DRIVing implementation and Evaluation of C2X communication technology in Europe

DRIVE C2X

Accelerate cooperative mobility

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SEVENTH FRAMEWORK PROGRAMME

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Executive summary

In the past decade co-operative systems based on wireless vehicular communication have received extensive world-wide attention, and significant advances both in research, applications and testing have been achieved. The DRIVE C2X project brought together various ongoing national activities into a large European testing platform to ensure the compatibility of emerging systems with the architecture defined and specified at a European level. DRIVE C2X identified four major objectives: (i) Create and harmonize a Europe-wide testing environment for cooperative systems (ii) Coordinate the tests carried out on parallel throughout the DRIVE C2X community (iii) Evaluate cooperative systems and (iv) Promote cooperative driving. The overall aim was to identify the impacts of cooperative systems on traffic system ranging from safety to mobility needs. Hence, the PRE-DRIVE C2X consortium with the majority of the European automotive OEMs, electronics and supplier companies specialized on vehicular communication opened up to additional partners and formed the DRIVE C2X consortium to carry out European-wide field operational tests on cooperative systems. Before the project could enter user tests, there were numerous other activities for the creation of technical readiness for FOT. Despite PRE-DRIVE C2X and predecessor projects built a technical basis for the upcoming FOT, a number of efforts were needed to have C2X-system functional for extensive user tests in field conditions. The different phases of the whole DRIVE C2X methodology to support pilot tests and FOT dealt with activities for the technical readiness is represented by the tasks such as "Setting up testing tools" and "Test sites preparation" and "Data management". These had to be in order – in addition to a user test design plan - before the piloting and actual FOT could be initiated. DRIVE C2X was by far the most complex FOT ever carried out from the point of creating technical readiness for the actual FOT.

In total eight different cooperative functions were successfully tested with 750 drivers in seven European countries: in Finland, France, Germany, Italy, the Netherland, Spain and Sweden. In total, more than 200 vehicles drove more than 1,5 million km and the faultless performance of system and functions under all relevant traffic and climate conditions proved that the system is mature for Europe-wide deployment .

The safety impacts of the DRIVE C2X functions are clearly positive. Drivers react to information and warning signals.

- IVS Speed limit and Weather warning showed most potential to decrease fatalities:
    - Assuming a 100% penetration rate, IVS speed limit that provides continuous information would reduce on average 23% in fatalities and 13% in injuries. Weather Warning would lead to 6% less fatalities and 5% less injuries.
    - It is assumed that the penetration rates would be in 2020 highest 12% and 76% in 2030. For IVS speed limit, this would lead to the reduction in fatalities up to 3% in 2020 and up to 16% in 2030.
- Assuming a 100% penetration rate, Road works warning would decrease fatalities by 3%, Emergency brake light warning and Traffic jam ahead warning by 2%. These functions would decrease injuries by 2% assuming all vehicles are equipped.

The DRIVE C2X project successfully measured and analysed direct and short-term effects of drivers' use of the DRIVE C2X functions. The safety impacts of the DRIVE C2X functions were found to be positive even for functions aimed at relatively infrequent events. Environmental benefits in terms of reduction in fuel consumption ad CO2 emissions were also achieved for three functions. Based on both user behaviour and preference measurements, the results of the project clearly show the significant potential of cooperative systems.

Also the results of the FOTs indicate positive impacts on travel comfort. Specifically, journey quality is improved in terms of decreased user uncertainty and stress, and feeling of safety and comfort.

Considering the proven safety impact as well as the perceived increase in comfort the promising user acceptance does not come as a surprise. Nine out of ten test users highly welcome the DRIVE C2X system, and that they are willing to use it if it is available on their vehicles.

In order to make cooperative systems happen on European roads DRIVE C2X was not limited to test and evaluation of C2X functions. The project did also describe deployment strategies for C2X communication based on realistic business models. The latter were developed on the basis of more than 50 interviews with representatives across all important stakeholder groups that showed evidence for economic viability and indicated that an open platform concept allowing commercial services by third parties is the key to economic success.

A working C2X system requires communication infrastructure on the roadside. Since it are still public authorities, who are supposed to invest in this, it is of utmost importance, that the ratio between the benefits of the system and its costs is clearly positive. To prove this the project has also conducted a benefit cost analysis, where monetary equivalents have been assigned to the benefits identified in the impact assessment.

Even with a low penetration rate the benefit cost ratio (BCR) was 2, showing twice as much benefit as compared to costs. With a high penetration rate the benefits could almost be seven times higher than costs. This clearly shows that an investment in cooperative systems is money well spent also for road operators and public authorities.

However, proving the benefits of a system and showing its economic viability and meaningfulness is only one side of the coin. It is equally important to create awareness for this new technology. Not only at experts´ side, but also at the side of the "interested public". To achieve this DRIVE C2X organized a series of test site events with the public invited to one of them and was also present on all major ITS conferences and congresses and even produced two short videos that explain the benefits of cooperative systems in an easy to perceive way.

Besides this DRIVE c2X also contributed to the standardization of cooperative systems at ETSI and CEN and ensured, that all DRIVE C2X developments were compliant as much as possible with the standards developed there. With this it is guaranteed, that future European ITS systems are clearly DRIVE C2X based.

1 Project context and objectives

1.1 Technical background

In the past decade co-operative systems based on vehicular communication technologies have received extensive world-wide attention, and significant advances both in research, applications and testing have been achieved. Preliminary results from these tests suggested that communication between vehicles and vehicles and infrastructure can substantially improve sustainable transportation by enhancing road safety, travel comfort, traffic throughput and decrease emissions. Thus, a general understanding of the benefits of cooperative systems was reached. However, the results were obtained in small scale trials mostly on closed test tracks and therefore, large-scale field operational tests were needed to test cooperative driving systems before engaging in deployment and commercialization.

In the European context, the pioneering studies in the 1980's EUREKA research program PROMETHEUS raised interest in cooperative systems and led to significant development in the past decades. Industry consortia, particularly the CAR2CAR Communication Consortium (C2C-CC), were created and many European and national projects initiated. Major related research and development projects such as SAFESPOT, CVIS, COOPERS and PRE-DRIVE C2X were completed with small-scale tests and demonstrations in 2010. Communication systems and their components were mature enough to be engaged in large-scale field operational tests. Several national field operational tests and programs with vehicular communication technology such as simTD in Germany, SCORE@F in France and Test Site Sweden in Southern Sweden were initiated. However, these national activities were limited to specific local needs and the testing methodologies as well as the technologies and the applications selected were not necessarily compatible. A Europe-wide integrated approach to large scale user tests of cooperative systems was needed in order to speed up the market introduction of interoperable systems and applications functioning across borders.

The purpose of the DRIVE C2X project was to bring together various ongoing national activities into a large European testing platform and ensure the compatibility of emerging systems with the architecture defined and specified at a European level by COMeSafety and PRE-DRIVE C2X projects. The project modeled on predecessor PRE-DRIVE C2X created a sound basis for Europe-wide field operational tests of vehicular communication technology. In collaboration with COMeSafety support action, PRE-DRIVE C2X has agreed on a system specification, which laid the basis for the ongoing standardization activities in ETSI TC ITS. Furthermore, PRE-DRIVE C2X validated the tools and methods necessary for testing and evaluation of cooperative systems in large scale field operational tests in particular the integrated simulation toolset that allowed the assessment of all aspects of vehicular communication technology. Also, test management tools were 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 were also used to validate these business models and verify the implementation strategies.

Hence, as a logical step the PRE-DRIVE C2X consortium with the majority of the European automotive OEMs, electronics and supplier companies, research institutes and academia opened up to additional partners from different stakeholder groups and formed the DRIVE C2X consortium to carry out Europe-wide field operational tests on cooperative systems targeted to more sustainable traffic.

The aim of DRIVE C2X was not only to show that the approach to study safety oriented functions 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 Union member states. Figure 1 below describes the relationship between the various projects and consortia that has led to the DRIVE C2X activities via the PRE-DRIVE C2X and other vehicular communication European R&D.

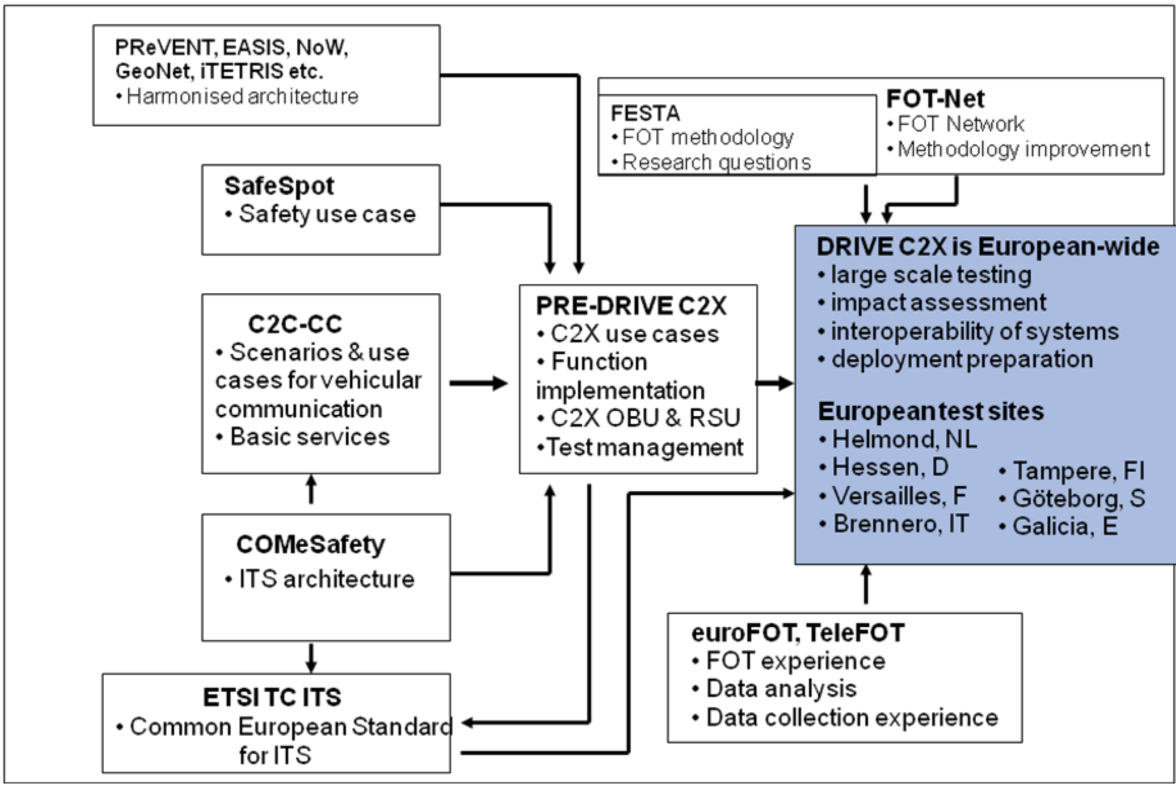


Figure 1: Drive C2X and its connection to other European activities in vehicular communication and related methodologies.

1.2 Objectives

The objective of DRIVE C2X was to assess cooperative systems on a European level by means of extensive Field Operational Tests (FOTs).

This target was reached by binding together and harmonizing the existing Europe-wide testing community comprising of seven test sites in Finland, France, Germany, Italy, the Netherlands, Spain, and Sweden for common testing. The project was above all a methodological activity aiming to show the most likely impacts of cooperative systems on users, environment, and society thereby providing useful information for further development and deployment of cooperative systems.

DRIVE C2X identified four major objectives as detailed below:

1. Create and harmonize a Europe-wide testing environment for cooperative systems
    - Create and activate a Europe-wide DRIVE C2X test community for carrying out extensive meaningful and complementary field tests on cooperative systems.
    - Harmonise the selected test sites in terms of compliance with the needs for field operational tests on cooperative systems at a European level.
    - Define and agree on a common testing methodology and implement it across all test sites.
2. Coordinate the tests carried out in parallel throughout the DRIVE C2X community
    - Create a formal, jointly agreed coordination procedure to ensure effective running of tests across the large European DRIVE C2X community.
    - 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.
    - Investigate functions common to all test sites as well as site-specific functions.
3. Evaluate cooperative systems
    - Study phenomena ranging from driver reactions all the way to societal impacts.
    - Carry out technical tests to show the cooperative systems functioning and acquire feedback for further development.
    - Draw conclusions and make recommendations for further development and deployment of cooperative systems for users.
4. Promote cooperative driving
    - Disseminate and promote effectively cooperative driving and its potential benefits.
    - Develop effective procedures of enhancing awareness and acceptance of cooperative systems among the public.
    - Study the deployment potential and create a road-map for the introduction of cooperative systems.
    - Promote integration and collaboration in cooperative system initiatives in Europe and overseas.
    - Improve and validate a testing methodology for cooperative systems for upcoming European field tests after DRIVE C2X.Main S&T results / foregrounds.

In addition to impact assessment, the tests also aimed at assessing technical functionality and robustness of the systems under adverse conditions, e.g. harsh winter conditions in Nordic countries. The collected user feedback and the results from technical tests enabled the development of realistic business models for the subsequent market introduction. In meeting the objectives, DRIVE C2X comprised the following main pillars in developing and implementing its methodology:

- FESTA handbook for FOT methodology, especially the V-shaped 'FOT-chain' to plan the testing procedure.
- Ongoing two large-scale European FOTs, TeleFOT and euroFOT.

- Partners' own experience in carrying out user tests in field conditions over the past 20 years.
- Results of PRE-DRIVE C2X tools and methods were necessary for successful test and evaluation of co-operative systems in a field operational trial.

1.3 Presentation of the project work

DRIVE C2x was an extensive and complex project. Its five subprojects contained 29 work packages in total. It is not possible to present here the work carried out in all work packages without making the report list-like. For this reason the presentation provides a synthesis of the main activities rather than presenting an exhaustive list of tasks conducted and results achieved. The respective subproject and deliverables are referred to for a more detailed picture of the activities.

The work focused first on the methodology part, how the PRE-DRIVE C2X-based vehicular communication system was transformed to field trials and the seven European test sites were prepared and functioned for a common FOT. After showing the preparatory phases, including piloting and FOT, this report focuses on the key results and conclusions reached after completion of the tests.

Chapter 1 describes the project background with a reference to previous work on standards and other communication projects in Europe, and concludes with objectives. Chapter 2 features the DRIVE C2X methodology and testing principles; and shows the numerous steps needed to set up a Europe-wide FOT. Chapter 3 "FOT" describes how the field tests were carried out, including challenges related to testing and events recorded. Chapter 4 "Evaluation" highlights the project work and presents the key FOT results both from the technical and user tests. Chapter 5 "Promotion" further discussed the work carried out and addresses the implications for the commercialization of cooperative systems in the market. Also the activities to promote DRIVE C2X work and achievements are presented. Chapter 6 "Lessons Learned" discusses what we have learned from this challenging project and what could have been done better. Eventually, Chapter 7 "Conclusions" contemplates the significance and meaning of the tests carried out, and the results obtained.

As told above, the DRIVE C2X subprojects were carried out in close cooperation, and the methodological core activity was done by SP2 "FOT Framework" for roughly the first third of the project duration so that partners from other subprojects participated actively in SP2 work providing input to the creation of the general DRIVE C2X methodology (Figure 2). SP2 main tasks were to lead and coordinate activities to achieve technical and methodology-wise FOT system for the implementation across the European cooperative testing community.

Figure 2 below shows that even though SP2 functioned as a methodology harmonisation entity, it couldn't do that work alone. Important roles in the process had also the other three subprojects. SP3 "FOT operations" brought in test site requirements and constraints for the work. The test sites differed in several respects, and these differences had to be taken into account in planning the overall methodology. Furthermore, SP3 was needed in the creation of a data management system without which the data analysis activities would have been far more scattered and time consuming. SP 4 "FOT evaluation" in turn – in addition to the evaluation of the data obtained - had a key role in the requirements for test design when planning the testable functions and what kind of research questions and hypothesis needed to be postulated as well as providing input to the simulation models to determine the expected number of events needed for statistical testing. SP4 set also requirements for the data logging system, and data management overall. SP5 “Cooperative driving promotion” contributed the overall methodology by designing the data acquisition for the business plans that actually highlighted the project promotion activities and drew a conclusion from the work carried out. Consequently, all the subprojects worked in close cooperation also in the methodology creation to enable the actual FOT.

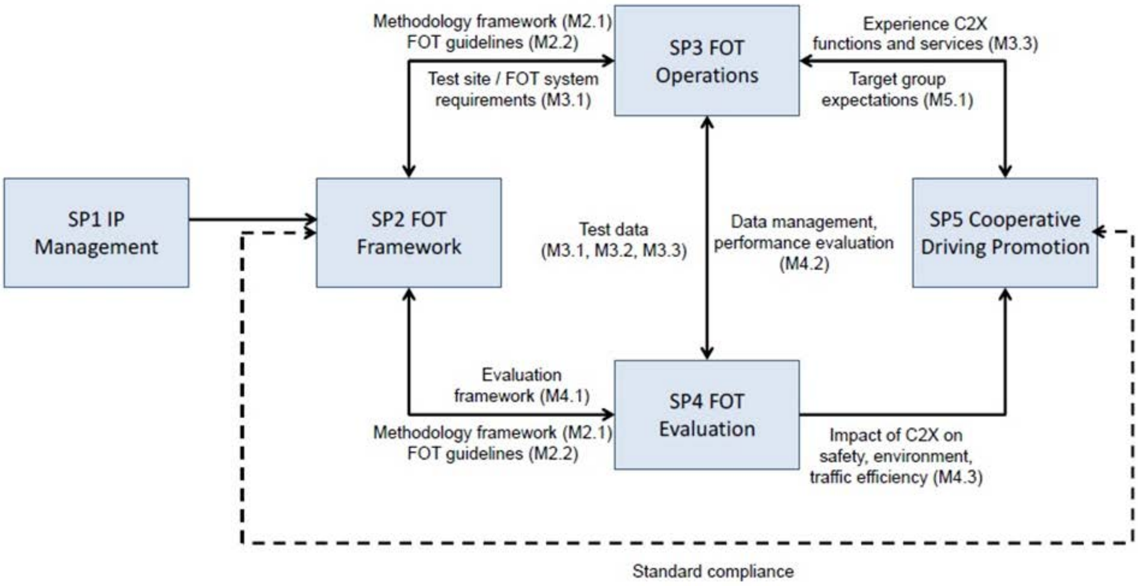


Figure 2: Interaction of DRIVE C2X subprojects.

Figure 3 shows, how the work was broken down to work package level in the DRIVE C2X subprojects.

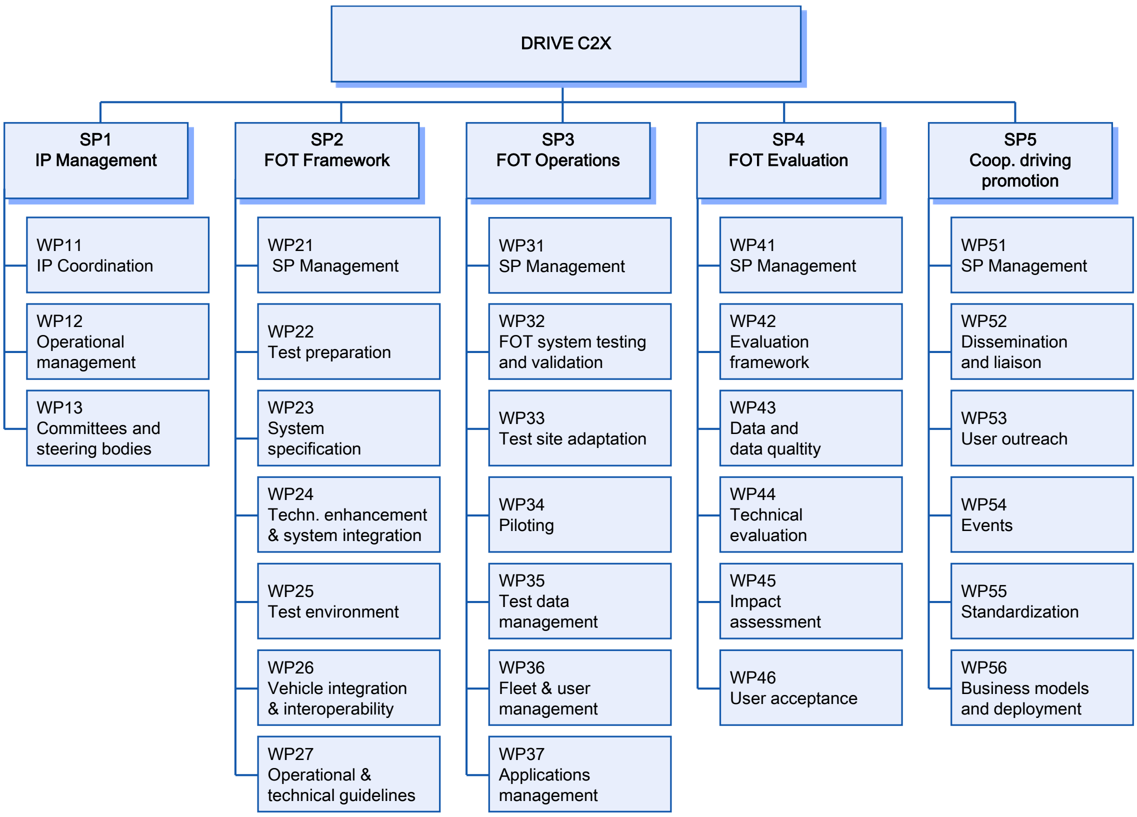


Figure 3: Work breakdown structure

1.4 European test sites

The DRIVE C2X tests were carried out across Europe in variable surroundings from harsh winter conditions in Finland to Mediterranean and Atlantic mild climate areas in Italy and Spain (Figure 3). It can be stated that the tests sites adequately represented various European travel and driving conditions.

