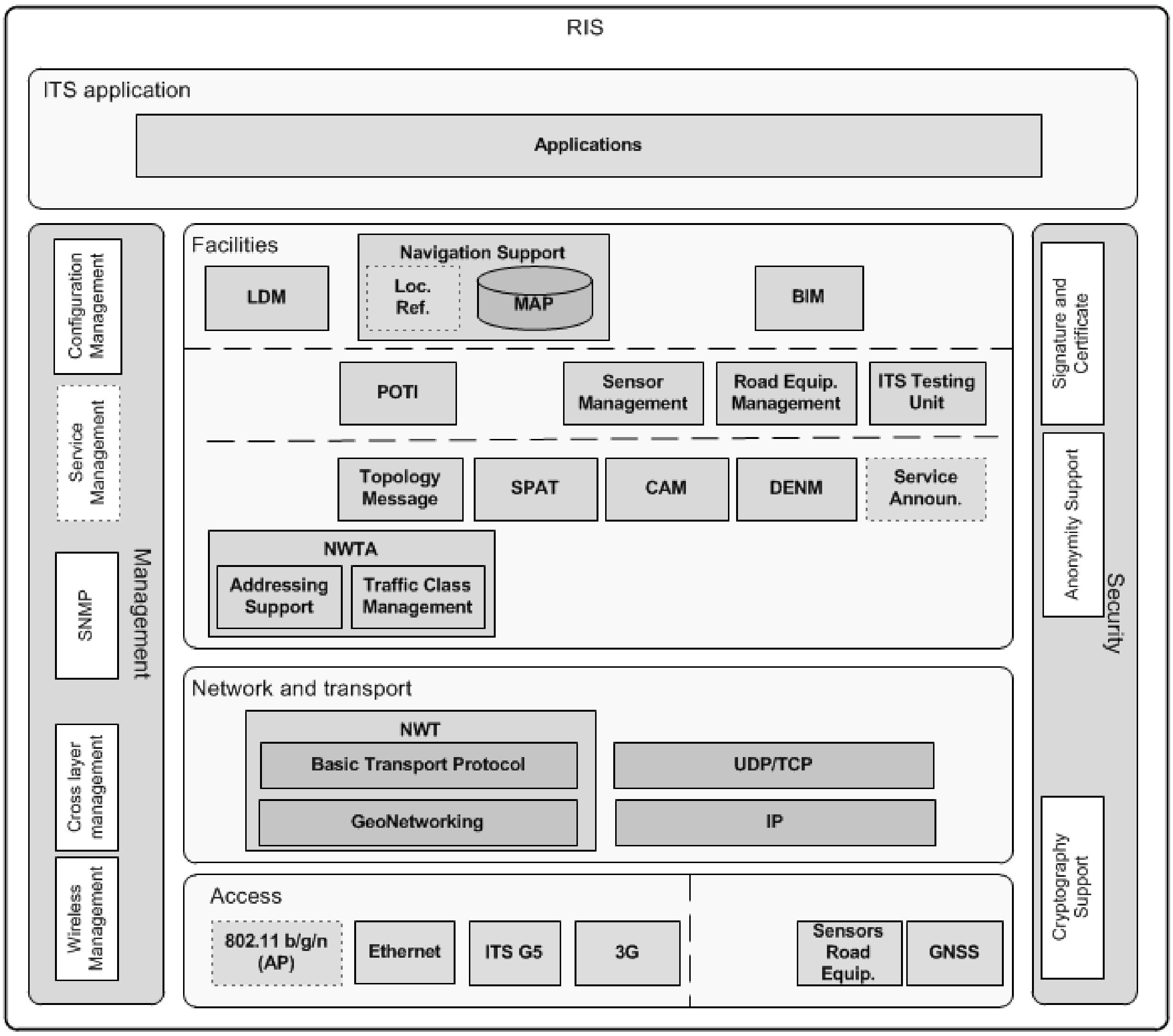


Figure 6: Technology components for the Roadside ITS station (work in progress).

The DRIVE C2X system includes two test environments that are specific for field operational tests. The two environments serve a dedicated purpose and apply different test methodologies:

Integrated simulation tool set: Multiple simulators (traffic, network, environment, and application simulator) are coupled to provide a fully virtual environment. The tool set is used to make an early evaluation of given aspects. By means of this set scalability effects can be studied, which even go beyond a FOT, for example traffic efficiency effects of thousands of vehicles.

FOT environment: This environment is based on real software and hardware prototypes for field operational tests. It is suited to run tests with moving vehicles and real drivers on closed test tracks and public roads in order to evaluate safety, (limited) traffic efficiency impact, and business systems. The capabilities of the FOT environment include communication aspects, driver interactions, and vehicle dynamics. The FOT test system has a focal point of control and observation, called Test Management Centre (TMC) and Testing Units for vehicle, roadside and backend communication equipment.

The combination of these test environments provides a comprehensive test system for evaluating and validating C2X systems. The use of multiple environments has the advantage that different aspects of component- or system tests can be addressed efficiently.

Because the development of functions and use cases is very time consuming and expensive, DRIVE C2X focuses on functions, which are fully developed and/or easy to implement. Functions which belong to the Basic Set of Applications (BSA) as defined by ETSI are therefore first choice because the standardization activities are focused on the support of these functions. The use cases should also belong to the predictable set of first phase functions for market introduction and should easily be understandable for the subjects. It is necessary to limit the number of functions in order to avoid an overload for the vehicle and road-side station and to find a feasible prioritization scheme.

2.4 Technology areas

DRIVE C2X has two technology areas. They are car-to-car communication (C2C) and car-to-infrastructure communication (C2I). Both technology areas are subject to road tests in this project. Table 1 shows the DRIVE C2X functions by technology area. These functions make the function-population out of which the functions are selected for a closer investigation in the field tests.

Table 1 lists all the functions defined first in PRE-DRIVE C2X and then by test site in DRIVE C2X. This set of functions comprises the pool for the selection of the testable functions as discussed below. The choice of technology areas is partly based on a need to test some functions on a European scale, while other functions are site-specific based on national needs.

Table 1: Potential DRIVE C2X functions by technology and test site as defined by PRE-DRIVE C2X (* = Associated test site).

Function	DRIVE C2X function	Test site specific function	NL	DE	SE	IT	FI	FR	ES*
Safety-related functions									
Road works warning	C2I		X	X	X	X	X	X	X
Traffic jam ahead warning	C2C		X	X	X	X	X	X	X
Car breakdown warning	C2C		X			X	X	X	X
Weather warning	C2I		X	X	X		X	X	X
Emergency Electronic Brake Light	C2C		X	X				X	X
Approaching emergency vehicle warning	C2C		X	X		X	X*		X*
Motorcycle approaching indication	C2C		X	X					
Post crash warning	C2I		X			X		X	X
Slow vehicle warning		C2C		X		X	X		X
Stop sign violation warning		C2I		X				X	
Obstacle Warning		C2C							X
Wrong way driving warning in gas stations		C2I				X			
Hazardous location notification		C2C				X			
Curve speed warning		C2C				X			
Traffic efficiency-related functions									
In-vehicle signage	C2I		X	X	X	X	X		X
Green-light optimal speed advisory	C2I		X	X	X			X	X
Regulatory and contextual speed limit		C2I		X	X	X		X	X
Traffic information and recommended itinerary		C2I		X				X	X
Decentralized floating car data		C2C		X	X				X
Selected infotainment, business and deployment-related functions									
Point of interest notification	C2I		X			X		X	
Insurance and financial services	C2I		X						
Dealer Management	C2I		X					X	
Transparent Leasing	C2I		X						
Vehicle software provisioning and update		C2I						X	
Fleet management		C2I							
Local electronic commerce		C2I						X	

3 Field Operational Tests overall concept and scope

3.1 Requirements for Field Operational Tests

Field Operational Test (FOT) is a tool currently being used and actually tested in therefore large-scale European FOTs, euroFOT, TeleFOT, DRIVE C2X and FOTsis. These projects are running and will provide new knowledge on the impacts of ICT systems and functions in vehicle environment. Furthermore, they also show EC and other stakeholders how the requirements for this relatively new type of R&D activity in the EC tools portfolio can be fulfilled.

The objectives FOTs with ICT systems must address have been defined in a number of workshops and Expert Meetings organised by the EC. They are summarised below:

1. Validate the effectiveness of ICT based systems for safer, cleaner and more efficient transport in real environment,
2. Analyse driver behaviour and user acceptance,
3. Analyse and assess the impact of intelligent safety and efficiency functions using real data,
4. Improve awareness on the potential of intelligent transport systems and create socio economic acceptance,
5. Obtain technical data for system design and product development,
6. Ensure the transferability of the FOT results at national, European and international level.

Furthermore, with regard to the nature of FOTs the EC said, that "FOT's shall focus on technically mature ICT systems including technical, user acceptance, efficiency and deployment aspects and shall raise awareness for the technologies tested" [2].

Based on the above quotations and objectives, the following issues and research questions need to be addressed in FOTs:

- Focus on ICT systems assisting drivers,
- Focus on mature systems and technology,
- Investigate different aspects such as:
  - usability and willingness-to-have aspects ("how new functions and systems suit the user"),
  - impacts on behaviour,
  - impacts on safety,
  - impacts on efficiency,
  - impacts on environment (economic / "green" driving),
  - socio-economic impacts,
  - technical and commercial feasibility / business models.
- Study also long-term impacts,
- Use robust scientific methods to study the impacts of ICT systems,
- Raise awareness among the public of the ICT systems in assisting drivers.

The core of the work according to EC requirements is to *test mature technologies and functions & services they provide* in Intelligent Transportation Systems (ITS) and to *show their potential and the road ahead* in improving sustainable traffic.

The Strategic Research Agenda for ICT for Mobility by eSafety Forum Working Group RTD (p.28, 2006) describes the challenges of Field Operational Tests as follows [2]:

"There is an urgent need to gain and extend knowledge, facts and real data on ICT based systems for driver support, safety and traffic efficiency as a basis for socioeconomic cost/benefit analysis, impact assessment on driver behaviour safety and efficiency and development of business models for the market deployment of these systems".

It becomes evident that there are different levels and aspects in new ICT-based systems FOTs need to address – from a single act of behaviour to societal level impacts.

Furthermore, the report presents several aspects (page 28) that need to be addressed in FOTs :

1. Confidentiality and IPR need to be guaranteed for the partners supplying the equipment, functions and services used in the FOT.
2. The FOT should not be designed as an exercise to compare and grade different branded products. It should instead focus on assessing the functionality of the ICT system and its impact on driver, safety, etc.
3. Experimental design of the FOT and evaluation of the collected data should be done by parties independently of suppliers of equipment
4. Experiences and results from FOT or similar trials done in EU member states, USA (such as VII) and Japan (such as VICS) should be used in building future FOTs.
5. Identification and, when missing, development of necessary and sufficient procedures, methods, assessment schemes, simulation methods, to plan, implement and evaluate a high quality FOT needs to be addressed.
6. Experimental and trial set-up of the FOT must not influence or distract the driver from his/her driving or normal driving behaviour.
7. FOT should be designed to obtain sufficient data (benefit, adding value process, revenue model) necessary to develop business models in a way that reflect real market conditions.

3.2 Basic concepts

3.2.1 System

A system is a combination of hardware and software enabling one or more functions. In a system, there are a set of elements (e.g. sensors, a controller, and an actuator) in relation with each other according to a design. An element of a system can be another system at the same time. Then this is called a subsystem according to FESTA-methodology. The DRIVE C2X system is based on C2I and C2C communication technologies.

3.2.2 Function

From an engineering point of view, a function is an action, activity or task that must be accomplished by a system to achieve a desired outcome. It indicates the outcome of the system from driver's point of view. The outcome of a function is directly related with driver behaviour and expected impacts on driver behaviour (EAST-EAA in IEEE Guide for Developing System Requirements Specifications; IEEE Standard P1233a, 1998).

3.2.3 Use case

A use case 'defines a subset of functionality of a system. It is a description of how a function is intended to interact with the driver in a particular target scenario. Use cases treat the system as a black box, and the interactions with the system, including system responses, are perceived as from outside the system. Each use case captures: 1) the actor (driver); 2) the interaction, how does the system react to driver input; 3) driver's goal (www.usability.gov).

3.2.4 Scenario and target scenario

A scenario is a synthetic description of an event or series of actions and events. A target scenario is a precise formulation of the problem situation to be addressed by a function or use case developed.

The target scenario describes the scenario where an envisioned system can be operational and proactive in order to prevent accidents or other undesired outcomes. A target scenario thus describes the problem to be solved, the accident scenario, but not the solution (the interaction between the system and the driver). The target scenario is defined in terms of environmental-, vehicle- as well as driver parameters

Use cases are generally derived from target scenarios. Thus, the target scenario defines the problem and the use case defines, on a suitable level of abstraction, how it should be solved by the function in interaction with the user. The next step is therefore to define *how* the intended functions should prevent/mitigate the undesired outcomes defined by the target scenarios. This is the role of the *use cases*.

3.2.5 Test scenario

A test scenario is a use case in a specific situation according to FESTA methodology. A situation is a combination of certain characteristics of circumstances and features of an application.

Test scenarios are test cases, and the sequence in which they are executed. Test scenarios are test cases that ensure that everything is tested from beginning to end. Test scenarios can either be independent tests or a sequence of tests where each is dependent upon the output of the previous one. Test scenarios are prepared by reviewing functional requirements and preparing logical groups of functions that can be further broken down into test procedures. Test scenarios are designed to represent both typical and unusual situations that may occur in/with the application. (www.robdavispe.com 10.2.2011) Specification of a test scenario defines which features of the application and which circumstances will be covered.

The relation of the basic concepts described above is illustrated in Figure 7 below with simplified exemplary cases.

Terminology	**Example**
System	DRIVE C2X cooperative system
Function	In-vehicle signage
Use Case	Driver is approaching a school zone sign and gets information about it
Target Scenario	Vehicle is approaching a school zone sign and does not react accordingly.
Test Scenario	▪ Driver approaching a school zone in the morning/ in the evening ▪ Information is given about 60s/ 30s before the traffic lights ▪ etc.

Figure 7: Relation of the basic concepts in DRIVE C2X with examples.

3.2.6 Hypothesis

A hypothesis is an assumption of an outcome of an event. In an experimental design a hypothesis is a testable postulate of that outcome. In the experimental language a hypothesis is the predicted and verifiable outcome of an experimental manipulation. This can be translated into the statistical hypotheses H0 and H1 which are statements about the conditional probability of data under a certain distribution within the population.

3.2.7 Event

An event is a specific driving situation relevant to the function. Time-wise, the event begins when the driver reaches the distance at which the function is activated or would be activated, and ends when the driver encounters the location/situation that triggered the activation of the function, or deviates to an alternative route.

3.3 Related Field Operational Tests

3.3.1 euroFOT

euroFOT investigates the impacts of ADAS in a real environment with normal drivers and for a sufficient long period that enables the collection and processing of data in a statistically sound way. Extensive field operational tests have been set up to assess the impacts of ADAS in real traffic, in order to determine in which ways the effectiveness of ADAS regarding traffic efficiency, safety and environment can be improved. Totally, more than 700 test vehicles from different manufacturers and with different ADAS take part in the FOT.

euroFOT investigates systems that are already on the market or sufficiently mature to be tested with target as commercial applications. Based on the recommendations from existing roadmaps and on the availability of well developed systems, the following group of nine functions was selected for euroFOT:

1. Longitudinal functions:

- Adaptive Cruise Control (ACC),
- Forward Collision Warning (FCW),
- Speed Regulation System (SRS).

2. Lateral functions:

- Lane Departure Warning (LDW),
- Impairment Warning (IW),
- Blind Spot Information System (BLIS).

3. Other functions:

- Curve Speed Warning (CSW),
- Fuel Efficiency Advisor (FEA),
- Safe Human-Machine Interaction for Navigation Systems (SafeHMI).

These functions are tested in different vehicles from different European OEMs using different data acquisition systems for logging different data (CAN-data, video, GPS etc.). The FOT is carried out via various test sites across four countries in Europe, which are managed by the so called vehicle management centres (VMC). The four test sites are:

1. Sweden: all vehicles will be managed through Chalmers with support from Volvo Cars Volvo Trucks internal organizations.
2. Germany: five OEMs manage their vehicles separately through their internal structures:
    - Ford
    - Audi
    - VW
    - MAN
    - Daimler
    - BMW
3. France: CEESAR will manage vehicles with the support LAB.

4. Italy: CRF/POLI, Questionnaire-based study will be conducted.

Compared to DRIVE C2X, euroFOT has the focus on testing timeline-wise applications that are preceding cooperative driving functions. The aim of cooperative driving system is foresighted driving, to support drivers in becoming aware of hazards before the range of ADAS that is some 200 meters.

Concerning synergies between DRIVE C2X and euroFOT, there are areas related to data collection and transfer. Since there are partly same partners in both the projects, these synergies are currently being used.

3.3.2 TeleFOT

TeleFOT addresses the use and impacts of aftermarket and nomadic devices such as smart phones and navigators providing driver support and travel assistance functions for drivers. The project work supports especially the development of upcoming cooperative driving applications.

TeleFOT comprises of three test communities in Europe (Figure 8).

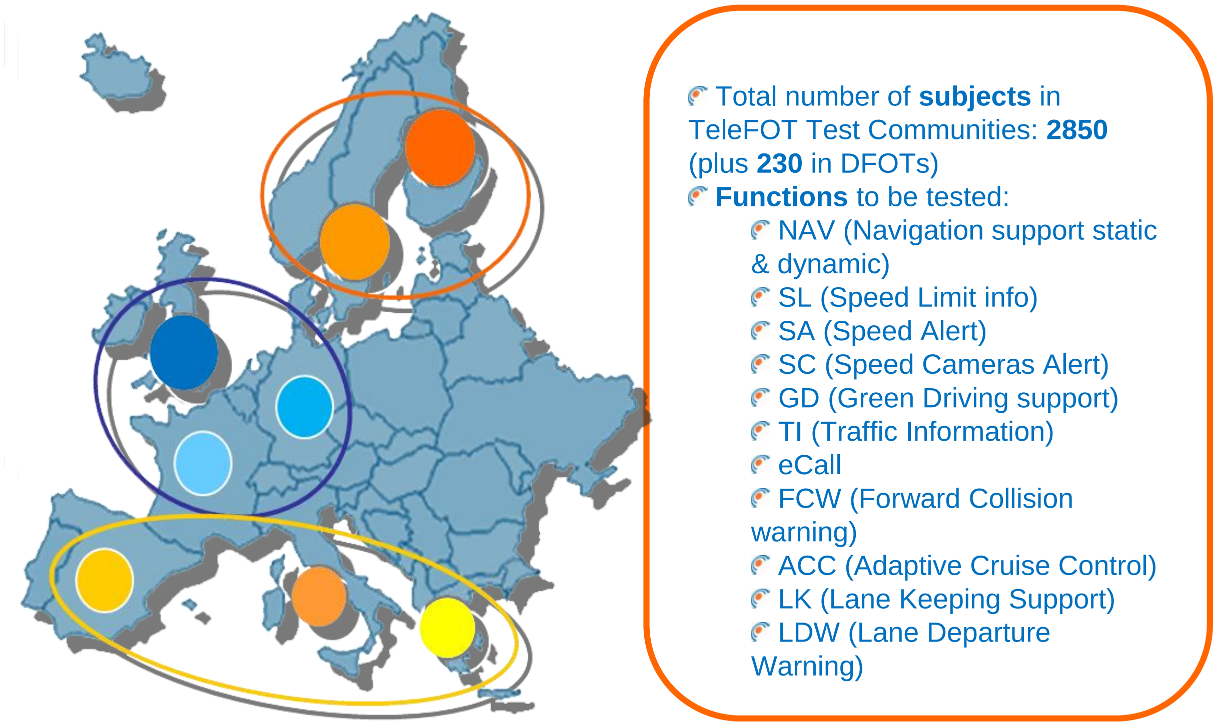


Figure 8: TeleFOT testing communities and functions under tests.

The functions and services to be tested and evaluated make basically three areas:

1. Widely recognized functions and services promoting safe driving. These are (i) *Speed management and driving behaviour support* such as speed alert, speed limit information and feedback on driving behaviour (ii) *Traffic information* such as information on congestion, incidents, road works and accidents (iii) *Road weather information* on adverse driving conditions and (iv) driving debriefing like 'pay-as-you-drive'-concept.
2. Functions and services supporting efficient and economic driving. These relate to (i) "green driving", (ii) navigation support and (iii) services for professional drivers.
3. A novel solution to eCall by means of retrofitted navigator integration is tested and compared with existing dedicated eCall devices/systems.

The project concept closely relates to cooperative driving – especially C2I - since aftermarket & nomadic devices used in vehicles receive the information contents from background systems through traffic information databases, GPS, telecoms operators and service providers. For this reason, the project provides an excellent opportunity to test functions and services foreseen in cooperative driving systems after 2015.

3.3.3 FOTsis

FOTsis (Field Operational Tests on Safe, Intelligent and Sustainable Road Operation) is a "Large-Scale Integrated Project" submitted for public European funding on April 2010 within the call FP7-ICT-2009-6 ("Mobility of the Future") under the 7th Framework Programme of the European Commission (EC). FOTsis is one of the two Large IP Projects (Integrated Project) granted in this call, promoted by Spanish infrastructure operators leading a Consortium of 23 companies and research centres from 8 European countries and over 13 million Euros budget, targeting a large-scale deployment and testing of cooperative services, in a multiple Pan-European environment.

Infrastructure operators have detected lack of definition of tools (standards, services and regulations), from the infrastructure point of view, with the aim of a deployment of cooperative systems in the European transportation infrastructures.

FOTsis is based on some of the main research lines of the OASIS Project (Operation of safer, more intelligent and more sustainable highways), a Spanish CENIT project with a budget of 30,5 million Euros, ending in December 2011.

The objectives of FOTsis are the following:

- Encourage the development, standardization and deployment of cooperative services in a large scale (information exchange between vehicle and infrastructure) to improve, by means of new technologies, the safety and mobility management in the highways,
- Contribute to a safer, more intelligent and more sustainable road transport system,
- Develop a common ITS & communication architecture for the European infrastructures, according to the European standards,
- Promote the implementation of this architecture and these services in the existing and future highways,
- Generate business models to promote these services,
- Dissemination of cooperative services vs. infrastructure,
- Ensure that the infrastructure is prepared to current and future cooperative services.

Services to be tested include:

- Emergencies and incident management,
- Intelligent congestion control,
- Dynamic route planning,
- Special vehicle tracking,
- Advanced enforcement,
- Safety systems assessment.

For mobility services, the highway traffic control centre can provide real time traffic information, acquiring data from both the infrastructure sensors and the vehicle travelling on the highway. Once the data is processed, this information can be forwarded to users, individually or by broadcast. Therefore, a user that sends his/her position and foreseen route, will receive the optimal route taking into account the real traffic situation, and other alternative routes, providing a better reliability on arrival time. On the other hand, the infrastructure operator will have different elements for traffic management, like variable speed limits, congestion management tools or route planning.

Regarding safety, the infrastructure operator can have an important role for incidents/accidents management, once it has been detected automatically through an emergency call from the vehicle (e-Call) or by means of the incident detection systems installed in the infrastructure: sending images of the accident in real time to the emergency vehicles will allow to improve the logistic of its management. Moreover, the emergency vehicles route can be optimized taking into account the real traffic situation and by means of automatic opening of toll lanes or infrastructure barriers. Furthermore, all safety services will include individual notice to warn other vehicles about safety hazard, depending on their given situation.

The services mentioned above will be tested in nine different scenarios in four different countries (Table 2). Every service will be tested in two different scenarios.

Table 2: Services and scenarios in FOTsis to be tested by country.

		Total length (km)	ADT (vehicles/day)	Services to be tested
SPAIN	M-12 Airport Axis (Autopista Eje-Aeropuerto; OHL Concesiones)	9,4	20.000	S1: Emergency Management S2: Safety Incident Management
	A2 1st stretch (Autovía de Aragón Tramo 1; OHL Concesiones)	56,1	90.000	S3: Intelligent Congestion Control S4: Dynamic Route Planning
	A2 3rd stretch (AUMECSA; IRIDIUM)	90,0	22.000	S2: Safety Incident Management S5: Special Vehicle Tracking
PORTUGAL	Baixo Alentejo (Planestrada)	247	17.000	S5: Special Vehicle Tracking S7: Infrastructure Safety Assessment
	Algarve Litoral (Marestrada)	346	28.000	S6: Advanced Enforcement S7: Infrastructure Safety Assessment
GERMANY	A99 (South-Bavarian Motorway Authority ABDS)	54	95.000	S3: Intelligent Congestion Control S4: Dynamic Route Planning
	A9 (South-Bavarian Motorway Authority ABDS)	529	130.000	S3: Intelligent Congestion Control S4: Dynamic Route Planning
	A92 (South-Bavarian Motorway Authority ABDS)	134	71.000	S3: Intelligent Congestion Control S4: Dynamic Route Planning
GREECE	Pathe Motorway (NEA ODOS)	186,5	90.000	S1: Emergency Management S6: Advanced Enforcement

4 Drive C2X FOT methodology

4.1 Principles of field tests

Over the last decades, a number of different methodological approaches to study driver behaviour and safety as a reaction to changes in the driving or vehicle environment in field tests have been developed. A typical and often used sound methodology for a comprehensive approach is depicted in Figure 9. Usually, the procedure is started by studies on usability aspects. Actually, these issues should be settled already in the applications development phase. However, often this is not the case, and a number of shortcomings in the applications have been identified. In terms of DRIVE C2X, this is also an issue, for instance how suitable small displays or simultaneous information through two channels (auditory, visual) are for a driver to cope with.

After usability and ergonomics issues, actual behavioural studies have their turn. They usually deal with driver workload and the assumed behavioural adaptation.

In long-term testing and depending on the method used, also incidents, hazardous or exceptional situations (level 2) can be recorded.

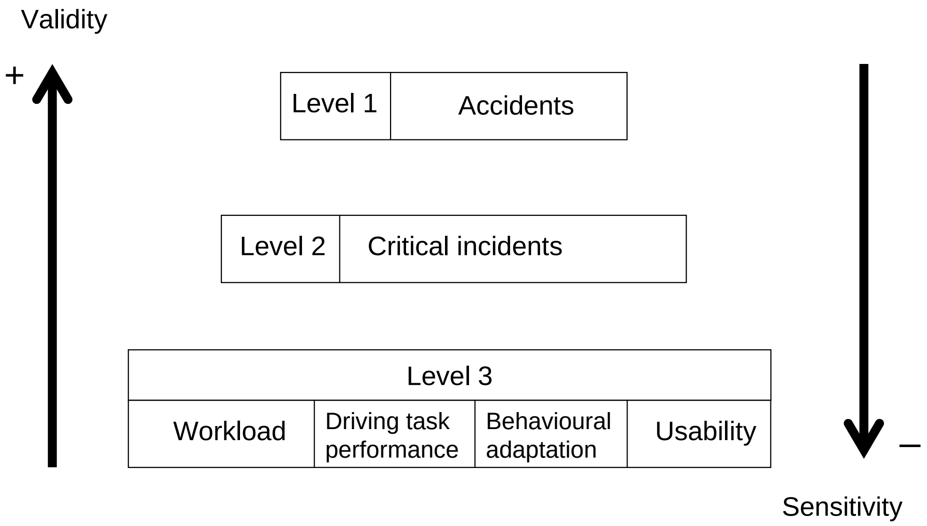


Figure 9: General methodology to assess the impacts of various measures on driver behaviour and safety.

The Traffic Conflict Technique (TCT) is perhaps the most developed indirect measure of traffic safety [10]. The technique itself is grounded in the ability to register the occurrence of near-accidents directly in real-time traffic and therefore offers a faster and, in many respects, more representative way of estimating expected accident frequency and accident outcomes.

The conflict technique emanates from research originally at the Detroit General Motors laboratory in the late 1960's for identifying safety problems related to vehicle construction [9]. The use of this technique soon spread to different parts of the world. TRL in England soon recognised the need to add a subjective scale for observed conflicts as a measure of severity [23]. This technique was based on observer judgements using time-lapse filming, thereby proving costly and time-consuming. The Swedish Traffic Conflict Technique (STCT) was developed at LTH in different projects during the 1970's and 1980's before finally reaching its present day level of development in 1987. The Swedish technique focuses on situations where two road-users would have collided had neither of them made any kind of aversive manoeuvre. The point at which the aversive action is taken is recorded through observation as the "Time-to-Accident"(TA). The TA value together with the conflicting speed is used to determine whether or not a conflict is "serious".

The association of conflicts and accidents is depicted as a pyramid showing the relationship between conflicts and accidents (Figure 10).

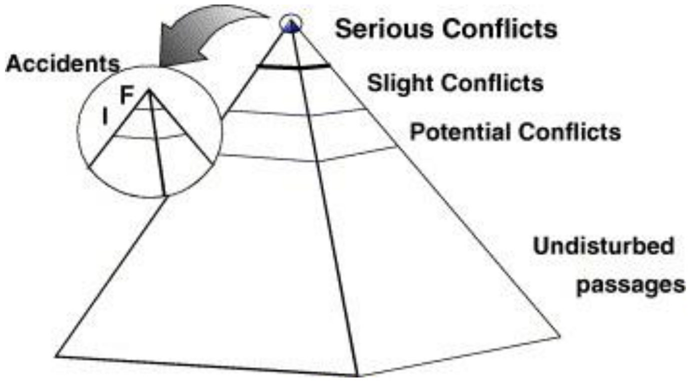


Figure 10: Relationship of critical incidents i.e. conflicts and accidents [10].

There have been validity concerns associated with the relationship between serious conflicts and the number of accidents. An American study [8] showed that normal conflict studies could produce estimates of average accident frequency that were at least as accurate as those based on historical accident data, and Svensson [24] concluded from Swedish data that serious conflicts provide a better estimate of the number of expected accidents involving personal injury. The results of studies in many different countries have also been compared to show that the relative statistics for conflicts and accidents are in agreement despite environmental differences. Depending on the design of the experiment, conflict technique – or a derivative of it - is one method under consideration in TeleFOT too. The real benefit of conflict technique resides in the relation of conflicts and accidents allowing the prediction of actual accidents based on the number of conflicts recorded.

Potential methods used in TeleFOT, euroFOT and DRIVE C2X-type of long-term studies are listed in Table 3 below. Often different methods complement each other and are not used alone. The following table gives a crude overview of possible methods that can be used in FOTs. Table 3 is only referential, since other combination of the methods/designs/significance testing than listed in the table can be created. Furthermore, intelligent vehicle technologies give totally new possibilities to use "old" methods in a novel way. For example, conflicts can be recorded automatically by means of vehicle systems and driver behaviour can be studied through driver monitoring systems developed for vehicles.

Table 3: Methods, design and significance testing generally used in FOTs to study driver behaviour.

Method	Design	Significance testing
In-vehicle instrumentation obtrusive (recording process visible)	Before-after with or without a control group	Multivariate tests, t-tests, non-parametric
In-vehicle instrumentation unobtrusive (no visible instrumentation or recording)	Before-after with or without a control group	Multivariate tests, t-test, overall parametric tests
Driving-log	Usually not related to a design; could be a part of experimental design	Mainly descriptive, non-parametric – but depending on the measurement scale also other possibilities
Observation (in-vehicle)	Usually not related to a design; could be a part of experimental design	Descriptive, non-parametric usually
Interviews / surveys	Could be a part of before-after design	Descriptive, non- parametric, parametric (with reservation)
Observation (outside vehicle) -usually focus on traffic flow or single behaviour features. Used less in actual FOTs - Traffic Conflict Technique (TTC)	Before-after with or without a control group	Multivariate tests, t-test, overall parametric tests

4.2 Basis for the methodology

4.2.1 Test design principles

DRIVE C2X project is above all a methodological activity, since the main objective is to show the most likely impacts of cooperative systems on users, society and provide useful information for further development of cooperative systems. The project resorts to the following main pillars in developing and implementing its methodology:

- Results of PRE-DRIVE C2X (and its predecessors) tools and methods necessary for successful test and evaluation of cooperative systems in a field operational trial.
- FESTA handbook for FOT methodology, especially the V-shaped 'FOT-chain' to plan the testing procedure [6].
- Ongoing three large-scale European FOTs: euroFOT, TeleFOT and FOTsis.
- Partners' own experiences in carrying out user tests in field conditions during the past 20 years.

As stated above, the project follows the 'V-procedure' introduced in FESTA as illustrated in Figure 11 below.

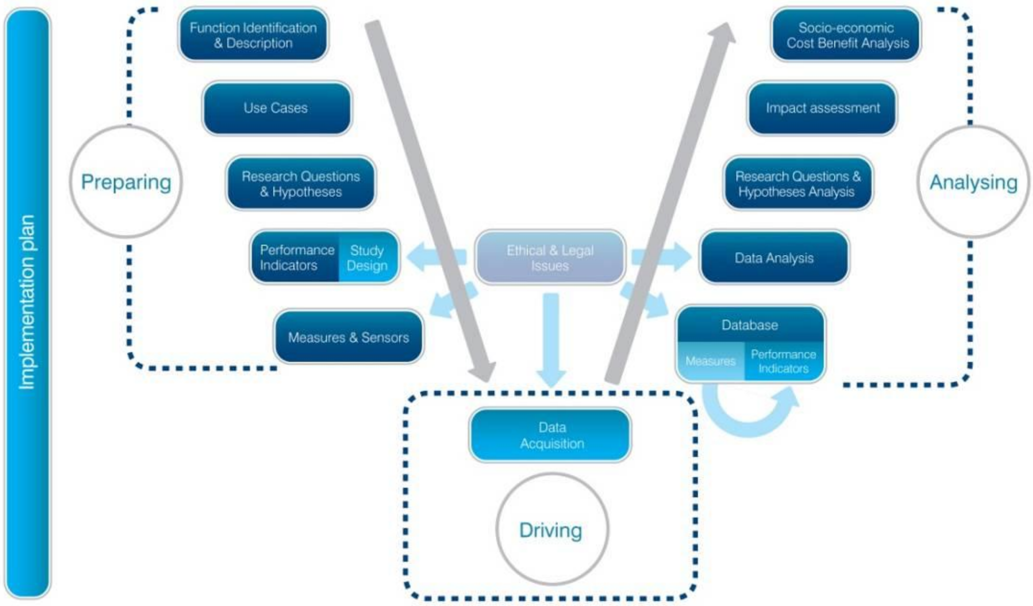


Figure 11: FESTA V-shaped FOT testing process [6].

Since DRIVE C2X builds strongly on PRE-DRIVE C2X work, where already main functions for testing were defined and use cases were identified, main emphasis in the following is put on the presentation of research questions & hypothesis, performance indicators and actual testing from the point of data acquisition and eventually, evaluation procedures.

According to the FESTA V-process, the identification of use cases leads to the creation of the research questions and hypothesis that are testable postulates on the outcome of a given use case. The use cases presented in this deliverable constitute the first step in a precise hypothesis formulation, and can be used when the related research questions on the major effects of the function(s), including differential effects by population subgroups, will be defined.

Based on the research questions, performance indicators for

- driving and system performance,
- system influence on driver behaviour,
- HMI and usability,
- traffic safety, efficiency and environmental aspects,
- system acceptance and trust and others

will be identified, described and compiled. The results of the FOT design are presented in the DRIVE C2X deliverbale D42.1 "DRIVE C2X FOT research questions and hypotheses and experimental design".The list of suggested performance indicators will be presented both with help of a matrix that specifies, which performance indicator can be used to evaluate which aspect of a FOT, and with a detailed description of how a performance indicator is calculated, which variables are needed for it, and in which way it is related to the various aspects of impact of the functions under test.

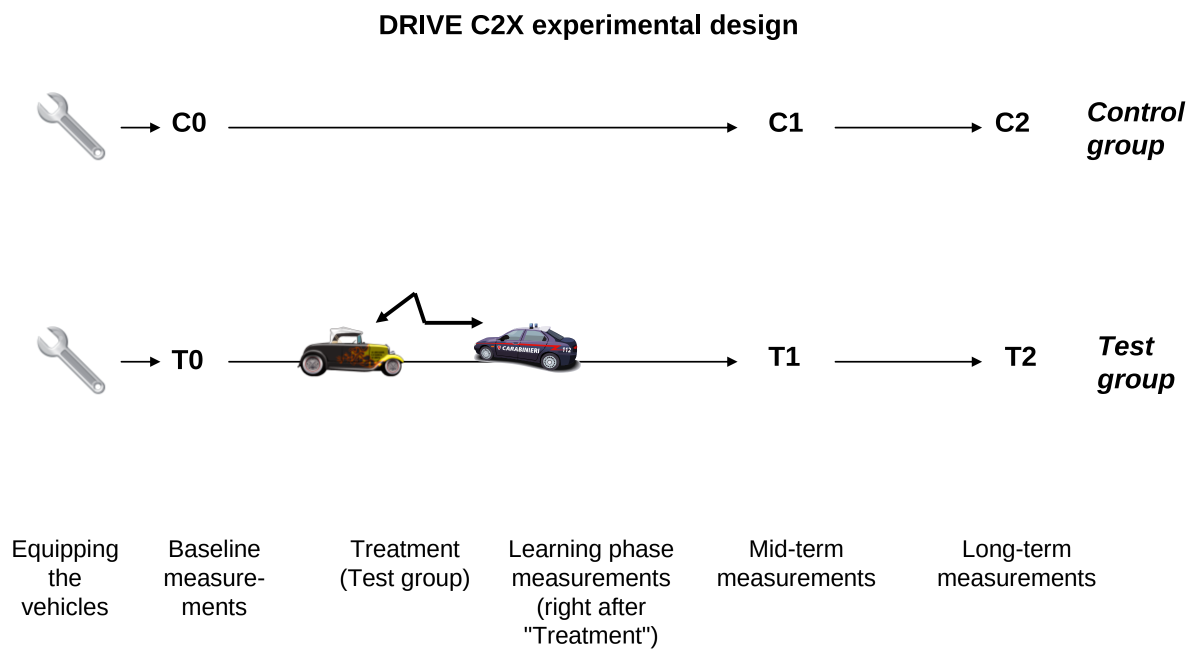
Overall, the following principles will be observed in the design of the tests:

- *Controlling random variation* (either through within-subject design or between-subject design). It is likely that both designs will be used: the first one in detailed testing and the second one in large-scale testing). The issue in testing is not that much the magnitude of the impact but rather the magnitude of error variance masking true effects. The main focus in study design is put on this factor.
- *Long-term testing* to find out the learning curve in impacts penetration and true impacts of the so called established behaviour.

- Subject recruitment follows established *sampling techniques* to eliminate bias in the generalisation of results. Proper focus on subject selection will decrease error variance too.
- An *Automated* system as far as possible for the data collection and for aligning the recorded data with its physical context and road location attributes saving a lot of time and resources in the analysis phase. Here the project will consult TeleFOT [11].

A very important step is the actual tests planning and therein the selection of the experimental design, since it has an impact on the subject recruitment, organising the testing activity and selection of statistical significance testing methods – all these labour-intensive activities. The selection of control is the key to isolating the real impacts from random fluctuation of behaviour. Here the robust control will be the primary goal (Figure 12). In the within-subject design subjects serve as their own control and between-subject design, subjects are split into two comparable groups, of which the only one will have the given functions for use while the other group will serve as a control group.

The decision on which type of control to use will be based on the overall methodology. The latter will be fixed in detail in the initial planning phase of the project, and it also influences the data management and functions selected for the tests. Both types of control methods are likely to be used, depending on the function to be tested.



Co = Control group measurements in the base-line situation; To = Test group measurements in the Base-line situation; C1 Control group measurements some time after test group has been exposed to treatment (e.g. Road works warning). T1 = Test group measurement after it has been exposed to treatment as explained above. C2/T2 = Long term measurements. Between Co and C1 / To and T1 the test group has been exposed to treatment.

Figure 12: Basic experimental design approach applied in DRIVE C2X.

Currently, the planning of the tests is underway, and it is likely that several designs will be used depending on the function to be tested. The precise test designs will be featured later in the deliverable D42.1 DRIVE C2X FOT Research Questions and Hypotheses and Experimental Design.

4.2.2 Data management

General principles

Data management is one of the core activities in the methodology development. It has been tentatively decided that all pre-processed and cleaned large-scale field operational test data will be collected to a central file storage. This is done to:

- Ease the actual analysis of the data – access to the data, harmonisation, being able to collaboratively analyse all impact areas of a FOT and not just a single FOT,
- Create a final storage,
- Enable easier comparison of functions across test sites and gain statistical relevance with low number of drivers – when in question.

Some naturalistic FOTs collect a large video archive for a later analysis. So far this has not been a goal in DRIVE C2X, so data collection to the central database would not include long video recordings. However, processed results from video data or short clips from events can be collected. Raw CAN data will not be collected either but variables extracted from CAN.

If needed (depends on list of hypotheses) and possible, national traffic, weather and service-related log data will also be collected to the central repository. Strictly confidential data and log files from special instruments (that require special software to process) should be kept out and analysed/processed on a test site level.

VTT has been planned to operate the central server and databases. The collection will include a number of FOT documents describing the study and providing additional details to support analysts. For an initial list of documents and questionnaire results to collect from a FOT, see chapter "Bundling FOT Data".

For privacy reasons, the personal information of the test users will not be collected to the central database but these contact lists remain with named persons at each test site. Each user will be represented by a unique, numeric user ID (e.g. 1000032, country_num_00_user_num, to be decided) in the central database. The same ID would be printed to user agreements and used when filling in questionnaires. Would a text form user ID (e.g. "FIN001" or an e-mail address) be used for questionnaires or other purposes, a conversion table needs to be created and included into the test control tools that links the text to a numeric ID that is much more efficient to use with databases.