The test-sites were divided into two categories:

- The Helmond test site in the Netherlands functioned as a system test site. It was equipped with a fully compliant DRIVE C2X system. This allowed the full implementation, testing and evaluation of all functions selected for DRIVE C2X. The main emphasis was on the validation of the DRIVE-C2X reference system and on the interoperability of the selected functions, since hardware and software components of various suppliers were used.
- The five other test-sites were serving as functional test-sites. For these sites full compliance with the DRIVE-C2X scope was not necessary. Their main purpose was to deliver test data for selected functions. The main idea was to investigate the impacts of cooperative functions on user behaviour and preferences in real road traffic. However, for the technical tests a fully DRIVE C2X compliant system was used.

Figure 4: DRIVE C2X test sites.

2 Methodology

2.1 Methodology building blocks

Before the project could enter user tests, there were numerous other activities for the creation of technical readiness for FOT. Despite PRE-DRIVE C2X and predecessor projects having built a technical basis for the upcoming FOT, a number of efforts were needed to have C2X-system functional for the impacts testing for a variable vehicle fleet in field conditions. The different phases of the whole DRIVE C2X methodology to support pilot tests and FOT are depicted in the following figure below. In Figure 4 activities for the technical readiness is represented by the blocks "setting up testing tools" and "test sites preparation". These had to be completed – in addition to a user test design plan - before the piloting and actual FOT could be initiated. DRIVE C2X was by far the most complex FOT ever carried out from the point of creating technical readiness for the actual FOT. These phases took ample time in order to ensure that the field tests could be carried out observing the testing methodology.

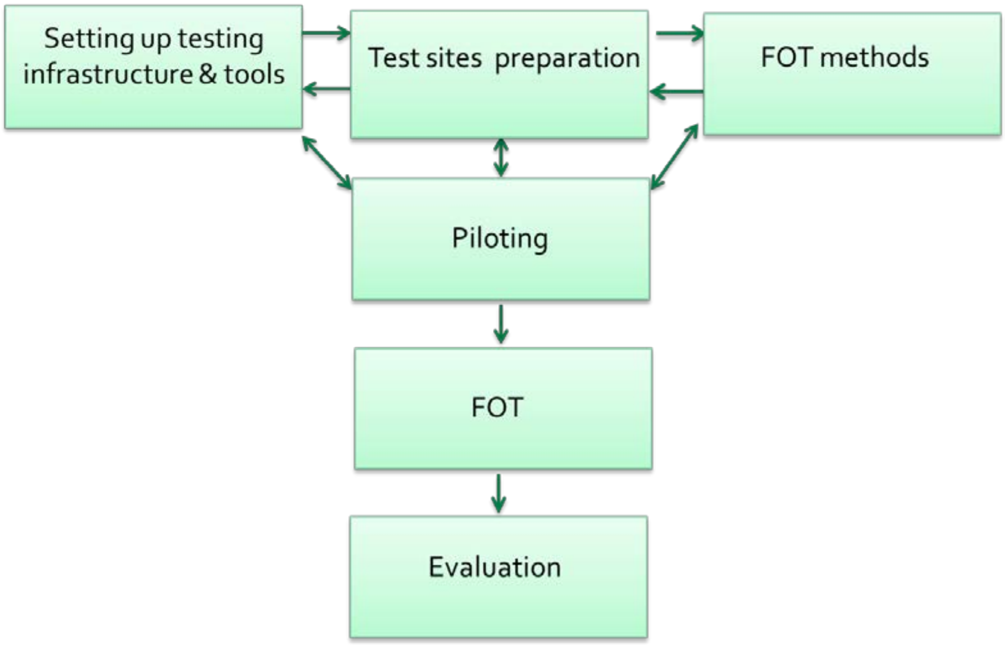


Figure 5: Drive C2X methodology building blocks.

The three uppermost blocks in Figure 4 describe the creation of overall methodology, in which the four SP's participated closely interacting: Setting up testing infrastructure and tools the main responsibility was with SP2 "FOT framework", test sites adaptation mainly was with SP3 "FOT operations" and SP4 "FOT methods", whereas SP5 contributed especially to the design of business models. The next level block "Piloting" was carried out jointly by SP3 and SP4. SP3 was responsible for running the tests in all tests sites observing the common methodology principles where applicable. Furthermore, piloting was providing feedback to the technical functionality testing personnel as well as to behavioural scientists responsible for user tests. SP4 conducted the evaluation of the data collected and transformed it to FOT results. It is stressed here that even though the figure features given activity areas in different SP's, the work was very much done in close cooperation between all SP's. The difference is more conceptual and showing responsible parties than reflecting fully separate activities; so much intertwined was the work in planning and carrying out the FOT work between different subprojects.

The process in the methodology development combined technical readiness activities and user tests methods planning. To develop FOT methods for field trials, there had to be an agreement on functions to be tested and data logging methods. This interaction between automotive engineers, ICT and behavioural professionals took its time before a common 'language' and understanding were created. So, both technical and behavioural activities were closely linked, and technical readiness activities needed to consider behavioural requirements as well as technical constrains especially in logging and overall in setting up the evaluation system.

The methodology is explained in the following paragraph, referring to the six blocks shown above.

2.2 Setting up testing infrastructure and tools

2.2.1 Different phases for the testing system

Setting up a technical system enabling FOT was a complex and long process – longer than expected - due to the need to enhance a number of different components and vehicles from motorbikes to different brands of various OEMs, and above all to make them interoperable. The main phases of setting up the testing infrastructure and tools are described below (Figure 5), and the text thereafter refers to Figure 4 above.

In addition to architecture, components and testable functions specification, the next phases to enhance the specification to working prototype that were interoperable and able to communicate with each other and the backend systems across Europe, was a next major exercise in the project technical readiness activities.

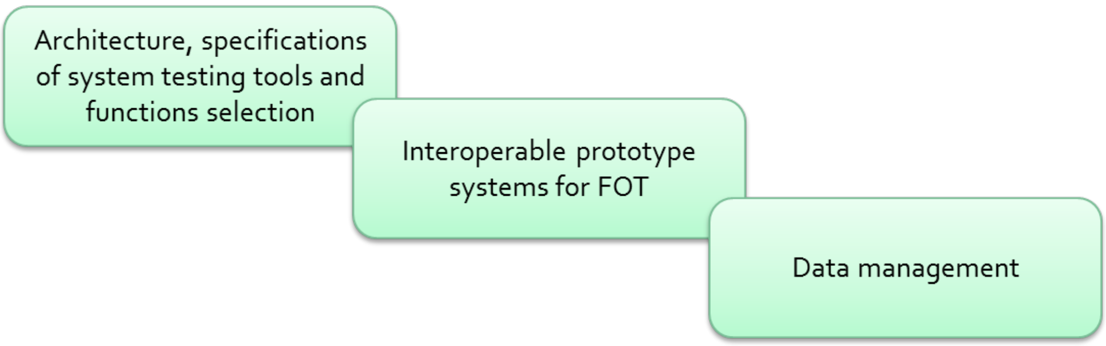


Figure 6: Different phases in setting up testing infrastructure and tools.

For the start of piloting with functions defined, the first task was to create technical readiness for the tests. Even though PRE-DRIVE C2X created a sound basis for the C2X system and developed a simulation toolset for assumed positive impacts of cooperative systems, it was by far not enough for large scale road tests. There were a number of issues to be solved before user tests were possible. Since there were different components manufacturers and OEMs involved in the project, the components specifications, the following DRIVE C2X architecture and interoperability-related open issues needed to be resolved first.

2.2.2 Architecture, specification of system testing tools and functions selection

<u>Basic components</u>

The project started by system specification described in work package 2.2 “Test Preparation and Methodology” (see D22.1 “DRIVE C2X Methodology Framework” and D23.1 “DRIVE C2X System Specification”). These first activities paved the way to an interoperable C2X system between different manufacturers’ vehicles and components providers. Specifications and related guidelines for individual components that form the DRIVE C2X system were needed. As the DRIVEC2X project involved many partners, each one of them responsible for a given component provision, a set of guidelines was defined to create a coherent specification at a component level. The first part in setting up the C2X communication system with architecture and components specifications was a laborious and complex process consisting of numerous phases to be introduced briefly below. For more detailed information see D23.1 “DRIVE C2X System Specification”.

The starting concept for a communication system set-up was an ITS station that is a functional entity providing Intelligent Transport System (ITS) communication dedicated to transportation scenarios. Co-operation among road traffic participants - and between road traffic participants and roadside infrastructure is based on different communication technologies. Information can be communicated between vehicles, from a vehicle to a roadside infrastructure element, and between vehicles and backend applications using, e.g., wireless access technologies to connect to the Internet.

Based on the ETSI standards on ITS communication architecture, the DRIVE C2X architecture comprises of the following basic components:

- Vehicle ITS Station (VIS),
- Roadside ITS Station (RIS),
- Central ITS Station (CIS),
- Personal ITS Station (PIS).

The four components could be combined arbitrarily to form a cooperative intelligent transportation system, where at least one component is necessary. In general, a cooperative system does not need to include all the components but may include a subset of the components (depending on the deployment scenario and the functions). These four components are able to communicate with each other using several communication networks. Communication can be performed either directly within the same communication network, or indirectly across several communication networks.

The project continued with the architectural specification for the DRIVE C2X communication system and comprised the following parts:

- General description of the Enhanced System Architecture,
- Introduction of different actors of the ITS network,
- DRIVE C2X Enhanced System Architecture description,
- A general structure of the messages used and
- Flow chart of the exchanged information.

Architecture

The architecture shows the DRIVE C2X communication system, and follows the general specification as described in D23.1. However, it represents a subset of the full ITS architecture and focuses on VIS, RIS and CIS. The PIS is not included in DRIVE C2X Enhanced System Architecture, since legacy roadside infrastructure, traffic management centre, etc. are out of scope of the project. On the other hand, as an addition, Figure 6 depicts a Test Management Centre that was used for the control and monitoring of FOT trials.

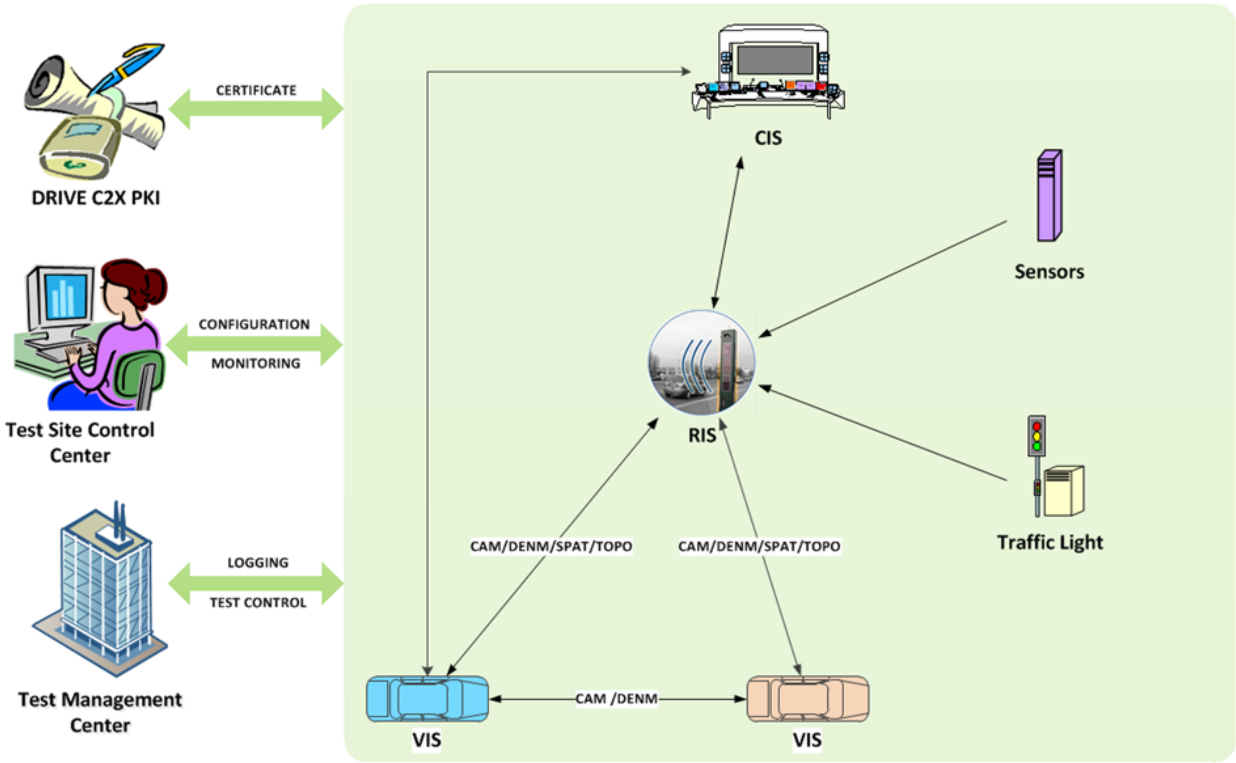


Figure 7: DRIVE C2X system architecture.

The architecture definition enabled and initiated further detailed work of components and functions specification to be followed later by vehicle interoperability tuning.

The next phases included components specifications such as (i) facility layer; (ii) network and transport layer; (iii) access layer and (iv) management layer. This all ended up in the testing of these components. Furthermore, security layer and component needed to be defined, specified and tested as well as HMI device provider.

The next major task in the definition and specification process was the discussion of realistically testable functions and their specification.

The DRIVE C2X function selection process was based on the existing scheme from PRE-DRIVE C2X and enhanced 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.

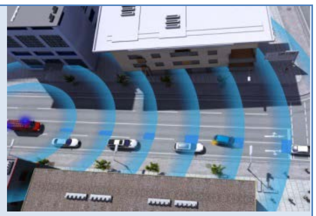
<u>Functions for FOT</u>

Furthermore, the performance prediction of selected functions was investigated by simulations, and possible complications were identified e.g. "critical mass" of equipped vehicles needed to see any benefits could be predicted by means of simulations. Eventually, real-world measurements from FOT could be also used to improve simulation models.

The following table provides the list of functions included in DRIVE C2X FOT and their description (Table 1).

Out of originally 19 functions developed within DRIVE C2X, eight functions were selected to be implemented in the test sites for user tests.

Table 1: DRIVE C2X functions for FOT and their description.

<table>
<tr><td></td><td>Approaching Emergency Vehicle Warning
AEVW</td><td></td></tr>
<tr><td colspan="3">The system warns drivers to give way to an approaching emergency vehicle, identified by flashing emergency lights and sirens. The driver is informed at an early stage to prepare for the approaching emergency vehicle, e. g. to get out of the way or to stop.

As a result the emergency vehicle can reach its target destination faster. Also, the risk of accidents between the driver's car and the emergency vehicle is reduced.</td></tr>
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<table>
<tr><td></td><td>Traffic Jam Ahead Warning
TJAW</td><td></td></tr>
<tr><td colspan="3">The driver is alerted when he is approaching a hazardous tail end of a traffic jam, e. g. tail end behind a hilltop or curve very fast. This system notifies the driver about traffic jams at an early stage. Based on that, drivers can react calmly and safely.

The system's objective is to avoid severe or fatal rear-end collisions which are often caused by traffic jams on highways. This increases the safety of both vehicles that approach a traffic jam and those at its tail end.</td></tr>
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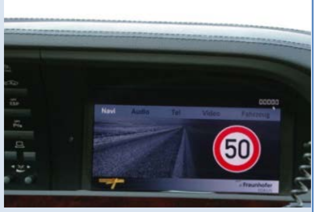
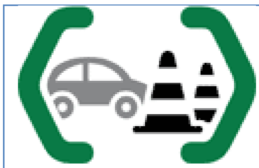
In-Vehicle Signage IVS



Via Infrastructure-to-Car Communication the driver receives information about currently active valid traffic signs. Road Side Units, mounted on traffic signs and also on key points along the roadway, send messages to approaching vehicles. They raise drivers' awareness of potentially dangerous conditions in case a traffic sign is not noticed. Traffic signs are displayed on the in-vehicle display.

In-Vehicle Signage was tested in three variations:

- **Speed Limit**
  When the driver approaches the speed limit sign, a pictogram of the speed limit sign is shown in the right side of the display. If the driver is exceeding the speed limit significantly, a background imitating a speedometer is shown in the middle of the display in addition to the speed limit sign. The driver also receives an audible alert.
- **Child Sign**
  When the driver approaches the child sign, a pictogram of this traffic sign is shown in the right side of the display. Information about the child sign can be displayed e.g. near schools or kindergartens.
- **Yield Sign**
  When the driver approaches the yield sign, a pictogram of this traffic sign is shown in the right side of the display. Infomation on the yield sign is shown only when the driver is obliged to give way in the intersection.



Road Works Warning RWW

The Road Works Warning-System warns drivers at an early stage when approaching a road works area, e. g. road building, maintenance, mowing. This alert prepares the driver for the impending event so that the driver can already start to slow down the vehicle, if appropriate.

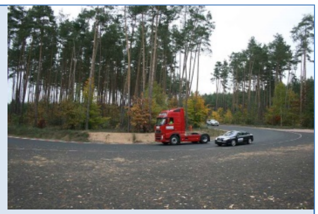
Therefore, safety relevant information will be communicated to the driver, e. g. speed-limit or lane closures. The system's goal is to reduce the likelihood of crashes during road works and to increase the safety of travellers and road workers.

Obstacle Warning
OW

The driver receives a warning about an obstacle lying on the road ahead. In order to reduce the probability or severity of an accident, the driver is prepared for an upcoming obstacle on the road, e. g. lost cargo.

As a result, he or she can slow down the vehicle.

Car Breakdown Warning
CBW



A vehicle brought to a standstill in the middle of the road notifies oncoming drivers of the situation, in order to alert a potentional risk of collision. This information is particularly useful when the vehicle concerned is not immediately visible, e.g. in a blind curve or on a crest, or in fog.

This information is provided to the drivers a few moments before they reach the halted vehicle. The cause for the standstill might be an accident, a breakdown, or a human issue.

Weather Warning
WW

The Weather Warning system gives the driver information and warnings about dangerous weather conditions like cross winds, fog, heavy rains and snow or black ice on the road.

The warning is automatically triggered by vehicles ahead reaching the area. The driver is encouraged to adapt his or her driving behavior to the weather conditions to avoid weather related accidents.

<table>
<tr><td></td><td>Green Light Optimal Speed Advisory GLOSA</td><td>
</td></tr>
<tr><td colspan="3">The driver receives a speed recommendation allowing him or her to pass a green traffic light ahead while sticking to given speed limits. If it is not possible to pass the signal within the given speed limit, no recommendation is shown to the driver. If the signal is red, information about the remaining time until the signal turns green is displayed.

According to the speed recommendation the driver is able to adjust the vehicle's speed within the given limit. The main purpose of the system is to optimize traffic efficiency: As unnecessary acceleration and deceleration is reduced, the traffic flow is optimized, and emission and fuel consumption is reduced.</td></tr>
</table>

2.2.3 Interoperable Prototype systems for FOTs

<u>Laboratory phase</u>

After the architecture and various specification activities were completed, the actual vehicle and road infrastructure design and building could start.

The building of test vehicles started in laboratory conditions in work package WP24 “Technology Enhancements and System Integration”. This work package had two main objectives: (i) the enhancement of the basic system according to the specification agreed in DRIVE C2X D23.1 “Enhanced System Specification” and (ii) the testing of the integrated system in a laboratory environment (see D24.1 “DRIVE C2X System Technology Enhancements and Plug Test Report”).

As a next step, the analysis took into account several aspects that were studied and developed in parallel, i.e. the methodology framework (WP22), system specification (WP23), test environment (WP25) and input from standardization (WP55). Based on the analysis, enhancements of the DRIVE C2X basic system were planned and structured into three subsystems of the so called DRIVE C2X *reference system*:

1. Communication system,
2. Management and security and
3. Facilities and functions/applications.

While the overall design of the DRIVE C2X basic system was taken as such, a number of software components were implemented or developed from scratch. Other components were considerably enhanced.

The activities faced several challenges. The high number of software components, which were typically implemented by different project partners, required an intensive coordination and physical meetings.

The reference system was tested in a laboratory environment with a reasonable coverage of test cases including most components. One particular aspect was the testing of applications/functions, which required data synchronized in terms of time and location information. This was achieved on the DRIVE C2X test bench already used in the simTD field trial and adapted to the requirements of the DRIVE C2X reference system. For eight of the DRIVE C2X applications/functions, test specifications and test cases were developed. The test bench then enabled to play traces, to emulate particular scenarios and to study the results in a laboratory. This was also particularly important when issues were observed in real test runs and the scenarios could be partially re-played in the lab environment. Hence, in comparison to testing with real vehicles, the test bench helped to decrease the overall efforts in the project.

The DRIVE C2X reference system also participated in two ETSI plugtests for Cooperative Mobility. In the preparation of the plugtests, test cases for interoperability were defined by the ETSI CTI, supported by DRIVE C2X partners. At one Plugtest, networking and facilities components were tested; those for which stable base standards and test specifications were available. The other plugtests for interoperability and test for standard compliance showed that the DRIVE C2X implementations of the tested components were mature.

To conclude, the DRIVE C2X reference system represented a good basis for the integration of the system into vehicles and roadside infrastructure. It was then further tested, validated and adapted to test site requirements in the later activities in field conditions. Eventually, it built a solid basis for the execution of the field tests for impact assessment of C2X communication systems.

Towards field conditions and interoperable systems

The next step was to take this development to field conditions and do vehicle integrations and the systems interoperable. For a more detailed description of the activities, please see Deliverable D26.1 "DRIVE C2X vehicle integration and interoperability check report".

Various communication units, 802.11p protocol stack implementations and other components where provided by the preceding work. The different partitioning of necessary functions forced the development of a reference block diagram. This diagram summarizes all functional blocks of a DRIVE C2X reference system on an abstract level.

Then the implementation of the DRIVE C2x reference system started. It was in the prerogative of the partners to integrate these systems into cars or motorcycles as reference VIS or as reference RIS into road side cabinets. Beside the mechanical and electrical integration of the systems the software adaptation to vehicle sensors or roadside infrastructure such as traffic signals, was a task that belonged to the partner-specific domain.

Numerous practical problems like timing synchronization of the components or sensor data availability were solved during the individual integration work. In addition, reception problems caused by antenna mounting were tackled.

The integration of the DRIVE C2X reference system was implemented into selected test vehicles of different manufacturers. At first, the common reference block diagram was introduced. Vehicle providers could select out of a variety of available communication units. The vehicle provider had the role of the system integrator. It was his responsibility to select the components, build these components into the vehicle and take care about the software of their reference system.

Finally, for all selected vehicles the individual flavour of the DRIVE C2X reference system implementation was described by the OEMs.

Further, building the DRIVE C2X reference system into selected road side units was carried out as follows. First the common reference block diagram needed to be introduced. Then the description of the reference block diagram was followed by the challenges that needed to be solved by the individual reference system integration.

The components were tested in laboratory conditions, and a given level of CAM and DENM interoperability was achieved. Beside the tests during software integration also, the ETSI plug tests assured compliance with these prerequisite.

For calibration and alignment of the equipped vehicles and the reference road side units initial interoperability tests were performed on a test ground at the System Test Site (STS) Helmond. The calibration of the vehicles enables the sharing of work in WP 34 (Piloting) sending only a limited number of interoperability checked vehicles to the test sites for pre-test and piloting.

Initial interoperability tests were executed during face-to-face meetings in four different workshops, where the last workshop was used for system stabilization final interoperability tests and preparation of the first validation tests.

To decide on the equipment for a test side the interoperability of the components was of utmost importance. The system set-ups from different partners were tested for interoperability to other ITS stations at the system test site in Helmond. A huge number of drives in CW25 and CW27 including the manual validation of the applications by the co-driver were performed in parallel to the analysis of the collected log files.

In this way the system set-ups for vehicle stations and road side stations demonstrated their interoperability and - together with the installed applications - the functionality of the DRIVE C2X system.

To conclude, after work package 26 the DRIVE C2X reference systems was available in several cars, motorcycles and road side equipment ready for test site adaptation. These systems proved to work together. In principle, interoperability of these systems was achieved.

The description of the various implementations was beneficial for building further systems to be used at the test sites. The available DRIVE C2X reference systems provided the base for further interoperability tests. By this, it was ensured that the DRIVE C2X system which was rolled out during the following months was interoperable across Europe.

Work packages with the focus on field test execution triggered – as expected - further stability improvements and one or the other correction of functions. Overlapping validation tasks with the focus on field test execution therefore contributed to the initiation of system improvements.

The ticket system that was introduced to follow up changes between workshops showed a good acceptance by the developers. This was found to be a reliable way to follow-up necessary changes beyond SP2 work.

2.2.4 Data management

As Figure 6 above suggests, data management was an essential part of the Field Operational Tests. Data management not only provided for storing the test results on specified files and databases, but was also keeping track on what's where. The scope of data management began mainly by verifying, that data collection with logging tools matched project requirements (see Deliverable D35.1 "Report on implementation of DRIVE C2X data management to test site"). Another type of a starting point was overseeing the formulation of agreements to be made with test users, ensuring that privacy, use of collected data and conditions for sharing the data between research partners were described in detail.

As the FOTs collected long periods of in-vehicle logger data – a FOT could cover the driving of a hundred drivers for one year – the sheer size of logs required data management processes to be put up. Also, it was not only vehicle speed and other basic sensor data that was collected, but also filled questionnaires, travel diaries, internet service logs e.g. on local traffic status, as well as manual annotations of video material.

Data management set up processes for collecting log files manually or automatically, setting up servers, decided backup practises and enabled sharing the data. It monitored data collection and frequently validated stored data, both manually and with the help of dedicated software tools. Even basic software scripts could be very effective for pointing out errors in data collection or system failures. The main motivation for frequent monitoring of data collection was to avoid repeating expensive tests due to broken-down systems or configuration errors.

DRIVE C2X followed the preceding TeleFOT project in setting up a central storage for collected data. A central data depository made it easier to access the data and enabled collaborative analysis of several tests. It could also help in harmonizing data formats and running common post-processing for all data. These common processing tools included data enrichment such as map matching and retrieval of weather data, and processing a common set of indicators such as average speed already during a test drive.

When a test site transferred their data to a central depository, they documented the ownership of data and conditions for sharing it. They also documented the test itself from an analyst's perspective: for example what was the study design, vehicle properties and anonymous information of the test users such as their age and driving experience. Further, the format of collected log data was described in detail, including information of the sources that generated the data. These documents are test and data description documents, metadata.

This documentation was necessary for an analyst who may have not been part of the data collection, to start analysing its data. Most aspects of the documentation are also necessary for the test leaders, to document details, dates and formats while they are still remembered, and to answer analysts' main questions.

The overall data flow presented in Figure 7 describes how raw data was collected from ITS stations (cooperative vehicles and roadside units) and generally from the test sites. ITS stations, by using logging software of the project's reference implementation, record (i) sensor readings such as the vehicle speed and (ii) function-related data, such as messages broadcasted to other vehicles and information displayed to the driver. The test sites additionally recorded and provide national traffic and weather data, special sensor data if available, video annotations, study documentation and survey results.

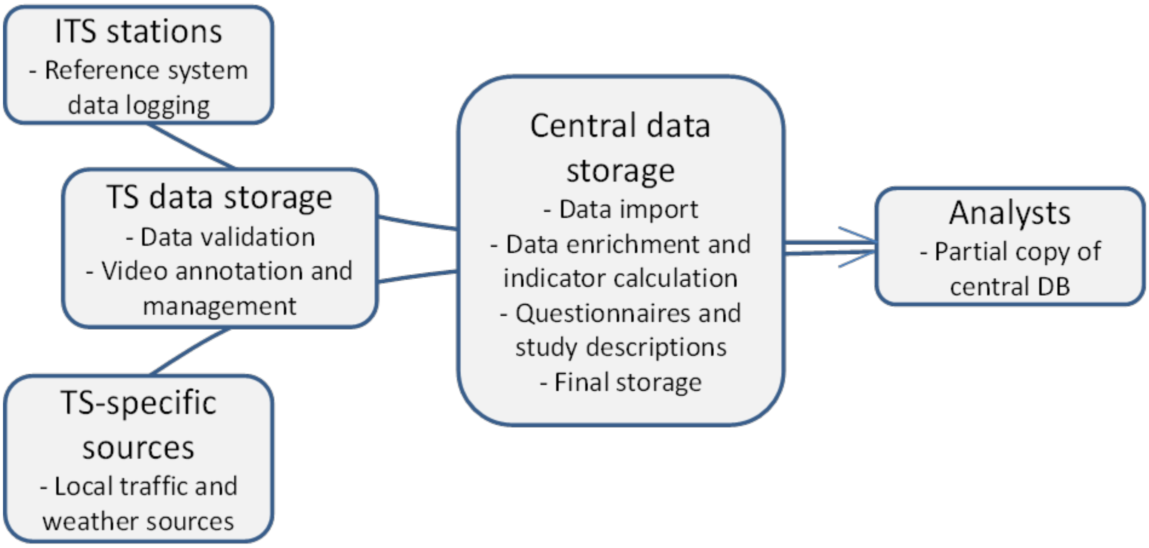


Figure 8: Overall data flow.

All data was first compiled into a national test site storage by collecting log files both manually and via internet.

The project offered the LogStation tool of Fraunhofer' FOKUS for partial automation of file transfer from vehicles to the national storage using USB drives. Wireless log data collection was not planned in this project, but the log files could be transferred in that way, when time and speed allowed. Roadside station data was generally retrieved via internet connections depending on test site implementation.

Data verification and validation steps were carried out frequently at test sites, ensuring that the logs were not corrupted and that all data was indeed received correctly. These manual checks were supported by the project's SW tools LogPro and LogMover, which provided fast overviews of the log data.

Confidential data remained at the test site. These include user contact details, video recordings showing the driver and possibly raw log files of proprietary format which need to be converted before sharing the content with other partners. Video material could be shared depending on driver consent, but generally the project shared only video annotations (e.g. Excel documents filled in manually), providing classifications of specific situations.

According to privacy laws, the links between user contact details and collected anonymous log data were deleted when this information was no longer necessary for executing the study.

As shown in Figure 7, test sites continued to upload checked data sets supported with metadata documentation into the central file storage, where project analysts could access them.

At the central storage, text log files were scanned with post-processing SW to extract log (a part of a trip where the car was used) and event information, i.e. periods of interest from all data. These periods were saved into a database. The project was using PostgreSQL open source database (http://www.postgresql.org/).

FOT data collection required significant resources, consideration and testing. Analyst wishes about data collection need to be balanced with available resources and number of vehicles that can be instrumented.

This project logged a wide set of signals from vehicles and road side units and further, saves national weather and traffic data from internet sources. The analysts requested detailed logging of traffic situations, causing the test sites to implement also video collection for control purposes to check what really happened on the road.

Efficient data validation right after testing was important to avoid having to repeat expensive tests. The WP35 "Test data management" has developed software to assist the test sites in the validation of test data. It was recommended to name a person to periodically monitor collected data, also going through selected data samples manually.

All the test data was collected to a central storage. This was to assist collaborative work and joint post-processing of the data. All related documentation and questionnaire results were collected together with the log data.

Compiling test and data documentation was absolutely necessary if FOT data was to be easily shared with other organizations. Test sites needed to document several topics also for their own use, when e.g. dates, times and test details were still remembered. The collected documentation explains the study design, test phases, number of test drivers, lists anonymous details of these drivers such as their age and driving experience, details the vehicles used in the tests, provides notes from test execution and a number of similar topics. Even during a single project, this documentation saves time for many persons, collecting all questions and answers.

Test use agreements made with users limited the possibilities for data re-use unless specific care was taken when formulating the wording of data release clauses. The project has provided checklists and reminders to assist the test sites, but also collected agreement templates to check the content.

Collected log data was processed centrally. Harmonizing logging and post-processing enables analysts to more easily cover several tests. Common post-processing such as map matching and calculation of basic indicators reduced individual work and ensured comparability. Summarized content gave an index into raw data and a fast start for evaluation.

2.3 Test site preparation

2.3.1 Different phases of the test site preparation

The test sites preparation is split here into three different phases: (i) test site validation (ii) testing tools and system and (iii) the actual test sites adaptation (Figure 8).

The overall objective of the adaptation and preparation activities was to prepare the test sites to carry out the field tests observing the guidelines supplied by WP2 in cooperation with SP4 and using to the extent possible DRIVE C2X reference system developed in the adaptation tools part of the WP3. The aim was to take the developed testing system to field conditions before entering pilot tests, where the whole system underwent final checks and fine-tuning before actual user tests.

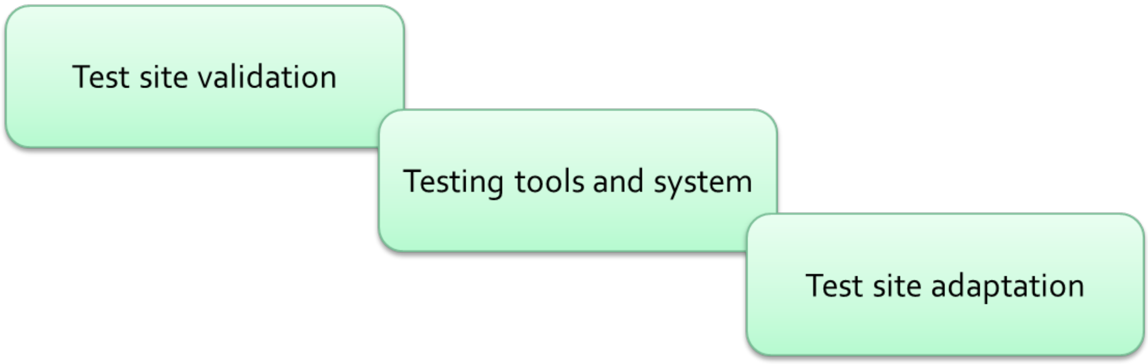


Figure 9: Test sites preparation main phases.

2.3.2 Test site validation

The purpose of test site validation was to show and prove the functionality of the reference system - the software that is developed in the project and designed to run on the test sites (see Deliverable D32.1 "DRIVE C2X FOT System Validation"). The validation tests were carried out on a single test site, the system test site in Helmond, NL.

The main added value of the activity was that the entire reference system was installed in practise on a single test site. This had in principle the advantage that major errors were detected early on, thus preventing the other test sites from running into similar problems. Also, the nature of the System Test Site allowed the evaluation of the reference system by using a system that operated independently from DRIVE C2X. Finally, the organisation of several test events where all vehicles participated allowed the testing of the overall interoperability of the reference system.

The aim was to validate the system in as much depth as possible and present the results to those test sites who intended to use the system and to the developers to explain remaining issues.

During the validation period, all applications available were tested on all vehicles. Basically, the tests followed a controlled testing approach. A number of relevant scenarios were planned for the applications, and the vehicles received instructions on how and where to drive. During each test run all or at least several applications were tested.

The validation activities proceeded according to the following steps:

1. An independent system (the Dutch DITCM) measured the overall system performance with respect to timing, position, communication range/quality and HMI. When a vehicle did not perform well on these aspects the rest of the system became obsolete.
2. Then the log data from all components was analysed in detail. The log data provided information about the vehicle and its driver during the FOTs following the validation phase. If the logged information had a wrong syntax or stored wrong information (e.g. position, time), there was no way in which this information could be retrieved later on. If that would be the case, an impact assessment was not possible. Also for validation it needed to be clear that the logged data can be trusted and can be used to validate the operations of the applications.

3. The Test Management Centre tools that had been delivered within DRIVE C2X and used in the validation tests were checked and introduced. These tools helped the FOT to define tests and to execute and monitor controlled test runs.
4. Finally the applications were validated. Each application was tested on all vehicles with different scenarios.

The validation identified a list of issues which were recommended to be resolved before the DRIVE C2X reference system could be used in a FOT, checked during piloting, and monitored during the technical evaluation.

The piloting phases of the FOTs were seen as necessary from the technical functionality point of view to ensure that the combination of reference system and proprietary systems work properly. In particular the following points deserved special attention:

- The modification of the software components was expected both due to planned changes in response to the validation recommendations and due to test site specific adjustments. It has been observed that changes in one component may unintentionally affect other components. Therefore, the test sites were advised to ensure that their full software platform is working properly, and not just the modified components. The piloting phases of the FOTs were found most appropriate for this.
- The test sites had to realize that the DRIVE C2X reference system was not plug-and-play. The implementation on the actual hardware devices and software settings had a big influence on the proper operation. Also, each test site was unique in terms of its road layout and its (proprietary) test site specific system, so unexpected behaviour could still occur in given situations.

An overall observation was that the specific implementation on a vehicle has a significant impact on the key aspects of the system like time synchronisation, communication range, and positioning accuracy. These aspects needed therefore be checked before a FOT was started, because potential problems would be difficult or even impossible to correct afterwards from the logging.

2.3.3 Testing tools and system

Data flow in the testing environments

Finally, the technical readiness of the test environment for the reference system concerning both vehicles and infrastructure needed still to be confirmed before entering the actual test sites adaptation. The results of the work are reported in Deliverable D25.1. “DRIVE C2X test environment: specification, implementation and tests”. This phase set up the whole testing system for the adaptation to the individual test sites and described the testing system architecture (Figure 9).

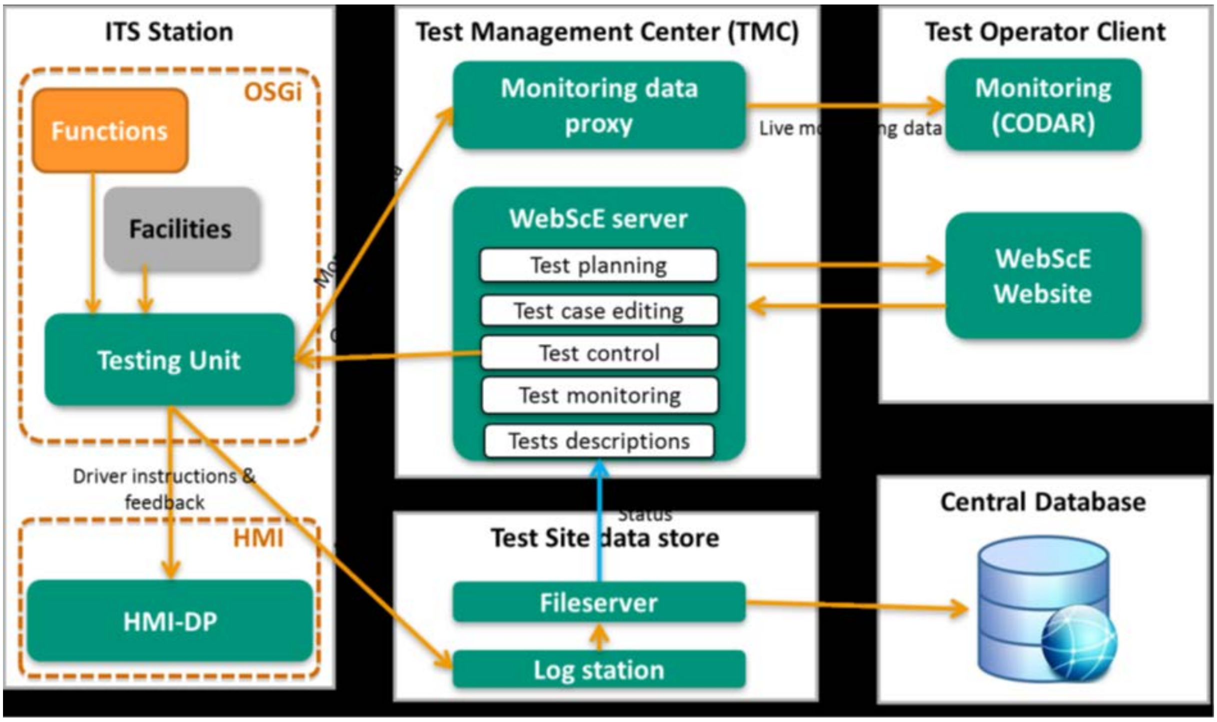


Figure 10: System architecture describing the testing environments and data flow.