One partner should volunteer to administer questionnaire data. Preferably the partner should be involved in designing the questionnaires. They could for example operate a server with an open source survey tool or make a contract with a commercial service. FOT leaders would use this service to translate and pilot copies of the main English questionnaires, would activate their national surveys and send reminders to FOT participants who fail to answer. Questionnaire results will be extracted from selected questionnaire tools and saved in Excel and .csv formats. National survey tools can be accepted from a technical perspective but the content should be the same.

Harmonisation of the data collection

There is one official logging component (Testing Unit) available in DRIVE C2X. This component is included in the reference Application Unit. Logging with an alternative logger is not supported.

The test sites will need to set up a data collection point, called the log-station. This is the counterpart to the Testing Unit, which collects all the data for one test site from all units.

The less variation in logging, the easier it is to harmonize and analyse the logs. Due to for example various applications, sensors, time zones and configuration options, harmonization is still an issue when analysing data from several FOTs. Generally speaking, there are maybe three steps where data harmonisation can be attempted:

1. In-vehicle logging produces an agreed set of variables. This is practical in a few given FOTs sharing goals and procedures. For example CAN messages are filtered and only defined information content is saved in a readable form (such as .csv files). Loggers that have a wireless internet connection (GPRS, 3G) might push their logs directly to an internet server (similar to floating car data collection).

2. A test site cleans and harmonises raw log file content in offline processing, before uploading the data to a central server (or next step of analysis). This can again include cleaning raw log files, post-processing video or deleting faulty logger data. The purpose is to convert input data into project harmonised format.

3. A central post-processing software going through raw log files and interfacing each format. A SW can produce an agreed set of derived variables (e.g. average speed driven during a test or driving diary leg). The goals of such SW are described later in chapter "Data post-processing".

Terminology

One easily ends up using terms such as 'pre-processing' and 'post-processing', but it is actually rather difficult to tell the difference. Here is an attempt to suggest project-level terminology:

In-vehicle, RSU- and logger-level data processing could be considered "**pre-processing**". This can include:

- CAN data filtering and saving defined variables only (into DRIVE C2X harmonised format),
- Removing faulty logger data,
- Interfacing a RSU to save its data,
- Trigger definitions for activating data logging (e.g. hard acceleration triggers event recording as in a black box),
- Even video software that records e.g. eye movement as a result.

If a test site processes raw data at a local server with an aim to harmonise, clean or filter some of the data before it is A) sent to the central repository or B) more advanced calculations take place, this will be also called pre-processing.

Further data processing with the following aims could be called "**post-processing**":

- Produce **derived variables** (e.g. fuel consumption during a trip. Some of the derived variables are indicators but not all of them),
- Extract performance indicators,
- Generate **driving diaries** and summary/event lists.

This post-processing is done using specific software that can run on central or local servers, mainly doing database work.

Map matching GPS coordinates and linking logger data with traffic/weather/other information would be called "**data enrichment**". It falls under post-processing mainly.

From analysts' point of view, the data they will receive has been A) logged and B) processed (as opposed to pre-processed). They will continue with research question specific calculations using tools such as SPSS and MATLAB. Analysts are also free to tackle the raw data where necessary.

Data post-processing

Due to the amount of raw logger data being collected, it will be necessary to create a server-side tool or several tools for post-processing and summarizing logger data. This post-processing provides final harmonisation of the data sets for further analysis. Further, it includes the knowledge of "data dictionaries", i.e. detailed formats of different log files and other differences in tests (time zone, activation dates, broken loggers), in the calculation. The analysts would get similar summary data/reports from each logger.

Variables derived from logger data need to be calculated exactly in the same way. Would a national site deliver indicators whose calculation formulas are not known and tested (e.g. coming from a 3rd party service), their use for impact assessment is not straightforward.

Where the loggers use triggers to activate recording, these triggers need to be known in detail. This includes documenting how logging starts and stops (ignition, movement, delays).

In DRIVE C2X, WP35 leads the collection of FOT data, provides a central storage and participates in post-processing. WP43 creates processes for using the data in analyses (creates SW interfaces and scripts, processes, user guides, documents data ownership) and defines advanced post-processing according to foreseen performance indicators.

Summary data can support in answering the main research questions, but analysts doing technical assessment or testing new ideas are likely to process also raw data. The analysts will possibly need some 250 derived variables (based on TeleFOT) and several lists (e.g. speeding events) to continue their work from post-processed summary data. Otherwise every analyst digs deep in raw data (of one or several countries).

Post-processing generally includes the following steps:

1. Map matching

Map matching can be done centrally or at test sites. Within a collaborative project, it would be required to have a rather similar output (minimum e.g. speed limit, road type and urban area flag). The license agreements and post-processing arrangements might be easier if the data is processed centrally.

2. Interfacing each log file / logger type and test site specific data

Even though the input data would be rather harmonised, some loggers log e.g. fuel consumption while others do not. This means that some derived variables will be given a "not available" value in the case the logging doesn't provide required data. The test sites have different time zones, lists of loggers or broken loggers etc. A SW interface (reader component) feeds raw data (any format, preferably harmonised DB or .csv) into general calculation functions and its design would include the information about data format.

3. Calculation of derived variables

The derived variables are calculated using agreed and tested formulas (e.g. compared to paper driving diaries to ensure that total distance matches). The variables can generally include three types of lists:

- Driving diaries, where each leg is described by a long list of variables and derived variables such as time stamps, number of hard acceleration events and RPM distribution
- Event lists, e.g. analysed speeding events or acceleration data during V2V communication. This format can give more information per event than driving diaries can.

- Area-level analysis to summarize events happening at intersections or summary of indicators for a test scenario etc.

4. Linking events or driving diary legs with other information sources, e.g. getting weather and traffic data for a certain trip; finding most common routes, classifying them and similar post processing.

If it's possible to post-process data already when the FOTs are running, it is possible to provide participants some reports on their driving, e.g. about their speeding behaviour.

Database selection and file formats

Data has to be saved in some form, not just "a database". SQL databases use different dialects and it is not that easy for someone to change from one to another (even with a conversion SW).

DRIVE C2X plans to use PostgreSQL or MySQL databases that are both free to use. It has been proposed to use PostgreSQL for storage of test scenarios, monitored data and post-processed results, but the raw data logs will be also saved as such.

Concerning file formats, .csv is about the only one that stands the tests of time. Therefore, it would be recommended to save the data *also* in .csv or other plain formats. Certainly the DB dumps, Excel documents and such are easy to use for a few years after the FOT and they are likely the main sources for analysts, since they can include a bit of metadata.

Accessing the centrally collected data

The data will be split in the central database according to A) country or test site B) month. This division is likely to be helpful for analysts.

The amount of log and post-processed data in the central server is generally too high to directly access a database over international connections. Remote desktop access or distributed databases to improve performance have not been considered as a likely option either.

A safe download site (secure ftp) will be set up for accessing partial copies of the data, e.g. Finnish data for March 2011. The data file would include a DB dump file (zipped and possibly encrypted) and an analyst would import it to a local database (instructions will be provided). Besides raw log data, the data packet would include additional tables derived from basic variables, i.e. the post-processed data, data dictionaries etc.

Processing and saving the data in parts helps to avoid performance problems. Only a few gigabytes are processed at one time.

If required, post-processed (actually a kind of summary) data could be saved and sent separately in .csv and Excel formats. The raw data files can be gigabytes or even terabytes in size while the summary files such as driving diaries may be possible to send over e-mail. If the content of these post-processed tables is sufficient for evaluation of traffic impacts, not all analysts need to study raw data.

Post-processed tables need to be recalculated whenever the logic for post-processing changes. This needs to be kept in mind when designing subsequent calculations such as SPSS scripts.

Monitoring the data collection and quality

A specific monitoring process has to be set up for a FOT. Main goals in naturalistic tests are to detect broken loggers and wrong system configurations and in controlled tests to observe the test progress. The changes in logger configuration need to be documented as they affect calculation of e.g. average values for a group.

Collected data needs to be verified with a software tool performing selected checks. This should be done as early as possible to learn about broken loggers and the need to redo a controlled experiment.

Data dictionary

The project has started to compile a data dictionary. This will give a set of basic variables to log (with naming, requested sample rate and definitions) and an early list of indicators. SP4 supports the work by providing lists of indicators per event that the analysts are likely to require.

Bundling FOT data for analysts and other projects

At the latest when a FOT has been carried out, all related and relevant documents need to be stored to a central storage. This includes:

1. A Word document describing the study design, contact information and ownership of data. It is important to describe the tested functions, list activation/phase dates and explain baseline. The document should hold some contact details about test site managers. Finally, the ownership of the data must be described. From some FOTs, the data may be fully available during the project but only partially for other/later purposes. This may be due to user agreements.
2. An Excel document of broken loggers or configuration changes. For example it could be that due to a configuration problem a logger did not output certain data before certain date. These configuration changes may affect logger data usage in calculating averages for a test group etc. Format could be e.g. ID, date, notes. An Excel document of user IDs and their test groups and other "anonymous" information (users' contact details should not be included due to privacy reasons).
3. A data dictionary (e.g. Excel document) explaining in detail the format of stored raw (logger) data where it differs from project's harmonized format. Besides a basic explanation, for each variable, e.g. minimum and maximum value need to be listed, the sensor that gave this data (and possible special properties of the sensor), unit, sampling rate and possible values indicating an error or signal availability.
4. Questionnaire results in .csv or an Excel-format.
5. Time zone and summer-time changes, documentation of main changes such as winter-time speed limits.

4.3 Key concepts in DRIVE C2X testing

4.3.1 System

Here the system being tested is called DRIVE C2X, a Cooperative driving system. The Field Operational Tests are targeted to the whole system. Within this system two different technologies will be tested, namely C2C and C2I. Then these technologies include a number of functions to be detailed later.

4.3.2 Functions

In DRIVE C2X there are basically two different types of functions. These are:

- C2C-functions using vehicle-to-vehicle communication technologies and
- C2I-functions using communication techniques between vehicle and backend systems.

Both types of technologies are represented in DRIVE C2X field tests. The following Table 4 shows the tested functions.

Function descriptions constitute the basis for the definition of research questions, hypotheses, target scenarios and test scenarios. In these descriptions the focus is not on the technical aspects but on how are the driving and driver decision-making conditions changed, what piece of information or which service is provided to the driver, when, how and in which circumstances. A separate template was created to complete the function descriptions. However, additional discussions with the function owners were needed.

Nine functions were selected for the full impact assessment. First, a scoring was given to each impact area: travel and driver behaviour, safety, efficiency, environment and mobility. The scoring indicated the expected magnitude of impact (1 = small, 2 = moderate, and 3 = large). Second, the natural frequency of events was scored (1–3). The sum of these scores was calculated. Finally, those functions were selected based on two conditions: (1) the sum was at least 8 and (2) the function was implemented on at least two test sites. In addition, those functions applied in many test sites were favoured.

The functions selection process for full impact assessment is described in more detail in Chapter 4.4 *Functions selection*.

The nine DRIVE C2X functions for detailed testing are listed below (Table 4).

Table 4: The functions entering the full testing procedure in DRIVE C2X.

Pictogram	Function	Abbreviation
Safety		
	Traffic jam ahead warning	TJAW
	Roadwork warning	RWW
	Car breakdown warning	CBW
	Approaching emergency vehicle	AEV
	Weather warning	WW
	Emergency electronic brake light	EEBL
	Post crash warning	PCW
Traffic efficiency		
	In-vehicle signage/Speed limit	IVS/SL
	Green light optimal speed advisory	GLOSA

4.3.3 Target scenarios

After the functions have been defined, the test scenarios can be detailed.

Target scenarios may represent different types of undesired behaviours or outcomes. The main focus in DRIVE C2X is on early information of drivers and eventually, accident prevention. Thus, this was the main focus behind the methodology developed, and it remains the main focus of this section. Other types of target scenarios, e.g. addressing traffic rule violations, may be derived according to similar principles.

Target accident scenarios can be defined in many different ways, emphasising different aspects of the causation or outcome of the accident. Since DRIVE C2X is mostly addressing safety functions, the key focus here was on capturing the events leading to a crash rather than the details on structural deformation and injury mechanisms, which is more important as the basis for protective/passive safety functions in ADAS –type of applications.

Target scenarios can be defined and operated on two levels:

(i) *Level 1* describes a prototype scenario in general terms, based on some existing *accident typology*. An accident typology is an established classification scheme that defines a finite number of accident types at a general level (for example the GDV Accident Classification System [20]). The accident typology is normally linked to one or more accident databases. Since it was foreseen that different accident databases may be used by the different vertical sub-projects, no specific accident typology was prescribed. However, it was required that the typology used should be clearly defined and referenced in the template. For each Level 1 accident scenario, general statistics regarding (absolute and relative) frequency and injury level distributions as well as key contributing factors should be reported based on accident data.

By contrast, (ii) *Level 2* descriptions provide detailed descriptions of the flow of events and causal mechanisms behind the accidents. This may include both driver-related failure mechanisms (e.g. inattention, erroneous situation understanding etc.) as well as approximate values of relevant vehicle kinematics parameters (e.g. speed distributions). Hence, while the Level 1 descriptions provide general information on the frequency and severity of general accident types (to be used, for instance, for early prioritisation of target scenarios), it is the Level 2 scenarios that make the basis for the use case definitions.

4.3.4 Use cases

The use cases definition starts from the flow of events based on the target scenarios and describes how the intended function, by means of interaction with the driver and/or direct intervention with vehicle control, prevents/mitigates the undesired outcome defined by the target scenario. The key role of the use cases is thus to provide a fairly general description of the intended functionality of the envisioned systems, with a time sequence of events, as a basis for the more detailed specification of the functional requirements. Use cases are generally derived from target (accident or other outcome) scenarios. Thus, the target accident scenario defines the problem and the use case defines, on a suitable level of abstraction, how it should be solved by the function in interaction with the user. However, there may still be use cases that are not directly derived from target accident scenarios (describing, for example, how a user interacts with a function to change settings, or how a function supports the driver to avoid exceeding the speed limit).

Use cases, stated simply, allow description of sequences of events that, taken together, lead to a system doing something useful. In the particular domain of DRIVE C2X, a use case refers to a description of how a DRIVE C2X function is intended to interact with the driver in a particular target scenario in order to prevent the accident or hazard in safety-related situations.

4.3.5 Test scenarios

Test scenarios are designed to represent both typical and unusual situations that may occur in/with the function (www.robdavispe.com 10.2.2011). Specification of a test scenario includes the features of the function and circumstances to be covered.

Test scenarios were created for each function. The two approaches (i) controlled testing and (ii) naturalistic driving was discussed separately. For both approaches, a table including the following items was filled in:

- Baseline for the event
- Use of control (trends)

- Event (definition, sent, perceived, action, number of events per route, number of events per test person)
- Test environment
- Road type
- Speed limits
- Location
- Lighting
- Weather

In addition, the tasks for the test persons are described in detail.

4.3.6 Research questions

Research questions are written in a question formats suggesting the assumed impacts. Formulation of research questions lies in a theoretical understanding of the factors that influence the relevant impact area. Research questions can be formulated for different levels, from general to detailed but still open-ended.

An example from safety is given:

- RQ level 1: Does the Function improve traffic safety?
- RQ level 2: Does the Function reduce crash risk?
- RQ level 3: Does the Function reduce speed?

The formulation of the research questions relies on the one hand on the theory or theoretical structure of the impact area (safety, environment etc.), on other hand on the function descriptions and target scenarios. This integrated Top-down and Bottom-up approach (TeleFOT D2.2.1 Testing and Evaluation Strategy) was applied and further developed as a tool to support an efficient and systematic process in hypotheses formulation (see chapter 4.5 Hypotheses formulation).

4.3.7 Hypothesis

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.

An excel template was created to support hypotheses formulation in a systematic and theoretically sound manner. It was based on principle that in order to have implications in safety, efficiency, environment or mobility, something must happen in travel and driver behaviour. Therefore, the hypotheses were in the first phase formulated only for changes in travel and driver behaviour (later some direct vehicle based hypotheses were added). The same hypotheses were copied for the other impact areas as implications of the behavioural changes. A sheet was created to each impact area.

The sheet of one single impact area was organised based on a theory. For example, the research questions and hypotheses of travel and driver behaviour were classified into three levels: strategic, tactical and operational level [14]. The strategic level defines the general planning stage of a trip, including the determination of trip goals, route and modal choice plus an evolution of costs and risks involved. At tactical level drivers exercise manoeuvre control, allowing them to negotiate the direct prevailing circumstances. Although largely constrained by the exigencies of the actual situation, manoeuvres must meet criteria derived from general goals set by the strategic level. Conversely these goals may occasionally be adapted to fit the outcome of certain manoeuvres. Operational level includes control and action patterns directly related to driving, e.g. turning the wheel or the use of pedals etc.

All the hypotheses were located on the sheet of travel and driver behaviour. Relevant hypotheses were copied to other impact area sheets and organised there based on theory relevant to that particular impact area. If new hypotheses were needed, they were always located on travel and driver behaviour sheet and copied from there to the other sheets.

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.

An excel template was created to support hypotheses formulation in a systematic and theoretically sound manner. It was based on principle that in order to have implications in safety, efficiency, environment or mobility, some changes must occur in travel and driver behaviour. The assumed changes in driver behaviour would be the targets for the measurements and logging as well. Therefore, the hypotheses were in the first phase formulated only for changes in travel and driver behaviour of the equipped driver (later some direct vehicle and infrastructure based hypotheses were considered). The same hypotheses were copied for the other impact areas as implications of the behavioural changes. A sheet was created for each impact area.

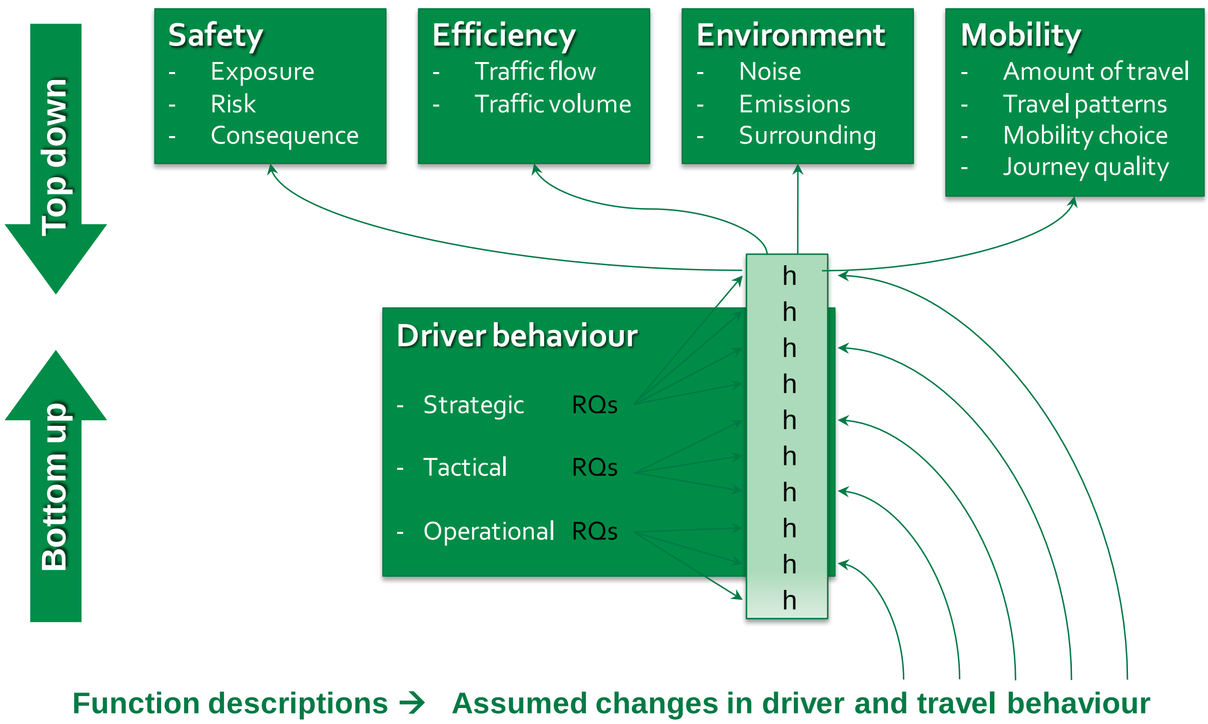


Figure 13: Schematic figure on creation of research questions and hypotheses.

All the hypotheses were located on the sheet of travel and driver behaviour. Relevant hypotheses were copied to other impact area sheets and organised there based on theory relevant to that particular impact area. If new hypotheses were needed, they were always located on travel and driver behaviour sheet and copied from there to the other sheets.

4.3.8 Performance indicators

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. A denominator (per time/per distance/in a given location…) is necessary for a performance indicator making it comparable [6].

4.3.9 Operationalisation of performance indicators

Performance indicators are operationalised as measurements. Measurement defines how the indicator is measured in the FOT. A measure does not have a "denominator". Therefore, it is not in itself comparable with 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.

4.4 Functions selection

4.4.1 Functions description template

A task force was setup to select the functions to be implemented in DRIVE C2X. It is essential to select functions showing the state-of-the-art C2X functionality suitable for the evaluation of the assumed impact on traffic safety, efficiency and that fit into the current research in other ongoing projects in Europe and beyond. Also an alignment to current standardization activities such as ETSI TR 102638 is of crucial importance.

In PRE-DRIVE C2X a set of 23 safety-related, 13 traffic-efficiency related and 17 infotainment and business-related functions have been identified, described and ranked in the work of WP4100, and described in Deliverable 4.1. Out of these 18 functions were selected for evaluation. 9 out of these 18 functions will undergo a complete impact assessment.

The functions selection process in PRE-DRIVE C2X had a two-fold cause: to select those functions to be investigated during the project and to get a view on functions to be evaluated in DRIVE C2X.

To get enough information, a description template was created. This template was filled out be partners that suggested one functions to be included in the selection.

Data included in the template is shown below (Table 5).

Table 5: Functions description template.

Template Function		
	Function Name	Function Name (here "Template Function")
	Function Short Description	A single sentence that describes the function
	Function Group	Choose from (1) Safety, (2) Traffic Efficiency, (3) Infotainment and commercial back end use cases, (4) Architecture/deployment and security use cases
	Primary Environment	E.g. Highway, Urban, Night time
	Stakeholders	E.g. Public Administration, vehicle manufacturers, suppliers, fleet managers, private car drivers, express company
	Actors & Components	
	▪ Actor 1	Describe the role of the actor concerning this function
	▪ Actor	See above
	▪ Component 1	Describe the role of the component concerning this function
	▪ Component	See above
	Use Case System Requirements	
	▪ Coverage	e.g. 100m / e.g. 5km
	▪ Latency	e.g. 100ms / e.g. 10min

▪ Complexity	FOT compliant or not (scalability)
▪ Penetration	See above
Required Functional Components	
▪ C2C / C2I	Choose from (must, must not, should, should not and may)
▪ UMTS / GPRS	See above
▪ HMI Warning (Visual, Audio)	See above
▪ Central Content Server	See above
▪ E.g. traffic jam detection	See above
▪ Add components not considered here until now	See above
▪ Required sensors	radars, lidars, cameras, rain, etc.
Testing Requirements	
▪ Simulation	Choose from (must, must not, should, should not and may)
▪ Test Bench	See above
▪ Trial Site	See above
▪ Test Site	See above
▪ Suited for PRE-DRIVE C2x or DRIVE C2X	Choose from DRIVE C2X or PRE-DRIVE C2X
▪ Minimum / Desired Number of Cars Equipped (trial or test site)	e.g. 2 / e.g. 10
▪ Minimum / Desired Number of RSUs (trial or test site)	e.g. 1 / e.g. 4

Safety Relation	Choose from ++, + , 0 , - , --
Traffic Efficiency Relation	Choose from ++, + , 0 , - , --

Objectives

Describe the objective of the use case.....

Requirements and Basic Required Functions/Sensors

Describe the general requirements (communication, spectrum, etc) and how the use case will use the system basic functions, like for example Cooperative Awareness Messages and Decentralized Notification Messages.

Scenario and general functioning

Describe at least a situation where the use case will happen and how the use case will perform/act.

Most important stakeholders

Please name the most important stakeholders equivalently to the entries in the table and describe their role as well as interest or motivation… (e.g. car manufacturer, private drivers, fleet managers, …

- Stakeholder 1

Describe his role and interest or motivation.

- Stakeholder 2

Describe his role and interest or motivation.

- …

Simulation (User Needs)

The simulation shall provide information about the optimal scaling of the FOT. That means, it shall determine the minimum number of (equipped) cars and RSUs, which are required to validate the implementation of the Traffic Jam Ahead Warning. Scalability, which is required especially in relevant sceneries (a very high density of vehicles is one of the characteristics of traffic jams).

Initial Evaluation

Please write a free text for evaluation. The purpose of this part is to help evaluating and selecting functions for tests during PRE-DRIVE C2X or DRIVE C2X.

Objectives

Describe the objective of the use case.....

Requirements and Basic Required Functions/Sensors

Describe the general requirements (communication, spectrum, etc) and how the use case will use the system basic functions, like for example Cooperative Awareness Messages and Decentralized Notification Messages.

Scenario and general functioning

Describe at least a situation where the use case will happen and how the use case will perform/act.

Most important stakeholders

Please name the most important stakeholders equivalently to the entries in the table and describe their role as well as interest or motivation... (e.g. car manufacturer, private drivers, fleet managers, ...

- Stakeholder 1

Describe his role and interest or motivation.

- Stakeholder 2

Describe his role and interest or motivation.

- ...

Simulation (User Needs)

The simulation shall provide information about the optimal scaling of the FOT. That means, it shall determine the minimum number of (equipped) cars and RSUs, which are required to validate the implementation of the Traffic Jam Ahead Warning. Scalability, which is required especially in relevant sceneries (a very high density of vehicles is one of the characteristics of traffic jams).

Initial Evaluation

Please write a free text for evaluation. The purpose of this part is to help evaluating and selecting functions for tests during PRE-DRIVE C2X or DRIVE C2X.

4.4.2 Functions selection process and criteria

While the focus of PRE-DRIVE C2X was on the preparation of a FOT and on showing the technical maturity and feasibility of C2X-communication, the actual pan-European FOT and the evaluation to be conducted in DRIVE C2X sets some significant new demands for the developed system and therefore also the functions selected. These new changes reflect to the selection process.

The selection was carried out by a task force consisting of all test sites, the sub-project leaders from SP2, SP3 and SP4 and the work package and task leaders for task T22.1 (Function selection).

It was decided to base the DRIVE C2X selection process on the existing scheme from PRE-DRIVE C2X and to enhance the metric with indicators for

- Test site commitment, on the basis that a function holds more value to the project, if it is executed on more test sites,
- Testability, e.g. the effort needed to execute the test case,
- Evaluation criteria, that determine the suitability for evaluation and
- Comparison to the EasyWay project and ETSI TR 1026238.

These values were added to the comparison table to calculate a new overall score for each function. The following sub-chapters describe each metric in detail.

<u>Evaluation metric from PRE-DRIVE C2X</u>

For the reason of completeness the safety related function selection criteria are based on PRE-DRIVE C2X functions ("use cases") selection procedure.

Safety functions were introduced in various projects before and have been a driver for C2C-technology for many years. Concerning the project PRE-DRIVE C2X, the relevance of safety functions is calculated with help of the following criteria: global traffic safety, individual safety and impact on road fatalities, deployment and time-to-market, and traffic efficiency. The corresponding weight factors were discussed and agreed during a finalization workshop.

Global traffic safety (weight 0.4)

The global traffic safety is a criterion to evaluate the impact of the relevant function regarding the overall avoidance of traffic accidents. That includes non-life threatening situations such as most rear-end collisions in urban environment.

Functions evaluated with zero points have a negative impact on traffic safety. That means its employment lowers traffic safety with respect to non-employment. Ten points means that it is expected that the function improves traffic safety substantially. Five points corresponds to neutral impact.

(harms traffic safety) 0 ●————● 10 (improves traffic safety)

Individual safety and impact on road fatalities (weight 0.3)

This criterion is suited to evaluate the impact of the relevant function regarding fatal accidents threatening the life of the car driver and its passengers.

Functions evaluated with zero points have a negative impact on individual safety and road fatalities. That means its employment changes decreases individual safety with respect to non-employment. Ten points means that it is expected that the function improves individual safety substantially.

(harms individual safety) 0 ●————● 10 (improves individual safety)

Deployment and time-to-market (weight 0.2)

This criterion is suited to evaluate the function regarding its real life implementation. That avoids selecting functions which have no relevance in real life, e.g., functions which require techniques that are not yet available or which require a very high penetration rate of OBUs or RSUs.

Functions evaluated with zero points are expected to be rolled out very late. That might be because a 100% OBU or RSU penetration rate is required. Ten points mean that the function is expected to be deployed at a very early stage of a C2X-system.

(unlikely market introduction) 0 ●————● 10 (quick market introduction)

Traffic efficiency (weight 0.1)

Even though safety Functions should be ranked, traffic efficiency must be concerned. That is because functions which might have a great impact on safety should not be implemented in case they have a great negative influence on traffic flow or traffic efficiency, respectively.

Functions evaluated with zero points have a negative impact on traffic efficiency or traffic flow. That means its employment changes traffic efficiency to the worse in respect to non-employment. Ten points means that it is expected that the function improves traffic efficiency substantially.

(worsens traffic efficiency) 0 ●————● 10 (improves traffic efficiency)

Extension of DRIVE C2X metric - quality of evaluation

New metrics were added to the PRE-DRIVE C2X metric regarding use case expected quality of evaluation. These metrics were identified in order to assist in the selection of the functions, especially for the impact assessment. The criteria were identified such that the most relevant functions from a European perspective would be chosen.

The metrics are described below, and are followed by a brief description of each criterion.

- Frequency of events infers that functions that are relevant or can be used in more events or situations receive a higher score. For example, a function that is relevant for events that occur frequently, receives a higher score.
- Test-site suitability refers to two elements that determine the level of suitability. The first is, how easy or difficult is it to reproduce the event for which the function is relevant, at a test site? The second is, how easy or difficult is it to measure or assess the use case? Events that are easy to reproduce and the effect on driver behaviour is easy to measure, receive a high score.
- Relevance for driver behaviour refers to what extent the functions has an impact on driver behaviour that is relevant to one of the impact areas. Examples of measurable changes in driver behaviour are changes in speed, following behaviour, level of braking, etc., that are directly attributable to the event.
- Performance indicators and impacts refer to the expected impact on safety, traffic efficiency, energy efficiency / environment and mobility. Given an event, use cases for which a larger impact on one or more of these impact areas is expected, receives a higher score.
- Assumed user preference refers to the expected attractiveness of the function to consumers and or end users. This score was derived from the PRE-DRIVE C2X assessment of the functions.

Together, these metrics assessed the relevance of the functions from the impact assessment point of view.

Extension of DRIVE C2X metric - test site involvement

The key element in DRIVE C2X is the involvement of multiple test sites throughout Europe. This reflects to the functions selection process, since functions, which are tested in more sites have a greatly higher value to the evaluation.

DRIVE C2X comprises of seven test sites:

- The system test site in Helmond, Netherlands will be the central site, where all functions are implemented and tested. This site will act as a reference for the whole project. From the context of function selection it is less important, since by definition all functions will be implemented and therefore, all functions receive the same score from this site. The only exception makes the wrong-way driving gas-station (WWGS) function with specific requirements. It will be implemented only in Italy.
- The large-scale test sites in Gothenburg, Sweden and Frankfurt am Main, Germany will conduct FOTs with a high volume of vehicles. They are therefore suitable for evaluation of impact in free-flowing test conditions.
- The small-scale test sites in France, Italy and Finland will execute tests with a smaller number of vehicles. They are therefore better suited for controlled testing and bring in

unique national specifics, such as harsh weather conditions or testing in high-density highway scenarios.

- An associated test site in Vigo, Spain will conduct a number of tests with selected functions.

Table 6: Test site commitment for safety-related functions.

	Marked for STS (Netherlands)	Marked for LSTS1 (Germany)	Marked for LSTS2 (Sweden)	Marked for SSTS1 (Italy)	Marked for SSTS2 (Finland)	Marked for SSTS3 (France)	Marked for ATS (Spain)
Traffic jam ahead warning (TJAW)	X	X	X	X	X	X	X
Roadwork warning (RWW)	X	X	X		X	X	X
Car breakdown warning (CBW)	X	X		X	X	X	X
Approaching emergency vehicle (AEV)	X	X		X	X		X
Weather warning (WW)	X	X	X		X	X	X
Emergency electronic brake light (EEBL)	X	X				X	X
Slow vehicle warning (SVW)	(X)	X		X	X		X
Stop sign violation (SSC)	(X)	X				X	
Post crash warning (PCW)	X			X		X	X
Obstacle warning (OW)	(X)	(X)					
Wrong-way warning gas-station (WWGS)				X			
Motorcycle warning (MW)	X	X					
HLN	(X)	X					

Table 7: Test site commitment for traffic efficiency-related functions.

	Marked for STS (Netherlands)	Marked for LSTS1 (Germany)	Marked for LSTS2 (Sweden)	Marked for SSTS1 (Italy)	Marked for SSTS2 (Finland)	Marked for SSTS3 (France)	Marked for ATS (Spain)
In-vehicle signage speed limit (IVS/SL)	X	X	X	X	X		X
Green light optimal speed advisory (GLOSA)	X	X	X			X	X
Traffic information and recommended itinerary (TIRI/ DFCD)	(X)	X	X			X	X

Table 8: Test site commitment for infotainment and business-related functions.

	Marked for STS (Netherlands)	Marked for LSTS1 (Germany)	Marked for LSTS2 (Sweden)	Marked for SSTS1 (Italy)	Marked for SSTS2 (Finland)	Marked for SSTS3 (France)	Marked for ATS (Spain)
Insurance and financial services (IFS)	X						
Dealer management (DM)	X					X	
Point of interest notification (POI)	X			X		X	
Vehicle software provisioning and update (VSPU)	(X)					X	
Local electronic commerce (LEC)	(X)					X	
Fleet management (FM)	(X)					X	
Transparent leasing (TL)	X						

The preliminary commitment of all sites has been included in the selection matrix. Each function's score is enhanced for each test site committed to implement and test it.

Evaluation results

The final ranking of use-cases for DRIVE C2X was based on the described indicators:

- PRE-DRIVE C2X score,
- Evaluation score,
- Test site score.

Also it has been considered, which functions are already available from the preparation project, and which have partners committed to them. Functions have been ranked according to this final score and the best of each category have been chosen to be evaluated in DRIVE C2X. These were:

Safety:

- Traffic jam ahead warning,
- Roadwork warning,
- Car breakdown warning,
- Approaching emergency vehicle,
- Weather warning,
- Emergency electronic brake lights,
- Slow vehicle warning,
- Stop sign violation,
- Post crash warning,
- Obstacle warning,
- Wrong way driving in gas stations and
- Motorcycle warning.

Traffic efficiency:

- In-vehicle signage / speed limit,
- Green light optimal speed advisory (possibly traffic light assistant in France) and
- Traffic information and recommended itinerary / DFCD.

Infotainment, business:

- Insurance and financial services,
- Dealer management,
- Point of interest notification,
- Vehicle software provisioning and update,
- Local electronic commerce,
- Fleet management,
- (Transparent leasing).

4.4.3 Alignment to other projects and standardization

Relation to ETSI TR 102638

The European Telecommunications Standards Institute (ETSI) is a standardization development organization that is officially recognized by the European Union. It is membership-based and contribution-driven organization with 120 working groups and 6000 industry experts/year. It is an independent organization, based on non-profit principles. It has clearly defined IPR policies and has well-established partnerships with other standardization organizations.

The ETSI Technical Committee ITS was founded end of 2007. While the TC has a broad scope, the initial work of the TC is currently focused on cooperative systems. The TC has five working groups: WG1 Application and user requirements, WG2 Architecture and cross-layer, WG3 Networking and Transport, WG4 Media and medium-related, WG5 Security.

ETSI, jointly with CEN, received the mandate M/453 for the development of standards for „Cooperative Systems for Intelligent Transport“. In the context of this mandate a list of minimum set of standards has been developed and a clear time schedule until mid 2012 confirmed. The mandate work is carried out in cooperation with CEN TC 278 WG16, whereas ETSI TC ITS develops standards for the protocol stack and car-2-car applications and CEN TC 278 WG16 covers car-2-infrastructure applications.

ETSI TC ITS has published a technical report TR 102 638 on the definition of a Basic Set of Applications; Vehicular Communications; Basic Set of Applications; Definitions” [25]. The intention of the technical report is to scope the standardization work in order to enable a deployment and market introduction of an initial system. For the selection of the BSA, a well-defined process was applied. Input from ITS stakeholders (vehicle manufacturers, suppliers, road network operators, public authorities, etc.) using questionnaires was taken into account. The technical report was developed in cooperation with the PRE-DRIVE C2X, the C2C-CC application working group and other European R&D projects.

The following Table 9, Table 10, and Table 11 compare the considered DRIVE C2X functions with these applications defined in the ETSI BSA. It turns out that for the majority of the functions an exact or good match exists. For other DRIVE C2X, a corresponding application in the ETSI BSA could not be found.

Table 9: Comparison between DRIVE C2X functions and applications defined in ETSI BSA: Safety functions /applications.

DRIVE C2X Function	ETSI application	Comment
Traffic jam ahead warning		No corresponding application in ETSI BSA.
Roadwork warning	Roadwork warning	Exact match.
Car breakdown warning	Stationary vehicle - vehicle problem	Good match.
Approaching emergency vehicle	Emergency vehicle warning	Good match.
Weather Warning Emergency	Decentralized floating car data - Visibility or Wind	Good match.
Electronic brake lights	Electronic brake lights	Exact match.
Stop sign violation	Signal violation warning	Good match (though stop sign is different from signal)
Post-crash warning	Stationary vehicle - accident	Good match.
Hazardous location notification	Decentralized floating car data - Hazardous location	Good match.
Slow vehicle warning	Slow vehicle indication	Good match.
Motorcycle warning	Motorcycle approaching indication	Good match.
Right-turn collision warning		No corresponding application in ETSI BSA.
Curve speed warning		No corresponding application in ETSI BSA.
Signal violation warning & pre-emption	Signal violation warning	Good match.
Left-turn collision warning		No corresponding application in ETSI BSA.
Cooperative glare reduction		No corresponding application in ETSI BSA.
Vulnerable road user warning		No corresponding application in ETSI BSA.
Intersection collision warning	Intersection collision warning	Perfect match.
Lane change assistance		No corresponding application in ETSI BSA.
Overtaking vehicle warning		No corresponding application in ETSI BSA.
Pre-crash sensing warning	Collision risk warning	Good match.
Cooperative merging assistance		No corresponding application in ETSI BSA.
Cooperative forward collision warning Obstacle	Decentralized floating car data - Hazardous location	Good match.
Warning Wrong Way driving in Gas Stations	Wrong way driving warning	Good match.

Table 10: Comparison between DRIVE C2X functions and applications defined in ETSI BSA: Traffic Efficiency functions/applications.

DRIVE C2X Function	ETSI application	Comment
In-vehicle signage / Speed Limit	Regulatory / contextual speed limits notification	Good match.
Green light optimal speed advisory	Traffic light optimal speed advisory	Good match.
Traffic information and recommended itinerary		No corresponding application in ETSI BSA.
Limited access warning	Limited access warning and detour information	Good match (DRIVE C2X use case appears as subset of BSA use case).
Decentralized floating car data	Decentralized floating car data	Good match (different sub-categories)
Enhanced route guidance and navigation	Enhanced route guidance and navigation	Perfect match.
Adaptive drive train management		No corresponding application in ETSI BSA.
Cooperative vehicle-highway autonomous system		No corresponding application in ETSI BSA.
V2I Traffic Optimization		No corresponding application in ETSI BSA.
Cooperative flexible lane allocation		No corresponding application in ETSI BSA.
Cooperative Adaptive Cruise Control Intersection management		No corresponding application in ETSI BSA.

Table 11: Comparison between DRIVE C2X functions and applications defined in ETSI BSA: Other functions/applications.

DRIVE C2X Function	ETSI application	Comment
Insurance and Financial Services	Insurance and Financial Services	Perfect match.
Dealer Management		No corresponding application in ETSI BSA.
Transparent Leasing		No corresponding application in ETSI BSA.
Vehicle software provisioning and update	Vehicle software / data provisioning and update	Good match.
Point of interest notification	Point of interest notification	Perfect match.
Local electronic commerce	ITS Local electronic commerce	Perfect match.
Remote personal data synchronization		No corresponding application in ETSI BSA.
Fleet management	Fleet management	Perfect match.
Car rental / sharing assignment / reporting		No corresponding application in ETSI BSA.
Media downloading	Media downloading	Perfect match.
Automatic access control / parking management	Automatic access control / parking management	Perfect match.
SOS service		No corresponding application in ETSI BSA.
Stolen vehicle alert		No corresponding application in ETSI BSA.
Electronic toll collect		No corresponding application in ETSI BSA.
Map download and update		No corresponding application in ETSI BSA.
Instant messaging		No corresponding application in ETSI BSA.
Design Re-Use and Change Management		No corresponding application in ETSI BSA.
Remote diagnosis and just in time repair notification		No corresponding application in ETSI BSA.
Business Intelligence for High-Volume Service Parts		No corresponding application in ETSI BSA.
Ecological driving		No corresponding application in ETSI BSA.

Relation to EasyWay

EasyWay is a project for Europe-wide ITS deployment on main TERN corridors driven by national road authorities and operators with associated partners including the automotive industry, telecom operators and public transport stakeholders. It sets clear targets, identifies the set of necessary ITS European services to deploy (traveller information, traffic management and freight and logistics services) and is an efficient platform that allows the European mobility stakeholders to achieve a coordinated and combined deployment of these pan-European services [27].

To achieve a really good grip on the effects of ITS, it is necessary to put the European road user at the centre of the perspective. The EasyWay programme activities stretch over a seven-year period, from 2007 until 2013, but set the targets for 2020 similar to the White Paper. To promote future creativity, more ambitious targets are set for future years [27].

For the development and deployment of the cooperative systems it is vital that different type of stakeholders have a good collaboration. For several cooperative systems some implementations in the road infrastructure is needed as well. Good cooperation, common planning of activities is needed for the whole road transport system including organisations responsible for the development of different sub systems and infrastructure. EasyWay has made some prioritisation of which systems will be promoted, and is advantageous to plan European FOTs such that they take these prioritisations into consideration.

EasyWay compiled a list of systems which were considered relevant, among which the first priority systems were selected. These systems were ticked by an "x" in the DRIVE C2X use case list.

In general, the selection of EasyWay functions match very well with the ranking of DRIVE C2X functions. EasyWay selected seven priority systems. Four of those were included in the top 22 systems of DRIVE C2X as identical. 'Hazardous location notification' and 'Decentralized floating car data' were interpreted to be among the top 22 with slightly different names – the main content was similar with some selected DRIVE C2X functions. The only exception was 'Automatic access control / Parking management' – it was not in DRIVE C2X ranking process whereas EasyWay had this system among the top seven.

4.5 Pre-Validation

From "The handbook for Vehicle-to-X cooperative systems simulation" [28]:

"*Simulation can be seen as a tool for the verification and validation of cooperative systems. It will flank the development process from the concept phase to market introduction.*

During the concept phase, simulation can support in proving and even improving the concept. Simulations are useful to evaluate the hypothesis made during the concept considering different constraints, borders and parameter sets. E.g. various use cases could be simulated to assess the impact for cooperative systems without building any prototype or even real hardware. This will decrease the costs and complexity in the early phase of the development process. Basic requirements could be derived and adjusted with simulations during a very early stage.

Going one step further to the prototype development, simulations are used as a tool for the qualification of prototypes. It is possible to perform impact assessments or performance analyses with the prototype of the cooperative system. The simulation represents the environment and stimulates the system to be able to perform the tests. These simulations and tests could also be performed in later stages of the development process, e.g. in serial production.

Another goal for simulations is the derivation of test cases and test scenarios. These test scenarios could either be used in a simulation environment or in the field to perform tests. Here simulations could help *to pre-qualify scenarios for tests and even obtain parameters (e.g. timing phases, penetration rates, etc.) for optimal test setups.*

FOTs and simulations go hand in hand and can effectively improve each other."

This "Motivation for Simulation" shows the benefits of using a simulation during the development of traffic engineering solutions in general and of C2X applications in special. Nowadays, every developed traffic light is designed and evaluated using a traffic simulation before being deployed in the real world. Simulations save costs by allowing the evaluation and optimisation of a system before actually constructing it.

In the following, the methodology for using simulation within DRIVE C2X is described. Then, an introduction to simulation tools is given. Then, the scenario generation is discussed.

4.5.1 Methodology

Before deploying solutions which may affect traffic safety, both FOTs as well as simulation runs have to be performed. Simulation runs are assumed to predict the performance of a developed application on a large scale and for different penetration rates. Also, possible complications, or the "critical mass" of equipped vehicles needed to see any benefits can be predicted using simulations.

On the other hand, simulation tools can highly benefit from performed FOTs. Both, traffic behaviour models as well as models for message exchange still offer possibilities to be improved (see next section), and these improvements highly relate on real-world measurements. For a continuous adaptation of the tools, a loop between the FOTs and simulation runs is necessary (Figure 14

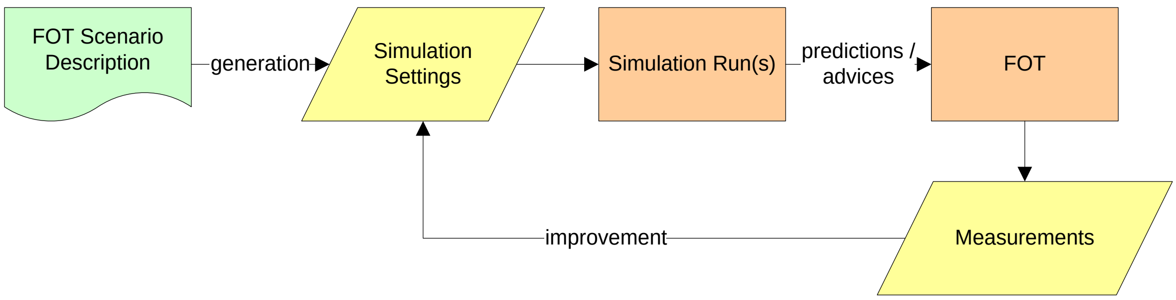


Figure 14: Interaction between FOTs and simulation.

In order to ensure the data gathered within FOTs match the simulation settings, a methodology for describing the scenarios is needed. "The handbook for Vehicle-to-X cooperative systems simulation" [28] includes a scenario description template which is assumed to be well-suited for this purpose. Being notated in XML, it includes meta-information about the simulation run and the performance metrics to use for evaluation. Beside this, the road network to be used by the simulation is stored within the description using the open DRIVE C2X format. As open DRIVE C2X is using XML notation, too, it can be directly embedded into the scenario description. The traffic demand is included in the description, too. The XML notation allows to extract the information stored, mainly the road network, and convert it into descriptions used by the simulation.

4.5.2 Simulation Tools

The simulation of intelligent transportation systems (ITS) requires models for road traffic/driver behaviour, communication, and the application itself. Usually, these models are developed by different specialist groups. Different architectures are used for joining them into an executable simulation software. In a few cases, the models are embedded into one computer program, either done during the development of a V2X simulation software, or by extending an existing simulation application, as done for VISSIM which was extended by the VCOM model [39]. More often, the re-usage of existing simulators can be found, where an existing traffic simulation and an existing communication simulation are connected. While the first approach reduces the amount of needed inter-process communication, reducing the simulation time, the second one promises an easier exchange of one of the involved models. Besides using well-established models, coupling existing simulation application from different research areas reduces the simulation software's complexity, making its development easier.

For both domains – traffic and communication simulation – large sets of different simulation applications and possibilities to combine them into a V2X simulation exist. Within the PRE-DRIVE C2X deliverable 2.1 [29], a survey on the simulations used by project partners was done. Other overviews on existing simulators can be found in [30], or within the C2C CC WG Sim reports. Two traffic simulations are used by more than one DRIVE C2X project partner, the open source traffic simulation SUMO [32, 33] developed by DLR, and the well-established commercial simulation package VISSIM [34] produced by PTV AG. Both are so-called "microscopic traffic flow simulations" [31]. Such simulations are used to resemble the behaviour of "normal" traffic. As incidents occur very seldom, they are normally not a part of the models used for computing the simulated vehicular movement. The simulations do not include an explicit psychological model of the driver. Due to this, the information presented on an HMI in reality cannot be passed to a part of a simulated vehicle/driver for being taken into regard when computing the simulated vehicle's behaviour.

As a conclusion, when simulating applications which change a driver's behaviour, assumptions about this behaviour have to be done and modelled. Often, the driver/vehicle models used within microscopic simulations are minimal in the number of variables what makes a meaningful mapping of the expected changes in a driver's behaviour onto the simulation model complicated. Of course, microscopic traffic simulations are a valid and usable tool for a set of questions. They can be used well to answer the following:

- How much does a trip duration change due to the change of the taken route?
- Do jams disappear due to routing vehicles around them? Are new jams formed by doing so?
- How much information can be collected during a trip?
- How well performs a chosen multi-hop routing algorithm?
- How does pollutant emission change if a vehicle's behaviour – speed or acceleration/deceleration – is changed?
- etc.

This means microscopic traffic simulations are a proper tool for simulating both efficiency and business/deployment/infotainment applications, whereas they are rather weak in predicting the performance of safety-related applications. The lack of proper models which allow to compute safety-related values was already recognised as a shortcoming of microscopic traffic simulation in PRE-DRIVE C2X deliverable 2.1 and was not closed in the meantime.

For answering safety-relevant questions, driving simulators should be involved. They allow to capture the behaviour of drivers who use a safety increasing application. In a second step, this behaviour can be embedded either directly into the chosen traffic simulation or into the simulated application for extrapolating the simulated safety application's benefits for a larger set of equipped vehicles. Of course, measures gained during FOTs can also be used, and are assumed to be of a greater benefit as the data is gathered under normal driving conditions.

Existing communication simulation models and applications cover a range spanning from fast, stochastic simulations up to models which ray-trace the message propagation. Some include the complete communication stack, other cover the propagation of messages only. The most common communication simulation tools used by DRIVE C2X partners is VCOM, a fast, stochastic simulation model developed by KIT and embedded into VISSIM, as well as ns2/ns3. The latter are US-American tools initially developed for simulating wired communication. Both have been extended by the possibility to simulate vehicular wireless communication. Investigations performed within the iTETRIS project [36, 37] co-funded by the EC have shown that ns3 is superior to ns2 in stability when simulating a large number of communication nodes. Also, ns3 should be preferred due to the better support, and due to improvements in software architecture against the – meanwhile outdated – ns2.

It is worth mentioning that the message propagation is often modelled based on theoretical work. Only few measurements of message propagation are available and can be used as an input to validate or calibrate communication models. Due to this, measures collected during the FOTs must be made available in order to improve the models.

Besides the combination of VISSIM and VCOM, two further systems for coupling traffic and communication simulations are used by DRIVE C2X partners. The first one is VSimRTI developed by FhG Fokus [35]. It implements a subset of the high level architecture (HLA), a middleware standard for coupling simulations of different granularity, originally developed by the U.S. Department of Defense. It allows to exchange simulations on-line, for example replacing a fast simulation by a finer, slower one as soon as it is needed. Also, it does not only allow to couple a traffic, a communication, and an application simulation, but arbitrary simulations. For example, a joined usage of two different traffic simulations, SUMO and VISSIM, was demonstrated.

The second system for V2X communication simulation used by different project partners is the iTETRIS platform, developed within the EC co-funded project of the same name. iTETRIS couples SUMO, ns3, and application instances using socket connections. The iCS – the "iTETRIS Control System" – is used for synchronizing the involved simulations and for passing needed information across them. iTETRIS is open source and available at: http://ict-itetris.eu/.

4.5.3 Simulation Scenarios

Microscopic traffic simulations and modern communication models which consider shadowing effects require a well-defined infrastructure model in which the simulated V2X application shall take place. Such simulation scenarios consist of representations of the infrastructure the traffic to simulate shall take place on, the traffic itself, and possibly additional parameters such as communication properties or additional infrastructure such as road side unit positions and their properties.

Two different approaches for simulation scenarios are common, the usage of abstract scenarios, and replication of real-world scenarios. Both are legitimate. Abstract scenarios allow to define all parts a test run consists of, making it easier to evaluate the obtained results and to derive well-defined measures. Hence, coherences between input parameters can be stated more easily, and it is possible to model and run these scenarios even if not every desired input is available. Replication of real-world scenarios requires a detailed description, but promises to generate results which resemble what can be seen in the following real-life field operational tests.

In the following, two examples of preparing scenarios for simulating the GLOSA Use case are given, starting with an abstract scenario, followed by a replication of the Helmond test site.

4.5.4 Abstract GLOSA Scenario

In order to appropriately model an abstract scenario the main characteristic of the considered scenario in combination with the regarded use case has to be considered. Depending on many factors and constraints the therefore necessary input that is either crucial for the use case itself or plays an important role for the metric under consideration has to be determined. Furthermore, there is in general a trade-off between on the one side fewer input parameters and therefore usually a better understanding of the remaining coherences and on the other side more parameters that might, however, then e.g. lead to side effects or mutual dependencies that are harder to evaluate.

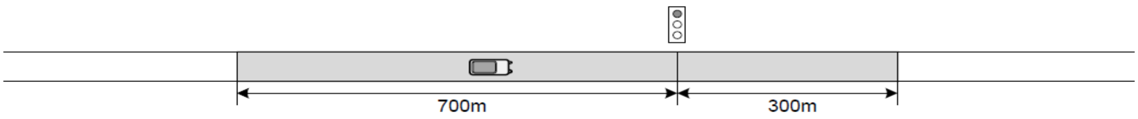


Figure 15: Abstract GLOSA scenario layout.

In Figure 15 an abstract GLOSA scenario layout is presented. This scenario layout is taken from [40], where the simulation setup is explained in more detail and the achieved results are presented. The scenario consists of a road with a total length of 1000 meters, whereby 700 meters are located in front of the traffic light and 300 meters behind. Since the primary focus was the identification of key influencing factors, the evaluation was initially only based on one equipped vehicle driving towards one traffic light broadcasting its signal timings. Dependencies between vehicles and networking effects were therefore initially not considered. In previous works (see e.g. [41]) the 802.11p communication system for a GLOSA-system was completely modelled and the authors stated the communication in this specific use case to be "uncritical" in terms of bandwidth and robustness. We therefore abstracted from a detailed communication modelling and focused our evaluation only on varying distances at which a vehicle becomes aware of the traffic light signal timings and can thus inform the driver. This distance is called *information distance* and was varied from 100 meters to the possible maximum range of 1000 meters.

The cycle time of the considered traffic light was 44 seconds, whereby the red and green phases were 20 seconds both, the yellow phase 3 seconds and the yellow-red phase 1 second. The resulting configuration can be seen in Figure 16.

In order to simulate varying approaching times and thus different varying stopping times in front of the traffic light each of the 44 indicated configurations (offset from 0 second to 43 seconds) had to be simulated. The desired velocity of the approaching vehicle was chosen from a normal distribution with a mean of 50 km/h.

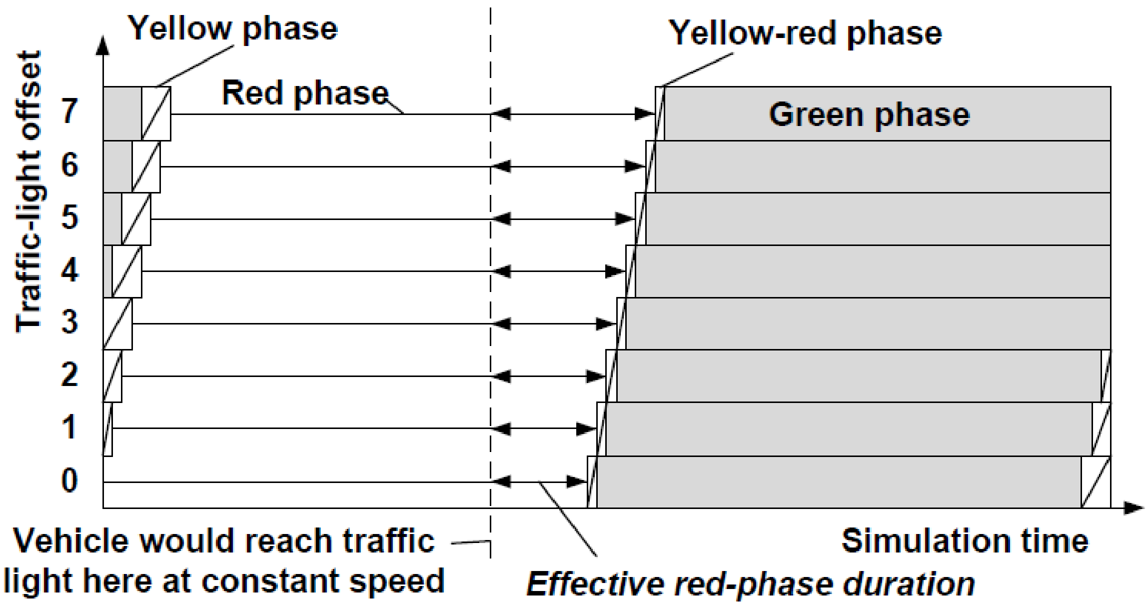
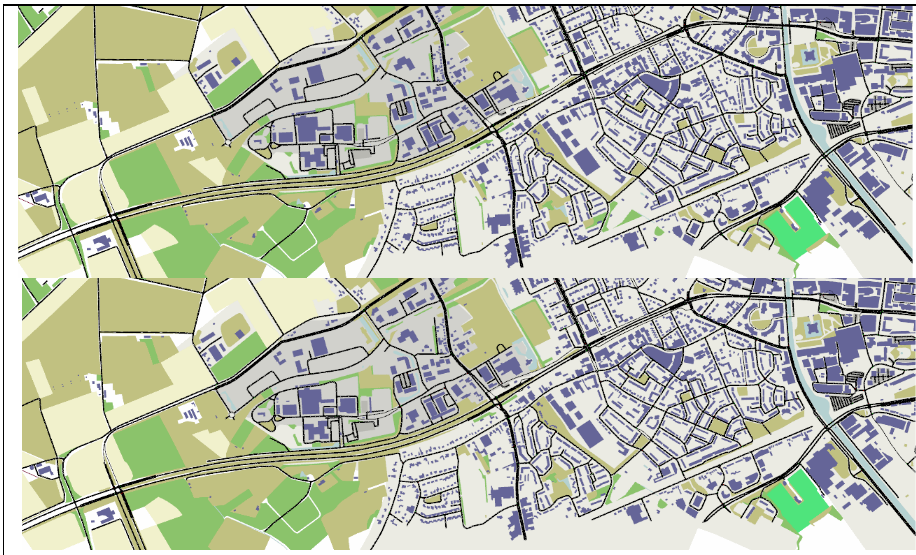


Figure 16: Abstract GLOSA scenario traffic light signal timings.

4.5.5 Replication of the Helmond test site for simulating GLOSA

Road network and infrastructure information was retrieved from Open Street Map [38]. Instead of using the complete area between Helmond and Eindhoven, only the inner-city area was chosen. This reduction was made in order to speed up the simulation, as loading the complete Helmond/Eindhoven network already needed about 30 seconds. The area is shown in Figure 17.



North:
~51.48°
South:
~51.47°
West:
~5.59°
East:
~5.66°

Figure 17: Used Helmond GLOSA scenario.

As Open Street Map data is targeted towards routing applications, it does not contain information necessary for microscopic simulations, such as the correct number of lanes, traffic light positions or plans, and information about which lanes may be used to reach the next edge. Due to this, after the initial import, the road networks had to be manually corrected. At first, the correct number of lanes, including road widenings was implemented. In conjunction, the directions that are allowed to take at each intersection have been modified on per-lane base. This work was done using images from Google Earth. This work was done for four subsequent intersections, in order to observe how GLOSA influences traffic behaviour along more than one intersection. Figure 18 shows the initial geometry of the Europaweg/Brandevoortse intersection, the respective aerial image from Google Earth, and the intersection obtained after the improvements.

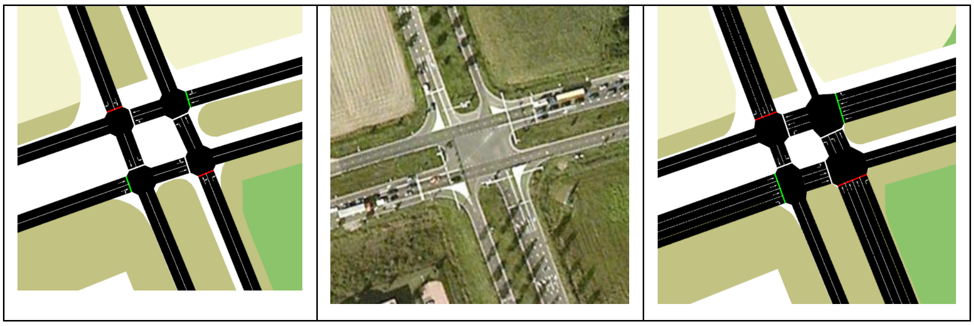


Figure 18: Adaptations to the OSM network; left: original OSM data, centre: Google Earth image; right: network after adaptation.

In a next step, the traffic light programs were set up, replacing the ones determined heuristically by the used network importing tool. The traffic light programs for the regarded intersections were fixed to an overall duration T of 90s, having 35s green and 5 seconds yellow for each direction and two additional all-red phases of 5s, as shown in Figure 19a).

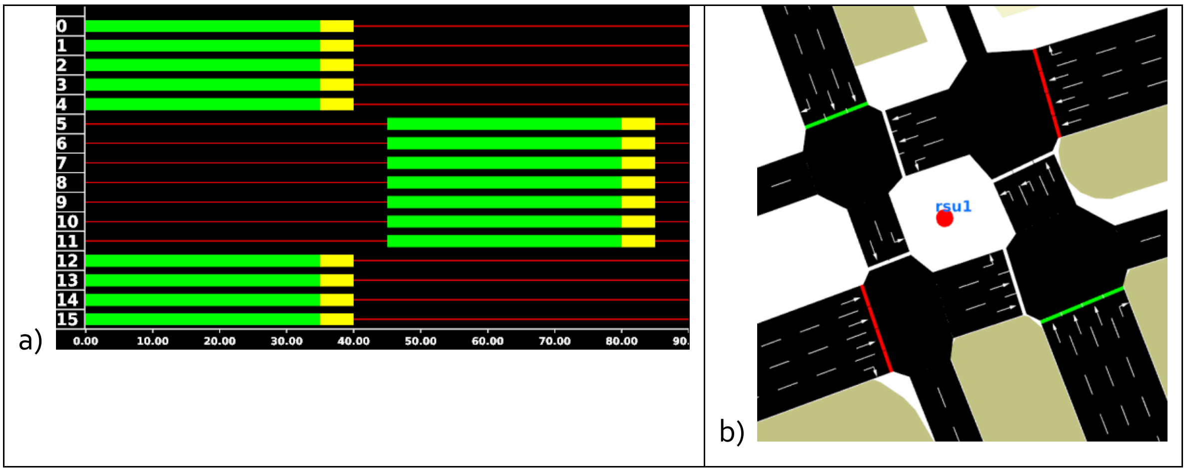


Figure 19: a) Used traffic light plan; b) location of a modelled RSU, here at intersection Europaweg/Brandevoortse Dreef.

This is of course a guess only. The traffic lights in Helmond are adapted in dependence to traffic. The replication would not only require the switch plans, but also the implementation of the adaptation algorithm. Both were not available during the scenario set up phase.

For simulating GLOSA, each traffic light controlled intersection has been equipped with a simulated RSU. The RSUs were placed in the centre of the according intersection, Figure 19 b) above shows the position of the RSU located at the intersection of Europaweg and Brandevoortse Dreef.

If made available, real-world traffic demands would allow to perform simulations which show which impact (on fuel consumption, travel times,...) can be expected from vehicles equipped with GLOSA along the day. Within the performed investigations, only abstract demands could be used as no counts from the real world were available.

4.6 Tools

Standard statistical testing tools will be utilised as well as simulation models. However, the final selection has not been made yet.

It is recommended to use statistical package such as IBM SPSS Statistics Professional Edition. It includes advanced statistical procedures to ensure the accuracy of the data analyses and table features.

The SPSS Professional Edition includes the following features:

- Linear and nonlinear models,
- Customized tables,
- Data preparation – prevents outliers from skewing analyses and results,
- Address data validity and missing values – increase the chance of receiving statistically significant results,
- Decision trees – Better identify groups, discover relationships between groups,
- Forecasting and
- Operating systems is supported by Windows, Mac and Linux.

The pros of such a tool are the following:

- Data can be read practically in any format.
- It is easy to combine and classify various data files.
- Significance testing can be carried out for multivariate analysis as well non-parametric tests.

- Easy to create additional parameters inside the data file.

4.7 Technical evaluation

Two main objectives of the technical evaluation in the project are: (i) to verify that the DRIVE C2X system meets the technical requirements of the selected functions and (ii) to gain detailed insights into the DRIVE C2X system's technical performance. The first objective ensures that the DRIVE C2X system works satisfactorily as an enabling platform for implementing the functions in the project. The second objective allows researchers and engineers to use the detailed insights into the DRIVE C2X system's technical performance for further development and refinements of the system. This second step is crucial for a large-scale pan-European deployment of cooperative systems. In order to conduct the technical evaluation for the DRIVE C2X system, five main steps are necessary.

- First, a set of evaluation criteria and parameters have to be identified for the functions selected in the DRIVE C2X project.
- Second, testing procedures and evaluation methods for carrying out field operation tests have to be designed.
- Third, appropriate equipments (hardware and software components) have to be prepared according to the defined testing procedures.
- Fourth, data collection will be carried out during the field operational tests to obtain the data necessary for conducting the technical evaluation.
- Fifth, the collected data will be processed to check that the DRIVE C2X system meets the technical requirements of the selected functions. Further data processing can be done to gain detailed insights into DRIVE C2X system's technical performance.

These five steps will be explained in more detail below.

4.7.1 Evaluation criteria and parameters

In the first step, we need to identify the criteria and parameters for the technical evaluation of the DRIVE C2X system. These criteria and parameters help us select the test metrics to be collected. Further, we provide recommendations for conducting FOT experiments. Our task is to define an experimental design for the technical evaluation that leads to reproducible and statistically significant data. For this purpose, it is important that multiple experiments are conducted for each function to avoid data anomaly and to attain representative results for the experiments. The most important measurements data for car-to-car and car-to-infrastructure communication (C2C / C2I) are communication range, packet reception rate (such as the reception rate of CAM and DENM as a function of the geographic distance between sender and receiver), and communication delay. These test metrics provide insights into the effects of C2C / C2I performance on the selected use cases in DRIVE C2X.

Test metrics are defined in detail below.

- Each data packet should carry a unique sequence number, the sender ID, the sender's timestamp, and the sender's geographic position.
- For each received data, the receiver should generate an event in its log file on a per-packet basis (no data aggregation).
- The event in the log file should contain: sender ID, sender's geographic position, packet sequence number, receiver ID, receiver timestamp, receiver's geographic position. For ease of processing, it is suggested to have log files in comma-separated values (CSV) format. We suggest that logging will be done at the facilities or application layer.

4.7.2 Testing procedure and evaluation methods

Two types of tests are derived from the selected use cases in DRIVE C2X:

- Car-to-car communication tests (C2C tests). Vehicles communicate directly with each other and no infrastructure equipments are required in these tests.
- Car-to-infrastructure communication tests (C2I tests). Vehicles communicate with infrastructure equipments in these tests.

It is suggested that each test is repeated at least 10 times (ideally 20 times or more) at each test site. Further details about C2C and C2I tests are provided below.

- For C2I tests, it is suggested that the infrastructure equipment broadcasts a message at a constant time interval. The chosen value for this time interval depends on the specific use case and varies between 1 and 10 Hz. Each of the transmitted messages should carry the parameters defined as above. The testing vehicle(s) should start from a distance of 500-1000m away from the infrastructure equipment and approaches this equipment at a normal speed (30-50 km/h in city and 80-120 km/h on urban/highway scenarios). When the vehicle(s) receive a message from the infrastructure equipment, they should generate a log event as defined above.
- The general principles for C2C tests are similar to those of C2I tests. Each vehicle should broadcast a message at a constant time interval. The chosen value for this time interval depends on the specific use case and varies between 1 and 10 Hz. Each of the transmitted messages should carry the parameters defined as above. Each measurement should start when the testing vehicles are 500-1000m away from each other. Vehicles should move at a normal speed (30-50 km/h in city and 80-120 km/h on urban/highway scenarios). When a vehicle receives a message from another one, it should generate a log event as defined above.

4.7.3 Components and equipments

Components and testing equipments have to be prepared according to the testing procedures and evaluation methods at each test site.

It is required that vehicles and infrastructure equipment are equipped with GPS devices to attain their own geographic position and accurate time synchronization with each other.

- Hardware: Vehicles and infrastructure equipment have to be equipped with wireless network interfaces that use the IEEE 802.11p and ETSI ITS G5 (ETSI ES 202 663).
- Software: Vehicles and infrastructure equipment need to use the specification of DRIVE C2X system defined in SP2. Multi-hop GeoNetworking is required for some of the selected functions.

For C2C tests: Multiple vehicles (more than 1) are required to be present at the same time at a test site.

For stress and scalability tests: Multiple vehicles (ideally more than 10) are required to be present at the same time at a test site. The purpose of these stress tests is to verify that DRIVE C2X system operate appropriately under stress conditions.

4.7.4 Data collection

Each test site in the project will carry out the FOT experiments according to the testing procedures defined above. Helmond is the system test site and will cover all functions selected in the project. Each of the other test sites conducts FOT experiments for some of the selected functions in a complementary manner such that the collected data will complement each other and provide representative results for FOT results at a pan-European level. It is important that the same testing procedures are followed to ensure coherent data across all test sites. Further, each FOT experiment should be repeated several times under different conditions (temperature, weather, driving speed and number of equipped vehicles) to account for a large range of experimental parameters.

4.7.5 Data processing

All collected data will be stored at a central server with password protection to prevent unauthorized access. Processing tools will be developed and executed on the collected data to verify that the DRIVE C2X system meets the technical requirements for supporting the use cases selected in the project. Our current hypotheses for the technical performance of the DRIVE C2X system are as follows.

- The DRIVE C2X system should be able to provide a communication range of at least 200m. Ideally, the communication range should be even larger by means of good antennae, high transmit power and multi-hop communication.
- The DRIVE C2X system should be able to achieve an end-to-end communication delay of at most 200ms within the communication range defined above. This communication delay ensures that critical safety data can be delivered in a real-time manner in order to support the safety use cases selected in the project.
- The DRIVE C2X system should be able to provide a data delivery rate of 90% via wireless communication within the communication range defined above. This data delivery rate ensures that critical safety data can be exchanged with a good level of certainty in order to support the safety use cases selected in the project.
- The DRIVE C2X system should offer good scalability features and should operate well even in crowded scenarios where a large number of equipped vehicles are present in an area. While a large number of vehicles will induce a high processing load on the DRIVE C2X components and incur congestion on the wireless medium, the DRIVE C2X system should still provide the communication performance as defined above under these stress situations.

4.8 Impacts assessment

Comprehensive knowledge of impacts of DRIVE C2X functions will be provided on different levels, ranging from individual user behaviour to the transport system and society level in Europe. The target area (safety, environment, efficiency, mobility) specific impacts are based on changes in driver behaviour. Therefore, the measures focus on driving and travelling behaviour. For each impact area, most effective measures compatible with the indicators and criteria will be applied. Furthermore, the target area specific impact estimates create the basis for regional and Europe-wide impact estimates.

The methodology for impact assessment is based on the FESTA methodology and follows directly from the evaluation framework developed in WP42. The methodology is first tested in the piloting phase, before applying it to all functions in the project.

The objectives of impacts assessment are to:

- Assess and validate the impacts on driving and travelling behaviour,
- Provide quantitative and statistically robust estimates of the impacts of DRIVE C2X functions on safety, environment, efficiency and mobility and
- For a limited number of impacts, draw conclusions on European level.

In Figure 20 an overview of the steps in impact assessment is given. The evaluation framework and FOT data provide the input for the impact assessment. Then first the impact on driver behaviour is assessed.

This provides input for the assessments on impact areas safety, environment, efficiency and mobility. If needed tools and models are used. The last step is scaling up of the effects to EU level.

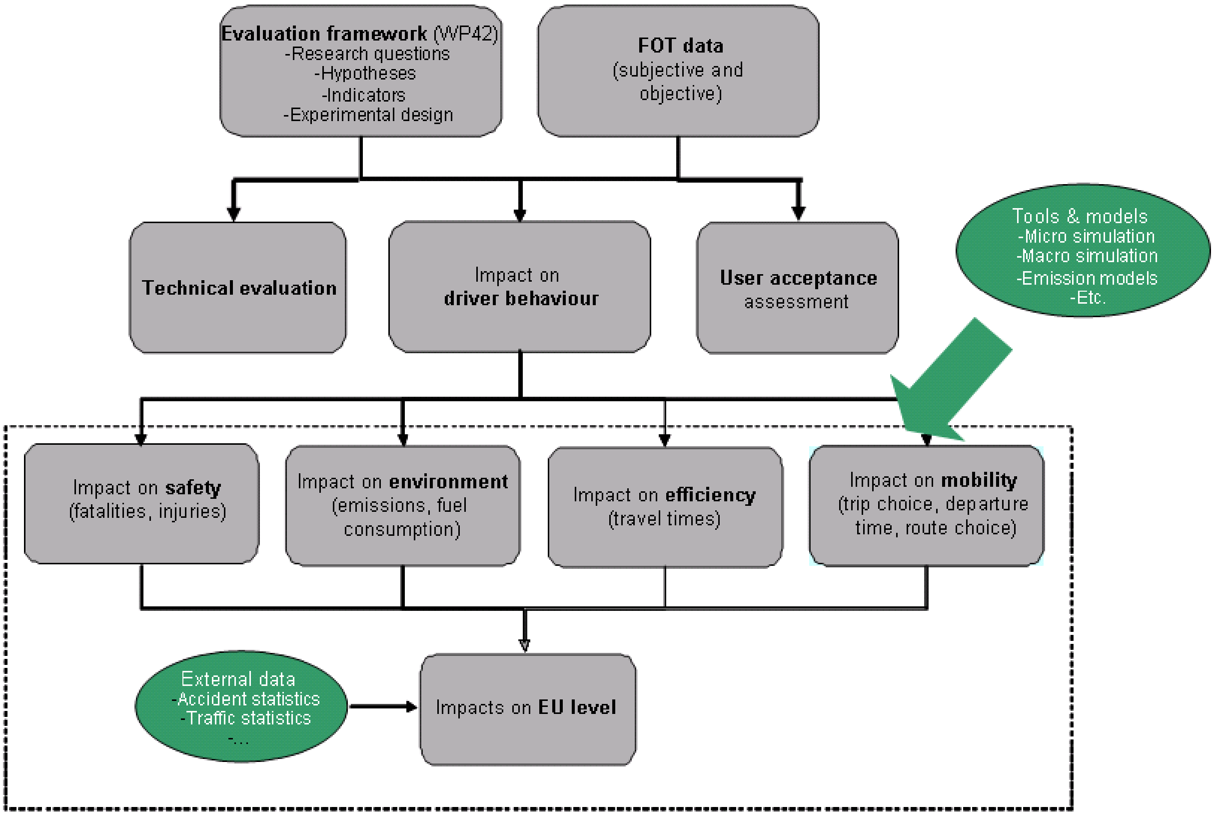


Figure 20: Overview of impact assessment in DRIVE C2X.

According to the Description of Work, WP45 starts in M10 (October 2011). However, the preparation work has already started already earlier, in M1.

Due to the iterative process of the tasks in WP45, task 451 (Piloting of the analysis tools) ends first: M10-M18. All analysis tasks take place from M10 to M36, with internal reports in M34. These internal reports serve as input for IP deliverable D11.4 "Impacts of cooperative systems and user perception". M36 has a milestone: M4.3 Data analysis completed, results documented.

All functions will be evaluated on a technical level and will undergo a user evaluation (WP46). WP45 focuses on the functions where large impacts are expected. The impact assessment will not be carried out for all functions but for a smaller set of functions; ten in total. These functions were selected according to the criteria described in Chapter 4.4.2.

A very short description of the nine selected functions for impact assessment is given below. PRE-DRIVE C2X deliverable gives a more detailed insight into the use functions. Also templates are filled in for the selected functions.

Safety functions:

1. *Road works warning*: vehicles approaching a road works site are warned in due time before they are reaching the road works area. The function works for stationary road works as well as for moving road works as they can be found typically on motorways.
2. *Traffic jam ahead warning*: the driver is warned if he/she is approaching an end of a traffic jam to avoid running into the last vehicle in the queue.
3. *Car breakdown warning*: approaching traffic is warned in due time before reaching a broken down vehicle to avoid running into the broken down vehicle or endangering people in the vicinity of the broken down vehicle.
4. *Weather warning*: information about bad weather conditions ahead is communicated to oncoming traffic to avoid entering of areas with adverse weather conditions at a speed too high.
5. *Emergency electronic brake light*: in case of a hard braking manoeuvre following traffic is warned to avoid rear end crashes and backing up.
6. *Approaching emergency vehicle warning*: approaching emergency vehicles warn surrounding traffic about their presence to ensure that they can proceed quickly even in very dense traffic.
7. *Post crash warning*: if an accident has occurred oncoming traffic is warned to ensure that drivers slow down and do not run into the vehicles that had an accident.

Traffic efficiency related functions:

8. *In-vehicle signage & regulatory and contextual speed limit*: traffic sign information such as "ban on passing" is communicated into the vehicles and indicated in the instrument cluster or in the head unit. Information on fixed and variable speed limits as well as on the recommended optimal speed is communicated into the vehicles and indicated in the instrument cluster or in the head unit. This application does in particular address variable message signs.
9. *Green-light optimal speed advisory*: signal phases of traffic lights are communicated into vehicles in order to inform their drivers about the optimal speed to pass traffic lights at green.

Infotainment, business and deployment related functions:

No infotainment, business and deployment related functions were selected for the DRIVE C2X Impact Assessment.

4.8.1 Data processing and preparation

The objective of WP 43 „Data and Data Quality" is to ensure that the data from the test sites are usable for the evaluation, both the technical evaluation and the impact evaluation. It serves as an "interface" between the evaluation sub-project 4 and the other sub-projects that create the data flow from the logging in the test sites to the final data exploitation to establish the impacts.

In order to ensure that appropriate data result from logging and finally feed into the evaluation process, the evaluation framework will set up research questions and hypotheses. From these the indicators are derived which are required to establish the impacts. These indicators are in terms of data the last step of the evaluation process and thus the last part of the data flow over the whole project. Within WP43 the indicators and their requirements like frequency or accuracy will be turned into requirements for the data to be fed into the evaluation WPs.

This means in general that WP43 has a "two-way structure": first it turns the requirements on the indicators into requirements on the data to be logged and on the whole process of the data flow. This task includes a matching between the evaluation's requirements to the possibilities of logging. In case the requirements cannot be met, or can only be met with too high an effort, suitable solution must be found. Then, when the data flow is set up WP43 will ensure that the requirements are fulfilled and data for the evaluation is available.

Inheritably connected with the data is, of course, the definition of suitable formats. These data formats must comply with requirements especially for their processing. Due to the expected large amount of data this requirement is mostly derived from a technical processing point of view.

Data from the tests will relate not only to the dynamic data measured, e.g. in vehicles, but also relates to the description of the scenarios under which a test was carried out. Such scenarios describe the conditions of an experiment, e.g. night-time during rain, but also the configuration of an application. Of course, the test site itself and the respective road network section must be part of such a scenario description.

At the end of WP 43, data which are ready for statistical analysis will be provided. Availability, data formats, accuracy etc. will be ensured by the first working step within which the requirements from the analysis side will have been translated into requirements on the data acquisition and on the processing of the data.

4.8.2 Piloting of hypotheses and tools

The impact assessment analysis tools will be piloted for both controlled and naturalistic test setup. Pilot data provided by WP43 will be processed and this task will test whether all hypotheses can be tested. This will then be analyzed from an impact assessment perspective, but not aggregated to EU-level or between test sites. The methods for impact assessment will be finalized by feeding back piloting results to methodology development and the data acquisition (SP2 and SP3). This task will be carried out in September –December 2011, in order to provide the feedback in time. Additionally, checks of the use of data from the test sites will take place at the beginning of the assessment phase, during Test site piloting in Q2 2012.

The work process is as follows. First, evaluation guidelines (D22.1 and D42.1) are studied and needs for analysis and simulation tools are identified. Second, analysis tools and simulation tools that fulfil these needs are identified and piloted. This piloting includes assessment if the tool can handle the huge databases that are needed in the final analysis.

Third, the research questions and hypotheses are piloted. In this piloting task the question is answered whether a specific hypothesis can be answered with the data provided i.e. whether is it possible to answer it. The piloting does not include preliminary results. Nevertheless, such results have to be provided so that each impact area is able to assess if it will be feasible to assess the implications to impact areas in the final analysis. Research questions, hypotheses and implications will be piloted by those partners that will analyse them in the final analysis.

Finally, conclusions are made, feedback and recommendations are given.

4.8.3 Driver behaviour

This task deals with the testing of the hypotheses. Functions and function combinations can affect driver behaviour in various ways by changing behaviour on different levels, namely on strategic (trip choice, mode choice, choice of departure time, route choice), tactical (related with interaction with other users: speed choice, lane choice, accelerating) and operational level (manoeuvring of the vehicle: steering, braking). Different hypotheses have been developed in WP42 on these possible effects, and these hypotheses are tested in this task.

To test the hypotheses different performance indicators or dependent variables have been identified and will be measured during the FOT under specific conditions/scenarios. These dependent variables can be objective (e.g., speed) or subjective (e.g., workload). The outcome of the analyses will show which of the hypotheses can be accepted and which can be rejected. In other words the analyses will show if and how drivers changed their behaviour when driving with the functions. The results of this work package will be used by the subsequent tasks that will deal with the implications of these effects for safety, environment, efficiency, and mobility.

Measuring and analysing driving behaviour

What drivers do, where they look, how they drive and what they experience can be measured. Measuring driving behaviour is needed when investigating the effects of any change in the driver's environment (e.g., changes in the infrastructure or changes through a driver support function). These measurements or performance indicators can be divided into two categories: objective and subjective performance indicators. Objective performance indicators are measured directly through sensors and do not require interaction with the driver. Subjective performance indicators do require a response of the driver. For example speed can be assessed objectively through sensors but also by asking the driver how fast he or she was driving. In general objective performance indicators are more precise than subjective ones.

Performance indicators can further be divided into longitudinal performance indicators (e.g., average speed, car following behaviour), lateral performance indicators (e.g., average lateral position in a lane, lane keeping behaviour) and 'effort' performance indicators (e.g., workload, stress). So there are six different ways of collecting data Clearly for certain performance indicators some ways of collecting data make more sense and are easier to be collected then others.

There is a difference between a performance indicator and what is measured. Speed for example is measured. But is most of the time not a performance indicator in itself, average speed is a performance indicator (see Figure 21).