Figure 9 shows that the DRIVE C2X testing system comprised of three main environments: (i) ITS Station (ii) Test Management Centre (TMC) and (iii) Test Operator Clients (TOC). Each ITS station had a virtual module called the ITS Testing Unit, which provided all test related functionality on remote stations. The test operators used normal computer terminals to plan, control and monitor testing operations. The modules CODAR and Web Scenario Editor (WebScE) ran in a browser on the Test Operator Client. The Test Management Centre was the connecting hub between a multitude of ITS Stations and TOC.

Several new DRIVE C2X requirements were deducted from the shift of scope from localized technical testing in PRE-DRIVE C2X to a pan-European Field Operational Trial. The national test sites were operated independently from the other test sites. The test sites had their local functionalities for test management, control and operation, logging, monitoring, and data management. Test site specific approaches needed to be harmonized with the DRIVE C2X methodology, process and tools.

Test scenarios had to be unified throughout the different test sites, to enable comparable data. This was not fully possible in all cases due to differences in test environments.

Field operational testing of cooperative systems was based on so called controlled testing in order to ensure a sufficient number of events in a timeframe realistic for DRIVE C2X. A structured approach to scenario-based testing was needed, and the testing tools were developed for this purpose. In addition, so called naturalistic testing was carried out, but didn't require controlled set-up for the FOT. Eventually it turned out that the number of events recorded in naturalistic tests was rather small – due the lack of controlled approach.

<u>How to manage test runs</u>

As a first step, the scenarios needed to be defined for controlled tests as follows:

- Create reference scenarios, based on hypotheses to be evaluated and on research questions by SP 4 (see deliverable D42.1. "DRIVE C2X FOT research questions and hypotheses and experimental design").
- Map the reference scenarios with individual requirements from the participating test sites.
- Operationalise the scenarios by mapping out specific routes to be driven for each scenario.
- Define events to happen at specific times/places during the trial.
- Create and appoint test runs as individual executions of scenarios.

During run time the same tool-set enabled test operators to coordinate the participating drivers in a way that the real test-run was executed according to the scenario. To achieve this aim the tools provided means to run and control the scenarios:

- Assign test vehicles to defined routes,
- Monitor vehicle status (received instructions, distance from starting point) before test start,
- Control test state (initialized, started, stopped),
- Monitor test-progress in real-time (Display vehicles on a map overlaying the created scenario),
- Show in-detail information of vehicle parameters, such as speed, heading, position, current information shown to the driver on the HMI, etc.,
- Give automated instructions to drivers based on test-progress and
- Manually give corrective instructions to drivers based on deviations from planned scenarios.

As seen in Figure 9 above, the DRIVE C2X testing system covered three different environments. Function-wise the test Operator Client was the terminal used by operators to create scenarios or test runs and to control and monitor testing in real-time. It held the functions for monitoring (CODAR Viewer) and the Web-scenario editor front-end for scenario creation and test control. Both tools relied on information provided from back-end servers in the Test Management Centre. While the CODAR Viewer used TCP/IP connection to a java-based server system, the Web-scenario editor was a web-based service. Both tools made the connection to vehicles and roadside stations over the TMC to the ITS Testing Unit, which was running as an OSGi bundle on the reference facility layer.

Monitoring the data was realised by sending UDP packets from the ITS Testing Unit to a central Monitoring Data Proxy. This proxy then forwards the packets to the CODAR Viewer and the WebScE server.

Test Control information was sent from the operators to the subjects by means of control messages. These messages were held in a server queue in a dedicated Web Scenario Editor (WebScE) server (see D25.1."DRIVE C2X test environment: specification, implementation and tests"). ITS Testing Units regularly polled for these messages to provide a near real-time message flow, where available. Control messages can either hold system-specific messages (such as setting a specific log profile or starting a test run) or instructions directed to the driver. In the latter case, the ITS Testing Unit forwards the instructions to the HMI-DP to alter the driver.

Log data flow

Finally,the log data was transferred either in real-time using the cellular connection (on high-bandwidth connections with limited log profiles, as used in naturalistic testing) or on a USB medium to be picked up directly from vehicles in controlled testing.

During the test runs large amounts of data were logged serving multiple purposes in different phases of the project. The most important usage was the impact assessment in SP4, but also debug information was needed by SP2 and SP3. SP4 required unified and structured data, pre-defined before test execution according to evaluation needs. However, SP2 & SP3 usually required flexibility, like dynamic addition of new measuring points.

When the logs were imported to a database, the entire log file could be analysed very efficiently. If the testing FOT revealed that some measurements were missing from a particular component, then the responsible developer could update the log definition, and a new log bundle was produced. To reduce the needed space for Logfiles on the ITS stations, the Logfiles were zipped very efficiently.

To make sure that all the transformations were 100 % correct, a code generator was created, generating an individual logger bundle on the basis of an uploaded xml definition file. This could be done by the developer of a component on the fly and as often as needed. When the developer changed his log definition, he had to upload the file and could use the new logger bundle instantly.

The scenario creation allowed to plan in advance the reference scenarios to be executed on a pan-European level. By adapting these scenarios to the specifics found on each test site, a comparability of collected results could be ensured.

In operationalization, the scenarios were used to create and schedule individual test runs on each site. Control and monitoring capabilities support test operators in successfully managing test runs to ensure maximum efficiency during the limited and expensive road testing phase.

Finally, the unified reference logging provided by the ITS Testing Unit allowed efficient and secure collection of measurands from each function and facility in each reference ITS station. A safe data transfer to the test-site data store was ensured by the test-site counterpart, the LogStation.

The testing tools were integrated into a tool chain, so that test operators had an easy overview of necessary tasks in conducting the FOT, and could adequately survey operations' progress and quickly react to potential problems.

Documented guidelines needed

Operational and technical guidelines made up the last phase in setting up the testing system for test site adaptation and later piloting, followed by actual FOT. The results of the work are reported in D27.1 "DRIVE C2X Operational and Technical Guidelines". However, it should be pointed out that the deliverable represented more an initial plan than the final word on how to carry out testing. The final feedback for testing guidelines could be provided only in the test site adaptation an piloting phases. These phases also indicated the constraints for observing the guidelines.

Finally, the process of managing test runs would not have been possible without a controlled approach both for running the tests and managing the data flow, including data check to ensure its accuracy.

2.3.4 Test site adaptation

<u>Different types of test sites</u>

After the preceding preparatory phases starting from definition of DRIVE C2X architecture and components specification to their testing, to the design and development to vehicle integration and interoperability to testing architecture and tools, the testing system was ready to be transferred and adapted to various national test sites. This procedure is described below. A more detailed picture of the process is found in D33.1 "DRIVE C2X FOT test site adaptation" and D37.1. "Report on implementation of DRIVE C2X Services/applications management to test sites".

The objective of the adaptation described in D37.1 was to make the selected test sites fit to the general FOT methodology, so that the tests could be carried out by using the DRIVE C2X reference system. The adaptation performed targeted the ITS system – but did not include application adaptation as these were addressed in WP37 "Applications management" - and the test system. At all test sites the work required and performed reached such a mature status, so that the reference system developed in SP2 was running and FOTs could be conducted in a highly test site-driven manner. This was of particular importance, since the status and background of the DRIVE C2X test sites were highly heterogeneous and the aspired level of DRIVE C2X compliancy was – in detail – rather different. Therefore, the performed adaptations were complex to align and difficult to compare.

The technical adaptation targeted two technical units: (i) the ITS stations with all its functionalities up to and including the facilities layer and (ii) the DRIVE C2X test system.

As introduced earlier, the project defined three different types of test sites: (1) a system test site (Netherlands), (2) large-scale functional test sites, and (3) small-scale functional test sites. System test sites served as reference test site to the other two types of test sites which are only differentiated in size. It must be stated that the type limits were eased during the project, and that the a-posteriori typing would not reflect the initial idea. Here is a short description of the DRIVE C2X test sites:

- Test site Netherlands

The system test site assumed a special role. It was the first and main test site, where the complete and original reference system was deployed and running. The system test site served as a role model for other test sites.

- Test site Germany

The test site Germany was based on the work performed in the nationally funded FOT project "Sichere Intelligente Mobilität Testfeld Deutschland (simTD)". The simTD project included a big FOT (about 120 equipped vehicles) and it runs in parallel to DRIVE C2X with a head start of about 12 months. The complete DRIVE C2X project benefitted from the experiences gained at the test site Germany.

- Test site Sweden

The Swedish test site was a test site in the CVIS, COOPERS and the SAFESPOT projects. The test site has been in use in close cooperation with Volvo Technology and with the Swedish Road Authorities. Compared to other test sites in the project, a special focus was put on naturalistic test, where subjects used the test vehicles in daily commuting and for other travel purposes.

- Test site France

The background of the French test site is the national project SCORE@F, which had a similar scope as DRIVE C2X. The two projects implemented different reference architecture systems, but had compliant data collection to perform impact assessment and driver behaviour analysis.

- Test site Finland

The test site Finland was located in Tampere with the addition of a closed test track in the neighbouring city of Nokia. The equipped part consisted of 21 km two- and four lane roads, but the tests could be carried out practically anywhere in the street network with portable RISs. Finnish experiences gained during the TeleFOT project were exploited especially to data logging and the analysis of the data. The DRIVE C2X project made use of the harsh winter conditions at the test site in Finland.

- Test site Italy

The test site Italy was a part of the Brennero highway, operated by Autostrada Brennero in collaboration with Centre Richerche FIAT. The test site implemented the original reference system and was the only test site where the wrong way driving in gas station application was deployed.

- Test site Spain

The test site Spain located near Vigo was operated by CTAG with the support of the Spanish Ministry of Traffic (DGT) and covered some 60 km of various road types. The test site was created by CTAG and DGT within the framework of the national funded project SISCOGA (SIStemas COoperativos Galicia). DRIVE C2X was built on systems developed during the nationally funded project.

Please see also D37.1. "Report on implementation of DRIVE C2X Services/applications management to test sites" focusing on the adaptation of the applications in the test sites and their correct operation. Special focus therein was put on safeguarding the interoperability between the different system parts. Furthermore, the scope of D37.1 included the description of the applications, their technical test site environments and the experiences made during the implementation. Moreover, the lessons learnt in the process were described as well as recommendations given for the further work.

The work in test site adaptation had the following design:

1. Analysis of test sites,
2. Adaptation requirements and
3. Test site adaptation.

<u>Analysis of test sites</u>

The work started with the analysis of the selected test sites. The objective of the task was to get an overview of the test sites capabilities in order to derive adaptation requirements in the subsequent step.

The test sites were particularly relevant within DRIVE C2X. Therefore, it was requested that the partners (representatives for SP2 and SP4) state their requirements and claims regarding the analysis of the test sites. The result of this joint work was captured in a questionnaire given to the test sites. The results were documented in an internal report, which was available to all project partners.

The test site analysis depicted the status of the test sites before the adaptation. It must be stated, that test sites started out with very different preconditions.

Adaptation requirements

Based on the detailed analysis of the test sites, the second step in the work package was to derive the adaptation requirements. The requirements were derived from information about the (i) reference system, (ii) the project's and test site specific evaluation objectives and (iii) last but not least, the capabilities of the test sites identified in the previous step of the work package. The adaptation requirements were collected from the test sites and were documented on different levels of detail.

Based on them, the following adaptation aspects and backgrounds were listed:

- Setting up a DRIVE C2X conform ITS system (excluding application management aspects),
- Setting up a DRIVE C2X conform test site (addressing the relevant test system)
- Fleet management,
- Field operational test aspects and
- Test site specific objectives.

The adaptation requirements formed the basis for the next step - the test site adaptation.

Test site adaptation

Having derived and collected the adaptation requirements in the second task of the work package, the adaptation work itself was initiated. Since the application adaptation is not part of this work package, the work was split into the adaptation or setup of (i) the ITS-system excluding the applications and (ii) the test system.

The adaptation was validated in the WP34 "Piloting".

It soon became clear that not only the starting conditions of the test sites varied a lot, but also the objectives of each test site were partly different in detail (e.g. implications from the list of applications selected to be deployed at test sites, level of use of the reference system given by SP2). Thus, the nature of adaptation became highly test site-specific and very challenging.

To conclude: the heterogeneous initial capabilities and varying objectives of the test sites resulted in seven different test sites. However, adaptation challenges with such a setup did provide some general advantages (which are not really associated with work package WP33 "Test site adaptation"): for example, it has been shown, that the DRIVE C2X reference system runs on multiple hardware platforms. Moreover, test sites exploited the capabilities of the OSGi approach, and exchanged (adapted) software components on demand. Generally speaking, the reference system has been adapted to meet very different environment and conditions – thus to function under more realistic conditions.

2.4 FOT methods

2.4.1 Testing principles

DRIVE C2X project was above all a methodological activity, since the main objective was to show the most likely impacts of cooperative systems on users and society, and to provide useful information for further development of cooperative systems.

As stated above, the project followed the 'V-procedure' introduced in FESTA as illustrated in Figure 10 below.

The FESTA procedure comprises of several phases starting naturally from functions that need to be tested. This was followed by a series of steps from use cases and testing scenarios definitions to testing research questions and hypotheses, further on to performance indicators and their constraints (e.g. how to operationalise the research questions). The next steps included testing the equipement and the actual user behaviour to be then moved on to the right hand arm of V with the data analysis and veryfying or falsifying the hypothesis postulated. Finally, the results were presented and conclusions drawn.

The process of defining research questions, hypotheses and indicators to specify the experimental design and to define boundary conditions was labourious and needed to go into detailed planning (see D42.1 "DRIVE C2X FOT research questions and hypotheses and experimental design"). The process served user groups: Test sites expected guidance how to conduct the tests, but also the research scientists, who were responsible for the analyss. Indeed, the purpose of designing the experimental procedure was to guide and make solid and consistent analyses possible.

As DRIVE C2X was an integrated project, the need was to harmonize the approaches on all levels from system design and implementation to the analyses. The experimental procedures designed in this report as well as the definition of common research hypotheses harmonized the tests and the data collection. This created the basis for a harmonized analyses and contributed to the integration of FOTs in different national test sites.

A specific tool was created for formulating the hypotheses. The tool supported a systematic approach and the intention to cover all anticipated impacts. Thus, a considerable amount of research questions were developed which were then prioritized.

The approach for formulating hypotheses was maintained in order to cover the large number of aspects and the study design could benefit from a large number of hypotheses that allowed a detailed evaluation of the functions. Although a structured approach derived from FESTA and the TeleFOT experience was adopted, the required effort was really large. This was due to the high number of hypotheses and functions analysed and the fact that, needing to be developed in the first period of the project, there were a number of changes in the boundaries (selected functions, function description, feasible measures, ...) during the progress. Prioritization of hypotheses also allowed to make a selection in case the effort should be too high to cover all hypotheses. One round to prioritize the research hypotheses was done in this phase. However, the amount was considered to be still too big, implying further reduction in the analyses.

The results were shared with the other SP/WP as soon as they were available, including a certain number of recycles. The respective deliverable was a sound specification for the preparation of the tests in the different test sites and for the tools for the impact analysis.

Nevertheless these specifications could not be considered totally rigid and it was up to the implementing partners to refine them with further details or to adapt some tests in case of problems, such as recruiting participants or generating particular scenarios. However, it was very important to keep all relevant parties informed and jointly agree on modifications, and thereby not jeopardizing the harmonization of tests. The continuity was ensured because most of the partners were involved in the next phases of the project.

A thorough description of the testing procedure and FOT methodology for user tests and analysis methods is given in Deliverable D11.4 "Impact Assessment and User Perception of Cooperative Systems". The impact assessment methodology is explained in D11.4 in seven sections. These were: (i) the specification of scenarios used in the impact assessment, (ii) the methodology to assess the driver behaviour with DRIVE C2X functions, (iii) the approach to safety impact assessment, (iv) the traffic efficiency impact assessment methodology, (v) the environmental impact assessment methodology, (vi) the mobility impact assessment methodology, and (vii) the scaling up methodology. Below is a brief overvew of the main points of the testing and evaluation methodology.

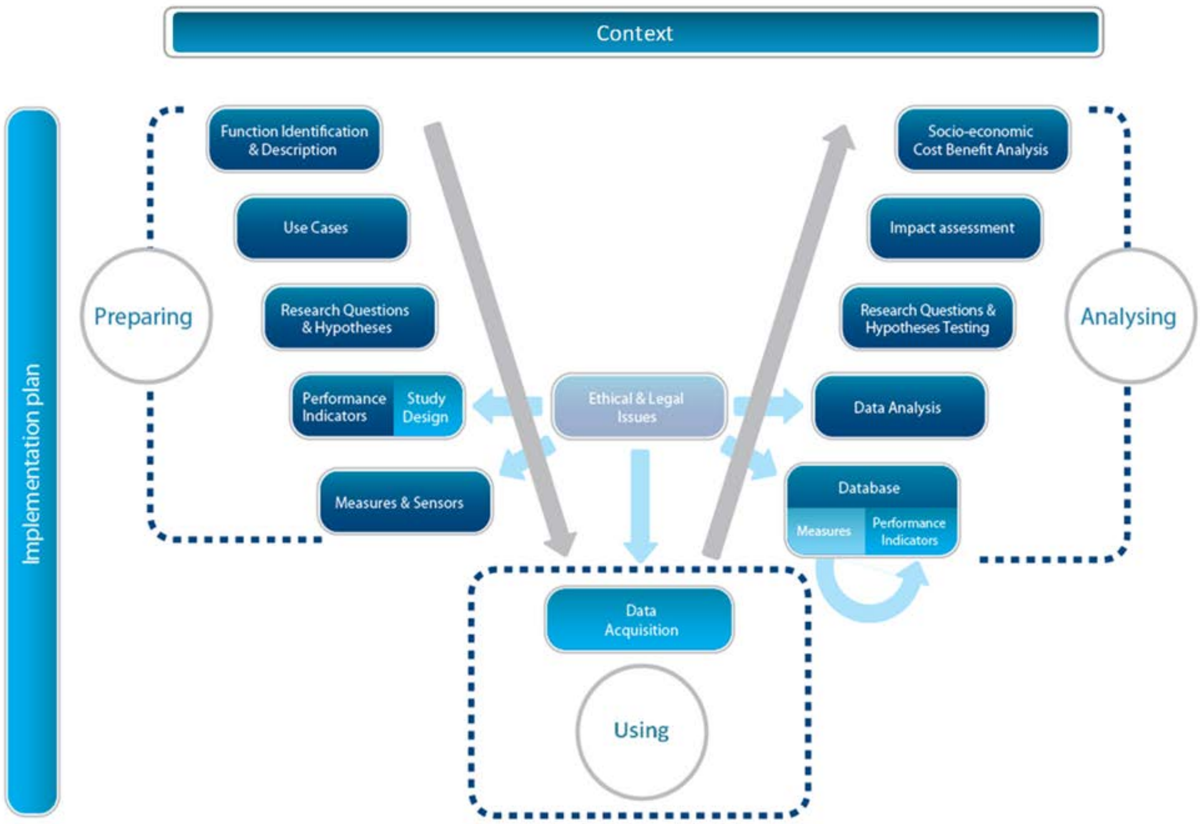


Figure 11: FESTA-V steps for carrying out a FOT.

2.4.2 Test design and scenarios

The FOT methods part described the actual user tests procedure in the preparation of user tests. This part of the project focused - together with the technical studies design - on the design of user tests and their implementation guidelines to the test sites.

Impact assessment compared the situation between "with" and "without" the systems examined in the DRIVE C2X project – the so called "Before-After" quasi-experimental design. This difference in behaviour, measured with given indicators, is the effect of using the system. DRIVE C2X impact assessment made use of scenarios to model the "with"- and "without"-situations. These scenarios provided a way to address both uncertainty in the future and the situational variables (like weather and traffic flow) which significantly affect the impacts of the systems analysed. The scenarios differed from one another in those aspects that play the most important role in affecting the impacts. For example, for traffic efficiency impact assessment, the driver of a vehicle makes use of information provided on the HMI differently depending on whether the driver finds him/herself in dense traffic or calm traffic. In the latter case, the driver is free to react in choosing his/her own speed, and thus the effectiveness of the system can be affected. Therefore, the traffic demand level differed between the scenarios.

The most important aspects that scenarios take into account are the penetration level of the cooperative system in Europe (EU-27) and the road types. For traffic efficiency and environmental impact assessment, the traffic demand also needs to be included in the scenarios. The following points provide more specific information about these essential situational variables:

- *Penetration level.* The percentage of vehicles and infrastructure equipped with the DRIVE C2X equipment will determine to a large extent the impact of the function. The penetration rates of the function in the vehicle fleet and for the infrastructure were determined in section WP56 "Business models and deployment". This WP56 developed three cases for the vehicle penetration rate: main, optimistic and pessimistic. In agreement with WP56, a passenger car and infrastructure penetration levels were selected for each scenario. Heavy goods vehicles are not equipped; no DRIVE C2X functions were tested on heavy goods vehicles. The passenger car penetration rates are the same for all functions for a given scenario. The infrastructure penetration rate differs by function. The scenarios are the base case, in which neither the vehicles nor the infrastructure are equipped. Table 2 provides an overview of the scenarios and their penetration rates.