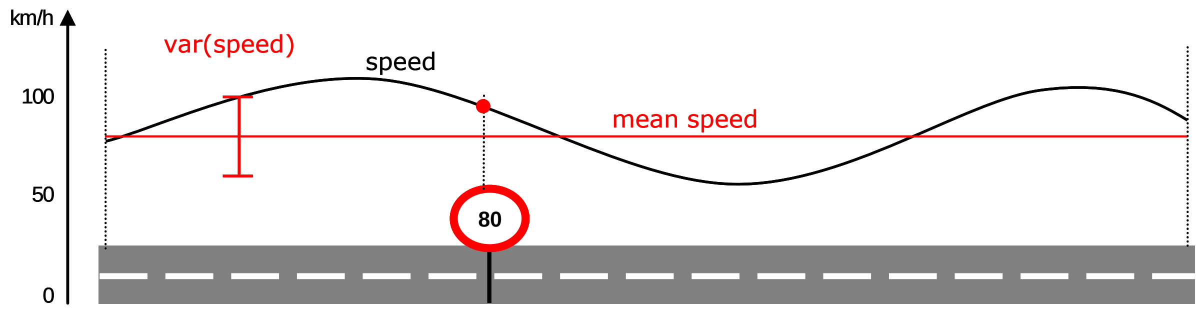


Figure 21: Illustration of the performance indicators "speed variance", "mean speed" and "spot speed" based on the direct measure "speed" (source: euroFOT D4.1).

The performance indicators are calculated on the basis of a measure. This is done for each driver and for minimally two conditions (control condition and experimental condition). The calculated values are statistically analysed to investigate whether driver behaviour has changed due to the experimental manipulation (e.g., in-vehicle function) for the specific performance indicator. The statistical tests are divided into parametric (e.g., analysis of variance) and non-parametric tests (e.g., Sign test). Parametric testing is more powerful (i.e., can more easily detect changes) but there are assumptions about the underlying distribution of the performance indicator. This means that they cannot be applied to all performance indicators (since they do not fit the assumed distribution). Non-parametric testing does not rely on assumptions about underlying distributions and can be used for any performance indicator. However they are therefore also less powerful then parametric tests.

Inputs and outputs

As input this task will use the evaluation guidelines from WP42 including study design, research questions and hypotheses. WP43/WP35 will provide the data in a pre-processed database, including indicators and situational variables.

The task will produce the effects of the selected functions on driving and travelling behaviour; this includes the results of hypothesis testing. These results will be reported in IR45.1 Effects of DRIVE C2X systems on driving behaviour (M34). The task will also deliver their analysis results to the other tasks in WP45 so they will be used in determining the implications of the functions on safety, environment, efficiency and mobility.

4.8.4 Impacts on safety

The traffic safety research questions about the impacts of the DRIVE C2X systems will cover traffic exposure (distance/time travelled), impacts on driver behaviour and accident consequences. In addition, focus of attention is dealt with as a separate issue. Both direct and indirect impacts should be covered. For traffic safety, surrogate measures will be applied. In projects such as AIDE, euroFOT and TeleFOT methods for evaluating driver behaviour have been worked out that can be applied to FOTs. These and others will be reviewed, and chosen methodologies adapted to fit the specific setup of this project.

This task produces the expected reduction in fatalities and injuries as a result of use of the specific functions or function combinations.

The effects of cooperative systems on traffic safety may appear in many, both intended and unintended ways. It is not possible to define in advance the group of accidents affected by the system, although system developers typically have as a starting point a target group of accidents for a system. Therefore, it is highly important that the analysis of cooperative systems covers all possible effects in a systematic manner.

The approach that will be used in DRIVE C2X is based on the system nature of transport. When one element of the system is affected, the consequences may appear in several elements and levels of the system, both immediately and in the long term, due to behavioural modification. Road safety is regarded as a multiplication of three orthogonal factors: (1) exposure, (2) risk of a collision to take place during a trip and (3) risk of a collision to result in injuries or death [17]. The same methodology was used in eIMPACT, PReVAL and CODIA projects [26].

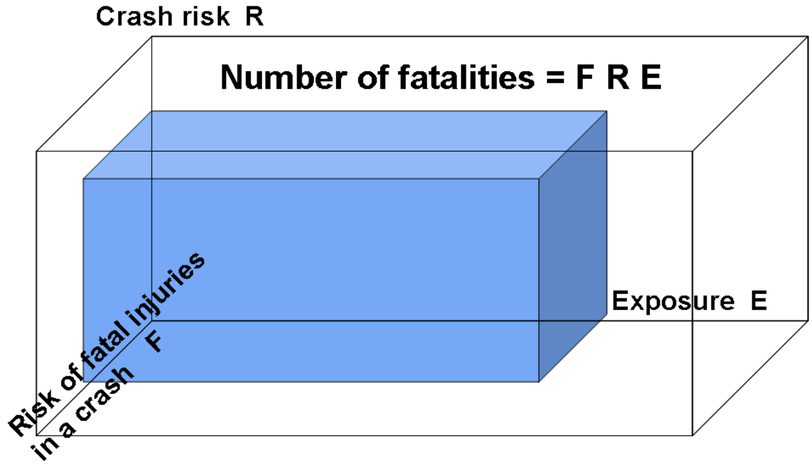


Figure 22: Dimensions of road safety [17].

The analyses cover the three main factors of traffic safety by nine behavioural mechanisms via which cooperative systems affects safety as first described in Draskóczy et al. [3]. The first five mechanisms are connected to the accident risk:

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-users.

The second group deals mainly with exposure:

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

Finally, there is the mechanism that deals with changes in accident consequences:

9. Modification of accident consequences.

Based on the travel and driver behaviour assessment, the traffic safety impact assessment analyses the functions under research by interpreting the safety impacts of relevant travel and driver behaviour changes tested by hypotheses and research questions.

Safety impacts are divided into three groups: changes in exposure, risk and consequences (Figure 22). Exposure covers time spent on road, transport mode, timing of journeys and used road types. Exposure increases and consequently safety decreases when mileage increases due to an increase in the number of journeys. Changes in transport mode distribution affect safety because public transport is safer than private cars. The timing of the journeys affects safety, too, as driving during peak hours and night time is more dangerous than driving in other times. Safety increases as proportion of motorway driving increases and decreases as proportion of urban driving decreases.

Risk covers speed, proximity, position, interaction, use of signals, driver condition, and attention. Risk and safety increase as speed, standard deviation of speed, number of jerks, or speed violations decrease. Safety also increases as following very close decreases or as lateral position is more stable. Safety increases as vulnerable road users are taken into consideration and as signals are used correctly. In addition, safety increases as driver condition is not deteriorated and focus of attention is allocated correctly. Consequences cover speed and vehicle. Consequences are more severe when the speed increases. Vehicle affects consequences and safety as bigger and stronger vehicles are safer in crash.

The safety impact assessment method developed in the eIMPACT and CODIA projects was developed further by VTT. This method can be applied also to the safety impact assessment of DRIVE C2X. In the analyses all nine safety mechanisms are taken into account. The effects for the sub-mechanisms are the results of the following multipliers: share of relevant accident types (from statistics), share of accidents that can be affected (from in-depth studies), and assumed share of accidents that can be avoided or mitigated. In DRIVE C2X some of the figures can be measured. However, field measurement will be complemented with statistics and expert estimations. Finally, the overall impact of functions and function bundles are calculated. Consequently, this task produces the expected reduction in fatalities and injuries as a result of use of the specific systems or system combinations.

Inputs and outputs

The effects of ten selected DRIVE C2X systems on travel and driving behaviour will be the input for this task. Needs for additional data sources will be identified.

The task will produce safety related performance indicators and results of hypothesis testing. These will be reported in IR45.2 Safety effects of the DRIVE C2X systems (M34) as numerical estimates of the safety effects of the selected DRIVE C2X systems. The task will also suggest methodology for scaling up to Task 457.

4.8.5 Impacts on environment

The environmental research questions focus on impacts of the DRIVE C2X functions on noise, energy consumption, emissions and surroundings. Cooperative systems can influence the environmental impacts of traffic in several ways. They can influence the distances travelled and the driving behaviour: choice of speeds and the variation in speeds. This will result in changes in the fuel consumption and emissions of vehicles (pollutants such as PM10 and NOx; also noise emissions can be considered).

From some vehicles, fuel consumption and emission data may be directly available from the field tests. If this is not the case, several different approaches towards vehicle emission and fuel efficiency estimation are possible, reaching from complex physical models to statistical methods. The variety of models is given by the variety of functions which greatly differ in terms of purpose. In general a model can be considered adequate if it delivers the required level of detail while being as simple as possible.

For DRIVE C2X purposes two levels of models are adequate:

- *Micro scale* traffic and emission models: these models use instantaneous vehicle speed and road gradient as input. Typically 1 Hz recording or simulation is applied to provide input data. The models deliver instantaneous fuel consumption and emissions of CO_2, HC, NO_x, NO2, PM, PN, CO, etc as well as engine speed and engine power course and several kinematic parameters.
- Network traffic and emission models (*meso scale*): these models depicture the street network as road sections, where each section is homogeneous in terms of traffic volume, driving conditions and road gradient. Inputs are the length and average road gradient of each section together with traffic volume and traffic situation and/or average speed. Results are fuel consumption and emissions per section.

If influences such as changes of driving behaviour or traffic control are to be studied the use of micro scale models is appropriate. If only the traffic volume and the length of routes is changing, meso - scale models are sufficient.

Micro scale modelling is more demanding for computation time than meso-scale modelling. Thus large networks with many vehicles on the road can be simulated more efficiently with meso-scale models. The emission factors for meso-scale models [g/km of the emissions per vehicle class] can however be computed by micro scale models, if changes in driving behaviour have to be considered too.

The vehicle fleet composition is input data for all model categories to simulate average vehicle fleet emission behaviour. The fleet composition describes the shares of cars, HDV, LDV and buses and within each category the shares of gasoline and diesel driven vehicles (optional also CNG, HEV, etc.) and the shares of exhaust gas standards (EURO-classes). In DRIVE C2X we can depicture single vehicles as well as any vehicle fleet.

The partners in this task have access to both micro and meso-scale traffic and emission models.

Inputs and outputs

The effects of nine selected DRIVE C2X systems on travel and driving behaviour will be the input for this task. Needs for additional data sources will be identified.

The task will produce environment related performance indicators and results of hypothesis testing. These will be reported in IR45.3 Environmental effects of the DRIVE C2X systems (M34) as numerical estimates of the environmental effects of the selected DRIVE C2X systems. The task will also suggest methodology for scaling up to Task 457.

4.8.6 Impacts on efficiency

Traffic efficiency concerns the travel time losses (delay) associated with travel. Available methods and tools include a direct analysis of the FOT data, and an indirect approach using traffic simulation. For functions without interaction effects, a direct approach may be the most efficient. This approach determines efficiency on the basis of FOT results regarding the travel time losses of the FOT participants, taking into account confounding variables, and scales up the results based on a simple model. For functions with interaction effects, FOT data are not sufficient because the interactions between FOT vehicles will be few and the penetration rates in the FOT will be low. In this case, simulation is the required tool to scale up the results to higher equipment rates. The partners in this task have access to traffic simulation models, which can be used for this purpose. These models need to be fed with FOT data. The required data depends on the system under analysis, and will include such items as the vehicle speed, headway, route, system status and use, as well as situational variables and confounding factors such as route, road type, weather, lighting, and driver behaviour related parameters.

Based on the driver and travel behaviour assessment, the traffic efficiency impact assessment analyses the functions under research by testing hypotheses and answering research questions. These research questions and hypotheses will be developed in WP42.

Traffic efficiency is affected by changes in traffic volume and traffic flow caused by use of the system under study. Changes in the amount of time spent on the road, car use, peak vs. off-peak driving, route and road choice affect traffic volume. Changes at the tactical driving level, such as changes in speed, accelerations and decelerations, proximity to other vehicles in terms of headways and lane change behaviour all affect local traffic flow indicators.

For four functions, significant effects are expected on traffic efficiency:

1. In-vehicle signage / Speed limit,

2. Green-light optimal speed advisory,
3. Traffic jam ahead warning; and
4. Post crash warning.

For only these four functions the traffic efficiency impact assessment will be carried out with use of a micro simulation tool (if the FOT data does indeed justify this): the *modelling approach*. For the other five functions, it is possible to test hypotheses directly with the FOT data: the *direct or linear approach*. This will be done depending on the data from the test sites.

Changes in amount of time spent on the road can be calculated with a *direct or linear approach*, taking into account situational variables. Both approaches are worked out in the next two paragraphs.

In Figure 23, a high level overview of the steps in the traffic efficiency impact assessment is given. A certain function is tested in an FOT and produces FOT results (performance indicators, situational variables). Effects on mileage/exposure can be calculated by a linear approach. Effects on speeds and travel times can be calculated by a linear approach (for functions where no significant efficiency effects are expected) or a modelling approach (for functions where significant efficiency effects are expected). The effects on strategic and tactical level together form the total traffic efficiency impact.

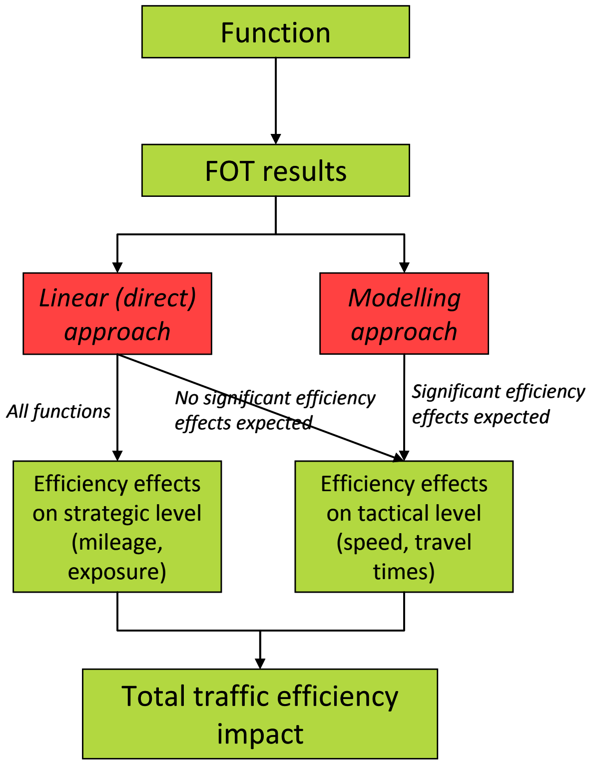


Figure 23: Overview traffic efficiency impact assessment.

<u>Linear approach</u>

In the linear approach FOT data is used directly to estimate impacts and test the hypotheses. This linear approach can be applied to all functions for assessing the impacts on the strategic level. Also for the functions where no significant efficiency effects are expected the linear approach can be used to assess the impacts on the tactical level.

Objective data can provide information on increase/decrease in exposure in a 'within subject' setting (the same group of participants first driving without the function, and then with the function). In a 'between subject' setting (two groups of drivers: one driving without the function, one driving with the function) change in exposure cannot be measured since there are two different groups of drivers.

From the linear approach, most hypotheses can be tested and research questions answered. This also provides input to Task 457 (projection to EU level). In Task 457 European statistics are available on kilometres driven split for the situational variables. A weighted scaling up can then be carried out to EU level from change in exposure and change in indicators (especially travel times), for a certain penetration rate. This scaling up step is described more in detail later in this chapter.

Modelling approach

Micro simulation uses FOT data such as speed, accelerations and headways as input. With micro simulation the interaction between equipped and non-equipped vehicles and changes in driving behaviour can be modelled as well as higher penetration rates, and traffic efficiency impacts can be assessed on a network level. The micro simulation tool needs information on the working of the function and on driver behaviour, in order to be able to implement the function and to implement the driver model.

Micro simulations will be carried out for the five functions where significant effects on traffic efficiency are expected.

The steps in performing micro simulation are as follows:

1. Implement the function under consideration in the micro simulation tool;
2. Implement the behavioural model in the micro simulation tool. The behavioural model describes the behaviour of the driver when driving with the function in his or her car;
3. Define the experimental set-up (definition of simulation scenarios): geographic region (network to be used in simulation), time span (period, hours that are simulated), year (base year, future year), traffic volumes, penetration rates;
4. Carry out simulations (for each scenario); and
5. Analyze simulation results

The micro simulation tool calculates the effects on speeds, variation in speeds, delays and travel times. These data are combined with the outcomes on change in exposure, which are calculated directly from the FOT data. After the simulations and calculations, all traffic efficiency hypotheses can be tested and research questions can be answered.

Inputs and outputs

Effects of the selected DRIVE C2X functions on driver and travelling behaviour will be the input of the task. At some points, external data may serve as additional input.

The task will produce efficiency related performance Indicators (exposure, speed, speed variation, delay, travel times) and interpretation of results for EU-level as well as results of hypothesis testing. These will be reported in IR45.4 Traffic effects of the DRIVE C2X systems (M34) as numerical estimates of the traffic efficiency effects of the selected DRIVE C2X systems. The task will also suggest methodology for scaling up to Task 457.

4.8.7 Impacts on mobility

Cooperative systems may influence the mobility of the users in various ways. The users may change the timing of his/her journeys, the destinations of travel, the mode used, the routes selected and may even decide on not to do specific journeys at all or to make new journeys that he/she did not consider before having the DRIVE C2X functions at disposal.

Mobility is willingness to move along with potential and realised movement rather than just physical movement of vehicles, people and goods. Along with transport and infrastructure it encompasses people's and road users' attitudes, opinions and choices in their daily travelling and movement. The concept of mobility is versatile. However, it is often reduced to transport or mixed up with accessibility or efficiency.

Based on the travel and driver behaviour assessment, mobility impact assessment analyses the functions under research by interpreting the mobility impacts of relevant travel and driver behaviour changes tested by hypotheses and research questions.

Mobility impacts are divided into three groups:

1. change in exposure (amount of travel),
2. travel patterns and
3. journey quality.

Amount of travel covers number and length of journeys. Mobility improves as the number of journeys increases and deteriorates as the length of journeys increases. Travel patterns cover transport mode, time budget and timing of journeys. Transport mode choice and route choice either improve or deteriorate mobility based on user preferences whether they favour car, public transport, etc. or motorway, rural roads, etc. Mobility improves as the time budget is narrowed. Journey quality covers travel comfort and feeling of safety. Mobility improves as they improve.

The best way to measure mobility changes is a travel diary together with questionnaire as logging covers only the use of car as mode of travel. However, travel diary is not a feasible method to be used with controlled study design as controlled driving tasks does not reflect the true mobility of the test participant. Consequently, for the test sites with controlled study design, the mobility impact assessment will be based on questionnaires i.e. subjective data. As those test participants do not get to use the functions in their daily lives, they must speculate the effects that the cooperative systems may have on their mobility. Nevertheless, the test drives give them some kind of idea what it would be like to use the system in everyday life. Therefore the results can be considered as indicative.

Filling the travel diary is laborious for test participants (to report several features of all their trips during seven days several times during the study). However, the TeleFOT project used it successfully. It is assumed that the efficiency functions have stronger influence on mobility than the safety functions. Therefore the feasibility of the use of travel diaries depends on functions applied on the test site. The amount of travel, route choice and timings can be studied based on logger data with respect to travelling by car. Travel patterns and journeys made by other travel modes than car would be best studied with objective data collected via travel diaries. However, subjective data on travel patterns can be collected with questionnaires. Quality aspects can be covered with questionnaires, too.

<u>Inputs and outputs</u>

Effects of selected DRIVE C2X systems on travelling behaviour will be the input of the task. Needs for additional data sources will be identified.

The task will produce mobility related performance Indicators and interpretation of results for EU-level as well as results of hypothesis testing. These will be reported in IR45.5 Mobility effects of the

DRIVE C2X systems (M34) as numerical estimates of the mobility effects of the selected DRIVE C2X systems. The task will also suggest methodology for scaling up to Task 457.

4.8.8 Projection to EU-level

It is necessary to scale up impacts to the level at which stakeholders can make decisions. Even large FOTs with thousands of vehicles only represent a tiny percentage of the vehicle kilometres and of the traffic composition at any given time. The translation of the results at the test site level to higher levels requires both methodological development as well as a coupling with computer models with high-quality data sources.

After the other tasks in WP45 are carried out, scaling up of the results to EU level can be performed. Results have to be translated to real world impacts by scaling up from the small scale (FOT region, simulated (local) network) to the whole of Europe, and from a simulated time frame (FOT time frame, simulated hours) to a full year. These real world impacts are then input for a cost benefit analysis.

Experimental conditions do not necessarily match with, or completely cover, real world situations. A number of steps are possible to scale up for these conditions: driver population, higher penetration rate of systems, time scale (times of the day) and geographical scale, different time periods (for example future demands instead of present demands), weather conditions, lighting conditions and road types, integration of other measures or systems, etcetera. Some of these aspects are taken into account in the scenarios that are used in simulation, for example penetration rate. Others have to be taken into account in scaling up.

The FOT data is a critical input via the impact assessment. The impacts on driver and travel behaviour, safety, traffic efficiency, environment, and mobility are determined in the previous analyses. Hypotheses are tested and research questions are answered.

There are two main methods to carry out scaling up: a modelling method (with the use of a macro simulation model) and a direct method (with the use of statistics). In DRIVE C2X, we plan to use the direct method. For this method, data on EU level is needed.

The direct method works as follows. Data on kilometres driven and situational variables (road type, traffic situation, etc.) are collected on EU level. Results from the impact assessment are also split for these situational variables. We provide a simplified example. Travel times (for scenarios with 100% penetration and 0% penetration or with/without function) are calculated for free flow situations on urban roads, rural roads and motorways, and for high density situations on urban roads, rural roads and motorways. So in total the travel times are calculated for six categories, for two scenarios (0% and 100% penetration or with/without function). Also the number of kilometres driven in the six categories for the two scenarios is available (from the traffic efficiency impact assessment).

Now the scaling up can take place; in fact this is a (weighted) multiplication of impact assessment results to the whole EU. For each of the six categories and for the two scenarios we know in the simulation how many kilometres were driven and what the travel times are. Also for the whole EU we know for each category how many kilometres are driven (per year). A weighted multiplication will then give travel times on EU level for the two scenarios, and a comparison of travel times can be made between the scenario with no penetration and the scenario with full penetration (with function versus without function).

How extensive the direct method is, depends on the amount of data that can be found on EU level and/or the possible estimations that can be made, as well as on the situational variables that are measured in the FOT. Situational variables include not only penetration rate and road types, but also weather and lighting conditions and characteristics of the population.

Similar to the approach in eIMPACT, a "cluster" approach to the scaling up is considered. Depending on the availability of data, relevant clusters of countries are developed. The countries in a cluster should be similar in relevant characteristics. For each cluster, one or two relevant countries are chosen, for which the (detailed situational variable) data is deemed representative for the entire cluster. This data is then projected onto the entire cluster, and used in the scaling up. For example, weather conditions for one of the Nordic countries are used for all the Nordic countries.

The relevant situational variables can also vary by impact area. Relevant situational variables for traffic efficiency include for example traffic situation, road type, speed and accelerations or hard braking. For safety, the situational variables mentioned above are very relevant, as well as lighting and weather conditions.

The outcomes of scaling up (changes in travel times and emissions on European level, the reduction in the number of fatalities and severe injuries in road accidents) can be used for different purposes, for example as input for cost benefit analysis and in follow-up activities like demonstration, business modelling, deployment and dissemination.

4.8.9 User acceptance

In order to evaluate the 18 selected functions the objective and subjective perspective has to be taken into consideration. The objective perspective will be covered in WP45 via impact assessments of the functions. As a complement WP 46 will perform user acceptance testing in order to obtain the subjective user perspective, i.e. attitudes, usefulness, likes and dislikes, benefits, willingness to use and willingness to pay for the functions.

Objectives and target groups

- To provide information and an understanding regarding the usage and perception of DRIVE C2X functions,

To identify the user groups and their expectations towards DRIVE C2X functions,

- To assess the acceptance of the functions and interfaces, usefulness, benefits and willingness to pay,
- To asses impacts on communication and interaction between users,
- User groups include: drivers, road operators, transport operators, service and system providers, public authorities.

Selected methodologies

1. Questionnaire – A written questionnaire that will be given to all test drivers/respondents before and upon completion of the test drive to compare expectations vs. actual satisfaction. The pre-questionnaire will measure the respondents' general attitude prior to testing the function and the post-questionnaire will compare reactions after having tested the function including satisfaction, attitudes and usability. This standardized and quantitative approach allows us to gather data from a large number of respondents.
2. Focus groups – Focus groups with a selection of test drivers at a couple of the test sites (e.g. DE, NL, IT) will be conducted after testing the function. As a complement to the questionnaire these qualitative in-depth discussions where test users are asked about perceptions, satisfaction level, beliefs and attitudes deliver deeper insights than a standardized questionnaire.

3. User panel – Upon completion of the first test runs a user panel will be set up with a selection of test users who are willing to provide their feedback regarding the functions over a longer period of time. This methodology allows for long-term analysis and investigates behavioural and attitude changes regarding the functions over time as opposed to one-time measurements.
4. Expert talks with stakeholders – During the course of WP46 one-on-one expert interviews will be conducted with various stakeholders e.g. road operators and public authorities. These interviews will provide additional insight into the general interest of DRIVE C2X.

Deployment of the selected methodologies correlating to functions

As it does not make sense to evaluate all 18 functions using the same methodologies a selection of the three first methodologies (questionnaire, focus group, user panel) listed above will be used on a case-by-case level. The selection of methodology will depend on the usage of the function which in turn depends on the occurrence of the specific situation/case. As an example a long-term measurement of changes in attitude toward the function e.g. "Car breakdown warning" does not make sense as a car breakdown hopefully will not occur very often during the course of the project/measurement.

4.9 Test design

4.9.1 Principles of data collection

Data collection can be event-based or time-based. An event is a specific driving situation relevant to the function. Time-wise, the event begins when the driver reaches the distance at which the function is activated or would be activated, and ends when the driver encounters the location/situation that triggered the activation of the function, or deviates to an alternative route.

Data is collected in a real driving situation when the driver is disturbed as little as possible due to the test arrangements. The principle of FOTs is to go into real traffic and let normal drivers drive lengthy periods and continuously with DRIVE C2X functions as long term impacts are important target of FOTs. Therefore even in controlled tests, the test subject is given a task and instructions when he/she is leaving for the test ride but is then left driving without further instructions on the way. The tasks must be planned in the manner that the security of the subject is ensured and no risks are taken.

To be able to measure the impacts a reference or baseline is needed. In a base line condition the test person drives same route, in same conditions, as during the tests – but without the application or possibility to use the function. After the baseline has been collected functions are activated (mostly one at the time) and driving tasks are repeated.

Base line data for each test person should be collected using the same car in same or similar area (speed limits, road type, link/intersection) and in similar conditions (lighting, weather, traffic situation) as in actual tests while using the function. Base line data will be needed for events relevant to the function. To complement this data, base line data will be collected for other normal driving situations as well.

There is always natural variation in driver behaviour. Therefore, a sufficient number of trips in base-line condition are needed to handle this variation. The base-line route should include the equipped sections (during base-line data collection without the service). However, the base-line route can be longer to avoid test drivers to learn too well or get bored with a short test route. The base-line data collection must be planned carefully – in some cases there might be a danger to spoil the test environment with the repeated trips (e.g. to learn too well the places where incidents occur and therefore loose the opportunity to warn about something not expected).

It is noteworthy that before the base-line data collection the test drivers must have the opportunity to drive the car and to become familiar with the car and the fact being monitored while driving.

4.9.2 Controlled tests

In DRIVE C2X there will be two different approaches: controlled and naturalistic approach. In the controlled approach the test drivers are called into the test and they are asked to drive the test route with some arrangements. One test includes several runs of the route. Several situational variables (i.e. circumstances) can be fixed and selected in advance. The experiments can be designed so that some variables are systematically controlled during the data collection. The controlled tests may be more practical to organize than naturalistic tests or in some cases essential for some functions, especially when several equipped parties are needed in the same location to provide C2X services. The advantages in the controlled approach is the possibility to decide in advance which circumstances and situations will be covered, and therefore have better control of these variables. In a controlled approach it is, however, difficult to cover any long-term impacts. In the controlled tests, within subject design will be used. This means that subjects serve as their own control; they are measured before and after the treatment and these behaviours are compared by means of statistical methods. The approach is assessed as appropriate for a relatively short term tests where no significant seasonal trends are expected.

4.9.3 Naturalistic tests

In the naturalistic approach the test drivers' behaviour is monitored in their daily driving and the routes are based on drivers' needs. The collected data is organized according to the independent and situational variables afterwards. In this approach, the design is applied to main part of the data afterwards. It is possible to catch situations not in control, e.g. weather.

Clearly, the advantage in the naturalistic approach is the better ecological validity than controlled tests, it will be more convenient to conclude what would happen in real traffic when the systems will be implemented and used widely. In addition, with naturalistic approach impacts on mobility and overall long term impacts can be assessed.

For the naturalistic approach with longer data collection period, the between subject design is suggested. This means that in addition to before-after situations, there is another control-situation realised by means of a so called control group that doesn't receive any treatment but serves only as a control to the test group(s). This group is measured in the before- and after situations of the actual test group (so in the same time). This is motivated to be able to control the trends e.g. related to seasonal variation of mean speeds in the traffic flow. For some functions, the within subject design might be considered in the naturalistic approach as well. However, there might be bigger risk to fail in the definition of the base line than in before-after design with control. A test site and function specific solution must be designed carefully.

4.9.4 Sample

Selection of the test persons determines to which population the results can be generalized. Therefore, it would be beneficial to have different kind of user groups in the samples.

On the other hand, each sub group in the data must reach a minimum size to enable conclusions. In addition, if the total sample is very heterogenic there will be more variance in the data which deteriorates chances to show statistically significant results. Furthermore, there might be more potential to show impacts of the functions for some user groups, e.g. an intersection support system could be more beneficial for elderly drivers and therefore show better results.

Consequently, it is important to consider which user groups are needed to cover. The four main background variables to be considered are (1) how experienced the drivers are in car driving and (2) use of new technology, (3) gender and (4) age. It is noteworthy, that in the samples there should not be biases but the age group demands should be fulfilled for both gender. In addition, the drivers should be familiar with the road network in the test site, and with the car they will use in the FOT.

Sample size defines the number of *research units*. The research unit refers to the unit which will be used in the analyses. Here, the research unit is defined as the number of events for a specified situation (road type, speed limit, other circumstances). For one test driver there may be several events, and for one test car several drivers. The estimate for the number of events per function per test route will be provided in the test scenarios.

To suggest the sample size demand, estimates for the magnitude of main impacts will be assessed. The estimated sample size is dependent on the magnitude of the estimated effect, critical value and allowed error.

4.9.5 Complementary data collection methods

Questionnaire – A written questionnaire that will be given to all test drivers/respondents before and upon completion of the test drive to compare expectations vs. actual satisfaction. The pre-questionnaire will measure the respondents' general attitude prior to testing the system and the post-questionnaire will compare reactions after having tested the system including satisfaction, attitudes and usability. This standardized and quantitative approach allows us to gather data from a large number of respondents.

Focus groups – Focus groups with a selection of test-drivers at a couple of the test-sites (e.g. DE, NL, IT) will be conducted after testing the system. As a complement to the questionnaire these qualitative in-depth discussions where test-users are asked about perceptions, satisfaction-level, beliefs and attitudes deliver deeper insights than a standardized questionnaire.

User panel – Upon completion of the first test-runs a user panel will be set up with a selection of test-users who are willing to provide their feedback regarding the system and functions over a longer period of time. This methodology allows for long-term analysis and investigates behavioural and attitude changes regarding the systems and functions over time as opposed to one-time measurements.

Expert talks with stakeholders – One-on-one expert interviews will be conducted with various stakeholders e.g. road operators and public authorities. These interviews will provide additional insight into the general interest of DRIVE C2X.

4.9.6 Constraints for field tests

The purpose of field trials is to test and acquire information on systems and services that are technically relatively mature and have undergone limited technical and user trials. Usually these investigations provide knowledge that help to take further decisions on what direction to choose. Until now DRIVE C2X systems have been subject to only small-scale and fragmented tests. Furthermore, it is known that travellers need assistance time-wise that extends beyond of ADAS range only.

This information combined led to large-scale cooperative systems FOT. The aim is to see in realistic conditions the potential of cooperative functions. However, also these trials are still tests and do not show us the whole picture of cooperative traffic due to the lack of sufficient number cooperative vehicles in traffic. For this reason, several tests need to be carried out in conditions that are in a sense accelerated tests and do not directly show the full or all impacts potential of cooperative functions. This applies especially to C2C functions that require rather complicated test designs to be able to measure how drivers use and react to communication between vehicles.

Calculations used to project results from these tests to larger vehicle fleets need necessarily taken with care can be taken first only indicative. However, together with subjects' interviews and driving logs, we will obtain enough information to take decisions on how to proceed with further development of cooperative systems and their commercialisation.

4.9.7 Piloting

The piloting of FOTs consists of three phases: (1) piloting of technical functioning, (2) piloting of field tests, and (3) piloting of analysis. The purpose of the technical piloting is to validate each function and the entire DRIVE C2X system to ensure the technical functionality of the implemented cooperative systems i.e. the technical functioning of devices and applications as well as cooperation of functions. The second element of the technical functioning is related to data collection and test control: logging, data transfer, monitoring and test control. The last element of the technical piloting is to ensure functioning of web-based questionnaires and recruitment web-site.

Once the technical pilot is complete and the technical functionality is ensured, field tests can be piloted. First, pilot test subjects are recruited outside of DRIVE C2X people. They use the recruitment test site and receive all written material that is prepared for the actual subjects. That includes contracts, instructions. If FOT includes test subjects installing any software or hardware to their vehicles, mobile phones etc. the pilot test subjects do the same. All phases of the actual FOT are conducted in small scale in the pilot. That should include all user groups, all shifts between functions and function modes, all function combinations. The pilot test subjects fill in all the questionnaires etc. to pilot if questions are understood correctly. The pilot subjects are asked to give feedback of all phases of the FOT pilot.

Third phase of the piloting is the piloting of analysis. The purpose of that is to make sure that the analyses can be performed as planed and research questions and hypotheses answered as well as implications made. Piloting of analysis starts from the use of database and validation of raw data. Then aggregation and pre-processing of raw data into variables that will be used in the analysis will be piloted. One important aspect is to check the interoperability of test user IDs in different datasets (logger data, questionnaires, etc.) to ensure incorporation of all data. Finally, the research questions and hypotheses can be piloted and implication to all impact areas made.

All problems encountered in any phase of the pilot must be solved before the FOT can start. It is highly recommended that even the recruitment of subjects does not start before the pilot is complete as delays cause dropouts and frustration to subjects.

4.9.8 Subjects management

The subject recruitment can begin when pilots have been completed and it has been ensured that everything works as planned. When the recruitment is done through a web site all the people who volunteer to work as subjects will not end up as such – even if the criteria and requirements are presented clearly. There are number of reasons: Either volunteers do not qualify, the timing of the tests does not suite them, they move to another location, they break their legs etc. As a rule of thumb based on TeleFOT experience: if you need N subjects, there have to be 1.5 N volunteers. For test that last relatively long period, the number of dropouts is significant and a plan has to be made how to replace them.

An efficient way to describe the project and tell about the role and tasks of subjects is to keep debriefings. Subjects can also sign the contracts there. However, the subject managers have to be prepared to keep several, even individual debriefings as it is impossible to find a time that would suite everyone.

If subjects are driving their own cars in the test sites with naturalistic design the subject manager has to be prepared to help with the installation of the systems. In addition, in tests sites with naturalistic design an online help desk is needed. Based on TeleFOT experience, it takes a full-time person to handle 100 subjects providing them help, keeping records up-to-date etc.

4.9.9 Tests

In the following, the driver tasks and some test arrangements in the controlled approach are described. Firstly, the test subjects must have the opportunity to drive the car and to become familiar with the car and the fact being monitored while driving before the base line data collection. After familiarization, the test subject is given a task: He/she is asked to drive the in advance agreed routes 3 to 5 times, from A to B – base line route and test route. The base line route may be longer than the test route but includes the equipped sections or sections designed for the actual tests. The driving is done during several days.

The route is indicated as a sequence of locations/nodes the driver must pass. The nodes must be chosen such that it is natural to pass by the equipped road section. There are three options to keep the test driver on the baseline route: 1) the nodes are marked on the map, 2) a test leader follows during the first run and advice the route, or a combination of 1) and 2). Same procedure should be followed in each test site. An additional option would be use of navigator. However, the disadvantage with the use of navigator is extra workload (devices) and distraction for the driver. In addition, during some tests the driver should be allowed to choose an alternative route.

A specific task is planned for the driver in point B (e.g. 'write down which flag is hanging on the window of a store'). Based on test drives an estimate is given how long it should take to do the task.

The test person is asked to drive as normally as possibly like he/she would drive with his/her own car in a similar area. It is told to the driver that his/her behaviour will be monitored but he/she is asked not to bother about the monitoring. The test persons must be motivated for both situations: for base line the motivation could be technical testing, the HMI is turned off; before the actual tests the test subject is told that some warnings may appear while driving. The application and functions will be introduced to the driver before the test drives.

In tests based on naturalistic approach, test drivers' behaviour is monitored in their daily driving and the routes are based on drivers' needs. The DRIVE C2X application is installed to the vehicle after the baseline period is finished.

4.10 Test sites

4.10.1 Test sites characterisation

Here a first overview on the current status (as of six months from the project start) of all seven test sites employed in DRIVE C2X.

These are:

- System test site in Helmond (The Netherlands),
- Large-scale functional test site Frankfurt am Main (Germany),
- Large-scale functional test site Gothenburg (Sweden),
- Small-scale functional test site SCORE@F (France),
- Small-scale functional test site Tampere (Finland),
- Small-scale functional test site Brennero (Italy),
- Associated test site Siscoga (Spain),

DRIVE C2X features two types of test sites: System Test Sites (STS) and Functional Test Sites - either Small-scale or Large-scale functional test sites (Figure 24).

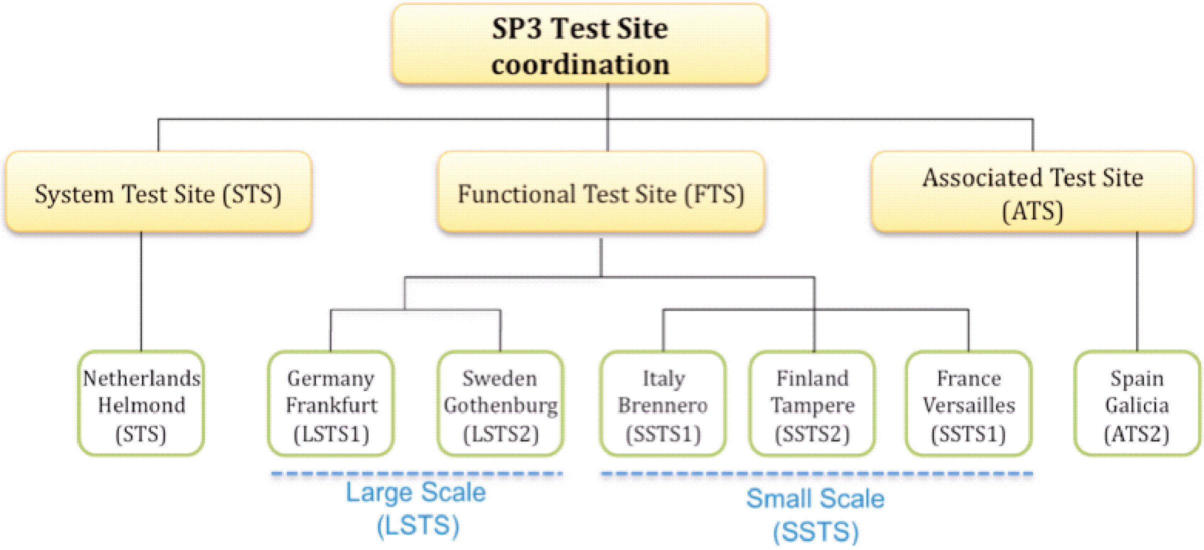


Figure 24: Test site types.

On a system test site the full DRIVE C2X system will be installed prototypically allowing implementation, test and evaluation of all functions selected for DRIVE C2X. Ideally, system test sites are test sites that feature newly equipped and do therefore not have to consider existing equipment. The cost for equipping a full system test site exceeds the envisaged budget of the DRIVE C2X project. Therefore, the DRIVE C2X system test site has to make use of sufficient national funding. From the test sites described in the following only the test site in Helmond, Netherlands, fulfils these requirements.

Functional test sites are test sites that do not necessarily comply with the full DRIVE C2X spectrum. However, they allow evaluation of functions that are similar to or the same as the functions agreed for DRIVE C2X. The purpose of the functional test sites is primarily to deliver data for the evaluations, so how drivers respond to functions being tested. Besides they will also serve for interoperability tests and for demonstration of the Europe-wide functioning of the DRIVE C2X system.

Test sites penetrate Europe from North to South (Figure 25).

Figure 25: DRIVE C2X test sites.

The associated test site will follow DRIVE C2X implementation guidelines and will contribute to the collection of FOT data. The figure above shows all DRIVE C2X test sites

4.10.2 Test sites by country

The Netherlands

The Dutch test site is called *The Helmond test site*. It is the DRIVE C2X system test site (STS), and it is located near Eindhoven. TNO is operating the site. The site consists of public roads, but the roadside equipment s owned and operated by TNO.

There are basically two test sites available in Helmond: (i) the A270 and (ii) Freilot. The test site A270 is owned and operated by TNO and it covers 4 km of highway and a 1 km of an urban network. Test site Freilot is operated by Peek Traffic and consists of 14 connected urban intersections with traffic lights. Although Freilot is closely related, it is not owned nor operated by TNO and hence it is not part of DRIVE C2X. The Freilot test DRIVE C2X is currently being considered for DRIVE C2X, but this has not been confirmed yet.

Description of roads and test track

The Helmond test site is a two-lane road comprising of a highway (A270) and an urban section (N270). The site stretches out from Helmond to Eindhoven. It is about 5 km long. In the urban area the lowest posted speed limit is 50 km/h, next 80 km /h and on the highway the limit is 120 km/h (Figure 26).

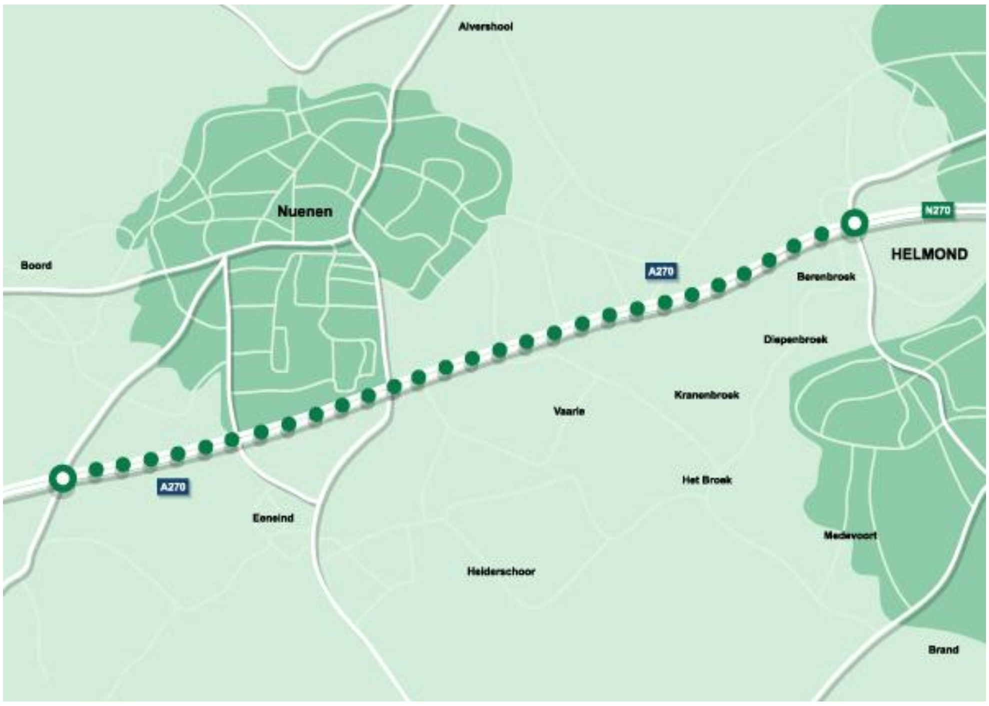


Figure 26: Test site in Helmond.

Figure 27 below gives a schematic overview of the test site. It shows two intersections, 1 bus entrance, 1 entrance, 1 exit and 4 viaducts. The small vertical lines denote the 48 poles that are installed along the test road.

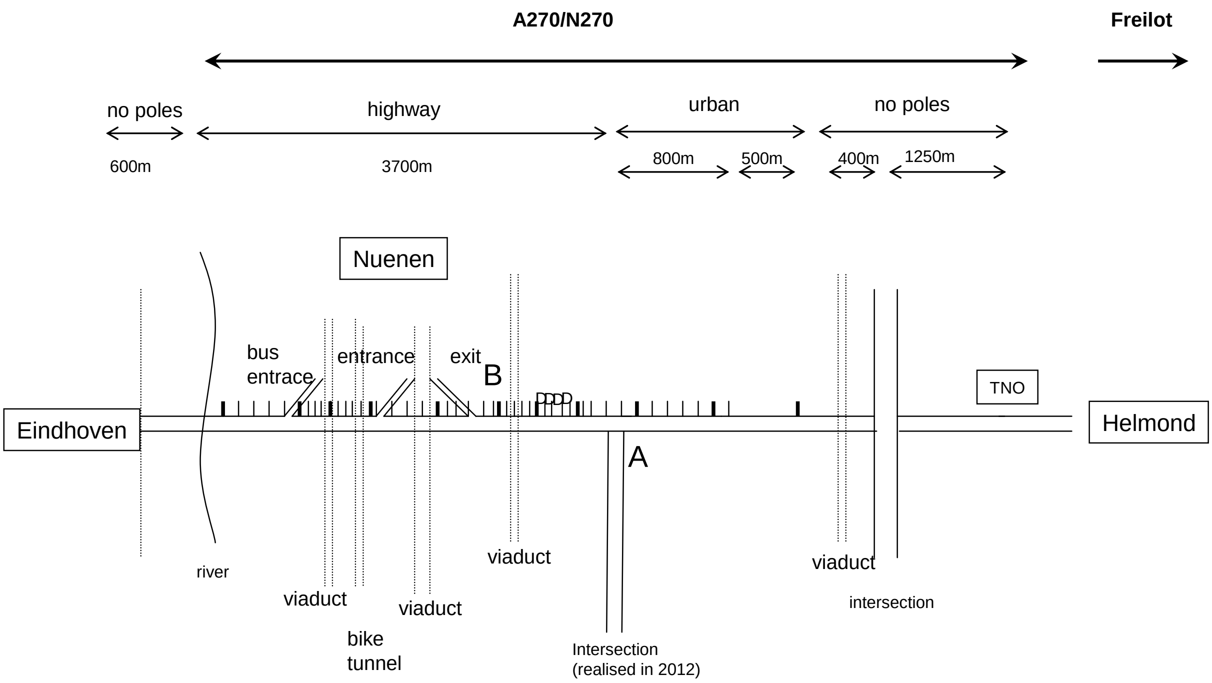


Figure 27: Schematic overview of the test site.

Available ITS and test infrastructure

ITS Vehicle Stations and Vehicles

The Helmond test site has several vehicles and OBEs in use. The OBEs and vehicles owned by the STS will be interoperable to communicate with the other DRIVE C2X partners' vehicles. Due to the dedicated nature of the existing OBEs and vehicles, it remains to be seen whether this equipment needs to be adjusted or replaced to support a given type of logging, HMI etc to be decided later. The current plan is that the existing equipment will be used mainly for preliminary testing of communication on the STS, because the goal of the STS is merely to test the interoperability and integration of the fleet of the OEMs and suppliers.

Logging OBUs

Within FEEST 50 OBU's have been created that log data. Basically these are TomTom systems where the GPS position, speed and acceleration can be stored on a SD card which can be read offline. The OBU's can easily be integrated in ordinary vehicles.

Communication OBUs

Within SPITS, 20 OBU's have been designed to communicate with the roadside. The OBUs are implemented on dedicated hardware (special PCB and aerial) and proprietary software on a Android platform. This includes interfacing with CAN, 802.11p and a GPS module. These OBU's can relatively easily be integrated in ordinary vehicles without the need for extensive adaptations. For instance, the aerial is attached to the roof by means of magnets.

Logging can be done on an SD card or by sending data directly to the RSUs.

Vehicles

8 Toyota Prius test cars. These Toyotas are adapted for the GCDC and C&D to implement automated driving in the longitudinal direction. They have installed 8 of the 20 communication OBU's.

Other vehicles. TNO Helmond owns more vehicles, but these are probably less suitable for the DRIVE project:

2 Citroen C4, where one of the two is automated driving in the longitudinal direction.
1 BMW used in the SafeSpot project, it does contain 802.11p and is used for "slippery road"-warning.
1 Jaguar, adjusted for automated driving in the longitudinal direction, used for tests on the vertical dynamics (e.g. suspension).

Logging is all done in-vehicle. Since these vehicles are not used within DRIVE C2X, no further details are required.

ITS Roadside Stations

The A270 contains 11 roadside stations (approximately every 500m), that have a complete coverage (including overlap). Freilot consists of 14 intersections with traffic lights.

Both the A270 and Freilot use the same type of road side units. They are equipped with 802.11p modules. The current differences between the ETSI standard used in DRIVE C2X and the CALMd (daemon) standard used in Helmond are visualised in the following:

	Applications
ASN.1*	ASN.1
Georouting	CALM fast
802.11p	802.11p*
Hardware	Hardware
ETSI	CALMd

OSGi
@ Control room

ITS communication
@ roadside & vehicle

Figure 28: DRIVE C2X vs. Helmond communication components

Next to communication, also the sensors form part of the roadside units (mostly cameras). All data (both communication and sensor data) is transferred via a dedicated fibre network to the control room. In the control room, the processing of the data is performed (decryption, parsing of messages, higher communication layers like geo-routing, logging etc).

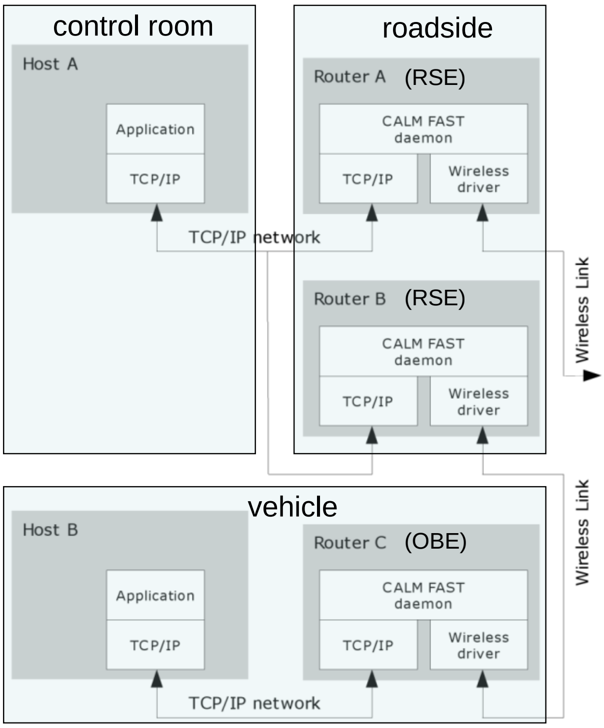


Figure 29: CALMd (daemon) implementation developed in SPITS.

This figure shows the physical architecture of the CALMd implementation as developed in SPITS. The communication platform, consisting of a host and router, is identical for both the roadside (RSE) and the vehicle (OBE) equipment. The only difference between the roadside and vehicle is that the roadside equipment is placed on two locations: the actual roadside (router) and at the control room (host). The advantage is that most of the hardware and software is physically present in an office environment so they can easily be adjusted.

In the figure the vehicle platform (OBE) is represented by host B and router C. This host and router are physically connected via a TCP/IP network. The vehicle (router C) is wirelessly connected to the roadside (router B). This router is physically connected via a glass fibre network to host A, which resides in the control room. The control centre is connected in a similar way to other RSE (e.g. router A).

The router can naturally simultaneously hold multiple connections (to a multitude of vehicles and roadside equipment) and a host can run multiple applications.

ITS Central Stations

All data is transferred to the control room. The control room delivered in February 2011 is a dedicated area on the Helmond premises that is exclusively reserved for test site management.

The glass fibre network consists of three independent rings. The rings are managed by four switches (one per ring and a central switch). Two cabinets stacked with 19'' PCs are dedicated for the image processing of the cameras to produce vehicle tracks. After that, the data is processed on different PCs with dedicated roles within the control room: display control, analysis, nagios, application control, safety, kvm client server control and two regular work spaces.

The Helmond site is not connected to a traffic management centre. The advantage is that TNO has full control of the test site.

There are plans also to connect the Freilot test site to this control room, and to connect to the existing induction loops and traffic light information on the test site (the municipality already has remote access), but both plans have not been confirmed yet and without further notice this will not be realised in the DRIVE C2X project.

In-car test data system

The Helmond TS aims to implement the given DRIVE C2X system both regarding the ITS stations and their components as well as the DRIVE C2X test system, which provides a logging solution and the test data flow from ITS Stations to the Helmond test control centre as well as the dedicated test driver HMI realised with help of Android cell phones.

Test site data sensors

The test road is equipped with a pole every 100m – 48 in total. The pole is 10m high and equipped with a cabinet that provides space for other roadside equipment. It comes with a 100 Mpbs fibre and five IP connections. It has 200W with 5 electrical sockets and five 230 V connections. This allows for a flexible way of installing new or temporary roadside equipment.

The complete road is equipped with cameras and can be monitored. Every pole is equipped with a fixed camera (Axis P1343). There is a vehicle tracking system installed, such that each vehicle can be seamlessly tracked from camera-to-camera (i.e. for every vehicle the position and speed in world-coordinates is provided in real-time with 30 Hz).

Additionally, 9 dome (i.e. Pan-Tilt-Zoom) cameras (Axis Q6034-E) are deployed every 700m on the poles. These cameras are used for overview images of the test site.

Also, in the middle of the track an RTK-GPS can be placed (Trimble SPS851). This sends a correction signal to allow for a more accurate positioning. This way, an accuracy of better than 50 cm can be reached in practise on the full length of the test site.

Currently, no other sensors are used on the test site.

Test management centre

There is a control room at TNO Helmond. It has a connection to each pole, and thus each camera.

Simulations can also be done on this test site.

Available facilities

TNO Automotive and High Tech Automotive Campus have headquarters near A270/N270.

The N270 has a petrol station; another petrol station is near A270.

TNO has a workshop for vehicle instrumentation.

The TNO premises in Helmond are available. In particular, three major facilities are present:

- Vehicle Hardware In the Loop (VEHIL) (active safety),
- Crash test lab (passive safety),
- Climate room.

Although these advanced facilities are probably not used , DRIVE C2X, the spacious halls and workshops could probably be of use during the interoperability and integral tests.

Germany

The German test site is called *The sim^{TD} test site*. It has been built up within the sim^{TD} project in the Frankfurt area. It comprises of public roads and a non-public test site.

The Frankfurt test site was originally set up for the sim^{TD} project. The sim^{TD} system and project has a similar scope like DRIVE C2X, but focuses only on one test site. sim^{TD} is aiming to use 100 hired drivers and up to 300 vehicles within the "free flow fleet". All sim^{TD} tests will be carried out in the Frankfurt test site.

Existing trials and projects made at parts of the site are CVIS, AKTIV, and DIAMANT. These projects do not conflict with sim^{TD} neither with DRIVE C2X. The AKTIV project is about to finish according to project plan.

Description of roads and test track

The Frankfurt test site is a major German traffic hub. Particular traffic hot spots or events are local traffic generators, such as the Frankfurt airport, the trade fair, and the football stadium. The test field area is characterized by high traffic density. It allows experiments on rural and inner-city roads as well as motorways. Further information can be found in Figure 30

The test site comprises of motorways around Frankfurt (see the blue roads), where there is usually a high traffic volume. It also covers some interstate roads (green) north of Frankfurt connected to the A5 motorway. These roads could be used as an alternative route. Furthermore, urban streets are included in the sim^{TD} test site. The urban test site is mainly located south-west of Frankfurt in an area called "Niederrad". This sub-urban area has not only highly populated, but it is also an "office city" which causes a lot of traffic during the peak hours, not only from Frankfurt itself but also from commuters driving on motorways A3 and A5.

Inside the sim^{TD} test site the motorways A3 and A5 have at least 3 lanes in each direction, the other motorways at least 2 lanes in each direction.

Cameras monitor the traffic all the time.

Variable information can be displayed across motorways to assist drivers, for example, recommending them alternative when the traffic is congested.

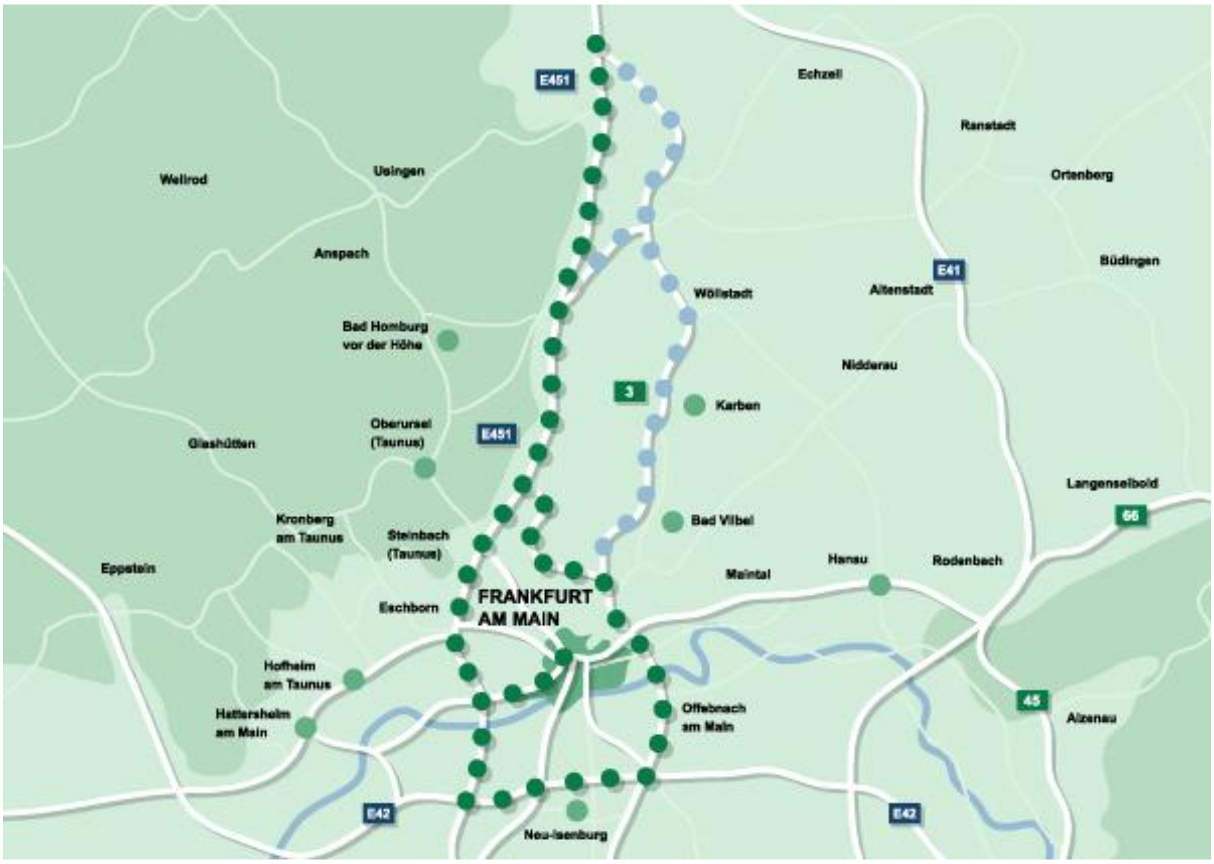


Figure 30: Test site (public roads) in Frankfurt.

Available ITS and test infrastructure

ITS Vehicle Stations and Vehicles

Each IVS consists of both a CCU (Communication Control Unit) and an AU (Application Unit). Functionalities of both CCU and AU have been specified and designed in the beginning of the sim^{TD} project according to all requirements.

As for HW, standard hardware is deployed to minimise costs. All software on AU is developed on the basis of the OSGi framework to allow for a maximum of independence. All applications are organised in OSGi bundles; the bundles can easily be updated from the ITS Central Station.

For a grand test such as sim^{TD} field test it is important quickly and safely to accommodate CCU and AU configuration files to enable variants to any given test. This is also accomplished via OSGi. There is a maximum of flexibility immediately to adapt to any test requirements.

The sim^{TD} project is equipped with 100 vehicles of internal fleet, i.e. for these vehicles there are well-defines test cases. There are also 100 hired drivers to conduct the test cases according to plans and schedules.

To allow for resilient and stressing statements about the evaluation of all test cases, randomness of logging data has to be included in the whole sim^{TD} project. There will be an "external" fleet of 300 cars, identically equipped with CCUs like the vehicles of the internal fleet. Those vehicles are eligible for the external fleet, which are very likely to be used in the sim^{TD} test site. However, the drivers of the vehicles of the external fleet are not subordinate to the sim^{TD} stage directors for the test cases.

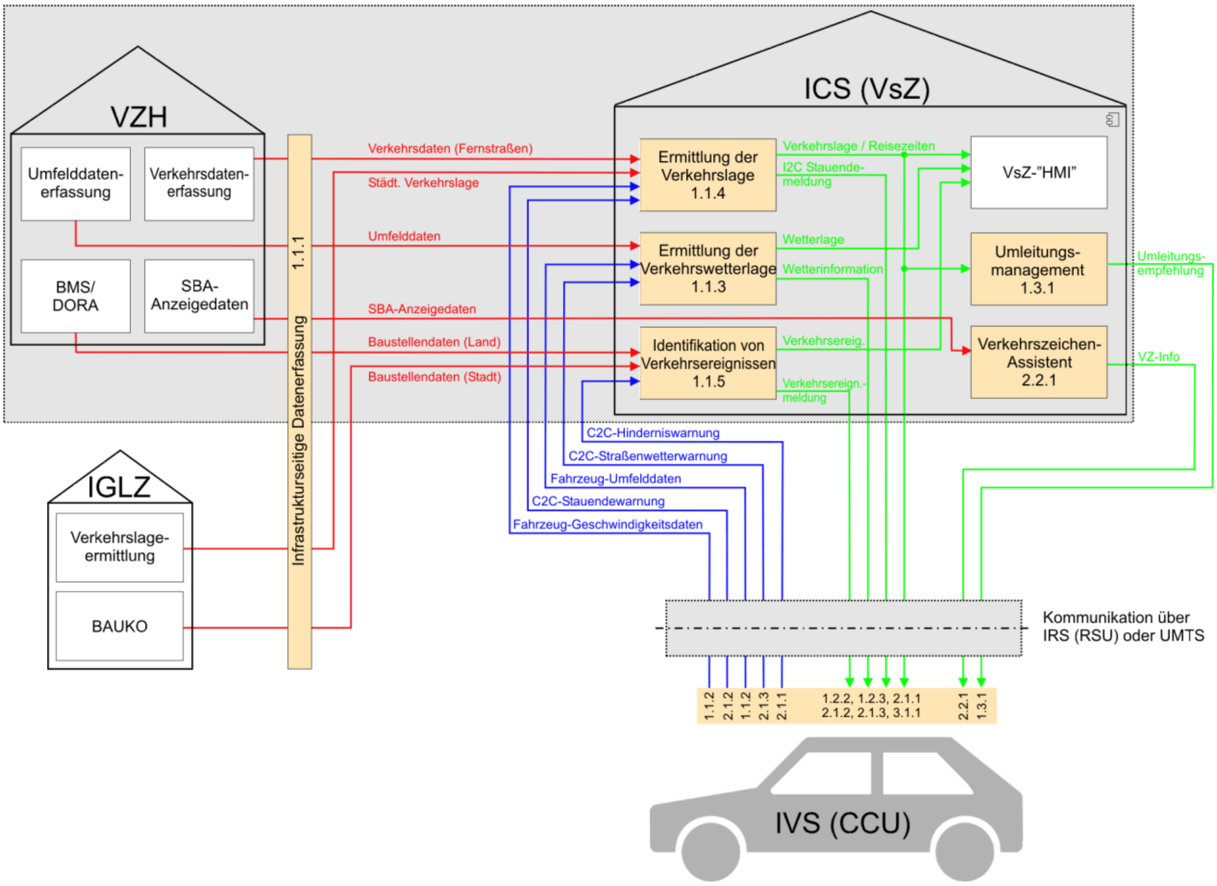


Figure 31: Basic architecture of the simTD ITS.

ITS Roadside Stations

Currently two simTD IRS exists. These are used for the interoperability tests and upcoming integration tests.

The IRSes are comprised of a CCU (Communication Control Unit) and an AU (Application Unit). The CU is mounted on a pole whereas the AU is placed into a roadside-cabinet next to the road.

All IRSes are connected into the ITS Central Station, either by fibre optic or via UMTS.

In the ITS Central Station there is a specific Management Centre (MC) for all the IRS. The MC acts like a network and system management centre for the IRS, monitors them and collects data about performance.

All IRS are equipped with 802.11bg and 802.11p as for communication with IVS (ITS Vehicle Stations).

IRSes deployed in the City of Frankfurt have an additional link (electrical interface) to the traffic light control unit. Thus they receive information from detector loops connected to the traffic lights, and also information about residual red light in the traffic light for a given direction of traffic flow. These additional information allow the general optimization of traffic flow resulting in more "green way".

IRS positioned along interstate roads (close to the city of Friedberg, 35 km north of Frankfurt) have an additional adapter to receive information from traffic lights. Thus they also contribute to providing more "green way".

All IRSes are equipped with a GPS receiver module.

From the figure below it can be seen that there is a section on the A5 motorway (25-35 km north of Frankfurt) where many IRSes will be installed for simTD. One of many strategic goals for HLSV is to find out about quality and performance of IRSes in the grand simTD field test and to receive reliable figures for a later roll-out of simTD.

Figure 32below gives a detailed overview on ITS Roadside locations (blue and pink circles).

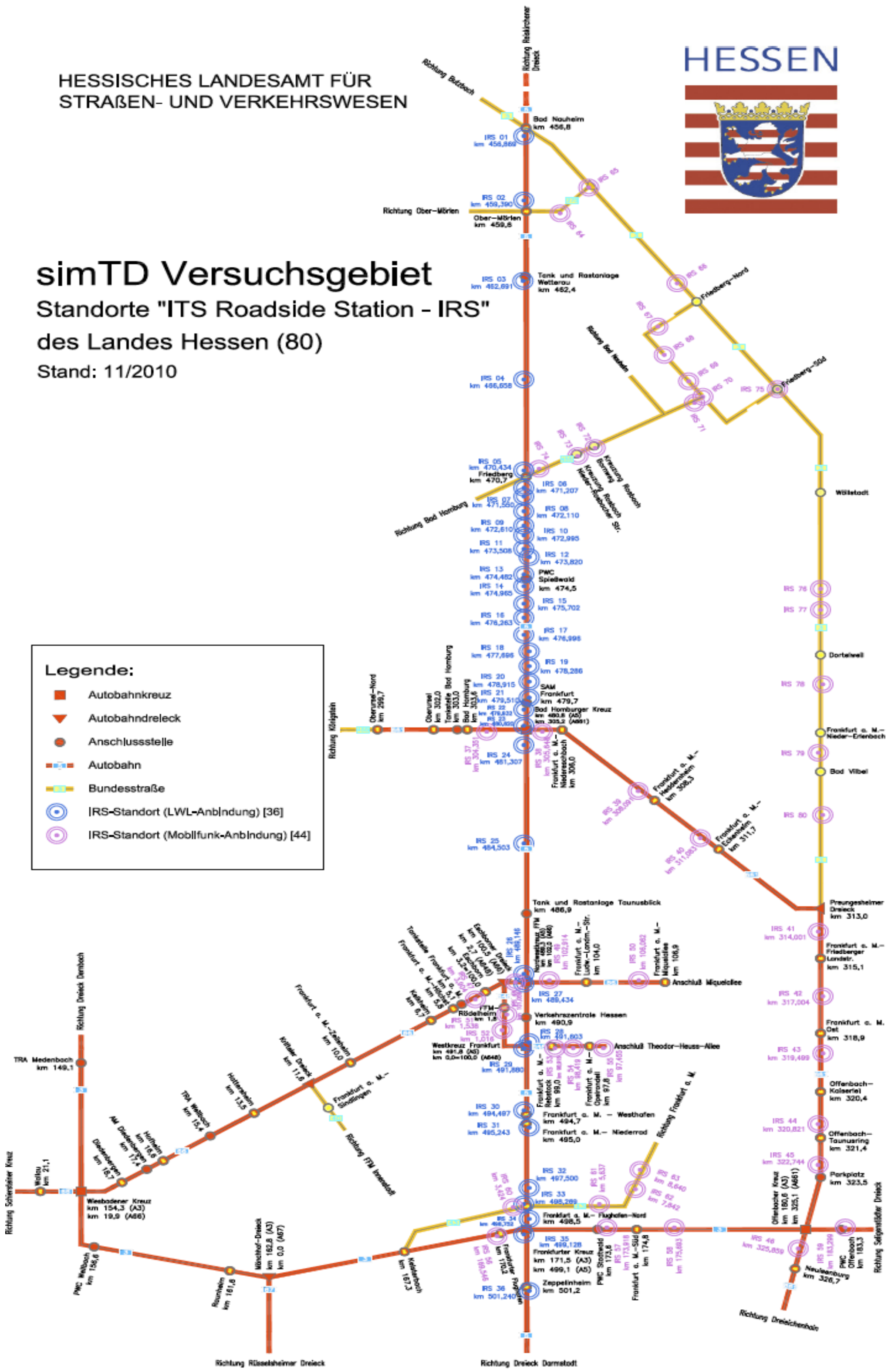


Figure 32: simTD ITS Road Stations and public road network.

Table 12 shows the number of deployed IRS allocated to road environments.

Table 12: simTD deployed IRS.

Motorways	58	
Federal roads	22	
Inner-city roads		24

Deployed IRS is already allocated to particular roads, as Table 13 shows.

Table 13: Detailed IRS location in simTD.

	A5	A3	A661	A66	A648	B3	B455	B43	B275
Number of IRS	35	4	9+1	4	5	12	5	4	1
Connectivity	FO[1]	U[2]	FO/U	U	U	U	U	U	U
km[3]	45	14	23	8	6	34	7	10	2

The sim[TD] IRS are equipped with the following hardware and software components (Figure 33).

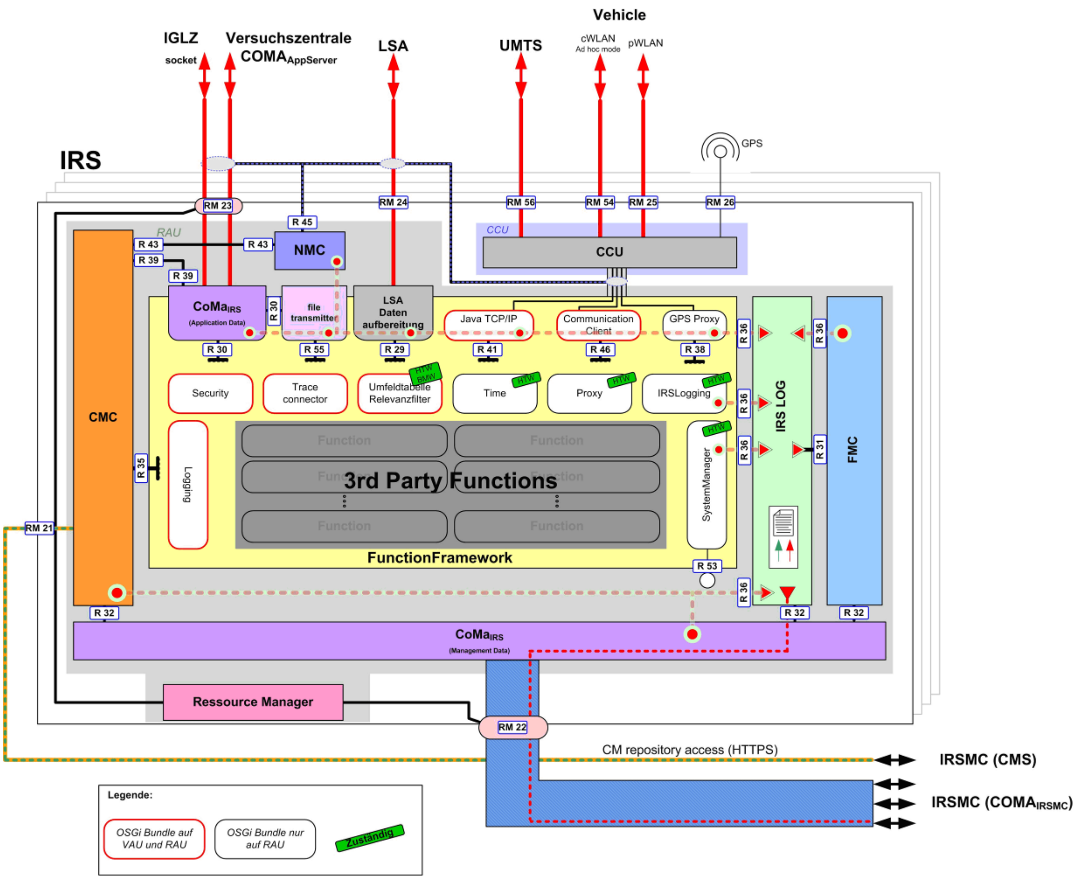


Figure 33: Components of simTD ITS Roadside Stations.

1 FO = Fibre optic.

2 U = UMTS

3 km – IRS supports bidirectional traffic flow, so the geographical distance should be multiplied by 2.

Currently there are already FO cables at the A5 within the sim^{TD} test site. Some more will be deployed for sim^{TD}. On all above-mentioned roads in the sim^{TD} test site where there are currently no FO cables, there will be IRSes with UMTS connection to the ICS. Though UMTS suggests "a mobile phone", these IRS will be places at fixed positions (see AutoCAD plan above "sim^{TD} ITS Road Stations and public road network").

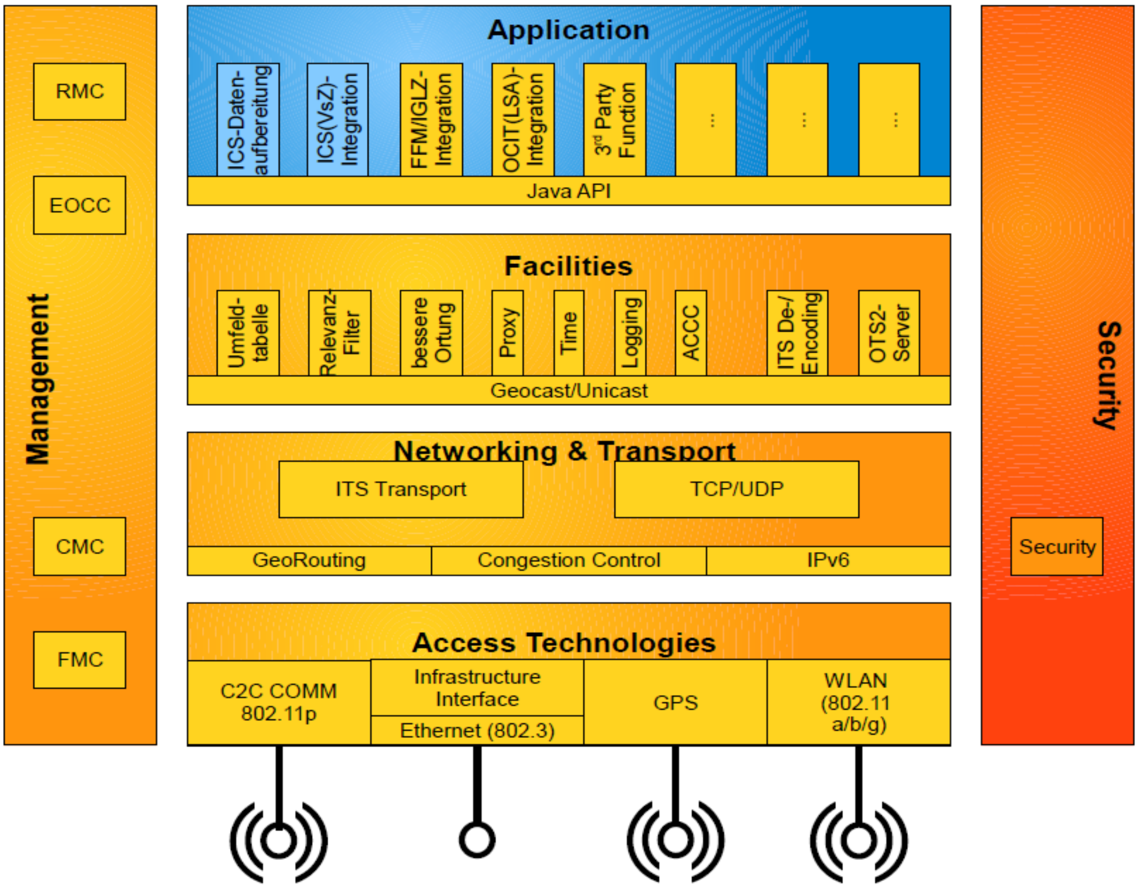


Figure 34: Architecture of simTD ITS Stations.

From a network point of view all IRSes will be grouped into sub-networks (IP terminology).

ITS Central Stations

There is a sim^{TD} ITS Central Station, where centrally deployed functions (or parts of it) are running. It also serves as a test management centre.

It is a centralized system for information processing, traffic control and data store throughout the whole sim^{TD} project. It is highly automated by software tools and algorithms for measures, evaluation and controlling of traffic issues.

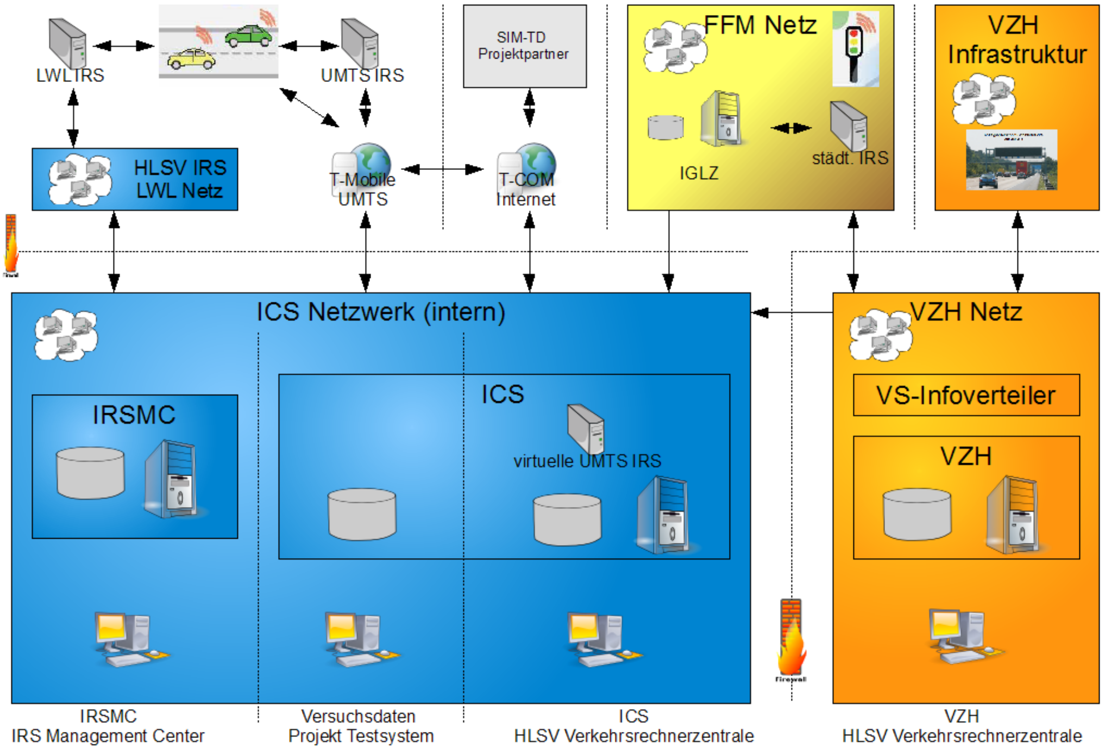


Figure 35: Integration of simTD ITS Central Station.

Simultaneous bidirectional exchange of information among:

- The test fleet,
- Mobile and stationary equipment,
- Communication partners in test field area.

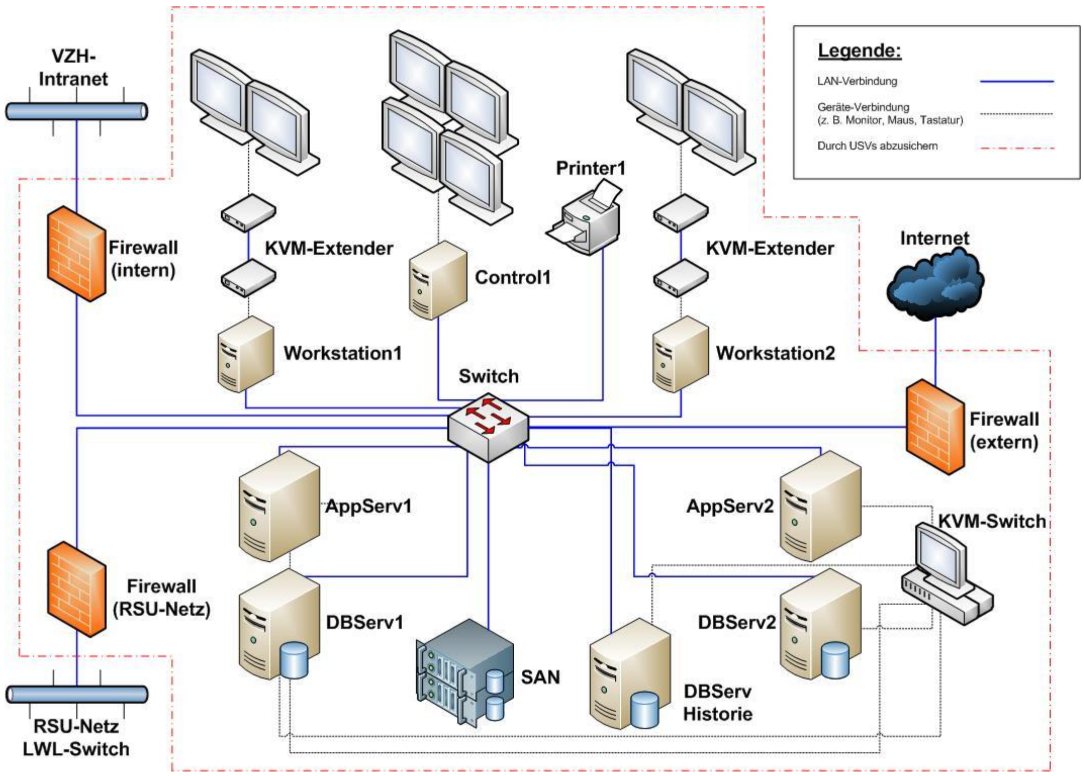


Figure 36: Network structure of simTD ITS Central Station.

In-car test data system

The test vehicle fleet are equipped with AUs and CCUs – forming the ITS Vehicle Station.

The ITS Vehicle Station is equipped with specific test components, which are responsible for logging and monitoring functionalities. Moreover, the test management centre is able to send test-specific information to these components. A test-specific HMI is included in the overall sim^{TD} HMI and share one HMI device.

All IVS support pWLAN (IEEE 802.11p) and UMTS communications. pWLAN is deployed for communication between IVS and IRS, for example exchanging traffic-related information; UMTS is deployed for communication between IVS and ICS. Furthermore, some IRSes are also connected to the ICS via UMTS, thus saving installation costs in those cases where there are no fibre optic cables available yet.