Table 2:Scenarios for passenger car peneration and infrastructure equipment rate.

Scenario	Passenger car penetration rate	Infrastructure equipment rate
Base Case	0%	0%
Low Case	10.39%	IVS:5%, GLOSA 0.5%
Medium Case	26.29%	IVS:10%, GLOSA 5%
High Case	90.84%	IVS:10%, GLOSA 5%

- *Road type.* Differences between road types are expected in terms of usefulness and effectiveness of the functions, and therefore differences between the road types are made in the simulations. The definition of motorways, rural road and urban roads differs between countries. DRIVE C2X uses a definition based on maximum speed limits. In the calculations, the high speed roads are roads with maximum speed limits >=100 km/h, rural roads are roads with maximum speed limits between 60-100 km/h and urban roads are roads with maximum speed limits <60 km/h.

- *Demand level.* The demand level influences the effects of the functions, so the effect is divided between the traffic levels low demand (free flow, off-peak) and high demand (not free flow peak). In free flow all drivers can choose their own speed, and can also choose the reaction to the warnings or information provided by the functions. Heavy traffic or congestion is a traffic situation in which the vehicles interact; the ability for the driver to receive or react freely to information or warnings provided by the functions is very different from the low-demand scenario.
- *Traffic composition.* The traffic composition (percentage passenger cars, busses and light and heavy goods vehicles) and overall traffic level changes and changes in the number of driven kilometres did not vary between scenarios. These levels changed during this period. However, the approach to the methodology chose to vary only a limited number of factors, due to the time limits imposed by the project timeline as well as the choice to focus on the most important factors. Table 7 shows the percentage of light vs. heavy vehicles used in the scenarios.

Safety impact assessment produced impacts for all functions examined in this project, taking into account the penetration rates and the different road types. Table 3 provides an overview of the relevant scenarios for the functions for which traffic efficiency and environmental impacts were calculated. Not all the combinations of situational variables were relevant for every function analysed in detail for traffic efficiency and environmental impacts. For example, high speed roads do not have traffic lights, so those scenarios were not calculated for GLOSA.

Table 3: Relevant conditions for scenarios in traffic efficiency and environmental impact assessment.

Road type and demand level	Base case	Low case	Medium case	High case
High speed roads (>= 100 km/h) Low demand	TJAW, IVS	TJAW, IVS	TJAW, IVS	TJAW, IVS
High speed roads (>= 100 km/h) High demand	TJAW, IVS	TJAW, IVS	TJAW, IVS	TJAW, IVS
Rural roads (60-100 km/h) Low demand	IVS	IVS	IVS	IVS
Rural roads (60-100 km/h) High demand	IVS	IVS	IVS	IVS
Urban roads (<60 km/h) Free Flow	GLOSA, IVS	GLOSA, IVS	GLOSA, IVS	GLOSA, IVS
Urban roads (<60 km/h) High demand	GLOSA, IVS	GLOSA, IVS	GLOSA, IVS	GLOSA, IVS

There are other situational variables that could play a role in determining the impacts of the functions. Examples include weather conditions, lighting conditions and traffic composition. With the exception of the Weather Warning function for rain and slippery roads, the analyses did not use this information. These are the factors that add to the error variance of the results, and make it more difficult to have statistical significant results from the tests. But these are issues belonging inherently to all road tests, and they are very difficult to control without investing considerable time and money for the test design and analysis of the data.

The work within SP4 followed an iterative process. In the first eight months of the DRIVE C2X project, Wp42 "Evaluation framework" set up the framework for evaluation. This comprises the definition of research questions, hypotheses and indicators. These indicators were translated into measures by WP43 "Data and data quality" that were requested to be logged by the logging apparatus in vehicles or collected by the test sites by some other means. The availability of these data, as well as the experimental design of the test sites, played a significant role in the results of the impact assessment.

The data used in impact assessment was uploaded by the test sites to the DRIVE C2X ftp site. The LogMover program carried out a brief data quality check, called a "sanity check" on the data to determine if the data was complete and whether the values were within reasonable limits. If not, the results of the test were reported to the test sites for improvement. If the data was complete and within the expected limits, the LogPro programme processed the data further into indicators for the use in the impact assessment tasks (Figure 11). At this point, an iterative procedure of data analysis, questions to the test sites and filtering took place. This iterative process took several months. The result was analyses of the test site data, but in some cases the analysts concluded that the data were not usable. This applied especially to the French data where the user tests data could not be included in the analysis, but from the French site only driver interview data could be used.

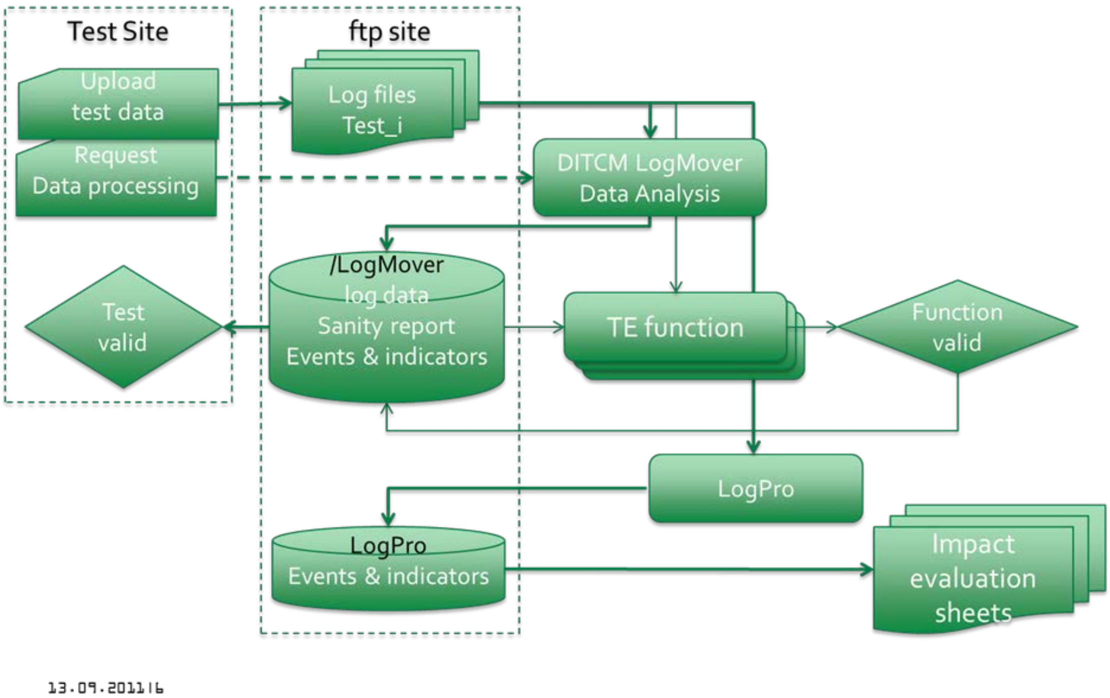


Figure 12: Overview of data processing steps from the test site to impact assessment.

2.4.3 Evaluation methods

Impact assessment and user acceptance made use of different methodologies in their assessment. They also came together in two analyses. Part of the driving behaviour and the mobility impact assessments integrated objective and subjective results to come to a final result.

Impact assessment aimed to draw conclusions about the use of the DRIVE C2X functions and their effect on driving behaviour, safety, mobility, traffic efficiency and environment. Figure 11 below shows an overview of the steps in impact assessment. FOT data provided the input for the impact assessment. The driving behaviour task analysed the data to determine the difference between how drivers drove with and without the DRIVE C2X function. For each test site, indicators such as speed, speeding, acceleration and braking for different circumstances were analysed for statistical significance, and then pooled with data from other test sites and analysed again. These analyses provided input for the assessments on the impact areas safety, traffic efficiency, environment and mobility. If needed, tools and models were used in the analysis. The last step was scaling up of the effects to the EU-level, and for this, external data were needed. In most tasks, scenarios were used.

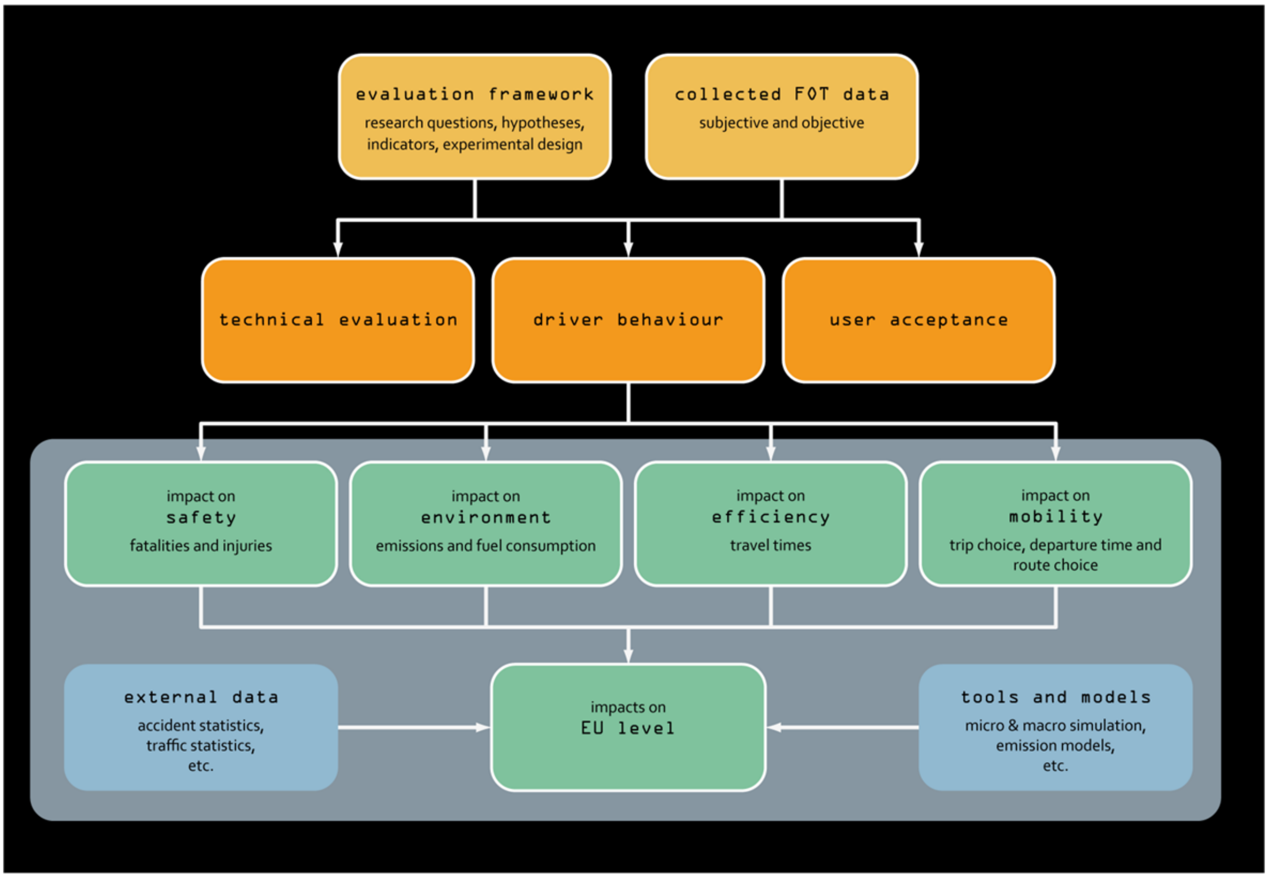


Figure 13: Overview of impact assessment process.

The scenarios took into account the most important aspects that affect the impacts of DRIVE C2X systems: the penetration level of the cooperative system in Europe, road types, traffic composition and the traffic demand (peak or off-peak). Table 4 provides an overview of the passenger car penetration rate for all DRIVE C2X functions. Heavy goods vehicles were not equipped; no DRIVE C2X functions were tested on heavy goods vehicles. All results shown in the impact assessment assume 100% of the infrastructure needed for the functioning of the system is equipped. Results were also calculated for lower penetration rates of infrastructure equipment.

Table 4: Passenger car penetration rate scenarios used for calculations.

Scenario	Passenger car penetration rate
Base Case	0%
Low Case	10%
Medium Case	25%
High Case	90%

2.5 Piloting

Piloting was carried out to ensure that all systems, test procedures and the methods which were to be used in the Field Operational Tests were working according to the design. Piloting activities are reported in Deliverable D34.1 "DRIVE C2X FOT piloting".

The pilot tests had to follow the defined FOT methodology as accurately as possible. This included the testing of the complete FOT chain from the "with" and "without" functions test runs to data collection. It also included to provide input to WP45 "Impact Assessment" for the first analysis of the data and to test the hypothesis postulated. The test scenarios comprised V2I and V2V application with their different functions.

Before launching the FOT, all preparation activities needed to be completed. To synchronize the test sites, a piloting plan was elaborated for the test sites. The pilot tests provided the first opportunity in the project to check the complete sequence of activities planned to be performed in the FOT.

As part of this documentation a pilot planning checklist was used to check and define follow up activities for the test sites to ensure compliance with the test design. A lot of effort was put to preparing, consolidating and harmonising the piloting activities among the test sites. This was a crucial measure for an easier and synchronized running of the pilot tests. The checklist turned out to be the enabler for the successful execution of the pilots.

The pilots were delayed compared to the initial time plan shown in the project documentation. It was essential to have all adaptation activities at the test sites completed and numerous debugging of software had to be resolved. Starting the pilots before finalising the adaptation would have rendered the pilot data completely useless. Firmware has been updated until the very end of the adaptation phase affecting the output data from the methodology framework.

The pilots focused very much on technical functionality due to a number of unexpected problems in the reference system. After that, the focus was on basic methodology issues such a fleet numbers, number of subjects, test design, HMI, instructions to the subjects, test conductance etc. For these reasons the piloting period was much shorter than originally planned.

The main challenges of the overall piloting plan were to:

- Exploit the full potential of test sites when using the DRIVE C2X reference system. With regard to this the adaptation of some applications was needed to take advantage of all information that may be provided by the infrastructure side.

- Obtain a sufficient level of vehicle data in a setting, where all the in-vehicle CAN-gateways had to be developed by the project without external support.

Piloting had three focus areas which were used as planned activities in the pilot tests. The first task, verification and validation of test sites against the DRIVE C2X framework, focused on the basic operation of functions. The objective was to ensure that the whole system behaves as required for every function, including HMI and subject instructions. In the piloting tests, all phases in the service chain were covered for all functions foreseen in the test site: an event occurred, it was detected, a warning was generated, received and displayed.

The second task was to pilot the test site tooling, logging and monitoring. The objective was to ensure that the data is recorded as planned for the analysis and test monitoring.

The third activity was to check that the FOT scenarios generate the expected data from the tests with subjects and their experience about the functions in real driving tests. These scenarios needed to be as accurately as possible to those planned for the FOT, including HMI. The difference between this phase and the FOT operation was that during piloting some changes were still possible (also based on the feedback of SP4 involved in the analysis) while in FOT operation the planned number of tests had to be carried out by applying the same procedure. To receive comparable data, no changes were allowed in the test arrangements or in the test scenarios in the FOT phase. The third phase was particularly important for those test sites based on controlled scenarios.

During piloting it was necessary that all activities that may occur in the FOT were validated to be performed as expected. A list of activities that all test sites covered during the FOT was compiled. These activities were then used to monitor the progress of tests on each test site.

The piloting checklist was used to synchronize the activities between the test sites (D34.1 "DRIVE C2X FOT piloting" Annex I: Pilot checklist). The checklist is split into three tasks or main objectives, each detailing verification and validation.

- Task 1: Verification and validation of TS against the DRIVE C2X framework,
- Task 2: Verification and validation of pilot TS tooling,
- Task 3: Assessment and validation of FOT data Scenario piloting.

Each test site regularly reported the status of the checklist to the work package leader. Therefore, it was possible to assess the progress of the piloting activities. The list included a date of completion for each activity, a responsible person or organization, status and general comments about the activity.

The execution of the pilot tests showed that all test sites were fully compliant to the guidelines of SP2. The test sites provided feedback to SP2 during the pilots regarding the DRIVE C2X reference framework. The execution did not entirely fulfil the specification of WP25 "Test environment". This was one of the main reasons for the delay of the pilot. The same situation had to be faced regarding the output data from the pilot. The data did not fully meet the defined requirements. Therefore feedback was provided continuously from all test sites during the pilots, and the framework was improved accordingly. The DRIVE C2X reference system tooling was used selectively by each test site. Some test sites developed solutions adapted to their existing systems. A general comment to WP24

"Technology enhancements and system integration" and WP42 "Evaluation framework" was that more extensive technical documentation of the tooling would have been desirable.

The TS Finland was unable to follow the initial time plan, because the DRIVE C2X reference system was not finalized on time.

The pilot at TS Sweden was primarily delayed due to problems with the reference platform and the use of a TS specific HMI. Much more resources were used than initially planned for the pilot. After the pilot the TS Sweden was ready for the baseline data collection, but not yet for the treatment. The Swedish FOT started on 25th of February 2013 with the baseline data collection. Not all vehicle signals requested by WP43 were provided as VDP (Vehicle Data provider) signals were missing. Feedback has been provided to WP42 "Evaluation framework" that the expected numbers of events during the FOT had to be adjusted.

The start date of the French FOT was 24th of April 2013. The initial time plan could not be kept due to underestimating the time needed to validate the data collection and to ensure the data quality. After the first controlled piloting, modifications were made on the HMI and the functions to enhance the system according to drivers' considerations.

The time plan for the German test site had to be adjusted according to the time constraints of the simTD project. The simTD field test was carried out from 2nd of July to 12th of December 2012. The DRIVE C2X TS could not be implemented until mid of October 2012. The execution met the requirements and specifications of WP25 "Test environment". No feedback was transmitted during FOT. The German tst site was fully compliant with the SP2 guidelines.

TS Spain was ready for FOT after the quality of the data logging had been verified by SP4. The FOT started after the SP4 confirmation.The test site was fully compliant to the guidelines of SP4 except for not using LogStation for data handling. SP2 received feedback regarding issues when using the DRIVE C2X system (e.g. coordinates problems, application performance according to TS conditioning). More documentation from WP24 "Technology enhancements and system integration" and WP42 "Evaluation framework" regarding the tooling would have been beneficial.

The main conclusion, as commented for later activities, a tighter coordination between test sites and SP2 and SP4 especially in terms of practical documentation would have been beneficial.

3 Field Operational Tests

3.1.1 FOT goals and preparations

Field Operational Test operations were carried out in six different European test sites, the so-called Functional Test Sites (FTS). The "FOT operations" sub-project was managed in DRIVE C2X in close relationship with the other sub-projects, needing to carry out parallel activities and took into consideration the preparatory work described earlier in the document. FOT operations are reported in Deliverable D11.3 "Report on FOT Operations"

The primary goals of the FOT activities were:

- Execution effective FOT operations, following the guidelines and lessons learned from other on-going projects, especially TeleFOT, and applying a common and harmonised methodology to testing.
- Collection of consistent and high quality data for the activities carried out in FOT Evaluation (SP4) for technical evaluation, user acceptance and evaluating the impacts of the implemented cooperative driving applications on driver behaviour, safety, environment and traffic efficiency.

The FOT testing process and operations are illustrated detailing the results in relation to the planned activity in Deliverable D34.1 "DRIVE C2X FOT piloting".

The "FOT operations" relied on strong collaboration with selected national test sites. For logistical reasons, each test site was responsible for its deployment of the cooperative ITS applications, as well as the coordination of its FOT operations. Ensuring the usage of harmonised FOT test processes and the provision of consistent FOT data for the impact and technical assessment, required to split the sub-project into four phases:

1. **FOT system integration and validation**: WP 32 "FOT system integration and validation" tested and validated the general FOT framework defined in DRIVE C2X in practice on a dedicated and fully DRIVE C2X compliant test site. System testing and in particular on the interoperability of the systems delivered by the partners had the highest priority. WP32 provided a full technical system validation including guidelines and requirements for effective functional testing on the chosen test sites.
2. **DRIVE C2X test site preparation and adaptation:** WP33 "Test site adaptation" prepared the test sites both from organisational and technical points of view in order to implement the common guidelines provided by SP2. Specific descriptions of each test site were delivered including full scale test scenarios for controlled and uncontrolled FOT approaches.
3. **Piloting:** WP34 "test site piloting" cooperated with each test site to pilot the adapted DRIVE C2X FOT tools and procedures to ensure that the test sites were ready for the collection of FOT data. WP34 validated each test site implementation before the start of functional testing.
4. **FOT management:** WP35 "Test data management", WP36 "Fleet & user management", and WP37 "Applications management" coordinated and supported the FOT activities of the functional test sites. But these work packages have also supported the activities relating to the above phases.

The four phases started successively, and timely overlap of the corresponding activities enabled the work packages to support each other.

A wide range of the activities was covered which were needed to establish and provide a consolidated and harmonized FOT test environment. The specific structure of the DRIVE C2X field trials is explained in D11.3 "Report on FOT operations", as well as the interaction with national projects and their partners contributing to DRIVE C2X. The test site adaptation and piloting are illustrated, followed by a presentation of the common testing process applied by all the test sites and finally a description of FOT operation process and results for each test site.

The efforts of the test sites are highlighted to observe the actual FOT methodology as accurately as possible ensuring that all the systems, test procedures and the methods were driving the FOT execution according to what they were designed for.

DRIVE C2X applications or functions tested in the different are described. They have been selected owing to their particular relevance from a European point of view and collecting data at a number of national European test sites with national use cases e.g. in Germany (Table 5).

The FOT operations were described separately for each test site: a short overview have been provided by the test leaders in order to describe the operations, describing the vehicles and users involved, the planned test scenarios and all the activity of data collection.

Specifically for each test site it is described how the harmonized methodology was applied in order to provide data compliant with the analysis requirements.

Each test site determined which functions would be tested. Table 5 provides an overview of the functions on each test site. The test sites determined the experimental design, identified and contacted the test persons, carried out the tests and submitted the data to the DRIVE C2X ftp site for checking and processing.

Table 5: Overview of functions tested at the test sites (CT=Controlled test; ND=Naturalistic test).

Function	Finland (CT)	Italy (CT)	Spain (CT)	Sweden (ND)	Germany (CT)	France (CT)
IVS/SL	X	X	X	X	X	X
IVS/SS	X	X	X	X		X
TJAW		X	X		X	
AEVW		X	X		X	
EEBL					X	
OWRWW/CBW	X	X	X	X	X	X
WW	X		X	X		
GLOSA	X		X	X	X	

3.1.2 FOT carried out

During the FOT operations, the DRIVE C2X partners succeeded to validate and deploy common and interoperable cooperative functions on all test sites. This was the initial condition to run the Field Operational Tests.

A strong cooperation between test site leaders and the assessment teams enabled the development of a common testing methodology, as well as the mean to control the resulting quality of data on each test site.

After field tests it is worthwhile to have a look at the results for the two following set of data, being the required inputs from the FOT operation to the FOT evaluation process:

- Log data and
- User feedback and acceptance (this is covered in Chapter 4.2.5 "User acceptance").

The log data will be used for the technical evaluation and the impact assessment. The user feedback was mainly used for the user acceptance evaluation.

As one pillar of the testing methodology, the data quality process was made available and used by the test sites to proceed with a quality check of the FOT. Therefore it was proposed to evaluate the overall log data by comparing the final number of events with the targeted number of events corresponding to the required sample size for the analysis

The Table 6 summarises the number of events per function, collected on each test site. The target column shows the targeted number of events on all test sites per function.

Table 6: Summary of the number of events collected (treatment + baseline).

Function	FI	F		DE	I	SP	SE	Total	*Target*
	CT	CT	NT	CT	CT	CT	NT		
TJAW	-	-	-	380	46	34	-	460	*380*
RWW	234	38	9	12373	60	40	17	12771	*991*
CBW	100	161	35	-	58	30	24	408	*849*
WW	240	119	-	24931	-	22	-	25312	*1603*
AEVW	-	-	-	1216	50	25	-	1291	*180*
IVS	1820	4872	59	218977	1288	40	583	227639	*3862*
GLOSA	-	-	-	30868	-	-	155	31023	*1640*
EEBL	-	-	-	3011	-	-	-	3011	*190*

Comparing the total number of events recorded on all test sites with the initial targets lead to the assumption that the FOT operations have reached their objectives for the number of events. This assumption is also linked to the effort made by all DRIVE C2X partners concerning the data quality, so that check procedures also included data integrity verifications.

However, only the detailed analysis process, which was carried out in DRIVE C2X during the technical and the impact assessment tasks, could accurately evaluate the consistency of the logs related to the FOT events.

The number of events and more globally, the amount of data is crucial for the technical evaluation of all functions. But as it was observed in previous FOT projects, a considerable number of events were not suitable for the impact analysis.

A huge difference of events among the different test sites is also obvious in the table summarizing the number of events.

Some functions like TJAW for instances could not be tested in naturalistic conditions, as the required number of equipped vehicle should be very high for the testing of this function. Additionally certain functions like EEBL or CBW raised some safety issues for the drivers and the environment. These functions were therefore tested on close tracks, not allowing enough naturalistic tests.

Therefore due to the nature of the cooperative functions, the assessment resulting from the log may significantly differ among the different functions.

3.1.3 Observations from the FOT

The Field Operational Tests were designed to enable the testing of the technical performances of the DRIVE C2X functions, to allow users to experience cooperative functions in real driving conditions on public roads and to collect data to evaluate the impacts of cooperative systems.

Thanks to lessons learned from previous FOT projects like TeleFOTor EuroFOT, DRIVE C2X FOT operations were successfully carried out with a short delay only compared to the project planning. The kick off meeting offered partners to learn about experiences and issues in the previous FOT projects and thus to pay more attention in the documentation and follow up of the three main pillars supporting the FOT operations: data management, fleet/user management and application management.

Recommendations to consider carefully the stability of the systems before starting the FOT and even more piloting were taken under consideration. Therefore, numerous different test methods were applied and tried out during the system validation phase including the involvement of the whole cooperative ITS community during the open interoperability events.

Piloting was also identified as a critical part of the FOT preparation and was therefore well documented and followed a comprehensive methodology. Significant delays during the first phase of the projects leaded DRIVE C2X to keep the piloting within a relatively short timeframe in order to avoid further delays in the project. Furthermore, corrective actions on the systems were undertaken during piloting. Consequently, piloting time and resources were not fully dedicated to validate the test process. Nevertheless the piloting phase provided the expected results because of the concentrated efforts of the technical experts and the piloting teams. But the DRIVE-C2X piloting experience confirmed past lessons learned recommending launching piloting with robust and stable systems only and reserving enough time for the pilot tests.

Thus, FOT operation could be started in good conditions with very limited delays. All test sites could execute their tests and deliver log data following a single guideline document provided commonly by the different actors of the FOT operation and the analysts. Using a common repository for all test sites and the WebScenario editor tool, all types of documentation were collected and checked by the task leaders. Data management tools (e.g. LogMover) enabled to verify the log data consistence on the fly and as necessary to take corrective action by running new tests. Problems arose with the French data from driving tests that couldn't be fixed to meet the testing requirements needed to make comparisons between the "with" and the "without DRIVE C2X" case. This meant that it was not possible to determine the size of the various functions' impact on driver behaviour for the French data.

The FOT operations were not left under the full responsibility of the test site leaders but had to follow a strict and well documented process. Furthermore FOT operations were coordinated by the FOT operation manager in cooperation with the experts for data management and analysis. Test sites were asked in particular to upload their log data on a regular basis (at least every two weeks) and to verify the data consistency with the common DRIVE-C2X tools. This commonly coordinated data management process allowed to apply corrective actions very soon when needed. DRIVE C2X recommends to implement this kind of coordination at project level, because it efficiently supports the efforts of the test site leaders and ensures data consistency.

Until writing of this report begun, many set of data were already handled by the LogPro tool, which interprets test logs and generates the corresponding events in the central event database. The number of events collected during the FOT operations was consistent with the targeted sample size. This result was very important for the impact assessment, as a minimum number of events was necessary for an accurate and reliable impact assessment.

As explained in this report, some test sites used their own systems including a specific data logger. This led to the creation of log data which required conversion in order to match the DRIVE C2X data format. This conversion process was difficult to be applied by the French test site for instance causing significant delays in the provision of validated log data for the impact analysis. Therefore DRIVE C2X strongly recommends using a common logger in a FOT project to avoid issues and delays due to data inconsistencies.

The DRIVE C2X project aimed at evaluating cooperative systems, which use communication between vehicles and the infrastructure. Interoperability was therefore a key enabler for cooperative systems. Compared to previous FOT projects, like EUROFOT for instance, where autonomous systems where evaluated, DRIVE C2X was very much challenged by the technical issues concerning cooperative systems, resulting in the need to pay particular attention to the interoperability and the performance of the systems. Therefore, a significant amount of testing was needed during the integration phase.

DRIVE C2X followed the FESTA methodology, which enabled a well-structured approach. FESTA offered, rather than a complete methodology, a checklist for planning and running a FOT according to sound scientific principles. FESTA proposes as well a very straightforward process from testable entities all the way to analysis of results. However, a significant level of creativity was needed to specify a suitable and detailed enough test process for all test sites, ensuring the provision of consistent log data. Therefore, the FESTA methodology requires further improvement in particular concerning the terminology and enhancements concerning the provision of test process methodology.

4 Evaluation

4.1 Technical evaluation

4.1.1 Objective and functions evaluated

The main objective of the Technical Evaluation was to evaluate the technical performance of DRIVE C2X functions in full-scale FOT operations. This section gives the main conclusions on the overall technical performance of the DRIVE C2X reference system. Technical performance is defined by a set of performance characteristics. The most important underlying characteristics are related to timing, positioning, communication and the content of driver advice. Conclusions on function-specific performance characteristics, end-to-end delays and time delays per component or processing step, events and anomalies, were provided at the end of every function section.

The DRIVE C2X reference system was tested and evaluated at several levels (Figure 13). The components and functions were tested in isolation in SP2, and the development phase was concluded with the integration tests as reported in Deliverable D26.1 "DRIVE C2X vehicle integration and interoperability check report". Implementations of the reference system were validated at the System Test Site (Deliverable D32.1 "DRIVE C2X system validation"). The validated systems were deployed and tested at the national test sites during pilot testing (Deliverable D34.1 "DRIVE C2X piloting") before commencing the FOT. Technical Evaluation is the final step in DRIVE C2X testing.

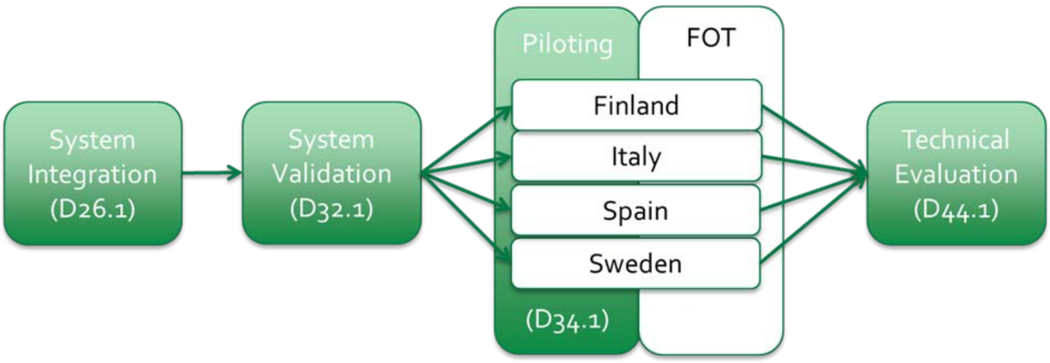


Figure 14: Technical testing, validation and evaluation process.

The system validation deliverable (D32.1) identified some open questions with respect to technical performance of the reference system and functions. Many of these questions were addressed during piloting, and could now be evaluated in more detail based on the FOT results.

The following DRIVE C2X functions were evaluated in detail: Motorcycle Approaching Indication (MAI), Approaching Emergency Vehicle (AEV), Slow Vehicle Warning (SVW), Green Light Optimised Speed Advisory (GLOSA), Obstacle Warning and Road Works Warning (OWRWW), In-Vehicle Signage (IVS), Traffic Jam Ahead Warning (TJAW) and Weather Warning (WW).

4.1.2 Evaluation methodology

The methodology applied to the technical evaluation of a function consisted of the following steps:

1. Analysis of a function, its specifications and implementation. Specifications yield target values for technical performance. The implementation identifies the relevant parameters for detecting events, states and transitions in function behaviour, and dependencies of function modules to other facilities.
2. Definition of performance characteristics or metrics. A characteristic was defined by one or more performance indicators, which were functions of the log parameters. The performance indicators were refined for anomalies encountered during integration, validation and pilot testing.
3. Evaluation of the test concept was essentially defined by the test scenarios of the test sites.
4. Analysis of the log data and assessment of the results.

Test scenarios were defined for the purposes of the national FOT programmes. The variety of scenarios and events was much larger than in technical testing and system validation. Events could be triggered from fixed road side locations or from vehicles. Warning distances and relevance areas were different for different weather conditions, traffic signs or road topologies for example. Communication performance varied with the environment. The FOT scenarios generated a large number of events, all of which had to be evaluated individually.

Data analyses were organised in a three step approach:

1. All batches of log data were automatically processed to verify the quality and plausibility for the technical evaluation. The LogMov was extended for example to check the availability of required log parameters, detect all events per function, check the consistency between event locations in the DENMs, function triggered and HMI events, and calculated the indicators per event. The output was a short list of events and log files per function for further analysis.
2. Detailed evaluation of all events per function. Scripts were developed to semi-automatically analyse and evaluate every event from the original log files. The scripts were function-specific, calculated all performance indicators, and detected any known anomalies in function behaviour or event definitions.
3. Anomalies were analysed in detail to determine the cause and assess the effects on function behaviour. Usually, the anomalies resulted from interactions between event configuration and function implementations, and the findings were fed back to test sites and data analysts for impact assessment.

The methodology was applied and reported in a technical evaluation plan for each function separately.

The full-scale FOTs conducted a large series of controlled and naturalistic tests organised in batches of test runs. A batch had a specific objective and a set of scenarios for realistic situations, for example, to test a combination of functions that logically occurred under given traffic and environmental conditions, and either in an urban or highway setting.

All events and anomalies were analysed in detail from the logged data. In total, all log files from 1488 test runs were analysed automatically from the Field Operational Tests in Finland, Italy, Spain and Sweden, with a total of 7497 hours and 19352 events. In addition, data from test sites in Germany and France were analysed to complement the analyses and increase the number of events for functions and performance criteria that are similar to the DRIVE C2X reference system.

Performance characteristics had to be defined as functions of DRIVE C2X log parameters. The national test sites provided the DRIVE C2X log data, and did not have additional measurement systems to monitor and verify the performance of the DRIVE C2X reference systems. No measurements were available to verify for example the absolute time synchronisation, accuracy of positions and speeds, timing of HMI events and the accuracy of HMI information.

Consequently, performance characteristics could only be determined from the logging of the test vehicle or neighbouring ITS stations. This provided relative performance metrics such as time offsets between ITS stations, delays between modules within the ITS station, and distances relative to host's own position.

Absolute performance measurements were carried out during system validation on the System Test Site (STS) and are reported in D32.1 "DRIVE C2X FOT system validation". This included the absolute differences between the DRIVE C2X log data and the actual situation. It could be assumed that the absolute system performance at the national test sites was similar to the performance measured at the STS, in particular for the accuracy of time, position and speed, and HMI activations. This assumption could be evaluated to some extend from the log data.

A series of automated evaluations were described on basic facilities that address the observations made in D32.1, in particular on time gaps in the logging, time synchronisation of ITS stations, position and speed accuracy, and HMI activations, and required log parameters. Also the communication performance was evaluated.

Offsets in time synchronisation of ITS stations had been observed in D32.1 in the order of 1.5 seconds. Although absolute time offsets couldn't be evaluated from the log data, several methods were applied to make relative estimates.

All log data was time stamped. Time offsets might have introduced errors in the fusion of data received through communication, for example, in filtering positions of other ITS stations or event times based on the generation times in CAMs and DENMs. Most functions however, did not use message generation time for filtering, so this did not affect the technical performance.

Time offsets also introduced errors in the alignment of the log data result from neighbouring ITS stations. This could be an issue for evaluation of functions where ITS stations cooperate directly, such as in the MAI, AEV, SVW and GLOSA functions.

Although performance characteristics were specific to a function, they could be broadly grouped in the following types:

<u>Latency or delay</u>

Latency is the time interval that has elapsed between consecutive processing steps, such as the processing time between the reception of a message and the delivery to a function, or the delay between the trigger for a first warning sent by a function to the HMI and the actual display of the message on the HMI. The end-to-end delay is the total delay between the occurrence or detection of an event and the first warning of the driver on the HMI.

Accuracy of warning distances or warning times

Absolute position variations were observed in D32.1 in the order of 10 m, depending on positioning systems and position update frequency. The absolute position error couldn't be evaluated from the log data, and it is fair to assume that this error remained.

In addition, variations were also observed in the warning distances to events of up to 20 meters. This is the distance between the position of the ITS station and the location of an event on the HMI. The safety margins to the event were defined differently for each function, for example by a warning time, distance or relevance area.

An important characteristic is the variation in locations where first warnings were triggered by the function. This variation is the net result of position update frequency and positioning accuracy, function control frequency, and processing delays for example.

4.1.3 Overall technical performance of the DRIVE C2X functions

Overall, the DRIVE C2X functions performed as specified from a technical point of view; i.e. function and HMI events to inform or warn drivers are generated at the right location, on time, and with the correct information.

When a function detects or receives an event it may or may not trigger an advice on the HMI. Functions assess the momentary risk status of the event and trigger the HMI at three risk levels; no advice, information or warning. The risk status is defined by a time or distance to the event. Technical performance of functions could thus be evaluated by two types of characteristics:

1. Accuracy or delay of event triggering at the defined time or distance to the event.
2. Accuracy of the content of the advice, such as the distance or time to the event.

The trigger conditions for the first characteristic were specific to a function, and depended for example on the type of hazard or traffic condition, the frequency at which the function monitored the risk status, and the vehicle speed. The trigger conditions could also be configured on the road side and Vehicle ITS Stations. Hence, the difference in trigger conditions for the time and distance to events could be expected in the scenarios and events configured at the different test sites. The performance was evaluated for the accuracy and variations relative to the time and distance to each event.

The accuracy and variations were also dependent on technical performance characteristics of the basic reference systems, such as the time synchronisation, positioning, and communication performance. These applied to the warning distances and times for triggering events as well as for the content of driver advice.

Some flaws were identified in the design and specification of a few functions that occasionally led to incorrect HMI event triggers. These were analysed in detail in the function specific sections, where adaptations were suggested from other functions to resolve these flaws and the incorrect events were identified for removal in further analyses of the DRIVE C2X system.

Considering the variations in configuration and the basic system performance, the DRIVE C2X functions were considered to perform as specified.

4.2 Impact assessment

4.2.1 General remarks

The main results of the user tests are briefly presented below. The impacts concern safety, traffic efficiency, environment and user perception (for more detailed results, please see Deliverable D11.4 "Impact Assessment and User Perception of Cooperative Systems").

The safety impacts of the DRIVE C2X functions are clearly positive, even for functions aimed at relatively infrequent events such as AEVW. Environmental benefits in terms of reduction in fuel consumption ad CO_2 emissions were also achieved for 3 functions, although not all effects were statistically significant. Greater improvements to traffic efficiency and the environment can be achieved with modifications to the DRIVE C2X function implementation. The drivers filling in the user survey reported that traffic flow is as important as safety. The system experience of DRIVE C2X functions could be expanded to encompass traffic flow, interpreted as efficiency and environmental issues, in addition to safety. An integrated approach to designing cooperative systems can identify where improvements in traffic efficiency and environment can be achieved, while still gaining the safety effects.

The DRIVE C2X project successfully measured and analysed direct and short-term effects of drivers' use of the DRIVE C2X functions. Most TS carried out controlled tests, which allowed the test-site responsible persons to maximise the number of events logged during the period of FOT operation.

Important indirect and long-term effects of using DRIVE C2X functions were measured for a few aspects at the TS Sweden, where the naturalistic driving approach was applied. At the cost of the number of events, this TS gathered valuable information about driver behaviour through video recording of the driver and his or her glances and compensatory behaviour. However, driver usage of the DRIVE C2X functions, that is, how often and under which circumstances subjects used the function, was not directly measured in any of the DRIVE C2X FOTs. The user acceptance survey did investigate the self-reported usage by drivers.

Future FOTs should study and determine the effects of bundled functions because in the future, functions will be deployed as bundles and not as single functions. This will provide a greater impact, with the same basic costs, leading to an improved benefit-cost ratio. However, questions of which functions, when combined, reinforce positively the desired impacts and act synergistically?

The effect on drivers of providing information and warnings from multiple functions in vehicles needs to be better understood. How should the driver be informed more effectively in terms of priority and also to avoid overloading or irritating the driver? The design and type of HMI design are essential in this.

4.2.2 Safety

To summarise the safety impact assessment, the main results showed that the functions affected traffic safety in a positive way by preventing fatalities and injuries. The most effective functions from safety point of view were IVS Speed limit and weather warning. However, even GLOSA function developed entirely for improvement of traffic efficiency enhanced safety slightly.