The logging data makes the largest amount of data generated in the vehicles. Due to bandwidth constraints in both pWLAN and UMTS communication, these logging data are stored on USB memory stick. At the end of each day, the simTD stage directors make these USB memory sticks collected, and empty ones issued to the vehicles. There will be provision that logging data are not overwritten or will get lost.

In the ICS there will be a NAS storage from which these logging data are forwarded to all subscribers (i.e. sim^{TD} partners who are interested in evaluating these data).

Test site data sensors

Approx. 50 signalized intersections in the city network are existing, 24 of them are equipped with IRSs.

Several traffic cameras are installed. Their photos are available within sim^{TD}.

On motorways there are static detector loops counting the number of vehicles and assessing the types of vehicles (heavy truck, van, car, motorbikes). Furthermore weather-related data (temperature of air, temperature of road surface, amount of rain, surface of road, etc) is collected and transmitted to the ITS Central Station once a minute. All data is available for processing for some time and will be archived later on.

Assessment of traffic situation is based from data from stationary detector loops or equivalent equipment. In sim^{TD} cars (IVS) also send a lot of data to the ITS Central station, also from locations where there are no detector loops. These additional data allow for a more granulated assessment of traffic situation. Results of the refined traffic assessment are reported back to all sim^{TD} vehicles.

The CAN bus of the vehicles deliver data at a frequency of 10 Hz. All the CAN data are recorded and logged. Furthermore all messages to and from other IVS, IRS and ICS are also logged.

For exact time correlation all IVS, IRS and ICS objects (and their data) have GPS time set.

Test management centre

The ITS Central Station (ICS) is the focal point for a sophisticated traffic management. All relevant data are thoroughly analysed, resulting in optimized traffic management.

The sim^{TD} ICS implements all functions which are necessary to support IVS and IRS .

The ITS Central Station includes the test management centre in sim^{TD}. It provides functionalities to plan, prepare, control, monitor, and analyze tests. All test data (30 TB) are collected here.

The sim^{TD} ICS is currently built, and ready for use in few weeks. Operating systems are Solaris and Linux, with some very few specific computers under Windows.

The heart of the sim[TD] ICS is a network of five SPARC computers, 2 application servers, 2 database servers and 1 database history server. The application servers are connected in hot standby, also the two database servers.

All functionalities on these SPARC servers are implemented as web services, managed by an Open Source Enterprise Service Bus (ESB)..

System management and network management is achieved by Nagios, an Open Source tool.

The sim[TD] ICS is connected to the internet via a 34MBit/s link which is extend to 155 MBbit/s link during the grand field test.

All sim[TD] vehicles (IVS) communicate with the ICS via UMTS data link, implemented as an IPv6 link. The connection is tunnelled though IPv4 because IPv6 is currently not available as a product by national carriers. For the whole lifetime of the research project sim[TD] the IPv4 tunnel will remain.

The sim[TD] ICS also hosts a PKI to assist in the signing and authentication of all C2X messages. Vehicles are permanently assigned another pseudonym after a configured time.

All independent ITS stations (IVS, IRS and ICS) need a common time. This is achieved by selecting GPS time. A common time coordinate is required to correlate all events in the log files as these entries come from different ITS stations.

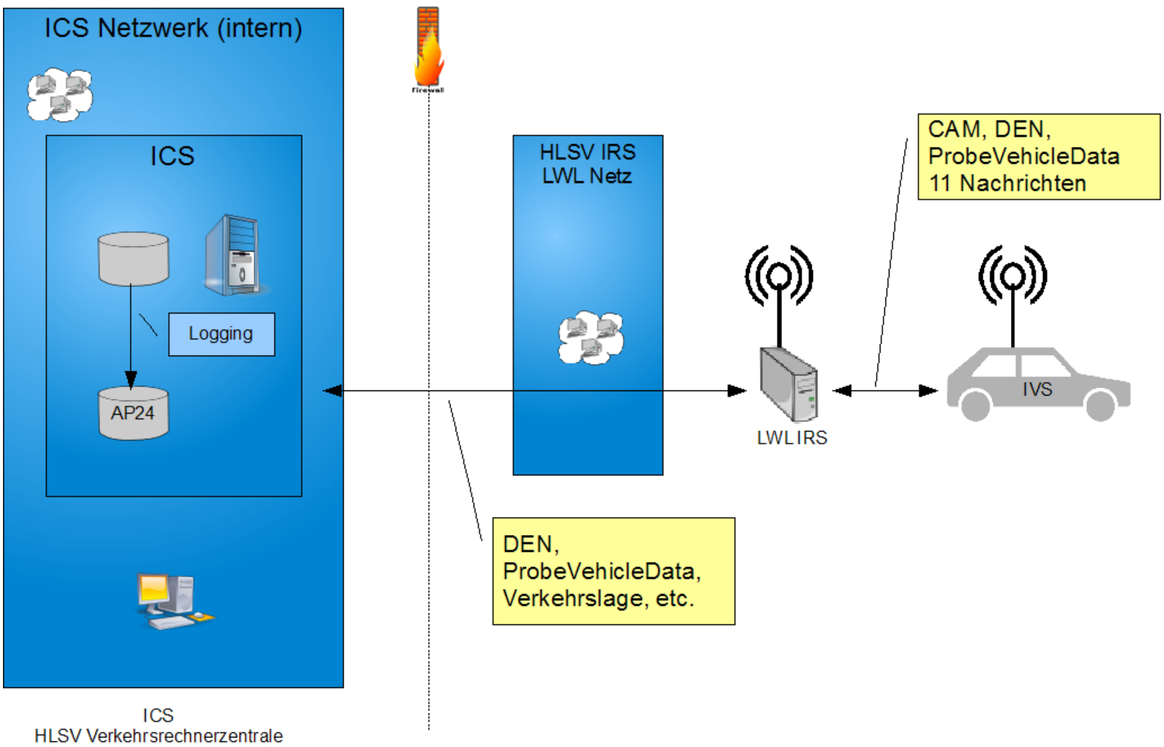


Figure 37: IRS and ICS logging; AP24 represents dedicated test systems.

The sim[TD] ICS also is in charge of collecting logged data from the test vehicles and forwarding them to the subscribed simTD partners for thorough evaluation of all tests and trials. A cascaded approach has been selected to minimize the overall time for forwarding.

<u>*Additional information*</u>

At the trial site, there are approx. 100 variable sign-posts including LED-signposts ("dWiSta"). There are also some 110 gantries with variable traffic signs (variable speed limits and road warnings).

Frankfurt has parking information systems in the city area.

Hessian Traffic Centre ("Verkehrszentrale Hessen") is a modern Traffic Management Centre with a long-term experience in traffic control and telematics.

The State of Hesse operates a traffic management centre on behalf of Hessian law. This centre is called "VZH" (Verkehrszentrale Hessen) . In sim^{TD} terminology it could be called "ITS Central station".

The sim^{TD} ICS and the VZH are completely disjoint. Except for the fact that stationary data (detector loop, road weather) is fed into both VZH and sim^{TD} ICS, both traffic centre are independent of each other. The VZH is the official ICS, whereas the sim^{TD} ICS is a research ICS, designed and built in such a way that sim^{TD} ICS experience could be very beneficial for a successor of VZH in the future.

The sim^{TD} ICS is operated by the State of Hesse. The City of Frankfurt also has a traffic centre, called IGLZ (Integrierte Gesamt-Leitzentrale; Integrated Overall Traffic Management Centre).

The IGLZ assesses the traffic situation of Frankfurt once a minute, and so does the sim^{TD} ICS for the sim^{TD} test site, except Frankfurt.

Both sim^{TD} ICS of HLSV and IGLZ mutually exchange their results (i.e. traffic assessment, etc.)

Non-public trial site

For sim^{TD}, there will be available also a non-public test site (trial site?). It is located close to Friedberg, about 38 km north of Frankfurt. The premises are managed by BIMA (federal institution for management of federal real estate objects).

The test site will be used for the integration tests (sim^{TD} TP3) as well as for specific tests during the grand sim^{TD} field test. These specific tests cannot be performed on public roads (motorways, interstate roads) due to safety reasons.

The Friedberg test site has buildings which can be used for offices.

The fleet base is connected to the sim^{TD} ICS via UMTS.

Fleet base

sim^{TD} also provides for a fleet base. It is a location close to sim^{TD} ICS from where all hired drivers start and to where they return after performing the daily tests according to test scenario books.

The fleet base is connected to the sim^{TD} ICS via 16 MBit/s DSL link.

Within the sim^{TD} project, NAVTEQ map data is employed. The map data already includes a lot of information relevant for particular use cases (e.g. road signs).

Sweden

The Swedish test site is called *the Gothenburg test site*. It is a large-scale functional test site located close to Gothenburg. The test site has been in operation since 2008. SAFER JRU is operating the site. It comprises of a public test site and closed test tracks.

Gothenburg is the second largest city in Sweden with about 800.000 inhabitants and with three major highways from the city, to the south, north and east.

For DRIVE C2X new company cars will be used. The test site has been employed as a CVIS and SafeSpot test site.

The Lindholmen Science Park is also responsible for the test site for the COSMO-project. Within COSMO, the "Green light optimal speed" use case. 20 busses equipped with 802.11p to communicate with the traffic controllers and a HMI to communicate with the driver. 20 busses are not equipped and serve as control vehicles. The COSMO test site includes three traffic lights.

Description of roads and test track

The Swedish test site is located in Gothenburg (Figure 38). It is split into two regions, off limits for normal traffic. Stora Holm, a closed test track 15 minutes to drive from Gothenburg city centre, is used for safety critical and non-traffic regulation compliant performance testing as well as the large closed test track used by Volvo Cars and Volvo Trucks.

The City Race Track in the middle of Gothenburg exists since October 2009 and was used for demonstrations of cooperative systems during a high level EU-meeting. It is a closed track can be used for development testing and demonstrations and located only 1 km for Lindholmen Science Park.

Figure 38: Test site in Gothenburg.

For COSMO there are three intersections planned to be used. The question whether other intersections throughout the city will be used depends on the final decision on the functions tested.

There is no conflict with other projects regarding the access to the different test sites.

For DRIVE C2X the present infrastructure will be reused and the positioning of the RSUs will be partly changed in order to support the decided UC. OBS / AUs will be procured for the 20 company cars from Volvo. The ITS central station from CVIS will be used and will also be used for the traffic control.

Available ITS and test infrastructure

ITS Vehicle Stations and Vehicles

The Gothenburg test site will have 20 Volvo company cars. All are equipped with 802.11p-enabled on-board units as well as the present euroFOT cameras and loggers, which can be used for DRIVE C2X too.

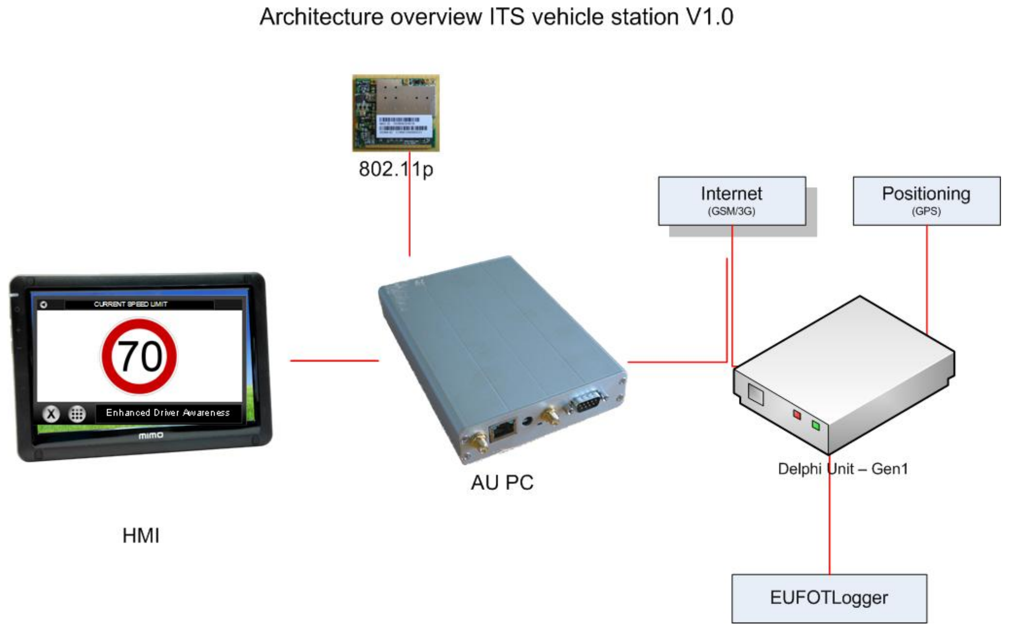


Figure 39: Architecture overview ITS Vehicle Station V1.0.

Below the Swedish test site architecture plan (Figure 40).

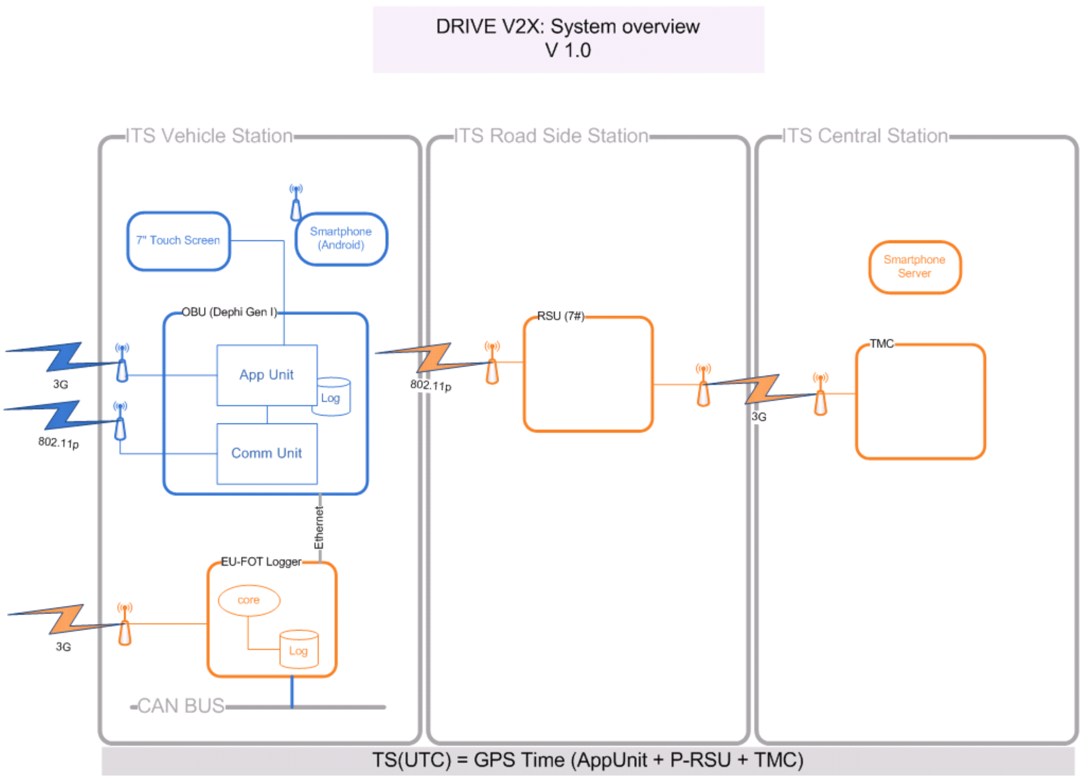


Figure 40: Preliminary idea of system architecture for DRIVE C2X.

ITS Roadside Stations

There are seven ITS Roadside Station deployed on the Swedish test site, as can be seen in Figure 41 It is considered to install three more in the context of the COSMO project. Three of these are mobile with an internal power supply if needed.

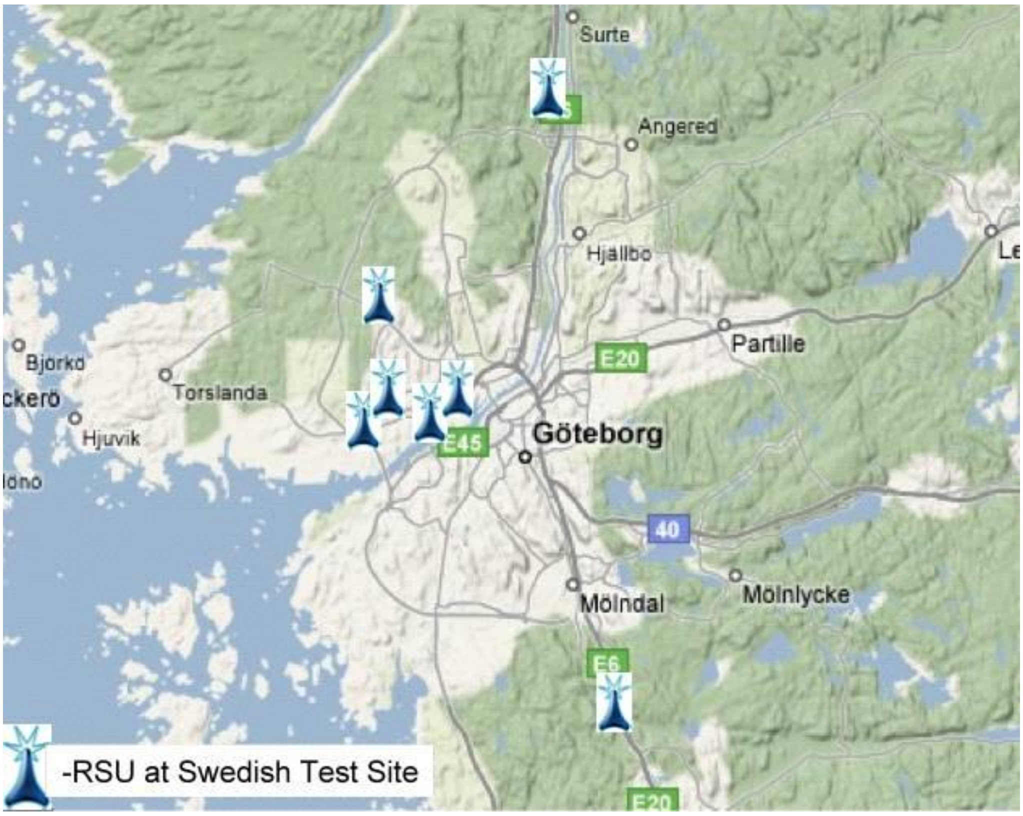


Figure 41: Locations of IRSs in Gothenburg, Sweden.

The ITS Roadside stations are located at the following locations:

- Lindholmen Science Park (1 RSU),
- Lundby Tunnel (2 RSU, one at each entrance),
- Closed Test Track (1 RSU, mobile),
- Storaholm,
- A6 highway (2 RSU),
- ITS World 2009 (1 RSU, mobile),
- Probably additional 3 RSUs at the COSMO Test Site.

ITS Central Stations

There is a so-called control centre on the test site. It is connected to the city traffic control centre (operated by STA, Swedish Traffic Administration), which has the following features:

- National road database,
- Local traffic management system,
- Local public transport traffic management (ITS4Mobility),
- Floating car data from 400 vehicles,
- Cameras for traffic flow calculation,
- From all vehicles in the public transport system, live information about speed and traffic flow is available,
- Information of variable speed signs' status.

In-car test data system

The 20 Volvo company cars that are planned to be used will be equipped with data loggers and euroFOT cameras. It is planned to equip 20 more vehicles with euroFOT cameras within the DRIVE C2X project.

The euroFOT logger is a PC-based data acquisition system for CAN, video, and GPS. There are the following data sources available (Figure 42):

- Four B/W video cameras. A frame grabber card with MPEG4 HW encoding is fitted in the PC Four CAN buses (two interfaces with two CAN buses each),
- GPS,
- Eye tracker (video + tracking data).

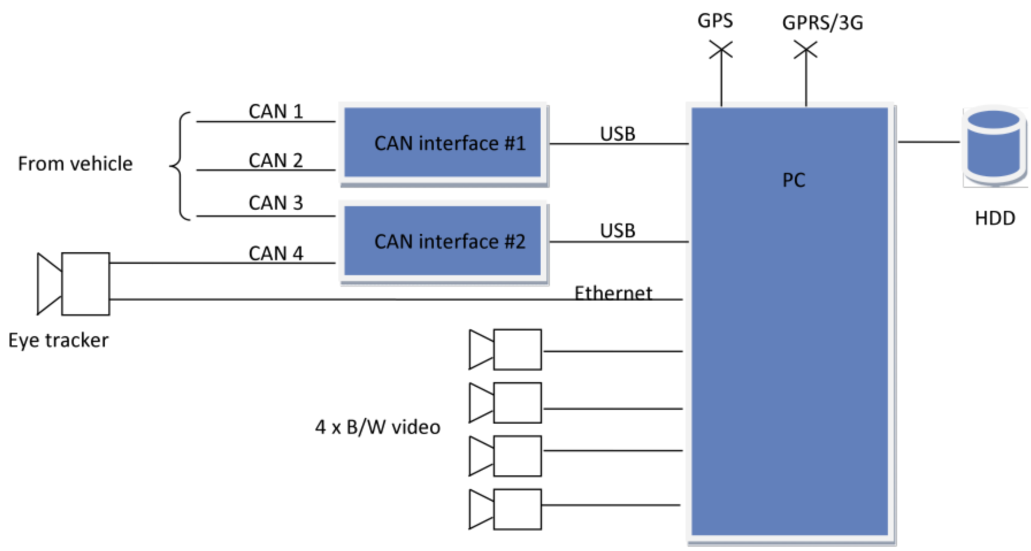


Figure 42: Available additional logger system.

The logger sends status reports to a web server over GPRS/3G. The logger has an inbuilt diagnostics tool.

The complete logger system fulfils the requirements for e-marketing. Furthermore, CAN interfaces are galvanically isolated and are operated in silent mode in order to minimize the risk of disturbing the vehicle.

The logger collects data continuously; there is no triggered data acquisition. All data from all CAN buses is collected. CAN data is stored as complete frames, signal decoding is done offline.

During an operation the data is stored on an internal CompactFlash memory. The next time the system is started data is copied to an external 500 GB HDD.

Test site data sensors

The connected traffic management centre has floating car data from 400 taxi vehicles for traffic flow information.

Moreover, the connected traffic management centre has cameras installed to calculate traffic flow information.

Test management centre

There is a control centre at Lindholmen used for CVIS, which will serve as a test management centre and which will run the traffic control applications.

Available facilities

Volvo cars facilities provide parking spaces and a workshop for maintenance.

Conference rooms could be used at the Lindholmen Science Park. Up to 500 persons can be seated.

Italy

The Italian test site is called *The Brennero test site*. It is a small-scale DRIVE C2X functional test site. It is located in northern Italy close to the City of Trento. Autostrada del Brennero (BRE) and Centro Ricerche FIAT (CRF) are involved in the Test Site.

The toll road Autostrada del Brennero (or Autobrennero, A22) was built in 1974 and is operated by Autostrada del Brennero Spa company.

It is a 314 km long Italian highway running from Brennero pass to Modena.

The DRIVE C2X Test Site is a 30km long section between Trento and Rovereto along the A22.

Non-public areas are available in the vicinity of the test site (the BRE headquarter and a road maintenance service centre are located approx. 10 km north of the test site; another road maintenance centre is located some 12 km south of the test site). Within the test site only public areas are available.

CRF Trento Branch is located in the vicinity, 9 km south of the Trento-Centro exit of A22.

In DRIVE C2X, CRF is responsible for the software and hardware adaptation and maintenance on vehicle side, as well as for the Test site organisation. Moreover, CRF will be responsible for the data gathering, logging and warning generation on vehicle side. CRF will provide 8 of the 10 vehicles foreseen in the Italian Test-Site.

BRE is responsible of the software and hardware adaptation, operations and maintenance on the infrastructure side. For the infrastructure-based use cases, BRE is also responsible for the data gathering and warning generation at the Traffic Control Centre. BRE will provide 2 of the 10 vehicles foreseen in the Italian Test-Site.

The test site is operated by CRF and BRE. CRF participated in PRE-DRIVE C2Xas a partner and as field test site. Activities in other projects do not conflict with DRIVE C2X.

Description of roads and test track

The Italian test site is a section on the highway A22 between Trento and Rovereto, see Figure 43. The section is a 30 km long toll highway.

Figure 43: Test site Brennero.

The Brennero motorway has two lanes per direction; however, the trial site has a so-called "third dynamic lane": in case of emergency or other needs, the hard shoulder can be opened to the traffic and used as a third lane.

Generally, the entire segment is available for the tests. However, two preliminary statements can be made:

- Most of the testing will concern direction south of the segment,
- Within the segment, a highly equipped subsection of 8 to 12 km length will be specifically dedicated to vehicle-infrastructure interaction.

The actual size of this section is now being evaluated. Depending on functions and use cases definition, technical requirements and equipment availability make a trade-off between communication coverage needs on one hand, and the price of the roadside infrastructure on the other hand. C2I and C2C scenarios are foreseen.

Available ITS and test infrastructure

ITS Vehicle Stations and vehicles

Currently the test site has 10 vehicles available. 8 vehicles are provided by CRF and 2 vehicles by BRE.

The basic vehicle architecture can be PRE-DRIVE C2X with DRIVE C2X enhancements. No integration of other projects/components is planned for the time being. Given this, no test-site specific interoperability issues are foreseen.

The vehicles could be divided into two groups: (i) vehicles for ordinary drivers and (ii) emergency vehicles.

Vehicles will exchange and process information and issue a warning to the driver in case of a hazard or other relevant situation. The cars will be equipped with

- (PRE-) DRIVE C2X ITS Vehicle Station. The DRIVE C2X processing unit should be a car-pc able to manage different interfaces. The main characteristics are represented by sufficient CPU power to ensure adequate performance considering the different applications and modules running at the same time on the system. Moreover, to allow a correct debug session, a large capacity hard disk is foreseen. The OBU should be a machine with a LINUX UBUNTU OS and the Knopflerfish 2.3.3 or above framework installed in.
- A vehicle gateway. It is dedicated to the collection of the minimum data set from the in-car network and feeding the framework on the main DRIVE C2X OBU. Moreover the same data will be provided to the Test Management Centre (TMC) to evaluate the testing conditions.
- Router WAVE IEEE802.11p compliant and
- UMTS module. The UMTS module is necessary to allow the data exchange with the TMC, dedicated to the data log collection. The data can be rough data (directly from the CAN BUS) or processed data by the applications.
- Positioning system. A GPS-based system will be set up to get the position of the vehicle.
- In-vehicle applications for Ordinary Driver Vehicles,
- HMI for drivers. The HMI will be composed by a screen placed on the dashboard, visible to the driver (mainly, but also to the passenger).

ITS Roadside Stations

Several units and devices have already been installed; however, the hw/sw architecture is based on COOPERS and has to be adapted to the project needs.

The roadside infrastructure, detailed in section 0, already includes 15 VMS gantries, traffic sensors, weather sensor, video cameras and currently one short range communication module. One rest area is equipped with a ghost driver warning system. All ITS Roadside Stations will be connected to the "Trento Centro" Traffic Control Centre via Gigabit Ethernet.

3 tolling stations are present within the Test Site segment.

Specifically concerning the short range communication, the test site is equipped with one roadside station based on IEEE802.11p, currently use for testing and optimising the communication range.

The DRIVE C2X adaptation of the infrastructure will concern the installation of 5 to 10 Roadside Units (RSU) according to the specifications of DRIVE C2X. In particular, the RSU will include a router WAVE IEEE802.11p and an on-site processing module. Communication among RSU and from RSU to Traffic Control Centre will be done via Ethernet connection.

Figure 44 provides an overview on the planned ITS infrastructure, which will be available by the pilot tests.

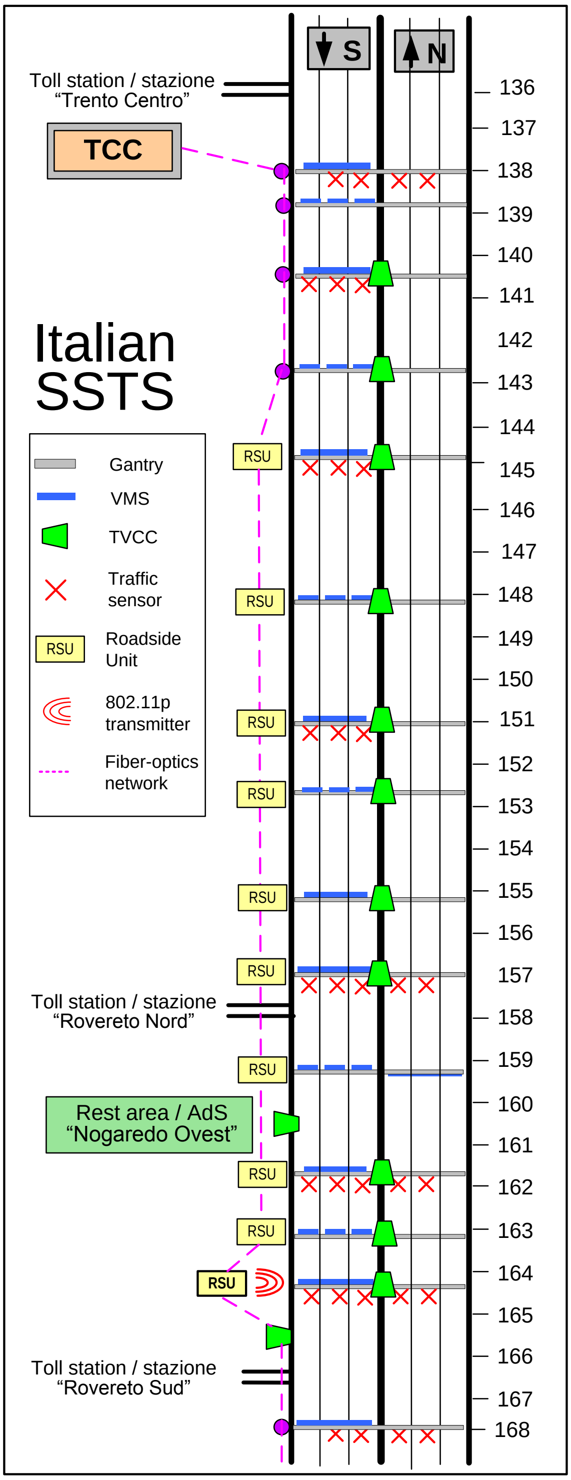


Figure 44: ITS infrastructure currently in place at the Test Site Italy.

A plausible configuration for a DRIVEC2X RSU will include:

- NEC Link Bird Communication Unit (following IEEE802.11p standard), with a double possible antenna configuration, (a) a couple of corner reflector antennas working at 5.9 GHz, (ex. Mobile Mark model SCR-5725), or (b) a single omni-directional antenna working at 5.9 GHz (ex. Mobile Mark model RM3-5500).
- Application Unit. [Detailed definition depending by SP2 that has to identify and formalize the hardware characteristics]. A possible choice is a model similar to the one used in PRE-DRIVEC2X project (ex: Jetway NC9C-550 Fanless board).

- Linux Operating System, running Knopflerfish OSGi framework, version 2.3.3 or more recent, for execution of Road Side Unit applications provided by the project partners.

Sensors may also be connected to the RSUs, depending on the RSU purpose, on the legacy components already in place and on possible equipment installations in parallel to DRIVE C2X activity.

1. Some sensors will be involved in functions as triggering elements. Their output will thus be processed by DRIVE C2X dedicated modules (on the RSU and/or in the TCC) to infer a situation and generate warnings.
2. Some sensors will be used for measuring parameters allowing the evaluation of functions (e.g. number of vehicles, average speed on the interested road segment)
3. Other sensors will provide support for additional data collection (e.g. weather, traffic parameters on nearby road segments)

As basic feature, all sensors are connected to the TCC via Gigabit Ethernet connection over optical fibre cables. The TCC manages the sensors and will make available raw and/or aggregated data from specific sensors for online processing or off-line analysis.

Additionally, for type 1 sensor dedicated interface with DRIVE C2X processing modules (on the RSUs or at the TCC) is needed, for on-line processing and function triggering.

The RSU itself is an off-the-shelf embedded PC with on-board graphics, hard disk and standard connectors.

The A22 Brennero Highway, along the subsection dedicated to vehicle-infrastructure interaction, have already installed several cabinets with dedicated 9 meter poles, every 500 meters. All this cabinets are connected with Trento TCC via Gigabit Ethernet connection over optic fibre cables, and a protected 220 volt electrical connection is provided.

ITS Central Stations

The headquarter and service centre (Traffic Control Centre –TCC) is located near the Trento Centro tolling station (city of Trento) close to the test site, and connected to all the roadside stations and sensors via Ethernet, as previously illustrated. Approximately 200 people are located at the headquarters / Traffic Control Centre in Trento.

At the TCC, 3 to 6 operators constantly monitor the entire highway (TVCC video images, traffic/weather sensor data, AID event alerts),

Communication with drivers is currently taken care of via VMS, RDS-TMC, Radio broadcasts, Bluetooth smart-phone apps and Internet terminals on rest areas.

Servers clusters are available for data processing and online real-time monitoring of infrastructure (network, sensors, VMS, etc.)

The local network is characterised by high data security.

To plan DRIVE C2X adaptation of the service centre, the following statements can be done *a priori*:

- The Autobrennero TCC will include DRIVE C2X module for sensing, processing and issuing warning/communication strategies in the Use Cases involving TCC (e.g. informing the drivers upon the happening of an event),
- Independently from the location of the test management centre (see related chapters) the Autobrennero TCC will be responsible to log the data involving the motorway infrastructure.

In-car test data system

Test vehicles are equipped with a computer and they are connected to the CAN bus, communication unit and an UMTS modem.

The on-board unit features the ability to run applications, facilities and logging.

No car is planned to be equipped with video cameras to monitor the driver, but this can be done if needed.

There is no dedicated on-board test system available or planned next to the test system developed in PRE-DRIVE C2X and DRIVE C2X.

Test site data sensors

The existing roadside infrastructure includes the following sensors:

- traffic sensors,
- weather sensors,
- 13 TVCC cameras,
- 1 RSU (IP 802.11p),
- 1 ghost driver detection and warning system at rest area.

A further extension is planned in 2011 and foresees full video coverage with AID detection (accident/incident, stopped vehicle, traffic jam) and virtual traffic loops, performing vehicle counting, classification and speed measurement.

Test management centre

The test management centre is expected to have the following functionalities:

- Logging/storage of test data (e.g. logging communication data during the functions testing.
- Storage of additional data as compendium to test data (e.g. aggregated traffic and weather data over a time period for statistical purposes),
- Test monitoring and support,
- (e.g. control, diagnostics, communication to developers).

As such, the test management centre will gather information from the TCC, from road infrastructure and from the vehicle fleet,

As preliminary hypothesis, the test management centre may have access to Autobrennero TCC and road infrastructure via a VPN, as is currently done in other activities.

The actual location and staff dedicated to the test management centre will be decided after the specification phase, depending also on the possible deployment of PRE-DRIVE C2X legacy components.

Available facilities

The Brennero test site includes the following facilities:

- Spacious shelters for hardware equipment located near the gantries along the test site,
- Premises for personnel are available at the highway headquarter near Trento,
- One rest area along the trial test site (Nogaredo Ovest) where petrol, mechanical support and food is available,
- Large parking spaces are available at the rest area along the trial site,
- Small emergency areas (2 cars) are available every 3 km,
- GPRS coverage is available along the entire trial test site; UMTS is available along 80% of the trial test site. PMR radio channel is available along the entire trial test site,
- The nearest airports are the Catullo Airport, 37060 Verona and the Bolzano Airport, 39100 Bolzano with both approx. 70 km distance to the site.

Finland

The test site in Tampere is a small-scale functional test site. It has a closed test track as well as a public site. The test site is operated by VTT. It was built in November 2009 and has been operational from April 2010.

The cooperative Traffic Test Site Finland is supported and funded by the City of Tampere and the Finish ministry of transport and communications within their intelligent traffic strategy.

The test site covers the Tampere urban region and parts of motorways E12 and E63 close to city. A test site for off limits for normal traffic by Nokian Tyres is dedicated for special tests not possible in normal traffic.

The Tampere test site is employed within the WiSafeCar project - an Eureka/Celtic ITS research project. The project aimed at developing a service framework/platform and an intelligent wireless traffic safety network between cars/other vehicles and infrastructure. It provides the possibility to exploit vehicle based sensor and observation data. The road weather services (RWS) play the most important role in WiSafeCar service palette. The pilot tests of WiSafeCar will be carried in year 2011.

Moreover, the Tampere test site is used by the EU-funded projects TeleFOT and ASSET and made part of the Finish national cooperative traffic research programme. All the above mentioned activities do not conflict the planned DRIVE C2X.

Aspects of the heavy vehicle and passenger car safety under harsh climate conditions have been investigated. The automatic detection of road surface friction and vehicle load from heavy duty vehicles, road weather forecasts and warnings, driver support for green driving and scheduling in addition to the friction and load were topics of research. Also new methods of deceleration measurements based on friction sensing and warning and camera-based automated occupancy for open parking areas were investigated. Due to Finland's cellular phone commitment the test site coverage with state of the art cellular technology for communication is superb (3G (HSDPA)/UMTS).

Description of roads and test track

The DRIVE C2X test site is an 8 km long open public road/street from Hervanta (VTT Tampere office location) to the Tampere railway station as illustrated in Figure 45. Negotiations with the above mentioned WiSafeCar project may add few more RSUs near the route in Figure 45. The main route properties are:

- Urban roads (four lane) 3 km,
- Urban trunk roads (four lane) 5 km,
- Intersections: 20 with traffic lights, 1 motorway junction, 5 others.

Figure 45: Test site in Tampere.

Next to the public DRIVE C2X test site, the Tampere test site includes the closed Nokian Tyres test track pictured in Figure 46. Almost all driving situations on northern roads can be simulated and tested on the test track. It includes 1800m long lap, 400m long straight and 5 intersections.

Figure 46: Nokian Tyres test track.

Available ITS and test infrastructure

ITS Vehicle Stations and vehicles

The Tampere test site provides the following vehicles:

- 2 vehicles equipped with ITS Vehicle Stations including IEEE 802.11p (NEC LinkBird),

- Up to 130 busses (3G communication, GPS positioning, acceleration sensors, FMS-logging),
- Up to 380 taxi vehicles (FCD via taxi dispatch system, equipment),
- Up to 50 test user vehicles (3G communication, GPS positioning, OBD-logging, aftermarket HMI),
- One of the two IEEE 802.11p communication enabled vehicle is equipped with the following additional sensors:
  - Road monitoring camera for the detection of road surface condition,
  - HDRC camera,
  - Thermal camera,
  - 2 Laser scanners,
  - 3 PCs,
  - Positioning unit (DGPS + IMU),
  - Driver monitoring camera. The basic architecture of the ITS Vehicle Stations is illustrated in Figure 47

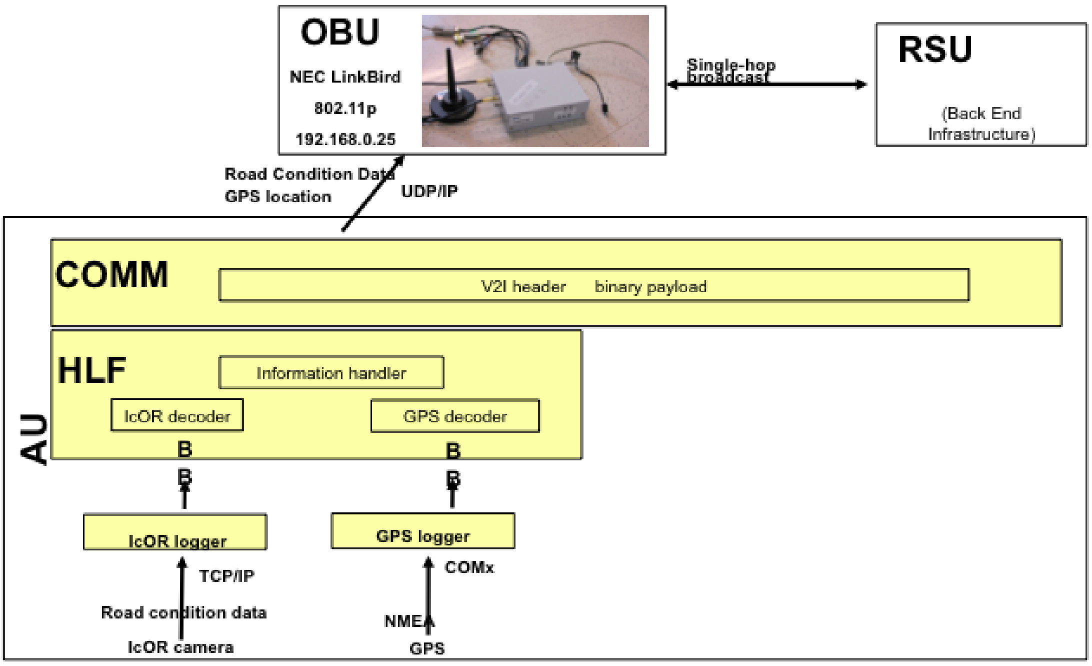


Figure 47: Basic architecture of the ITS Vehicle Station deployed at the Tampere test site.

ITS Roadside Stations

The Tampere test site has the following types of ITS Roadside Stations:

1) ITS Roadside Stations with IEEE802.11p (one of them is mobile) with road monitoring sensors:

- Mobile ITS Roadside Station (in a tandem axle trailer)
  - Battery (or generator as backup) powered on road side,
  - The 3D camera system for detection of license plate number, vehicle speed, distance between two vehicles and vehicle dimensions,
  - The road monitoring system will detect the road surface condition (dry, wet, ice, snow) (IcOR),
  - 3G and IEEE802.11p (NEC Linkbird) communication.

2) ITS Roadside Station (3 stationary):

- Installed in traffic light intersections,
- The road monitoring system will detect the road surface condition (dry, wet, ice, snow) (IcOR in 2 of 3 stations),
- Video camera (To be confirmed with City of Tampere),
- IEEE802.11p (NEC Linkbird),
- 3G modem.