With given vehicle penetration scenarios (2020: low/2.8%, medium/7.9%, high/11.6%) the reduction in fatalities were up to 3% for IVS speed limit that provides continuous information (the most effective function) but for most functions less than 0.5% in 2020 and even smaller for injuries. Penetration scenarios were higher for 2030 (low/19.9%, medium/68.7%, high/75.6%) and consequently the proportion of prevented fatalities and injuries were higher than for 2020 penetrations. With 2030 penetrations the IVS speed limit that provides continuous information (the most effective function) would prevent up to 16% of fatalities and other functions up to 1.0–3.4% except for AEVW (up to 0.8%) and GLOSA (up to 0.1%). The impact on injuries would be correspondingly up to 8.9% reduction for IVS speed and up to 0.7–3.3% for all other functions except IVS pedestrian crossing ahead and child signs (0.5%) and GLOSA (0.2%).

If all DRIVE C2X functions were to be provided as a bundle the overall impact would be 0.9–5.5% reduction in fatalities and 0.7–4.2% reduction in injuries in 2020 and 7.4–26.3% reduction in fatalities and 5.0–19.3% reduction in injuries in 2030 with given vehicle penetration scenarios. It is acknowledged that this type of estimate is very theoretical and does not take into account all possible interactions between the functions. However, it provides an overall estimate and is justified because DRIVE C2X in most parts focused on different problems (road works, emergency vehicle, broken car, slippery road, speeding etc.). In any case, it is assumed that bundles of functions will be a reality, but will be built based on market demand.

Safety impacts were analysed as a combination of (1) previous expert assessments found in the literature, (2) expert assessment of DRIVE C2X, and (3) results of driver behaviour results found in DRIVE C2X field studies. Previous expert assessments, such as eIMPACT [6] and CODIA [5], addressing similar functions which were now applied to field tests have reported the assumptions concerning impacts on driver behaviour transparently. Therefore, it was possible to compare the previous assumptions with the findings in DRIVE C2X field test. In many cases the same performance indicator was studied, and the assumptions of previous expert estimates could be verified or adapted; in some cases an estimate of a performance indicator could not be measured in the field (e.g. headways) and the estimate from expert assessment was used. For each function, some evidence from DRIVE C2X field studies was utilised.

The approach in interpreting driver behaviour results in terms of safety varied by magnitude of impact, by consistency of findings, and by impact distance – the distance during which the information was provided.

IVS/ Speed limit and weather warning provided information for relatively long distances – to these two functions the Nilsson model was applied which provides the relationship between change in average speed and share of fatalities and injuries. For weather warning also changes in headways and increased attention were taken into consideration by referring to the CODIA project. WW driver behaviour results indicated effects in one place, but not in all places. Therefore, the effect found was applied only for a part of the adverse conditions. The local effect found was somewhat greater than was assumed in earlier expert assessments; the mean effect which could be applied to all accidents occurring in adverse conditions was very close to earlier estimates.

Fairly many functions were such that they focused on limited safety problems in limited areas or road sections; these were AEVW, CBW, RWW, IVS/Child sign and pedestrian crossing ahead, EEBL, TJAW, GLOSA. In case of very short warning distances, Nilsson's model was not found useful, but changes in driver behaviour due to the function were interpreted in terms of increased attention and thereby avoiding accidents. If the effect was substantial and consistent, a bigger safety effect was assumed than in case of smaller and less consistent findings. For example RWW and IVS/Child sign and pedestrian crossing ahead showed quite consistent results: in all test sites and locations decrease of speed was found. Furthermore, the magnitude of the speed decrease due to IVS for these signs was more substantial than some earlier studies regarding road side information have shown. It was concluded that the driver behaviour results in this case suggest quite good potential to reduce number of accidents related to inattention from drivers' part. Inattention was assumed to be relevant in half of the target accidents [2].

EEBL and TJAW target specifically rear-end accidents. Naturalistic driving studies indicate that inattention may play a big role in causation of this accident category [1]. However, the field results for these functions were partly inconclusive and, therefore, the effectiveness of these functions to reduce the targeted accident was assessed as smaller than for some other functions with more consistent driver behaviour findings.

To project the results to overall expected safety situation, the following can be concluded:

The safety impacts of the DRIVE C2X functions are clearly positive. Drivers react to information and warning signals.

- IVS Speed limit and Weather warning showed most potential to decrease fatalities:
    - Assuming a 100% penetration rate, IVS speed limit that provides continuous information would reduce on average 23% in fatalities and 13% in injuries. Weather Warning would lead to 6% less fatalities and 5% less injuries.
    - It is assumed that the penetration rates would be in 2020 highest 12% and 76% in 2030. For IVS speed limit, this would lead to the reduction in fatalities up to 3% in 2020 and up to 16% in 2030.
- Assuming a 100% penetration rate, Road works warning would decrease fatalities by 3%, Emergency brake light warning and Traffic jam ahead warning by 2%. These functions would decrease injuries by 2% assuming all vehicles are equipped.

4.2.3 Traffic efficiency

This study was designed to assess the traffic efficiency impacts of the five DRIVE C2X functions for which non-zero impacts could be expected. The functions TJAW, GLOSA and IVS/Speed limits have been analysed directly and with traffic simulation. The functions WW and RWW have only been analysed directly.

The main results showed that delay is slightly increased for GLOSA and IVS/SL, due to reduced vehicle speed caused from either the speed advice or to stricter enforcement of speed limits.

TJAW did not show any statistically significant changes in traffic efficiency. This was in line with expectations because the effect of the jam itself is what determines traffic efficiency. The safety feature of TJAW which influences the way drivers approach the traffic jam does not produce any second order effect of "shortening" the traffic jam. To reach such an effect, e.g. by shockwave damping, obviously a different system with a larger area of impact is required.

OW/RWW effects on speed are very concentrated around the events and are not expected to have any effect on speed elsewhere hence the overall traffic efficiency is expected to be negligible. WW can have an impact on a larger geographic area, but the impact on overall traffic efficiency as implemented in DRIVE C2X is expected to be negligible.

Compared to earlier findings, the effect of stopping time in GLOSA is not as high as expected [3, 4]. The reduced communication range and inter-junction distance can explain this change, as well as the modelling of the yellow phase of the light.

The traffic efficiency simulations showed the role that traffic conditions play in determining the overall effect of functions. In peak traffic conditions, the ability to choose one's own speed is diminished; the interaction with other drivers determines the overall speed driven, regardless of the advice provided by a DRIVE C2X function.

Greater traffic efficiency effects can be achieved with slight modifications to the functions, for example, by providing information earlier such that drivers may choose a different route or mode, or by providing advice that takes into account the current traffic conditions.

4.2.4 Environment

The functions influence actual target speeds, acceleration levels and the number of stops and accelerations, and do thus reduce the turbulence in the traffic flow. Smooth driving with the reduction of unnecessary braking reduces energy consumption and emissions. To optimise the C2X functions it shall be considered, that in the case braking is necessary, the best behaviour in terms of emissions is a coasting at zero gas pedal position with followed by a standstill (most future vehicles will have a start/stop system for the engine which leads to zero emissions at standstill at most conditions). Suggesting as alternative very low target speeds to the driver (approx. below 30 km/h) would increase emissions and energy consumption since the engine operates then at worse load points. The actual turn-over velocity depends on the present vehicle technologies, on local street and traffic conditions and on the driver behaviour.

The functions GLOSA and IVS/SL show reasonable reduction potential for energy consumption and emissions. For GLOSA the reductions result mainly from the optimisation of the speed to avoid unnecessary braking and acceleration manoeuvres. The local effect certainly will depend on the quality of the existing traffic light coordination and on traffic volumes etc. The better the basic situation with a more limited number of stops, the lower the GLOSA effects will be. In urban road networks approximately 3% emission reduction from GLOSA is expected at high penetration rates of the system in cars and in the traffic signal infrastructure. With increasing shares of hybrid vehicles the GLOSA effect will be reduced.

For IVS/SL the influences on emissions result from a general reduction of the velocity. The effect is more pronounced on highways than in rural and urban regions since the velocity has disproportionately high effect on engine power demand. More than 5% emission reduction may be achieved on motorway roads at high penetration rates.

The TJAW function has only very local effects since it will influence mainly the deceleration area upstream of a traffic jam. In a worst case TJAW may lead to a bit longer driving at low speed and to some extra acceleration events which could increase exhaust gas pollutant emissions on a very local level. The influence on fuel consumption and CO2 emissions from TJAW is rather positive due to an earlier speed reduction

It is to be noted that all the driving cycles used in the simulation of environmental impacts for all scenarios have a high rate of insignificant values. Thus results are rather uncertain though.

4.2.5 User Acceptance

The results from user acceptance measurements indicate clearly that DRIVE C2X is perceived as a highly appreciated and long anticipated driving assistance technology. As 91% of the test users state that they are willing to use the system if it was available in their cars, it can be assumed that basic acceptance of the system will not be a severe barrier to overcome the penetration dilemma. If the technology was offered as standard equipment, it can be expected that uses appreciate the additional services and see them as an essential support for future driving.

At the same time the result of only 42% of the drivers indicate to purchase the system as special equipment, support the theory mentioned in many stakeholder interviews that the critical threshold to solve the penetration dilemma can't be overcome if C2X packages are only offered as special equipment against an additional charge.

Especially in the first phase of market introduction, while the actual experience especially in terms of C2X related functions is still limited due to the low penetration rate, OEMs should not consider a model with costs for the end user.

The preference of functions seems to be closely connected to the innovation level of the technology. According to the user feedback, functions like GLOSA or AEVW are especially attractive as they offer differentiation potential to existing solutions sometimes even available on smartphones as WAZE or Coyote, which were mentioned more frequently.

Based on this result further development should focus on those functions where the special benefit of C2X can be perceived most directly. Functions like IVS already work on a high level on navigation solutions. Real additional benefit from IVS can only be achieved if the development grade of C2X infrastructure has reached a level that allows having a broad coverage of road side units that are sending the relevant information. In a long term perspective this may lead to a seed indication that has legal relevance and replace common traffic signs. Until this point is reached it is a long way to go, where further functions might have a higher priority.

The limitation of infrastructure development and penetration rates also means a clear restriction for the implementation of new functions. While the highly favoured Emergency Electronic Brake Light function will not be a realistic option due to the needed critical penetration rate, functions like AEVW and RWW can be used by equipped vehicles in the near future.

In the context of the Cooperative ITS Corridor project, the first road works sites in the participating countries Germany, Austria and the Netherlands will be equipped with C2X modules warning drivers about road works in a the first implementation phase. As RWW was not one of the most preferred functions, AEVW could even have a higher impact on public perception in an upcoming implementation phase.

Also the GLOSA function can be expected to be implemented soon. In addition to be used on passenger cars, an even a higher interest can be expected from fleet managers as the comfort benefits for private users are easily surpassed by fuel-saving benefits for trucks. Clearly this function can be regarded as one of the economically most promising functions, even if reactance can be expected from municipalities.

Another main barrier for implementation is the aspect of implementation of the functions towards the user. Information accuracy needs to reach a clearly higher level in a market-ready solution as drivers are easily distracted in the event of inaccurate information. At the same time innovative concepts are needed to provide appropriate HMI solutions that do not lead to distraction of the driver.

The best example for this type of typical barriers for cooperative systems is Obstacle Warning OW, which requires highly specific information in order to provide the needed level of certainty about the location of the potential hazard. At the same time, this accuracy of information can't be provided by the driver himself because of inappropriate interfaces and the risk of distraction.

Also data privacy and security aspects should not be underestimated. On one side the high percentage of 88% of the respondents that agreed to be willing to provide their data for traffic related services in anonymous form indicates a positive signal, but on the other side almost 50% also have doubts that concern misuse of data by public authorities for tracking position or even speed violations.

Furthermore, the agreement to provide data for commercial purposes is rather low. Only 27% would accept that their data is shared with private third parties in anonymous form in order to offer customized services. As this economical commercial potential might be a necessary source of revenues to refinance the investment in the on-board unit by the OEM, this could indicate the more relevant barrier.

In any case, the open feedback from the participants showed that there is a considerable percentage of road users that have a very critical and sceptical perspective towards data security and privacy. Therefore, the topic should be handled carefully and with a high level of sensitivity.

Another noticeable result was the high interest in traffic efficiency benefits of the respondents. Even if DRIVE C2X did not cover actual traffic efficiency use cases, it reached the same level of interest as traffic safety with regard to the future development of the system.

The most relevant dissemination measures selected by the respondents, besides practical field tests and positive recommendations from friends, was the simultaneous launch of C2X technology by all leading automobile manufacturers. This is another indicator for the influence of the market launch from industry side on the success of the technology. The MOU of the Car-to-Car Communication consortium already built the groundwork for this scenario, now it is up to the OEM to make this approach come true.

Finally, also the use of the technology in public transport and taxis is regarded as a highly influencing factor on opinion making which should be considered as motivation for public stakeholders to support in this specific sector and generate a critical mass with a high impact on public perception.

5 Promotion

The deployment of cooperative system needs collaboration, the collaboration of a large number of stakeholder groups to make cooperative systems a success story. Hence DRIVE C2X dedicated a specific subproject to promote cooperative driving as future technology improving traffic efficiency and safety. To tackle the refinancing problem of C2x technology the commercial potential was an integrated part of the impact analysis. The promotion was done with a threefold approach addressing the public sector, the private sector and the end user and stipulating mutual exchange and joint initiatives wherever possible. The ambition was to bring technical and business perspectives together right from the start.

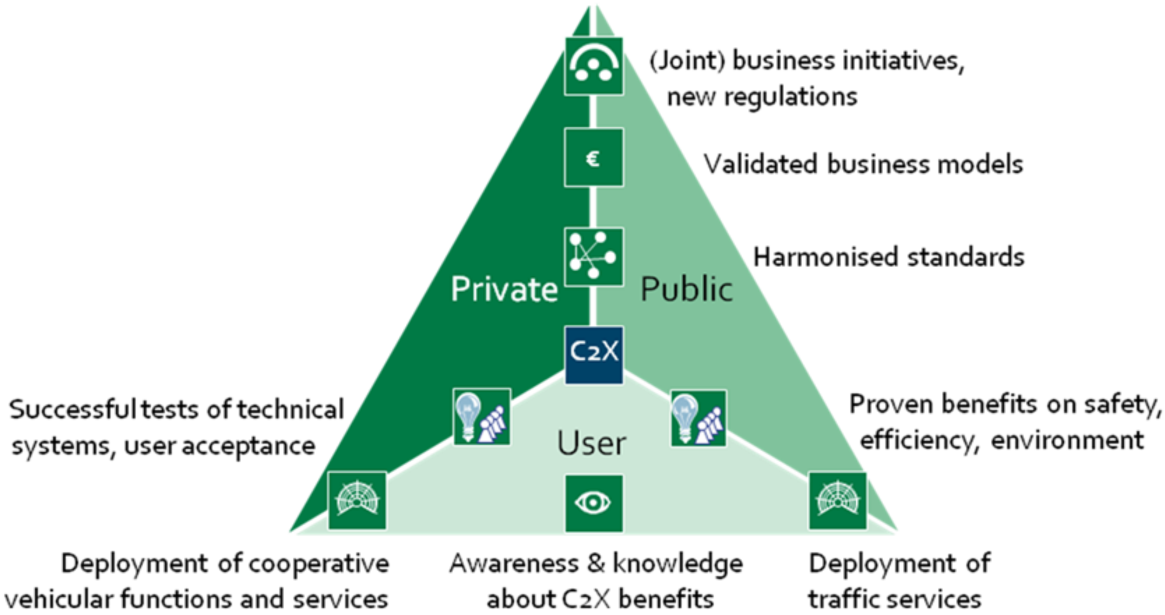


Figure 15: DRIVE C2X approach to maximise impact

The centre piece was to show European interoperability of C2X systems. This was achieved by the DRIVE C2X reference system and the subsequent integration of national FOTs into the DRIVE C2X platform activities. The work on the reference system and the various functions was fed into standards and deployment strategies.

Not only experts but also consumers were set as target groups. Using tailored means of communication and dissemination, DRIVE C2X created awareness not only among experts but also from the general public. While promoting cooperative systems, the project deeply studied the socio-economic impact of the technology. DRIVE C2X scrutinized possible future deployment strategies and the challenges to be faced therewith.

DRIVE C2X was the first project funded by the European Commission that initiated a promotion campaign. With the campaign "Making cooperative systems cooperate" DRIVE C2X pushed for deployment by initiating exchange, discussion and cooperation of stakeholder groups.

5.1 Socio-economic impact

The socio-economic pillar of DRIVE C2X was a cost benefit analysis (CBA). CBA is a preferable method for assessing C2X systems, because it provides an undisputable methodological background, the absence of a weighting scheme leads to objective results and the calculation procedure within CBA can be used for other evaluation methods. The CBA can provide input to the financial analysis, the cost-effectiveness analysis, the break-even analysis, the multi-criteria analysis and to the business case calculations. The applied methodological steps for the determination of benefits and costs are shown in Figure 15 below.

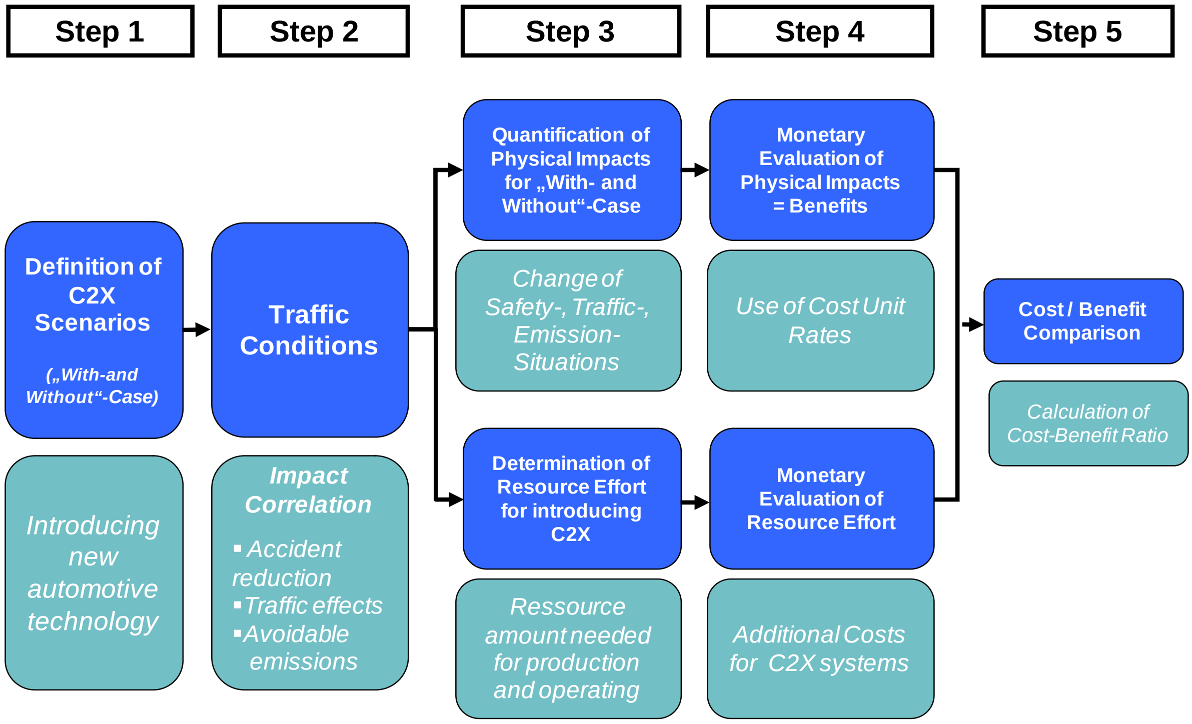


Figure 16: The five steps of a cost benefit analysis

Benefits in the socio-economic sense are defined as the monetary value of the physical impacts of the C2X-technology. Hence, safety-critical and non-safety-critical effects were distinguished.

Safety benefits of C2X-technology are defined as the potential of avoiding accidents, fatalities, severely injured, and slightly injured. Furthermore, the reduction in the severity of the accidents is considered. This means, that a fatality is reduced to a severe injury or even a slight injury. In order to assess potential benefits resulting from safety-critical effects, a cost-unit rate was applied.

The safety benefits were calculated for the years 2020 and 2030 assuming an increasing market penetration over time. Additionally, for each scenario year three sub-scenarios were considered taking into account different developments for the market penetrations with C2X-technology.

Benefits result from an increase in safety (less or less severe accidents) and from less congestion that disturbs traffic flow and causes costs. Basis for the calculations were the results of the impact assessment of the DRIVE C2X functions done in SP4.