3) ITS Roadside Stations (without IEEE802.11p) operated and connected to the Tampere Traffic Management Centre:

- 6 Road Weather stations with road and air temperature measurement, moisture measurement, road friction estimate, video camera.
- 20 Traffic stations with traffic flow measurement.
- 17 Traffic stations with controllable video camera.

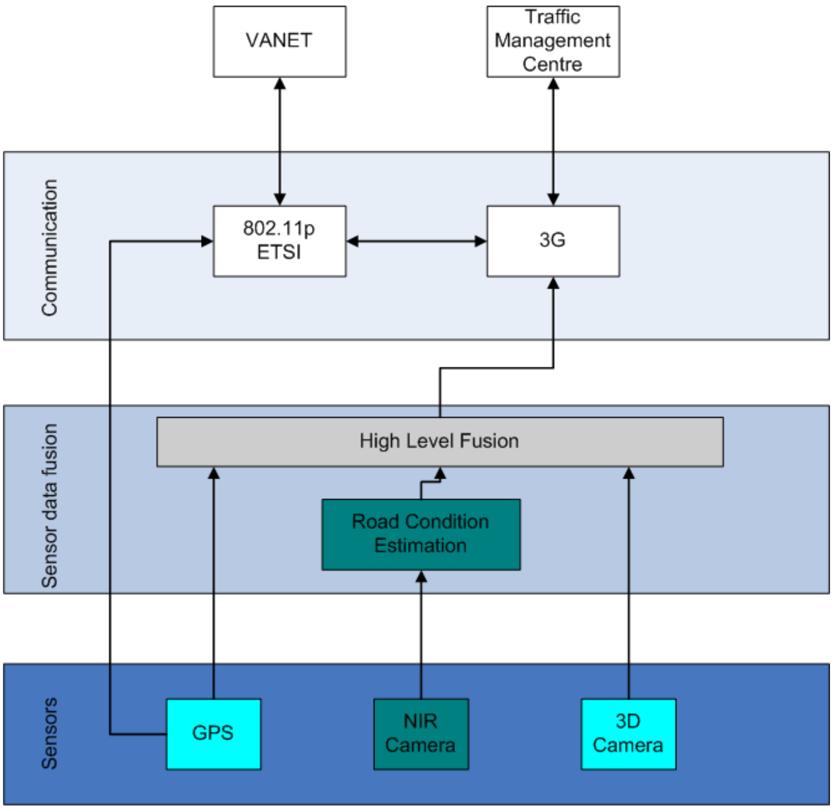


Figure 48: General architecture of the DRIVE C2X specific ITS Stations.

ITS Central Stations

The Tampere test site is cooperating with the local traffic management centre which is operated by the City of Tampere and the Finish Road Administration.

The traffic management centre collects real-time data from various sources:

- Road weather information,

- Real-time traffic information (based in floating car data by more than 300 taxis and 20 ITS Roadside Stations,
- Access to road works database,
- Tampere Traffic centre manages traffic through:
  - 10 variable traffic signs, which provide real-time traffic information (accidents, road closure and roadwork) and helps drivers adjust their route choice, and warning sign (e.g. slippery road or road works),
  - variable speed limit signs,
  - traffic / weather warning communicated via partners and service providers.

In-car test data system

The Tampere test site has a fully equipped instrumented vehicle for data logging, data fusion and data manipulation. The platform in the instrumented vehicle includes MS Windows XP computer units for running the data logging and fusion software. The fusion platform reads data from the installed vehicle sensors. Currently following sensors sensing the driving environment are available: the Road Friction Monitoring System – IcOR, an inertial unit, a thermal camera, a High Definition Range Camera, laser scanners, and a GNSS device. To monitor driver's state currently two sensors are available; the uEye system detecting driver's distraction level and a seat foil sensor. The equipped demonstrator vehicle has total of 3 TByte data storage capability.

Other vehicles are installed with 3G-based data logging.

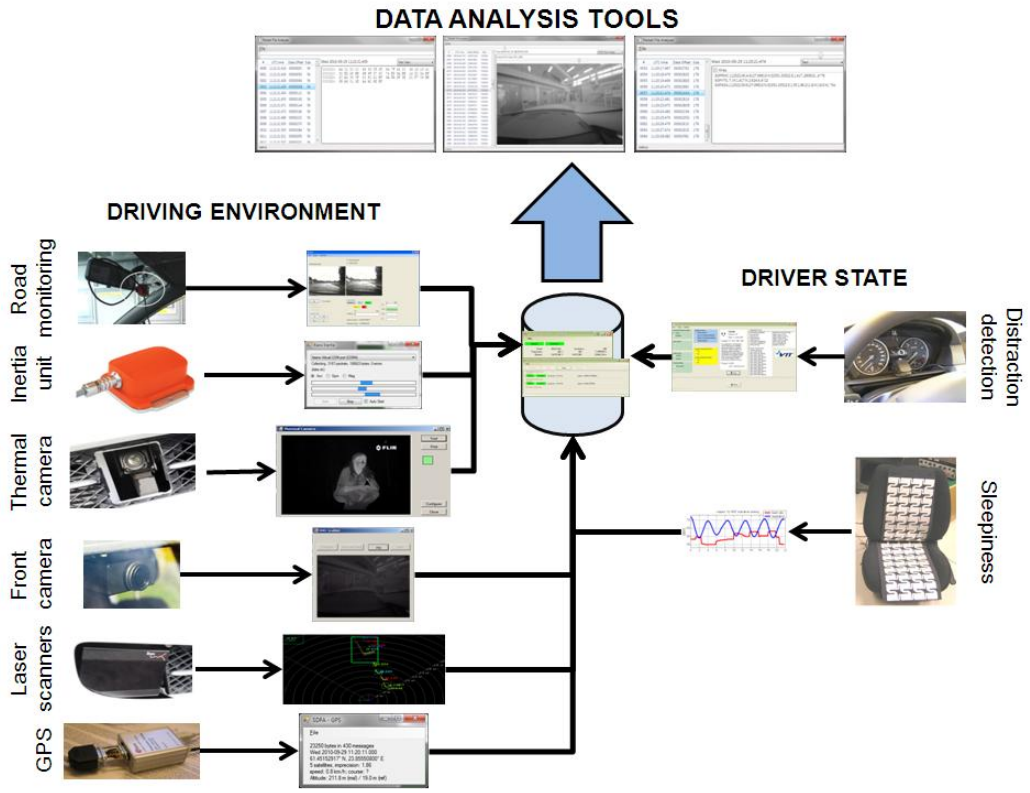


Figure 49: On-board data gathering platform of the VTT's instrumented vehicle.

Test site data sensors

The test site is RSUs equipped with multiple test data sensors and recorders. These are:

- A roadside vehicle identification system (portable RSU),
- A roadside road friction monitoring system (all RSUs with IEEE802.11p communication),
- A seat belt detection system (portable RSU),
- Road temperature sensors (Road Administration and City RSUs).

Test management centre

The test site Tampere is equipped with a data fusion system combining data from roadside sensors.

A PostgreSQL is available for the test data collection. The ITS Roadside stations are sending information depending on their sensors (vehicle type, vehicle speed, vehicle dimensions, license plate number, seat belt usage, emissions caused by traffic, road weather, location information of the roadside unit).

The connection to the ITS Roadside Station is a secured connection via 3G or Flash-OFDM .

Available facilities

The VTT premises in Tampere feature the following:

- Outdoor parking place and short-term overnight parking for one vehicle indoors,
- Workshop for maintenance (for cars and trucks),
- Internet connection via Ethernet,
- Conference facilities.

The closed Nokian Tyres Proving Ground provides:

- Maintenance and office buildings,
- Parking place,
- Is located at the distance of 18 km from VTT premises,
- There is no gas available directly at the site, but a public gas station is very close outside the proving ground,
- The site is covered with 3G (HSDPA)/UMTS and Flash-OFDM wireless broadband.

France

The French test site has several locations, primarily around Versailles, 15 km west of Paris but also in Orleans and north of Paris. It is currently built up in within the SCORE@F project. The different locations are as follows:

- Test track LIVIC (now IFSTTAR) at Versailles Satory,
- Open roads CG78 around Versailles (on RD10),
- Open road COFIROUTE around Versailles (toll tunnel on A86),
- Open road COFIROUTE around Orléans (toll highway on A10),
- Test track UTAC (Union Technique de l'Automobile du motocycle et du Cycle), North of Paris.

Renault, PSA, INRIA, IFSTTAR and Cofiroute together with other partners have formed the SCORE@F national project. It was started in October 2010 and will be running until March 2013. More information can be found on http://scoref.inria.fr until the official web site is established at http://www.scoref.fr.

The SCORE@F project has originally been constructed around the Versailles Satory test tracks, then expanded to UTAC test tracks (used for certification) and roads operated by Cofiroute (initially around Orleans, and later on expanded to a new toll tunnel that Cofiroute recently started to operate. Yvelines territory council (CG78), which partly finances SCORE@F then decided to join forces and offered to use open urban roads that are managed and maintained by CG78. This urban road joins Renault's R&D centre, Versailles-Satory test tracks, PSA's R&D centre (Vélizy-Villacoublay) and the south-most entry of Cofiroute's tunnel. INRIA is located close to one of the two other tunnel exists (A13 Vaucresson). So, SCORE@F test site is ideally located and configured to implement all types of functions such as road safety, traffic efficiency, and comfort/business.

Description of roads and test track

The French test site is comprises of five distinct sub-test sites:

1. Private test tracks in Versailles Satory,
2. RD10 open urban roads around Versailles Satory,
3. A86 open toll tunnel around Versailles-Satory,
4. A10 open toll highway around Orléans,
5. Private certification test track from UTAC north of Paris.

The SCORE@F test sites are divided into three distinct geographic locations:

- Versailles-Satory, comprising test tracks, open urban roads and a tunnel,
- Orleans, limited to open toll highway,
- UTAC, limited to certification test tracks.

All sub test-sites can be used for DRIVE C2X, even though DRIVE C2X tests are to be carried out mainly on public roads in Versailles-Satory and Orléans areas.

The Versailles-Satory test site is illustrated on Figure 50 to Figure 56 and comprises of roads with the following characteristics:

- 3 test tracks exploited by IFSTTAR (10 km in total): a flat road test track (3.6 km long); a natural environment test road (forest with curves and short slopes; is naturally slippery); and a speed test track (2.2 km straight line). These are shown on Figure 50, including the location of current roadside ITS stations installed for CVIS testing purposes.

- RD91 is a 4.5 km long semi-urban road operated by CG78 (territory council), between Renault R&D centre at the south-bound (turn about) and RN12 at the north bound (big intersection with RN12 - a heavy traffic road). Most of the road has got two lanes in each direction. There is a dangerous speed-limited stretch with traffic lights, then getting down steeply in the valley, a curve at the bottom, then getting up steeply with another curve in the middle of the slope. This portion can be slippery. The complex RD91/RN12 intersection is served by a set of traffic lights. The RD91 is shown on Figure 51. IFSTTAR test tracks are also visible on the left hand side of the curved RD91 portion. Figure 52, Figure 53, and Figure 54 are showing respectively the RD91/RN12 interaction at the north, the roundabout at the south, and the hilly and curved portion in the middle.

- A86 tunnel is operated by Cofiroute, between N12 at Vélizy Pont Colbert and RD913 at Rueil-Malmaison: 10 km long, two levels, one in each direction, 2 lanes each, with three entries. The effective use of the tunnel for testing purposes depends on the result of interference tests to be conducted, since the entries are equipped with DSRC toll gates.

Figure 50: Versailles-Satory test track.

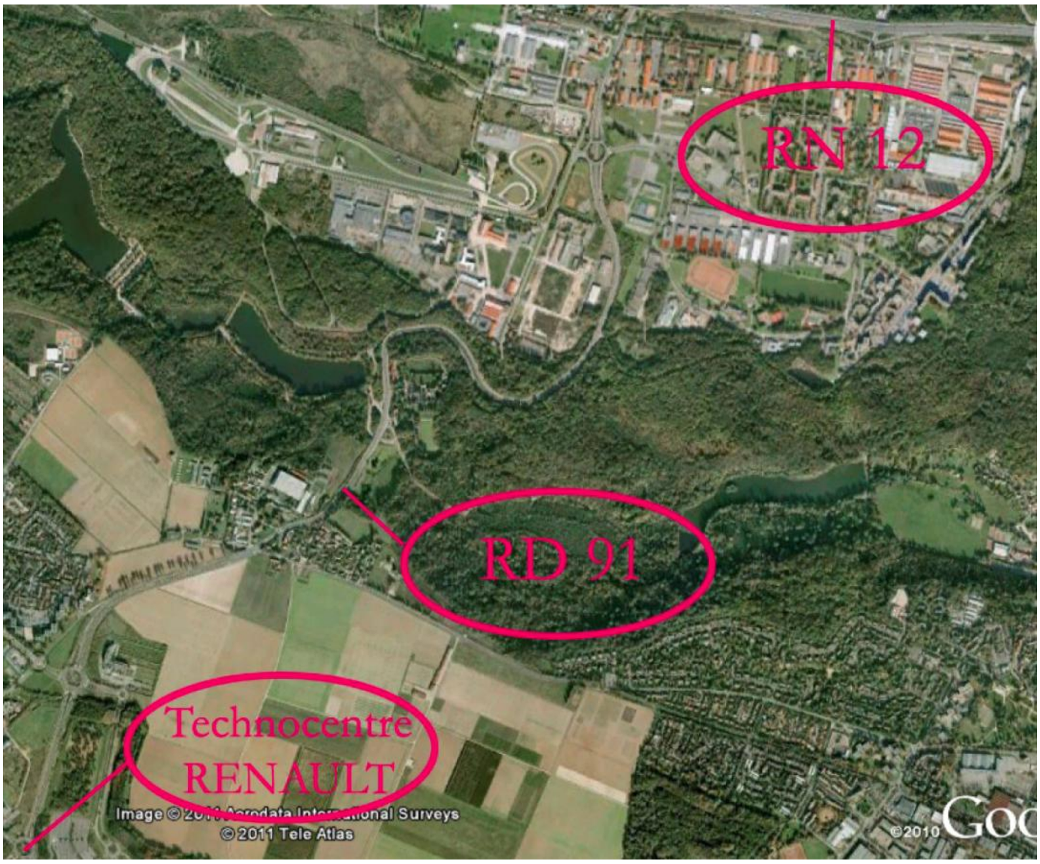


Figure 51: Versailles-Satory RD91.

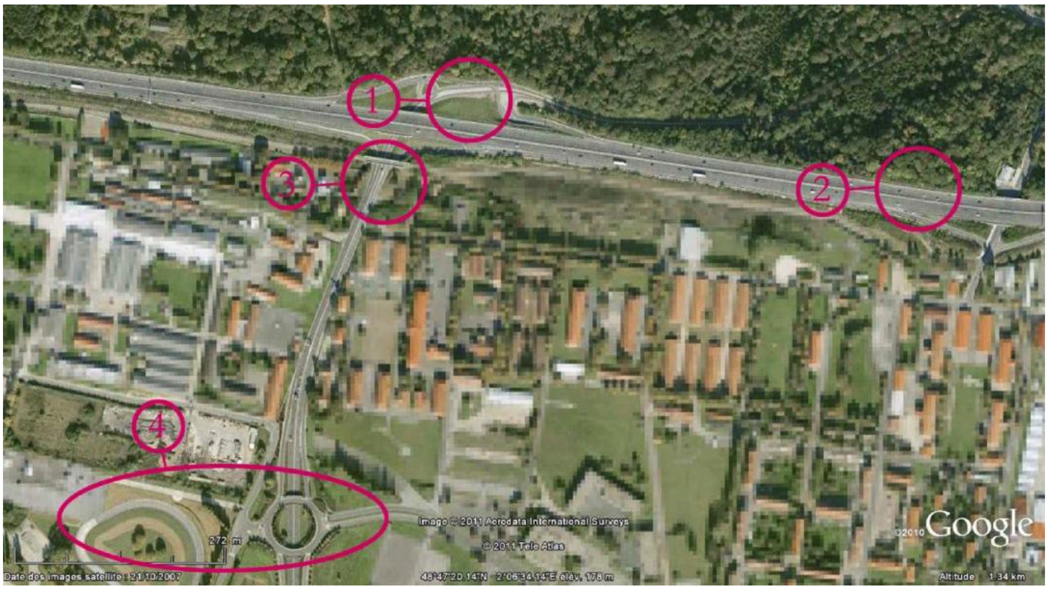


Figure 52: Versailles-Satory RD91 - northern part near IFSTTAR.

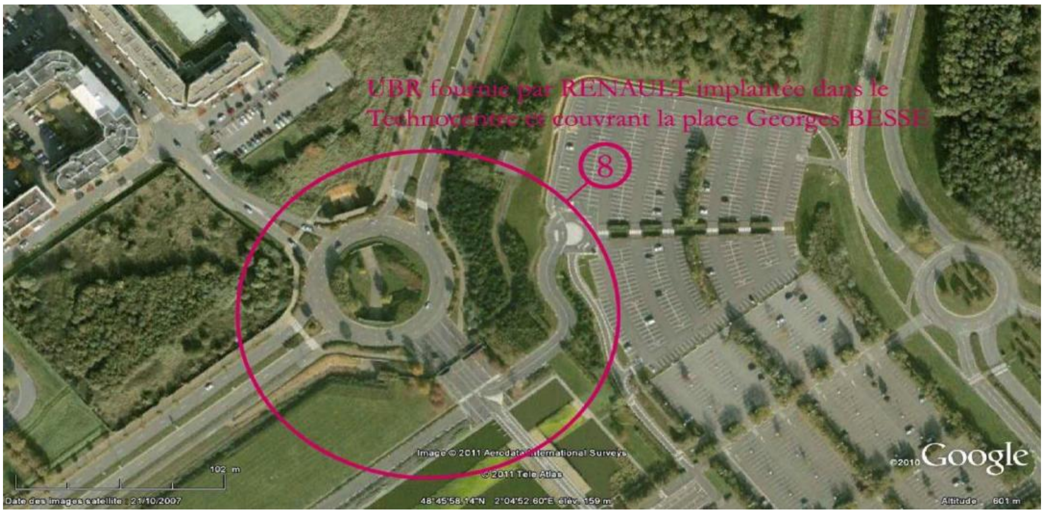


Figure 53: Versailles-Satory RD91 - southern part near Renault.

Figure 54: Versailles-Satory RD91 - hilly and curved area.

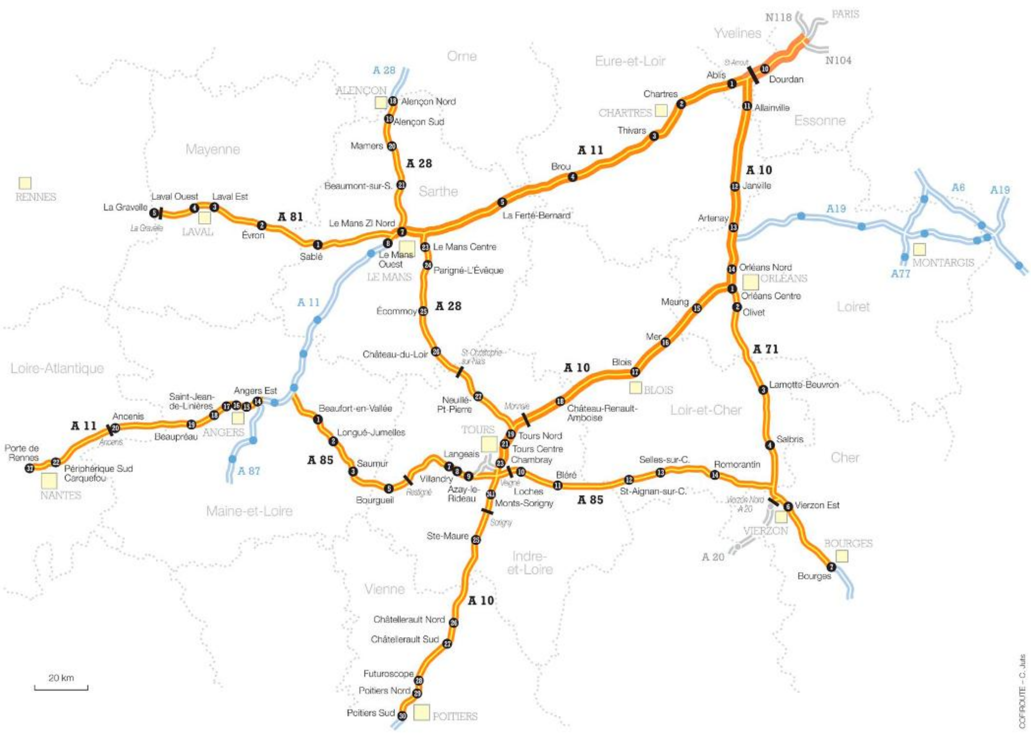


Figure 55: Road network exploited by Cofiroute, incl. A10 Orleans area.

The Orleans sub-test site is a toll-road highway (A10), 13 km long, between Janville and Artenay toll gates.

Figure 55 above shows the complete road network used by Cofiroute, whereas the specific test area is illustrated in Figure 56.

Figure 56: Zoom on A10 portion near Orleans (exploited by Cofiroute).

- The UTAC test site has roads with different characteristics:
- Two speed rings with a length of 2.5 and 3 km,
- The race track with a length of 3.4 km,
- The low grip track with an length of 200 m and the,
- Road track with variable profile and with length of 6.5 km,
- A low adherence track with length of 120 m,
- An urban track with length of 1.7 km including an 800m straight line,
- A comfort track with length of 1.5 km,
- An off-road track with 4.5 km modular,
- An off-road track.

Available ITS and test infrastructure

ITS Vehicle Stations and vehicles

The number of test vehicles depends on the cost of the hardware, and it is estimated to vary from 30 to 70 vehicles. Vehicles will be equipped with 802.11p and possibly 3G and/or 802.11n/b/g interfaces. The exact configuration of the vehicle ITS station (one box or two boxes) depends on the type of 802.11p equipment available for purchase.

ITS Roadside Stations

In total, there would be a minimum of 10 and up to 30 roadside ITS stations deployed in various sub test-sites. Given the amount of equipment needed to cover the entire test site area, some of the roadside ITS stations will be installed permanently and others will be installed in turn for an extended period of time in different locations (Orléans and Versailles-Satory) according to a time plan to be discussed early on between SCORE@F partners and DRIVE-C2X and according to functions to be demonstrated in France.

- There are no roadside ITS stations deployed in any of the sub-test sites besides the 3 roadside ITS stations for CVIS on Versailles-Satory test tracks (ISO CALM compliant, with Qfree ISO CALM cards and IPv6). The gantries (cabinets) hosting the CVIS hardware will remain but will host newly purchased hardware, comprising 5.9 GHz 802.11p radios. These roadside ITS stations deployed on the test tracks are connected to the Internet via a Wimax network.
- In the open road infrastructure, gantries will be installed to host SCORE@F roadside ITS stations. The actual number of roadside ITS stations will be determined by the cost of the hardware and should number up to 30. In principle, 7 roadside ITS stations will be deployed along the RD91 road (5 from CG78, 1 from Renault R&D centre, 1 from IFSTTAR). Roadside ITS stations from CG78 will be connected to the central ITS station through a 2G/3G communication link and will mostly serve road safety and traffic efficiency functions. The roadside ITS station deployed by Renault will be used to illustrate commercial functions.
- UTAC test track has no existent ITS system and no network connection from operator rooms to the site.

ITS Central Stations

Not yet defined.

In-car test data system

Not yet defined.

Test site data sensors

A10 operated by Cofiroute in Orléans has the following features:

- Traffic counting stations,
- Weather stations,
- Emergency call boxes,
- CCTV,
- Automatic Incident Detection System,
- Automatic License Plate Recognition.

The test site in Versailles-Satory has not data sensor available for testing purposes.

Test management centre

Not yet defined.

Available facilities

In Versailles-Satory:

IFSTTAR has facilities available for test operators and drivers and could provide IT infrastructure,
Cofiroute has meeting rooms and service areas with Internet connection and power supply,
In Orléans sub test-site:

- None,
- UTAC has no existent ITS system and no network connection from operator rooms to the site.

Spain

The Spanish test site in Galicia is called SISCOGA, and it serves as an associated test site. It is located in the North-Western part of Spain. It is about 60 km long and has motorway and highway roads with city entrances. The test site is operated by CTAG and DGT (Dirección General de Tráfico, Spanish Ministry of Traffic).

From the end of 2012 some urban non-public test tracks will be available at CTAG facilities.

This test-site has been created by CTAG and DGT in the framework of the national funded project SISCOGA (SIStemas COoperativos Galicia) pursuing the following objectives:

- Preparation of a permanent intelligent corridor for C2X FOT purposes,
- Pilot testing of the corridor with safety and convenience cooperative applications,
- Definition and implementation of evaluation methodologies applied to cooperative systems,
- Interoperability assessment between different C2X technology providers and vehicles,
- Final FOT with around 20 vehicles / users and assessment of results.

Since some of these objectives are shared with DRIVE C2X objectives, and while CTAG has been considered an associated partner in DRIVE C2X, SISCOGA activities will be aligned with those carried out in the DRIVE C2X project. The compatibility of technologies is assured through the usage of 30 x NEC Link Bird-based Road Side Units and the implementation of DRIVE C2X applications.

Description of roads and test track

The road network of the Spanish test site is illustrated in Figure 57. It consists of motorway and highway roads with at least two lanes per direction (some highway sections have three lanes in each direction). The maximum speed in these roads is 120 km/h but specific limits are posted in given stretches due to the special characteristics of particular sections of the road (i.e. sharp curves). It also consists of city entrances.

Figure 57: Spanish test site.

The general characteristics of the area could be described by the following features:

- City Entrance,
- Sharp curves,
- Slopes,
- Road-works (usually) and
- Inclusion of tunnel (over 1 km length).

In the future, depending on agreements with Councils and Local Administrations, there are plans to extend the Test Site to urban scenarios. Moreover, an extension towards Portugal (Portuguese border is just a hundred meters from one Road Side Unit) is foreseen.

Available ITS and test infrastructure

ITS Vehicle Stations and vehicles

The Spanish test site provides 20 test vehicles. Most of them (18) are designed for naturalistic tests. These are equipped with:

- IVS (NEC Link Bird MX following IEEE802.11p standard), with a 5.9 GHz DSRC antenna (Nippon Antenna / Mobile Mark),
- An application Unit composed of a Mini PC board (Avalue EMX-945GSE-A1_DVIR with a RAM memory and Compact Flash) plus a WiFi card (Microtik R52 Wireless mini PCI 802.11 a+b+g),
- A GPS receiver (Globalsat BU-353),
- A CTAG Datalogger,
- A specific HMI (Apple iPod Touch) with a CTAG designed and implemented application for HMI purposes.

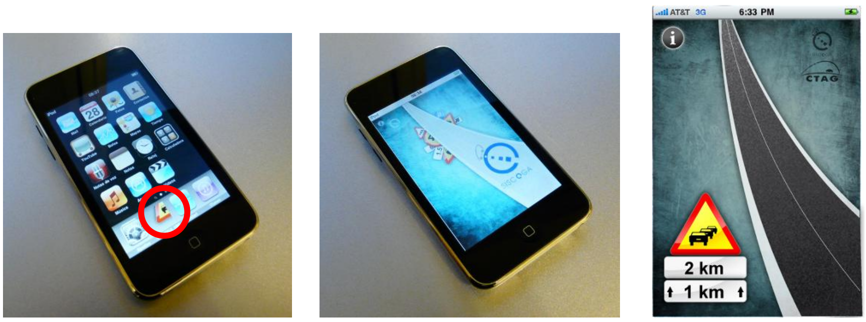


Figure 58: Spanish HMI device and Design for the 18 naturalistic test vehicles.

The other two vehicles are research vehicles for advanced functions (e.g., merging assistant). In this case, an specific in-vehicle HMI will be implemented.

The basic architecture of the in-vehicle system is illustrated in Figure 59.

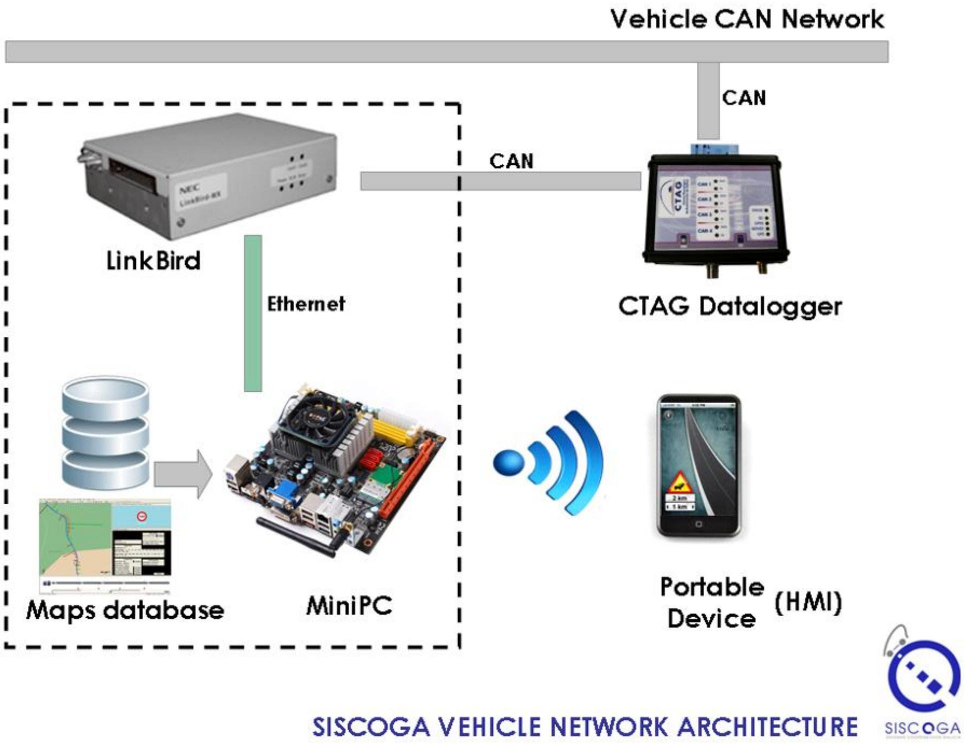


Figure 59: Basic architecture of the in-vehicle system.

Regarding SW, the Application Unit runs Java-based SW (since the NEC Linkbird SDK is also Java- based). On the other hand, the HMI is programmed under a MAC environment and CTAG's Data-logger can be specifically programmed by Python Scripting

ITS Roadside Stations

The Spanish test site will be equipped with 30 ITS Roadside Stations (NEC Linkbird-based). 6 of them are already installed. The local Traffic Management Centre operated by DGT has a direct connection via Ethernet to these roadside stations.

All ITS Roadside Stations (IRS) have access to an Oracle database linked to the Traffic Management Centre and operated by DGT. Within this Oracle database the IRS can receive real-time information from the test site sensors (Inductive loops, Weather stations and Variable Message Signs)

CTAG is able to access IRS remotely via Ethernet so that IRS Software can be remotely updated and CTAG can perform regular traffic messages status checks.

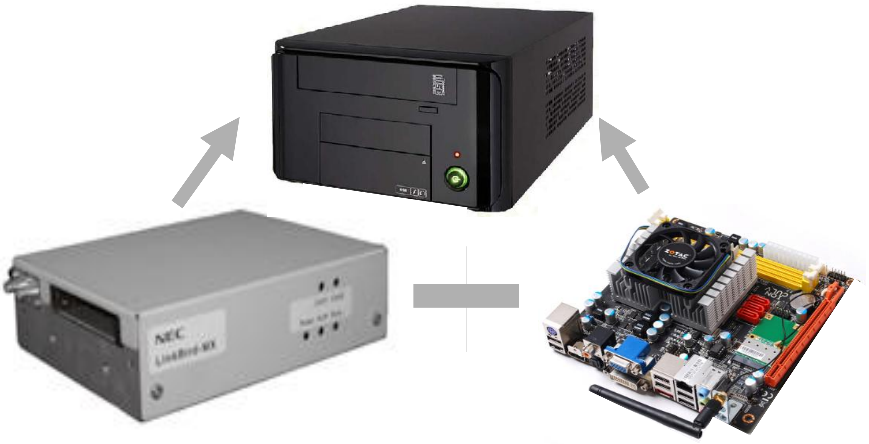


Figure 60: Basic architecture of the ITS Roadside Stations system.

The Spanish Test Site will have up to 30 IRS equipped as follows:

- IVS (NEC Linkbird MX following IEEE802.11p standard), with a 5.9 GHz DSRC antenna (Mobile Mark),
- Application Unit composed of a Mini PC board (Avalue EMX-945GSEA1_DVIR with a RAM.

Roadside cabinets from DGT are available all along the Test Site and are used for IRS installation. These cabinets have power and Ethernet connection available, which is currently used for IRS and can be also used for other DRIVE C2X purposes.

The positions of these cabinets and the IRS for DRIVE C2X are depicted in Figure 61 below.

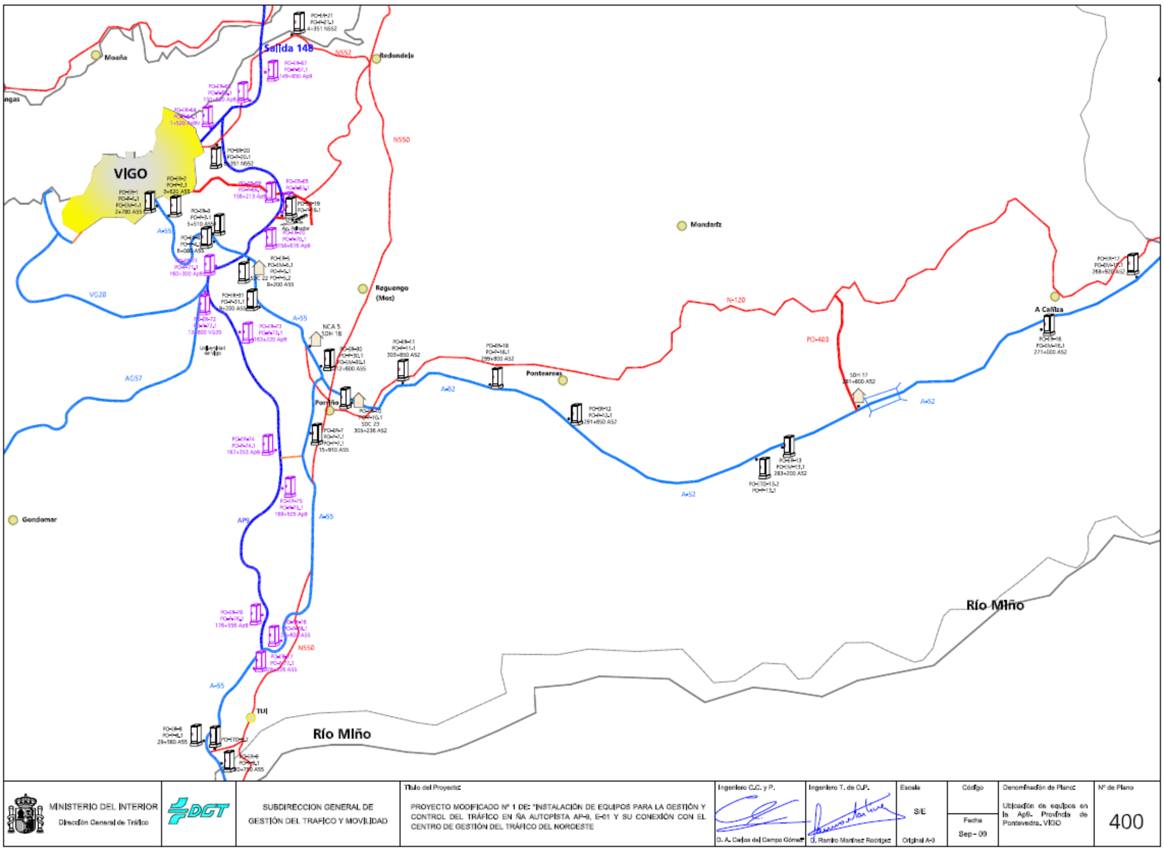


Figure 61: Detail of cabinets (ERUs) positioning in a MAP.

Figure 62 provides an overview of the basic test site technical architecture including roadside stations.

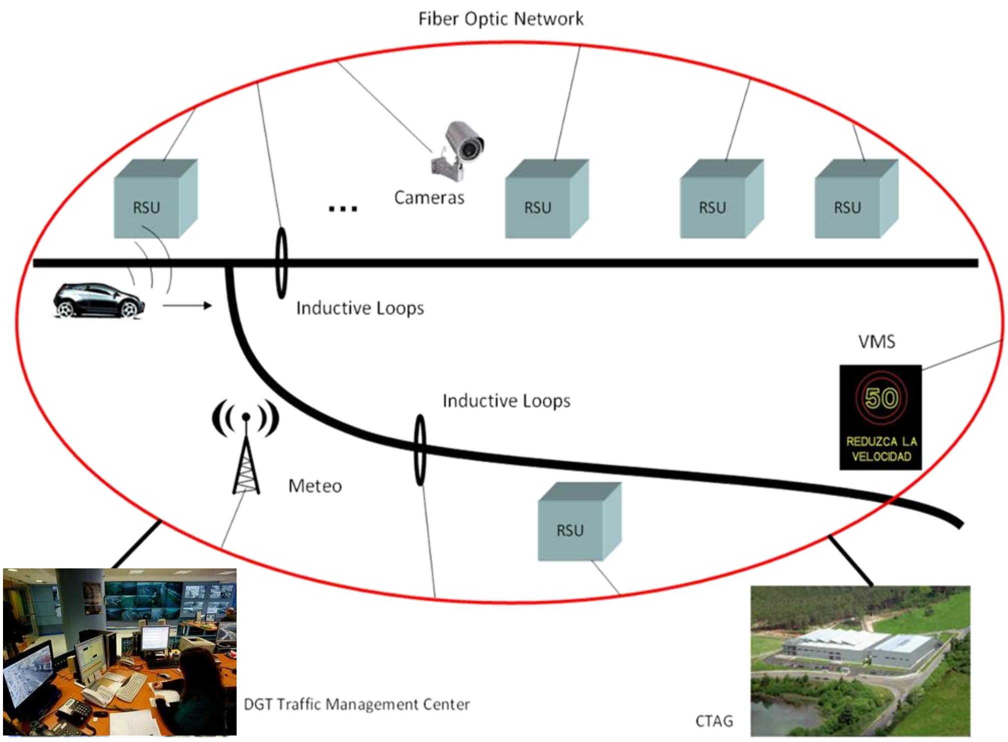


Figure 62: Architecture of the system.

ITS Central Stations

The Spanish test site includes a local Traffic Management Centre (TMC) operated by DGT. TMC is in operation 24/7.This Traffic Management Centre controls all the traffic of the North-Western part of Spain. By the direct view from the video cameras, the information collected from the inductive loops and the weather stations decisions can be taken and drivers warned by means of different messages on Variable Message Signs through a fibre optic ring.

This fibre optic ring establishes a direct communication link with all the Test Site sensors and IRSs. Moreover, via Ethernet through this fibre optic ring, sensor information is collected and managed in an Oracle database, which is being read by the IRSs.

A central data server for the DRIVE C2X FOT is located at CTAG site.

In-car test data system

Apart from the On Board Communication Unit (IVS), a specific CTAG data logging system is installed in 20 vehicles. This logging system has the following features:

- CAN-based logging capability (up to 4x CAN channels),
- Built-in GPS receiver,
- Remote GPRS data transmission capabilities,
- SD data storage,
- Seamless integration,
- Python Scripting possibilities

All collected data will be transmitted to a CTAG-owned central data server.

Naturalistic Driving is foreseen in the Spanish TS, so no specific instructions besides the first system explanation will be provided to the drivers. They will drive normally with their own vehicles with cooperative functions installed and compliant with DRIVE C2X methodology.

The specification of the available logging system (CAN Logging) is the following:

- Data output compatible with Vector products,
- Sample Server application (Internet-based solution) for remote fleet management (tracking, logging, data-logger, configuration, etc.) provided,
- Python scripting enabled (can sending, traffic analysis, possibility to implement other services according to ISO 14229),
- Contact (Kl15) behaviour emulation low consumption (<0.1μA when KL15 off),
- GPRS quad band modem / GPS receiver (Siemens XT 65),
- CAN 2.0B channel logging,
- CAN baud-rate configurable by user,
- Build-in real-time clock (with internal battery),
- SD & SDHC compatible,
- External trigger input,
- USB 2.0,
- LED functional indicators,
- Configurable application logging parameterisation (CAN Filters) and data conversation,
- Support .dbc databases for signal selection,
- Firmware upgrade through GPRS.

Technical data:

- Dual 32 bit processor architecture,
- 16MB of flash memory, 64 MB SRAM,
- Open protocols and formats,
- Python scripting enabled,
- Battery powered real-time clock,
- High speed CAN transceivers TJA1040,
- Modem XT65 Siemens,
- SD & SDHC compatible for log data,
- Power supply range: 12V (9-18), 24V (18-30),
- Temperature rage (operational): -30°C to + 70°C,
- Dimensions: 32 (W) x 106 (H) x 80 (D) mm,
- Weight: Approx. 220g,
- Housing: aluminium enclosure model type ALUBOS 1000 (BOPLA),
- Customizing cable on demand,
- Automotive compliant connector.

Available interfaces:

- USB 2.0,
- High speed 480 Mbps, configured as MSC (mass storage device class: firmware upgrade, RSYNC data-logger synchronization, data-logger reconfiguration,
- GPRS,
- Firmware upgrade, real-time monitoring, data-logger RSYNC synchronization, data-logger reconfiguration),
- Configuration application,
- Configuration manager,
- Selection of logged CAN channels, CAN channel baud-rate, database selection, filtering options, signal selection, data sampling configuration, GPRS configuration, XML file based configuration,

- Import manager.

Output format ASC (vector compatible format)

- Related server application:

- Real-time data monitoring,
- GPS tracking,
- Data storage,
- Remote reconfiguration and administration,
- SD files management (file uploading),
- Remote SD access,
- Data synchronization.

Test site data sensors

The Spanish test site is equipped with the following features for test data acquisition:

- Inductive wiring for real time monitoring of traffic density and media speed per lane. Also traffic jam information is available on the Oracle database coming from these sensors.

The variables that these kinds of sensors are capable of measuring comprise of all needed variables for the driver behavioural analysis.

- Real-time variable message signs (19 units). Accident or road-works information is written here by the DGT operators and can be directly read from the IRSs. Fog and Rain condition information is provided using the images of the above-mentioned cameras.

Any circumstance which could affect the traffic flow or have influence on driving can be shown on these signs by means of text messages and traffic signs pictograms.

And usually the distance from the VMS to these events or the road situation (milestone) of the mentioned situations is also available.

Test management centre

A central data server for the Test Site use will be located at CTAG's premises. This data server will collect all the information gathered from all the FOT vehicles (IVSs) and IRSs

Besides the server, a direct connection with the IRSs and Oracle Test Site sensors database is available via Ethernet (optic fibre link) so their current status can be checked and monitored continuously.

The vehicles fleet can be also monitored remotely by the CTAG data-logger server tool (Figure 63).

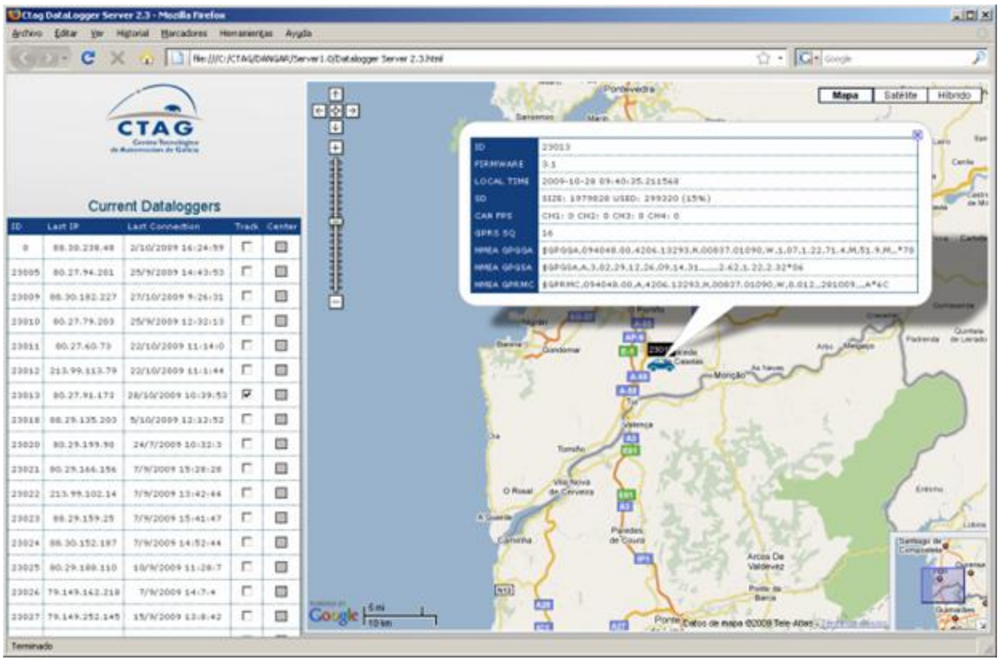


Figure 63: Screenshot from CTAG Data Logger server tool.

Available facilities

The TS is located in the surroundings of CTAG. The test site has the following features:

- Workshops for vehicle integration and maintenance are available at CTAG,
- Conference facilities at CTAG (≈100 people),
- Parking spaces,
- Hotel accommodation is available in the vicinity.

4.11 Assessment of future potential of cooperative systems

The knowledge on the economic viability is crucial for assessing the future potential of cooperative systems and their successful implementation in Europe because considerable investments into this technology are necessary from the different key stakeholders such as automotive OEMs, authorities or the operators of the data back ends needed for data aggregation and processing.

Those investments will only be made, if they will pay off within a reasonable timeframe. This may be achieved by user fees, selling of data to third parties or through vehicle owners willing to pay for the equipment. Paying off through money flow is one important aspect especially for businesses.

Furthermore, it is a common agreement that investment in cooperative systems will also pay back through improved road safety and efficiency as well as through positive environmental effects. The benefit/cost analysis which is the basis for investment decisions of governments and public authorities is quantifying these effects by calculating the resulting societal costs.

PRE-DRIVEC2X has developed a comprehensive calculation model to assess cooperative systems from the business economics (i.e. calculation of the return on investment) and political economics (i.e. benefit/cost analysis) point of view and has drafted first viable business models for this technology. First business economics and political economics calculations have been done in this project for the system specified along the COMeSafety architecture description on the basis of assumptions for the system costs, accident and traffic data for Germany, simulation results and the outcome of numerous stakeholder interviews. This led to a first impression of the economic feasibility of cooperative systems and gives an indication for the viability of the envisaged business models.

It is now the task of DRIVE C2X further elaborate on this calculations by putting them on a broader data basis using the test results from the seven European DRIVE C2X test sites and by collecting detailed information on expected costs for system set up and operation, where only assumptions could be made in PRE-DRIVE C2X.

The following chapters describe the methods for economic assessment developed in PRE-DRIVE C2X and to be applied in DRIVE C2X in more detail.

4.11.1 Socio-economic impact analysis

Logic

On the level of the overall society, the socio-economic impact assessment can make use of different methodological approaches. Depending on the goal dimensions (one goal / several goals) and the degree of impact appraisal, three methodological approaches can be broadly distinguished (Figure 64):

- Cost-effectiveness analysis (CEA),
- Multi-criteria analysis (MCA),
- Cost-benefit analysis (CBA).

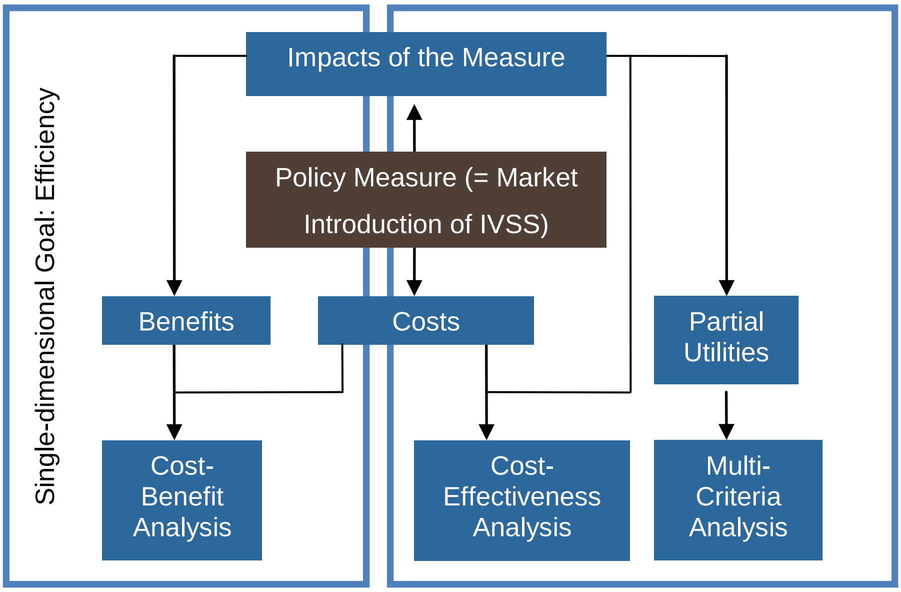


Figure 64: Methodical approaches for socio-economic impact assessment (Source: eIMPACT 2008).

Cost effectiveness analysis (CEA)

Cost-effectiveness analyses (CEA) aim at identifying the measure with the best goal achievement among different measures of equal costs. Alternatively, it will identify the measure with minimum costs that leads to a constant satisfying goal achievement. Hence, cost-effectiveness analysis is able to reflect multi-dimensional goals. Effectiveness indicators usually express the goal achievement. These mostly physical indicators are often laid down in a specification sheet. In contrast to CBA, the different effectiveness indicators will not be transformed into monetary terms. This represents a substantial shortcoming of the cost-effectiveness analysis.

The CEA is particularly suitable for those assessment and decision situations, in which the costs play an important role and therefore they are accounted separately.

The cost effectiveness analysis is subject to the following criticism:

- Due to different aim criteria that are based on at the analysis it is not possible to make statements about the absolute national economic profitability of a project. The cost effectiveness analysis is only able to compare alternative plans of the same aim and to place these into a ranking.
- During the determination of the ranking of several projects, one must carry out standardization and weighting of the different effectiveness scales, if a project is not superior to the other projects with regard to all aim criteria. This task is left to the political decision makers in the context of the cost effectiveness analysis. The subjectivity of the decision is increased in considerably by this procedure.

Multi-criteria analysis (MCA)

Generally, multi-criteria analysis (MCA) aims at establishing preferences between options by referring to an explicit set of objectives. The objectives have to be identified by the decision-making institution itself. Moreover, it is necessary that measurable criteria be defined to assess the extent to which objectives have been achieved. Scoring and weighting play also important roles within MCA.

With that, MCA techniques can be used for the identification of the most preferred option, a ranking of options, and a selection of most promising options for further detailed assessment of a short-list or a distinction between acceptable and unacceptable options.

A crucial feature within MCA is the so-called performance matrix (=table of consequences). The performance matrix may serve as the final product of the analysis within a basic form of MCA. Intuitive processing of the data can be effective and fast. Hence, in an analytically more sophisticated MCA technique, the information in the base matrix is usually converted to consistent numerical values.

Scoring means that the expected consequences of each option have to be assigned to a numerical score that reflects the preference for each option under each criterion. Scoring scales that run from zero to 100 are commonly used. Zero represents the least preferred option and 100 the most preferred option. The result is that the more preferred options have a higher score on the scale than less preferred options.

Weighting is assigned to each criterion of an option. The weight of a criterion expresses how important the criterion is. The weighting process can lead to the result that low scores of a criterion become more important if the weight for this criterion is higher than the weight of a criterion with a higher score. That means that with the weighting process compensatory effects are possible.

The main limitation of MCA is that the results of the weighting process give no indication whether an option adds more to welfare than it detracts. In contrast to CBA, there is no rationale, which leads to a final judgment that welfare is improved or not. Depending on the weighting scheme, it may be the case that the best scoring option of the multi-criteria analysis is associated with a welfare loss. The MCA gives the decision maker the indication that an option is preferable within his assessment scheme, whereas it is not from an overall societal point of view.

The Multi-criteria analysis as a valuation method meets the following points of criticism:

- The variety of the possible aim criteria has the advantage that not purely economic aims are in the centre of the judgment. It is problematic, though, that with the multi-dimensional target socially advantageous but economically not acceptable projects can be carried out.
- A considerable subjectivity to the assessment results since the decision makers weight the single aims and classes have to be formed for the solution of the dimension problem.

- The MCA is a snapshot. Long-term developments are not looked at over the usage time like in the case for the cost-benefit analysis. However, advantageous at this procedure is that the problem of the discounting of measure effects is dropped.

A simple string of the projects is made during the MCA. Statements with regard to the economy do not take place. A string, however, can only be made, if different alternatives are being compared with each other. In a MCA an absolute individual valuation of a single project is not possible.

Cost-benefit analysis (CBA)

Cost-benefit analyses are a traditional method to ensure efficient use of public financial means (maximization of the optimal national product), by summarizing direct (i.e. internal) and indirect (i.e. external) costs and benefits.

The procedure of the Cost-benefit analysis formally corresponds to the capital investment budgeting: The accumulated social benefits during the lifetime (resource savings) are discounted to the point of investment.

The so-called potential Pareto or Kaldor-Hicks criterion is basis for the judgment of the national economic profitability. From that point of view, a measure is advantageous to the national economy; if the economic benefits are bigger than the costs, (i.e. the Cost-benefit difference is greater than zero or the cost-benefit ratio is greater than 1).

With:

CBR: Cost-benefit ratio,

t: Examination time period,

Bt: Benefit per year t,

Ct: Costs per year t ,

i: Interest rate.

The break-even point lies with a cost-benefit ratio (CBR) of greater than 1. In this case, the benefits exceed the costs. The literature offers the following graduations:

CBR = 1 : "weak",

CBR between 1 and 3: "acceptable",

CBR > 3 : "excellent".

In order to assess the benefit, the saved costs are being determined with costs considered as loss of benefit. The economic success scale is the saving of resources. The benefits can occur on both a microeconomic and macroeconomic level. It is, however, decisive that the resource saving is not included twice.

The determination of the cost-benefit ratio depends on the assumed time projection. Costs and benefits usually do not occur in their full extend directly but are realised later in the course of time. Since benefits result from resource savings, they are considerable for the national economy. As a rule, they usually do not automatically lead to a monetary payment to beneficiaries of a measure. Therefore, and as a principle, they are economically different from the costs. The costs lead to actual expenditure that the affected persons by the measure or the performer of a measure have to usually pay themselves. Due to the different monetary qualities of costs and benefits, future benefits are handled differently to future costs.

In the cost-benefit analysis the cost streams, which occur at different times, must be related to a collective point in time. This happens with the help of a social discount rate. The higher the chosen interest rate is, the lower the costs are that occur later. The society's preferences in comparison to today's and future consumption are part of deciding on an interest rate.

For the choice of the discount instalment, auxiliary quantities (time preferences, future manufacturing conditions, opportunity costs) are consulted. Interest rates are usually between 2% and 5%. In the context of the method convention, set by the department of the environment a discount instalment is set for 3% for an assessment that contains periods of up to 20 years. Since the examination period is set from 2010 to 2015, this discount rate is chosen.

Unlike the costs, it can be insinuated that the future benefit has the same place value as an appropriately present benefit. Only because benefit arises in the future, it is not worth less from today's perspective, but as much as from today's perspective. Behind this lies the question how future generations evaluate benefit. For the examination on hand this means if for example one general human life of today (2009) has a benefit in the amount of 1,159,693 € due to an avoided road accident, the benefit in twenty years will be in the amount of 1,159,693 € from the point of view of the performance. This means that zero is the discount instalment of the benefit with generation-spanning assessments.

Independently from this, the real growth of the national economy is, however, important for the extent of the benefit effects. According to the long-term growth forecast of the EU commission an annual growth for 2.4 % is expected and set. For the above-mentioned example, this means: Because the national product has grown, an aged person is really worth more. The benefit therefore is not 1,159,693 € in the year 2030 anymore but at 1,908,281€ instead.

The general price increase in the traffic sector area is at an average of +2.5% for the period from 2000 to 2009. The general price increase must neither be taken into account for the costs nor the benefits since the results of the cost-benefit analysis are shown for the level of prices of the year 2009.

It has to be taken into account, however, that the meaningfulness of the cost-benefit analysis (CBA) of a measure is limited to the resource savings (= allocation effect). It is the general objective of the CBA to determine only the resource savings on the society perspective because the value of the resource is a part of the "total value" of the overall economy.

Besides the benefits because of the resource savings, further benefit effects appear to the stakeholders (e.g. automotive OEMs, public authorities, operators of the data back ends, insurance industry, and automotive customer: = car driver, transport firms, fleet owner). These benefit effects on the stakeholders (= distributive effects) are not subject of the cost-benefit analysis. They are nevertheless noteworthy because they have in economic terms following impacts:

1. First, they will have an impact on the production- and decision functions of automotive OEMs, public authorities, insurance industry, and data back end operators. That means the willingness to introduce and to support C2X systems depends on the benefits they stakeholders can realise.
2. Second, the consumption function of the customers of the automotive industry is influenced. Benefits for these groups enable a shift of their budget line to reach a higher utility scale. With that, the willingness to buy C2X system is increased. From the sales or marketing point, these benefits have an impact on the consumer decisions like advertisement or price reductions.
3. Third, both effects on the production-/decision functions and on the consumption function have interdependencies, which can increase or decrease for both sides the benefit effects. Therefore, it is necessary to identify the elements that could lead to an increase of the benefits on both sides. This is the input from the business case analysis.

For this reason, cost-benefit analysis and stakeholder analysis are the appropriate socio-economic evaluation tools for the assessment of C2X systems. However, the stakeholder analysis needs the input from the business case analysis. Whereby, the business case analysis needs the input from the cost-benefit analysis. Therefore, for the C2X systems the overall assessment approach consists of three elements:

1. Cost-benefit analysis,
2. Stakeholder analysis,
3. Business case analysis.

4.11.2 Methodology for business economics assessment

With the establishment of a business case, more will be known about the economic viability of the C2X communication functions from the perspective of the OEM's and other investors. The purpose of the business case is to provide more insight in financial and non-financial performances and based on this the investors and all other parties involved in deployment of vehicular communication technology can plan and make decisions. Before reaching this end result, a specific business case logic, guarantees a structured and efficient approach. The following paragraphs will explain more about the business case logic, which has been developed PRE-DRIVEC2X and will be further detailed and applied in DRIVE C2X.

Business Case Logic

The establishment of the business cases with the financial models is a process of identifying business impacts under each scenario, measuring impacts (in financial and non-financial terms) and then assigning the end scenario (Figure 65). This makes the business case an excellent decision support and planning tool that projects the likely financial results and other business consequences of the implementation of the DRIVE C2X system.

In order to create such an extensive decision support and planning tool, the following methodology is used:

Figure 65: The business case logic developed in PRE-DRIVE C2X and applied in DRIVE C2X.

1. Definition of project & use cases
2. Definition of objectives and the scope
3. Definition of the business case logic tree & financial metrics
4. Setting up of the assumptions & indicating the sources
5. Establishment of the sensitivity analysis & scenario

Based on the results of the tests and simulations of these functions, the social impact of the C2X communication was determined. The results of this work provide the basis for the Socio-Economic impacts and business economic impacts.

The five steps of the business case logic are described in the following:

Ad 1: Definition of project & use cases

Details on DRIVE C2X and the planned functions & use cases can be found in chapter 2 “DRIVE C2X concept” of this Deliverable.

Ad 2: Definition of objectives and scope

Objectives:

The business case logic continues with the definition of the objective(s) and the scope. For the DRIVEC2X project the objectives are as follows:

- Acquire a clear insight in DRIVEC2X involved stakeholders, costs and revenues.
- Evaluate which investments have to be made by the OEM’s when implementing the DRIVEC2X driving system
- Know when the investments will be paid off by money flow within a specific timeframe
- Evaluating the expectations from the market and project them in the Business cases.

The above mentioned objectives are translated in a set of key performance indicators (project yield) and business case variables which can be found in the financial model.

Scope:

There are two major themes applicable when discussing the scope of the business case calculations:

- ***Country and user group***

  In PRE-DRIVE C2X the business cases to be developed were limited to Germany because it was the primary task of the calculations in PRE-DRIVE C2X to verify the calculation model. The large-scale data gathering within the PRE-DRIVE C2X time schedule made it impossible to include more countries in the study and made it necessary to highly rely on assumptions for system costs. It is the task of DRIVE C2X now to extend the calculations done in PRE-DRIVE C2X to European level and to replace cost assumptions by verified figures.

- ***Number of Business cases***

  Originally it was the idea of PRE-DRIVE C2X to describe one business case, which included all PRE-DRIVE C2X use cases. In the course of the project it became obvious that this would made the calculations too complex and it was therefore decided to establish two model business cases instead, distinguishing between data services and comfort and infotainment services. This approach provided good results and it was therefore decided to continue with it in DRIVE C2X. In Figure 66 the two business cases with their different perspectives are visualised.

It can be seen that business case 1 (BC 1) assesses all the traffic data and other data services which will be calculated from the perspective of the consortium. Traffic data services are all those information services which positively affect the safety and efficiency of the traffic. Other data services can be data services to insurance companies, certification companies and public authorities. This can be relevant information about car status, car driver, driving behaviour etc. The target groups of the business case 1 are the public authorities and the businesses. Business case 1 communication technology is based on an extensive and expensive infrastructure with RSU’s and a CMU. Of course there can be country-specific variations in the business case logic, depending on the given infrastructure in their countries.

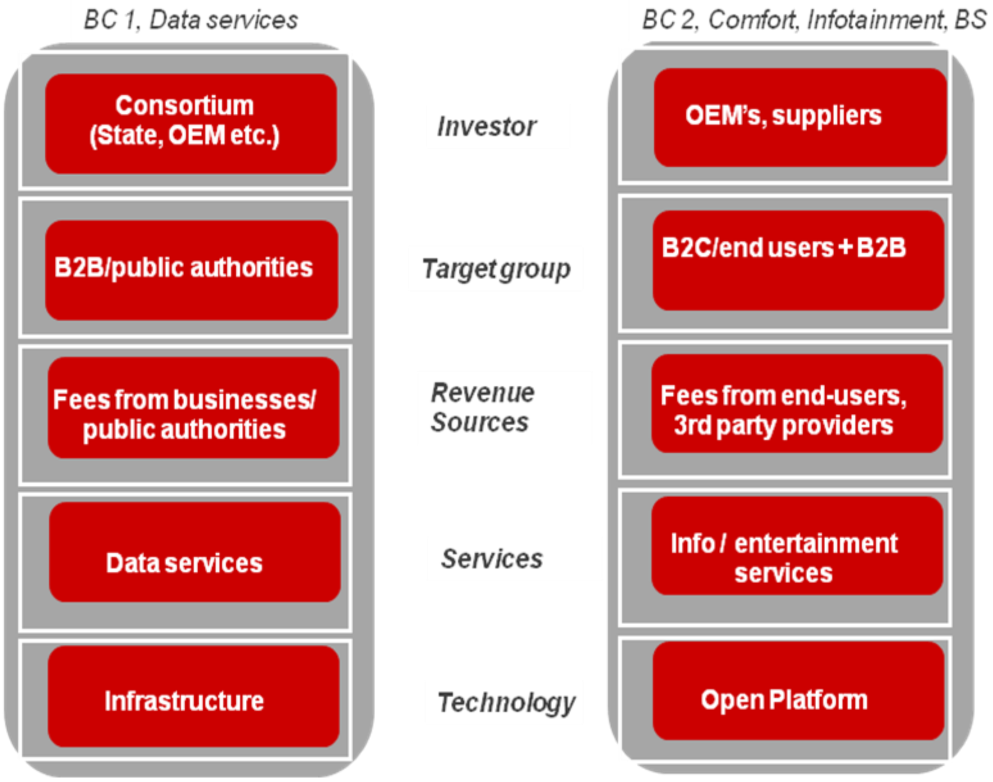


Figure 66: The model business cases developed in PRE-DRIVE C2X.

Business case 2 (BC 2) assesses all comfort and infotainment data business services which will be calculated from the perspective of the OEM's. Comfort and infotainment services are all those services which positively influence the comfort & entertainment level of individual car drivers. Here one can think of point of interest information services and media download. Business data services are those services with which businesses can improve their processes and service to the final customer and which affect in the end positively the comfort level of the final customer. An example of a business service is the "Insurance use case" with which claims management processes can be improved. The business case 2 communication technologies are based on an open platform (internet) which can be accessed via the on-board unit in the car.

In more detail this means that business case 1 is set up in order to see the extent of the investments and to see what is necessary to refinance the investments for the needed infrastructure. This calculation is important, since costs of the c-2-x infrastructure is very high and is not expected to be (completely) refinanced with the income from commercial functionalities or use cases. This income from the commercial functionalities is calculated in business case 2 where they bring revenue and help financing the on-board units.

Ad 3: Business case logic tree & financial metrics

The business case objectives result in a set of key performance indicators (project yield) which can be retrieved and calculated when working with the business case logic tree (Figure 67)

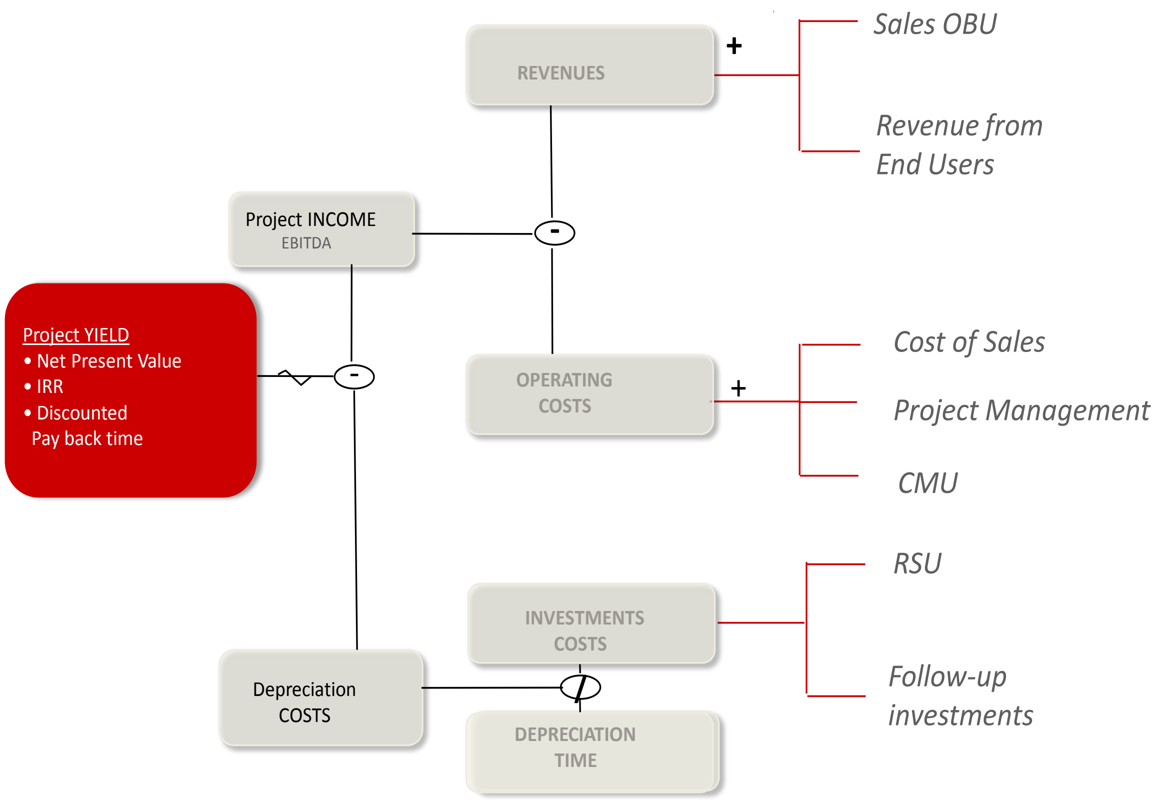


Figure 67: PRE-DRIVE C2X business case logic tree.

When looking at the project yield box in the picture above, it can be seen that there are three major performance indicators on which future decisions of C2X project will be based. These performance indicators will be explained in the text below.

- The most basic financial metric is the cash flow. Cash flow measures cash that actually flows in or out of the company or organization.
- *Net profit* = Gross profit minus overheads minus interest .
- *EBITDA* = Earnings before interest, taxes, depreciation and amortization.
- *IRR* = Internal Rate of Return is expressed as a percentage. Some organizations use the IRR as an internal hurdle rate. Companies must project an IRR above the hurdle rate in order to receive funding. When one or more scenarios compete with each .
- *Net Present Value* NPV is an indicator of how much value an investment or project adds to the firm. Each cash inflow/outflow is discounted back to its present value (PV). Then they are summed. Therefore NPV is the sum of all terms.
- *Discounted pay-back time*: is the amount of time that it takes to cover the cost of a project, by adding positive discounted cash flow coming from the profits of the project.

All performance indicators tell us something about the profitability of the investments. Insight in the overall profitability of the project can be retrieved by studying the business case logic tree (see Figure 67) and understand of which *project income* and depreciation costs the DRIVEc2 x business case consists off.

The insight in stakeholders, costs and revenues is retrieved by detailing/describing the selected use cases and this way identifying all the cost, revenue and stakeholders variables.

Based on the use case descriptions, further detailing of the business cases in financial components can take place. These components for the PRE-DRIVE C2X business case can be found in the right column of the logic tree:

- ***The cost components; infrastructure, people and products***. Cost items in the business case are the items where the OEM's spends money on, for goods, services and resources of all kinds. Depending on which business case (business case 1 or 2), there are also depreciation costs for long-term investments in infrastructure. The cost model helps identifying and organizing all cost impacts in the business case. These become line items in the cash flow statement.

- ***The revenue components; Sales of products (OBU), usage fees, Cost savings***. Selling the On Board Unit will bring revenue. Another option for creating revenue is letting the customer pay a specific usage fee for using a specific application/function (not specified in BC).

Other revenue components are the cost savings. Cost savings are viewed as hard benefits. These benefits come from the cost analysis, by comparing cost estimates under different scenarios (a proposal scenario compared to a business as usual scenario). In former projects (Network on Wheels) especially savings on logistics and production costs are mentioned to be high.

The last revenue flow can be expected from third party suppliers. Third party suppliers such as CMU provider, Insurance companies, Telecom companies etc might be willing to pay for functions and data.

- ***The investment (costs);*** Investments costs of the consortium and different stakeholders. Especially business case 1 will reflect investment costs which are caused by investments in the infrastructure (Road Side Units). Investments are taken fully in the cash flow together with the expenses. Investments are depreciated over a time period and the corresponding depreciation is taken as a cost component.

Ad 4: Sources and assumptions

With the set up of the business cases, come also many assumptions because recipients want to know how cost and benefit values are determined and what the sources are. Therefore creating assumptions is a major part of a business case. Assumptions are important because the case deals with the future and predictions are always assumptions. Assumptions are also necessary to simplify data requirements and to clarify exactly what the scenario describes. Sources for financial and qualitative components are amongst others; business/consultancy reports on C2X communication and cooperative driving. Next to this, expert interviews (with several stakeholders) and the friendly user test, lead to a better insight in perception of potential drivers and stakeholders.

Ad 5: Sensitivity analysis & scenario

Sensitivity and risk analysis of the financial model shows how the results are controlled by the different assumptions and the likelihood that the business case results will differ from the predicted results. The changing of one variable in the sensitivity analysis can lead to a completely different project yield which can also be considered as a different scenario.

5 Conclusions

This deliverable presents the methodology for the road tests as it stands about five months after the project start. So far all the functions to be tested have been selected, pre-validation carried out to provide input for the actual test planning. Furthermore, the process from the DRIVE c2x system level to functions, use cases, target scenarios and test scenarios were identified. Also the technical test plan was created.

What still needs to be done in setting up the complete methodology are defining all the research questions, hypotheses and performance indicators. After that the actual field test design process can start. The tested functions need different designs, and this process has just started. This deliverable will be updated after the pilot tests have been completed. Not until then the complete DRIVE C2X methodology can be presented.

Concerning compatibility of the tests across European test sites, also here the precise testing process description will be a key factor contributing to the comparability and a possibility to merge data from the test sites. The commitment of test sites to this process is vital.

Consequently, the greatest challenge in creating the methodology is to harmonise the test sites in terms test design, testing procedure overall and HMI across test sites. All these have an impact on the final results. Finally, long-term testing needs also to be planned and agreed throughout the testing community. Even though we are entering large-scale field trials, the results from these tests are still indicative due to the lack of sufficient penetration of cooperative vehicles and needed interaction. However, the results combined with the systematic collection of user experiences and opinions will yield a picture that warrants taking decisions on the continuation of cooperative driving systems.

6 Glossary

Abbreviation	Explanation
ACC	Adaptive Cruise Control
ADAS	Advanced Driver Assistance System
AEV	Approaching emergency vehicle
AIDE	Adapted Integrated Driver-vehicle Interface (a project)
AKTIV	Adaptive and Cooperative Technologies for the Intelligent Traffic
ASN.1	Abstract Syntax Notation (defines the abstract syntax of information)
ASSET	Project: Advanced Safety and Driver Support for Essential Road Transport
ASV4	Project: Advanced Safety Vehicle (Japan)
ATS	Associated test site in DRIVE C2X (Vigo, Spain)
AU	Application Unit
AutoCAD	Computer Aided Design or Computer Aided Drafting
BIM	Backend Integration Module
BIMA	Federal institution for management of Federal real estate objects
BLIS	Blind Spot Information System
BSA	Basic Set of Applications
CALM	Communication Access for Land Mobiles
CAM	Cooperative Awareness Message
CAN	Controller Area Network
CAR2CAR	Consortium by European vehicle manufacturers to the objective of increasing road traffic safety and efficiency by means of cooperative systems
CBW	Car breakdown warning
CCU	Communication Control Unit
CEN	Comité Européen de Normalisation (European Committee for Standardisation)
CENIT	A Spanish project
CMC	Communication Management Centre
CNG	Compressed natural gas
CO	Carbon monoxide
CO_2	Carbon dioxide
CODIA	An Impact assessment study for cooperative systems
COMeSafety	Support action on issues related to cooperative intelligent road transport
COMM	Communication
COSMO	Cooperative systems for mobility and energy efficiency (a Swedish project)

CPU	Central processing unit
CSW	Curve Speed Warning
CVIS	Cooperative Vehicle-Infrastructure Systems (a project)
C2C	Car-to-Car communication
C2I	Car-to-Infra communication
C2X	General term for cooperative communication (C2C, C2I)
DB	Databank
DEN	Directory-Enabled Networking
DENM	Decentralized Environmental Notification Message
DFCD	Decentralized floating car data
DGPS	Differential GPS
DIAMANT	Dynamische Informationen und Anwendungen zur Mobilitätssicherung mit Adaptiven Netzwerken und Telematik-Infrastruktur (project)
DM	Dealer Management
DRIVE C2X	DRIVing implementation and Evaluation of C2X communication technology in Europe
DSL	Digital Subscriber Line
DSSS	One of two types of spread spectrum radio
EASIS	Project: Electronic architecture and system engineering for integrated safety
EAST-EAA	IEEE Guide for Developing System Requirements Specifications
EasyWay	Europe-wide project for the deployment of ITS on the Trans European Road Network
EC	European Commission
eCall	Automatic emergency call activating after a crash
EEBL	Emergency electronic brake light
eImpact	A project to evaluate the impacts of ITS
ESP	Electronic Stability programme, also ESC
ETH	Ethernet
ETSI	European Telecommunications Standards Institute
ETSI TC ITS	Responsible for test standards and may develop complementary communication standards to consider specific European needs
EURECA	European Research and Collaboration with Asia
euroFOT	FOT on ADAS
FCD	Floating car data
FCW	Forward Collision Warning
FEA	Fuel Efficiency Advisor
FESTA	Project. Field opErational teSt supporT Action
FESTA-V	V-shaped testing process
FFM	Frankfurt am Mein
Flash-OFDM	Fast Low-latency Access with Seamless Handoff, Orthogonal Frequency

	Division Multiplexing
FM	Frequency modulation
FMC	Fixed Mobile Convergence
FMS	Fleet Management Standard (interface to CAN)
FO	Fibre optics
FOT	Field Operational Test (Field trial, Field test, Field experiment)
FOTsis	Project: on cooperative traffic
FP	Framework programme (by European Commission)
FTB	File Transfer Protocol
GCDC	Grand Cooperative Driving Challenge
GD	Green Driving Support
GDV	German Insurance Association
GEONet	Project: implements a reference specification of a geographic addressing and routing protocol
GLOSA	Green light optimal speed advisory
GNSS	Global Navigation Satellite Systems
GPRS	General Packet Radio Service
GPS	Global Positioning System
HC	Hydrocarbon
HDD	Hard disk drive
HDRC	High Dynamic Range Camera
HDV	Heavy Duty Vehicle
HEV	Hybrid Electric Vehicle
HLF	High level fusion (data)
HLN	Hazardous location notification
HMI	Human Machine Interface (or interaction)
HTTP	Hypertext Transfer Protocol
HW	Hardware
Hz	Hertz
IcOR	Road surface monitoring camera system
ICS	Internet Connection Sharing
ICT	Information and Communication Technology
ICW	Intersection collision warning
ID	Identification
IEEE	Institute of Electrical and Electronic Engineers
IFS	Insurance and Financial Services
IGLZ	Integrated Overall Traffic Management Centre (in Frankfurt)
IMU	Inertial Measurement Unit

INTELLIDRIVE™	US connected vehicle research programme
INTERSAFE	PReVENT sub-project on cooperative intersection driving
IP	Information protocol
IPR	Intellectual Property Rights
IPv6	The second version of widely used Internet Protocol
IR	Internal report
IRS	ITS Roadside Station
IRSMC	ITS Roadside Station Management Centre
ISA	Intelligent Speed Adaptation
ISO	International Standardisation Organisation
iTETRIS	An open source vehicular communication application
ITS	Intelligent Transportation System
IVS/SL	In-vehicle signage/Speed limit
IW	Impairment Warning
Helmond	The Dutch test site
HLSV	Software that facilitates online gamers the world-wide locating of game servers as well as game server owners or operators the maintenance and administration of their servers.
HSDPA	High-Speed Downlink Packet Access
HTTP	Hyper Text Transfer Protocol
LDM	Local Dynamic Map
LDV	Light Duty Vehicle
LDW	Lane Departure Warning
LEC	Local electronic commerce
LimeSurvey	An open source survey tool
LK	Lane keeping support
LST	Large-scale test site in DRIVE C2X
LTH	Tekniska Högskolan i Lund
MIB	Management Information Base
MW	Motorcycle warning
MySQL	A relational database management system
N	Stands for the number of observations or subjects in tests
NAS	Network-attached storage
NAV	Navigation support, static & dynamic
NIR	Near-infrared
NMEA	National Marine Electronics Association
NO_x	Nitrogen oxide
NO2	Nitrogen dioxide is one of the nitrogen oxides (NOx)
NoW	Network on Wheels

NWT	Network and Transport
OASIS	Operation of safer, more intelligent and more sustainable highways
OBD	On-Board Diagnostics (in cars)
OBE	On-board equipment
OBU	On-board unit
OEM	Original Equipment Manufacturer
OpenStreetMap	A project with the goal of creating a free world map
OSGi	A set of specifications that define a dynamic component system for Java.
OW	Obstacle Warning
PCB	A board used to build electronic devices
PCW	Post crash warning
PKI	Public Key Infrastructure
PM	Particulate Matter (emission)
PN	High Particle Number Emissions
POI	Point of interest
PostgreSQL	Open-source Object-Relational DBMS supporting almost all SQL constructs
POTI	Position and Time
PRE-DRIVE C2X	Project: Preparation for driving implementation and evaluation of C2X communication technology
PReVAL	A sub-project of PReVENT to evaluate the impacts of PReVENT functions
PReVENT	Project: Preventive and Active Safety Applications
PROMETHEUS	Project: PROgraMme for a European Traffic of Highest Efficiency and Unprecedented Safety
QVGA	Quarter Video Graphics Array
R&D	Research and development
RMC	An Energy-Aware Cross-Layer Data-Gathering Protocol for Wireless Sensor Networks
RQ	Research question
RSE	Remote System Explorer
RSU	Road-side unit
RTD	Research and Technology Development
RTK-GPS	Real Time Kinematic GPS
RWW	Roadwork warning
SA	Speed alert
SafeHMI	Safe Human-Machine Interaction for Navigation Systems
SAFER	Vehicle and Traffic Safety Centre at Chalmers, Sweden
SafeSpot	Integrated Project
SC	Speed Camera Alert
SCORE@F	Système COopératif Routier Expérimental Français (French field operational test for cooperative systems)

SD	Secure Digital (card)
simTD	Sichere Intelligente Mobilität – Testfeld Deutschland
SL	Speed limit information
SMARTWAY	US transportation program
SOA	Service-Oriented Device Communications
SP	Sub-project
SPITS	SPITS is a Dutch project, tasked with creating Intelligent Traffic Systems
SPSS	Statistical Package for Social Sciences; data analysis tool-package
SQL	Structured Query Language
SRS	Speed Regulation System
SSC	Stop Sign Violation
SST	Small-scale test site in DRIVE C2X
STCT	Swedish Traffic Conflict Technique
STS	System test site in DRIVE C2X
SUMO	Simulation of Urban Mobility (simulation tool)
SVW	Slow vehicle warning
SW	Software
TA	Time-to-Accident
TB	Terabyte
TC	Technical Committee (of ETSI)
TCC	Traffic control centre or Telecommunications centre
TCP	Transmission Control protocol
TCT	Traffic Conflict Technique
TeleFOT	FOT on services and functions on mobile devices in vehicles
TERN	Trans-European Road Network
TI	Traffic Information
TIRI/DFCD	Traffic information and recommended itinerary
TJAW	Traffic jam ahead warning
TL	Transparent Leasing
TRL	Transport Research Laboratory
t-test	Statistical significance test
TVCC	Video camera-system
UDP	User Datagram Protocol
UMTS	Universal Mobile Telecommunication Standard
USB	Universal Serial Bus
VANET	Vehicular Ad Hoc Network
VAPI	Virus-scanning Application Programming Interface
VAR(Speed)	Speed variance

VCOM	Voice Compression Module
VDP	Video Display Processor
VEHIL	Vehicle Hardware-in-the-Loop (software tool)
VICS	Vehicle Information and Communication System (Japan)
Vigo	A Spanish associated test site in DRIVE C2X
VISSIM	A microscopic, time-step traffic simulation model
VMC	Vehicle Management Centre
VMS	Variable Message Sign
VSPU	Video Switching and Power Unit
VZH	Hessian traffic centre
WAVE	Wireless Access in Vehicular Environment
WG	Working Group (in ETSI Technical Committee e.g.)
WiFi	Wireless Fidelity (wireless networking)
WILLWARN	Wireless Local Danger Warning (a PReVENT subproject)
Wimax	Worldwide Interoperability for Microwave Access
WiSafeCar	Cooperative traffic project
WLAN	Wireless Local Area Network
WP	Work package
WW	Weather warning
WWGS	Wrong-way Warning in Gas-station
XML	eXtensible Markup Language
3G	Third-Generation Cell-Phone Technology
802.11p	An approved amendment to the IEEE 802.11 standard to add wireless access in vehicular environments (WAVE)

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