The analysis clearly showed that the benefits increase from 2020 to 2030 in all scenarios. This is strongly influenced by the fact that an increase in market penetration is assumed. Network effects let the benefits increase.

Comparing the benefits of C2C and C2I-technology, it can be concluded that the benefits resulting from infrastructure based systems are slightly higher than those from C2C-technology. However, it strongly depends on the cost structure of each system whether this ration between C2I and C2C remains larger than 1.

In general, it can also be seen that the safety benefits are significantly higher than safety benefits resulting from a reduction in congestion.

Among the C2I-technology, the highest benefits result from IVS speed systems with 2,338 Million EUR in the high market penetration scenario in 2020 and 4,050 Million EUR in 2030, and congestion benefits of 111 Million EUR in 2020 and 400 Million EUR in 2030.

These benefit calculations are an essential part for the benefit-cost ratio (BCR). For the C2C-technology, the BCR can be calculated comprehensively with the inclusion of safety effects. Potential efficiency effects (e.g. emission reductions were not empirically measured within the project).

For the C2I-technology safety effects and efficiency effects were measured and calculated for some scenarios. Nevertheless, the information of the efficiency effects is still incomplete which impedes the calculation of a full BCR. As a main case, the high market penetration scenario is applied.

Table 7: BCR for **2020** and 2030

BCR	Infrastructure cost - Efficiency	low	high	medium
BCR 2020	5-30	0.9	3.9	2.6
BCR 2030	10-50	2.0	6.8	6.0

The table shows two levels of BCR for infrastructure related systems. It shows the BCR in 2020 where it is assumed that 5% of the infrastructure costs already cover 30% of the efficiency. In 2030 the ratio decreases to: 10% of the infrastructure costs lead to 50% of the efficiency.

The table indicates a BCR between 2 and 6.8 depending on the market penetration rate. In consequence, in all cases an acceptable or even excellent BCR is achieved.

The results of the CBA for DRIVE C2X in terms of the benefit-cost rate (BCR) are most important for every kind of decision-maker interested in the evaluation of DRIVE before deciding on market introduction, deployment or promotion of C2X-systems.

5.2 Innovation impact

The second economic pillar dealt with the innovation impact of cooperative functions. From a business economics perspective, the user benefits are eventually evaluated with regard to the willingness to pay. The core idea of C2X technology is to improve traffic safety and traffic efficiency based on the main advantages of C2X as a fast, direct and reliable information flow in the immediate surroundings of the vehicle. However, it is a wide spread opinion that automotive customers are not willing to pay for safety functions, but expect them to be standard equipment of a car.

Based on this theory a special focus was put on the third type of C2X functions, the commercial functions and two business cases were defined for analysis. While business case 1 focused on the refinancing of infrastructure investments, business case 2 investigated the economical options to cover the OEM investments for the on board equipment.

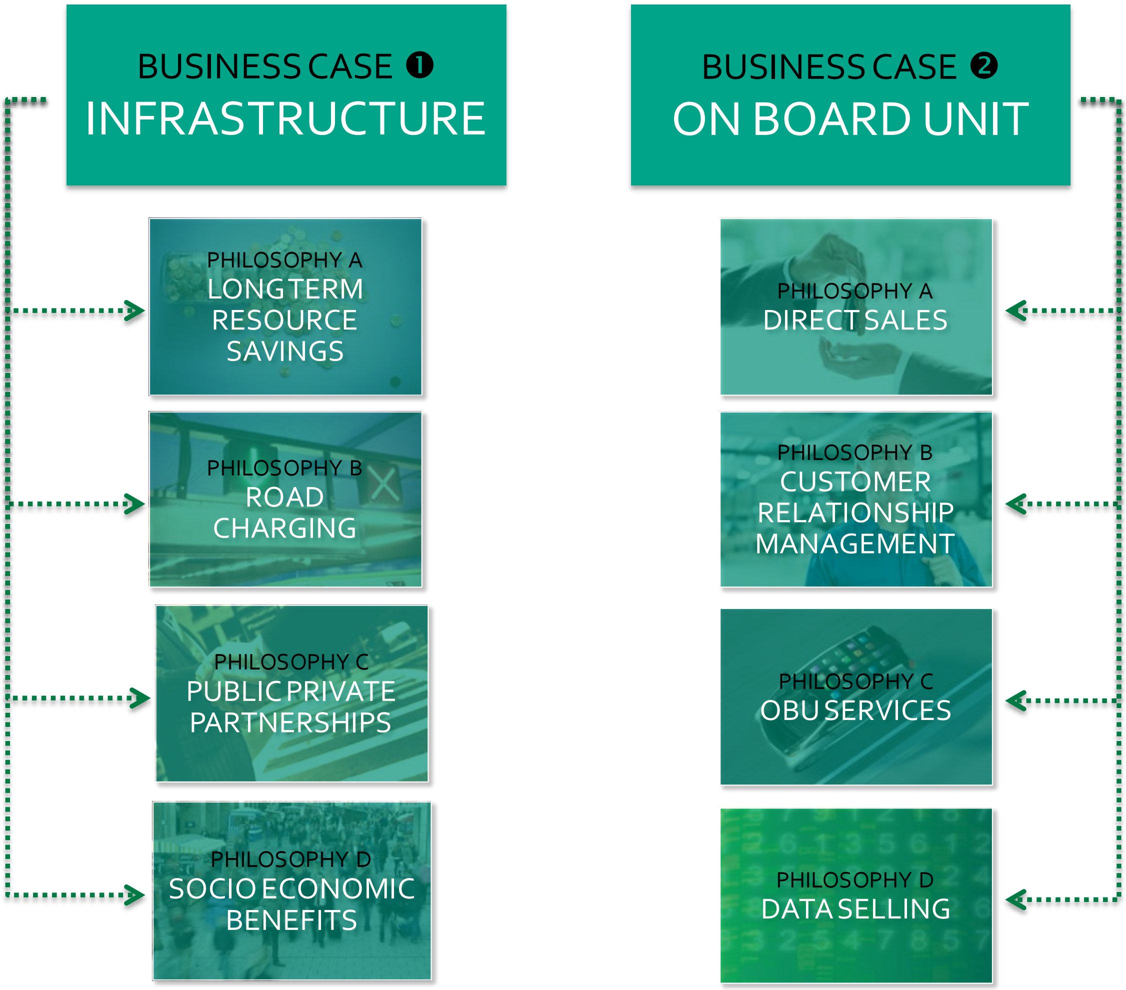


Figure 17: The two business cases: infrastructure and on board unit

To depict a broad range of relevant interests and influences along these two business cases a qualitative approach was applied. The different stakeholder needs have been identified, business models have been developed and recommendations were given to support successful market introduction. The purpose of the business modelling approach was to overcome the isolated perspectives of individual stakeholders about potential in- and outputs and to generate a structured decision base showing the interrelatedness of players and actions. Complemented by the value networks method and a simplified calculation approach the business potential of cooperative functions was analysed in-depth.

Based on 54 interviews with representatives across all important stakeholder groups evidence for economic viability could be shown. With regard to the refinancing of C2X infrastructure and C2X on-board unit a significant economic potential and a general belief in the economic power of cooperative systems were expressed. Unsurprisingly there was no single solution propagated, but a number of philosophies how to refinance and to leverage the market potential. A widely shared opinion was that a promising measure is the setting up of a C2X operating organization where business potential could be bundled, synchronized and shared, allowing various investors in C2X to participate. Cooperative systems' launch both as standard equipment and open platform to offer additional services by third parties is also considered to increase the economic potential significantly.

Despite the positive response towards the economic viability of cooperative systems, the interview partners identified many hurdles to overcome for a successful deployment. The main challenges and recommended mitigation strategies are listed in the table below, offering the decision base to the decision maker in public and private organizations.

Table 8: Deployment challenges and recommendations

Challenge	Main problems	Recommendations
Initiation	• Limited functionality at insufficient penetration rate • Low willingness to pay • No economies of scale	• Renewal of C2C-CC MoU • Synchronized launch of C2X OBU by all OEM as standard equipment • Invest in infrastructure to provide fast C2X experience • Equip emergency vehicles • Support retro-fit solution • Offer truck related services • provide hybrid solutions • support retro-fit solutions
Harmonization	• Synchronization on regional level • Interoperability (tolling, public transport) • Synchronization on regional & functional level	• Setup C2x operating company as centralized player • Provide EC initiated stakeholder forums • Offer boundaries for further development
Implementation	• Technological challenges • Uncertainty related to roles, system architecture & certificate framework	• Fast setup of organizational framework & responsibilities • Encourage PPPs to bring in industrial expertise for infrastructure setup • Support further HMI development
Collaboration	• Limited willingness to share data by OEM • Structural differences between automotive industry and adjacent industries • Incompatibility of public and commercial interests	• Support open C2X platform • Involvement of industry in infrastructure setup (PPP) • Point out win-win situations

Challenge	Main problems	Recommendations
Persuasion	• Low commitment of municipalities • Heterogeneous organisation of decision makers	• Financial incentives for participants in C2X city pilots • Organize road show to generate commitment of decision makers
Acceptance	• Potential doubts reg. data privacy & security in public • Perception of C2X benefits	• Transparent & sensitive communication • Early involvement of data privacy related stakeholders • Use of C2X in public transport

For the roadmap of deployment a first phase (2015~2020) is foreseen, where a consolidation is regarded as necessary, to leverage the synergy potentials. EC initiated forums and a joint roadmap could help to increase commitment and binding agreements. Within these forums role models need to be developed, business models discussed and final legal and technical decisions made (Root Public Key Infrastructure (PKI) certificates, data ownership and dedication of frequencies 5.9 vs. 5.8). Meanwhile forerunners among road operators and cities need to create case studies that prove C2X benefits in a real world scenario, financial incentives could help to encourage fast movers, especially among municipalities.

In a second phase (2020~) the aim will be to reach the broad market and use practice proven case studies to generate further commitment and implement solutions based on acquired experience and agreed standards.

5.3 Outreach of DRIVE C2X promoting cooperative systems

5.3.1 Standardization

The DRIVE C2X FOTs took into account aspects of research, deployment and standardization. With its mission, the DRIVE C2X system relies on mature standards as a solid basis for the impact assessment and a pre-requirement for deployment. During the whole course of the project DRIVE C2X was actively contributing to standardisation activities on regional as well as global level.

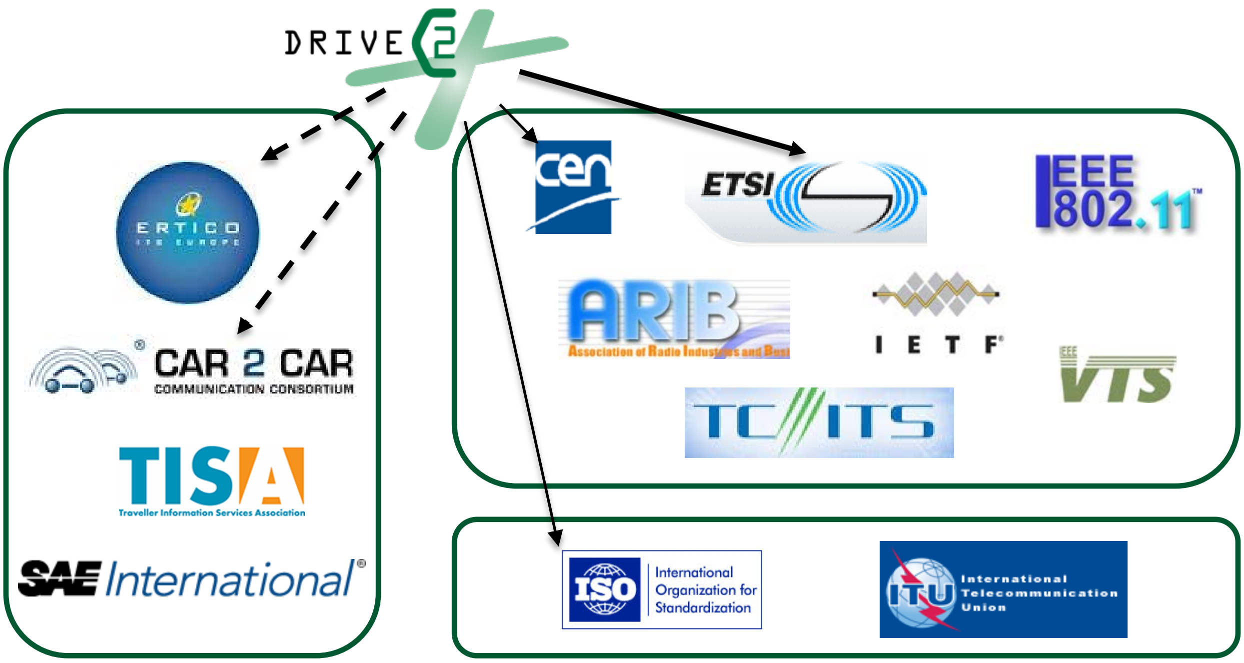


Figure 18: DRIVE C2X and the standardisation landscape.

In the context of DRIVE C2X, most relevant are standards developed by ETSI TC ITS and CEN TC 278 due to the mandate M/453 by the European Commission to develop a minimum set of standards for the deployment of cooperative ITS in Europe [G1][G2][G3][G4].

DRIVE C2X analysed the compliance of the system with standards for cooperative ITS. D55.1 "“Report on compliance of DRIVE C2X system and applications with international ITS standards” provided a list of standards mainly being part of the minimum set of standards in the mandate M/453, and assessed its relevance for the DRIVE C2X system. The list includes numerous standards, i.e. those related to the communication architecture, ITS Access Technologies, ITS Network and Transport, ITS Facilities, ITS applications, management and security. A set of 11 core standards was selected and analysed in more detail. As a conclusion of the analysis, the DRIVE C2X system is considered to be compliant with the core standards to an extent which is necessary for the execution of field operational tests; the compliance includes standards for the communication architecture, ITS-G5 radio, GeoNetworking protocols, facilities (CAM, DENM) and security.

For the standards that were completed after the DRIVE C2X system was implemented, in particular the core standard for DENM [P6] has got considerable effort and updates. While the DRIVE C2X system is compliant with the TS version of the CAM and DENM standard, the update and creation of the European Norm (EN) implies some changes that result into incompliance between the DRIVE C2X system and the upcoming implementations of the new standard versions. However, it can be stated that the changes in the standard are such that only very minor impact on the results of the impact assessment on safety and traffic efficiency – the primary goal of the DRIVE C2X system – is expected. Besides the CAM and DENM standards, a couple of other standards were completed, for example the standards for interfaces inside an ITS station, that were not considered, because they were not available at the time when the DRIVE C2X was implemented. Except the standards that are listed as gaps at the end of this section, several standards are regarded as having no impact on the impact assessment at all and are therefore not considered to be core standards.

For the standards that are in revision process, the DRIVE C2X system is compliant with the version that was published when the DRIVE C2X system specifications were fixed; typically, a TS version of the standard was available, which was the case for CAM [P5], GeoNetworking [P3] and BTP standard [P4]. For various aspects, the DRIVE C2X goes beyond published and draft standards and implements optional features that were then proposed for the standard revision. This implies that the DRIVE C2X system cannot be fully compliant with the latest drafts of the standards for CAM [D3], GeoNetworking [D1] [D4] and BTP [D2]. Instead, the DRIVE C2X project provided input to the standardization process and ensured the consistency of the overall standard set.

The compliance of the DRIVE C2X system with the network standards for GeoNetworking/BTP (ETSI TS 102 636) and facilities standards CAM and DENM (ETSI TS 102 637) was proven. This was achieved by conformance tests based on test standards (ETSI TS 102 870, ETSI TS 102 787, TS 102 868 and TS 102 869) and the conformance test bench developed and set up by ETSI STF 424. DRIVE C2X partners participated in the STF and even validated the test bench since they provided the DRIVE C2X reference implementation. Furthermore, the DRIVE C2X reference implementation successfully participated in the 1st and 2nd ETSI Cooperative Mobility System Plugtest in 2011 and 2012. The results of the ETSI Plugtests have shown that the DRIVE C2X system was interoperable with other vendors' implementation, such as from the ecoMove project. On November 2013, the 3rd Cooperative Mobility System Plugtest was held, where further standards were tested, such as those for ITS-G5 [P1] and security [P2][P7][D5].

For other standards, test specifications did not exist or were developed only recently. Therefore, they were not included in the previous Plugtests for interoperability testing. However, for these standards, compliance with the DRIVE C2X system could be verified by the analysis, which results are presented in D55.1.

Main gaps between standards and the DRIVE C2X system can mainly be identified in areas, where standards do not exist or are still at a preliminary stage.

5.3.2 Test site campaign

To support the project objective of establishing a European reference of C2X technology, DRIVE C2X initiated the cooperative driving campaign "Making cooperative systems cooperate". There were three particular reasons for having events on the DRIVE C2X test sites:

First, they served to promote DRIVE C2X and its outcome as the European reference for vehicular communication and showcased the project progress. Second, the events gave the test sites a platform to present themselves to the ITS community and to showcase their capabilities. Third, they were an effective means to establish a continuous information exchange with developers and potential users of ITS systems all over the world.

The cooperative driving campaign consisted of

- A unique series event format developed by and for DRIVE C2X: a series of test site events with driving demonstrations
- Driving demonstrations at the ITS World Congress 2012 and a dedicated press event during winter tests 2013. Another drive-by demonstration is planned for the DRIVE C2X final event on 16-17 July 2014 in Berlin, Germany.

- Flanking information and dissemination material addressing experts and general public, such as videos, brochures, and website.
- A consistent appearance during all events an all event items in terms project identity.

Figure 19: Banner **cooperative** driving campaign

The particular events were (a comprehensive description of all events can be found in D54.1 "Report on cooperative driving campaign"):

- DRIVE C2X @ simTD in Friedberg, Germany on October 13, 2011,
- DRIVE C2X @ DITCM in Helmond, The Netherlands on July 5, 2012,
- DRIVE C2X @ TSS in Gothenburg, Sweden on June 13-14, 2013,
- World Congress 2012 in Vienna, Austria on October 22-26, 2012,
- Winter test event in Tampere, Finland on December 11, 2013,
- In preparation: DRIVE C2X final event "DRIVE C2X on the road to deployment" at EUREF Campus in Berlin, Germany.

Early integration of stakeholders

The test site campaign brought together relevant stakeholders from an early project stage on. It updated all stakeholders of current status and results. The campaign initiated discussions about deployment strategies among expert groups. The campaign became a platform for other projects and initiatives to present themselves as well as for the project partners to present their own products and solutions, such as OEM-specific HMIs. One the technology was mature enough, the event opened during the general public, creating awareness among potential future users about the upcoming market introduction of C2X technology.

Target groups of the test site campaign were:

- ITS experts, infrastructure operators and decision makers from public authorities and industry
- Media representatives as multipliers for topics of public interest
- General public as future users of C2X technology

Increasing visitor numbers

DRIVE C2X invited to its first test event, DRIVE C2X @ sim^{TD}, at an early project stage. The project milestone M2.1 "DRIVE C2X methodology and system specification defined" was just completed. Nevertheless, 120 experts from industry, academia and science followed the invitation. This remarkable number of visitors resulted from an attractive programme focussing on driving demonstrations. Besides hands-on experience of DRIVE C2X technology, all events offered highly informative presentations followed by panel discussions as well as an attractive exhibition.

The success of the first event convinced DRIVE C2X partners to stick on the event concept. Therefore, DRIVE C2X @ DITCM (2012) and DRIVE C2X @ TSS (2013) were set up in a similar way with the driving demonstrations at the core, added by presentations and panels as well as exhibitions.

Together with the project progress and increasing visibility of DRIVE C2X, the number of visitors increased:

- 2011: 120 experts,
- 2012: 153 experts,
- 2013: 290 experts and visitors from general public.

All DRIVE C2X test site events got a very positive feedback from the participants. This is also reflected by the sharp increase in the number of visitors from test site event one to two and from two to three. The first test site event attracted 120 guests, which was not bad considering the increasing number of similar events organised by national and European project. The second event was visited by 153 guests from all over the world, which is an increase of close to 30%. The third event attracted nearly 300 guests (around 190 from expert community, over 100 from general public). The number of participants has increased by more than double.

During the ITS World Congress 2012 DRIVE C2X hosted two Special Interest Sessions and contributed seven technical papers to the conference programme. In addition, DRIVE C2X had a stand at the European Commission exhibition area. Referring to numbers of the congress organization, the ITS World Congress 2012 hosted on four expert days and one public day more than 10,000 participants from 90 countries and over 300 companies in the exhibition.

At this event, the DRIVE C2X reference system powered the Joint Cooperative Mobility demonstration by the Car 2 Car Communication Consortium and Austria's Testfeld Telematik. Due to a high number of demonstration vehicles, ca. 1,200 congress participants could experience 30-minute driving demonstrations on public roads.

The winter test event in Tampere, Finland, promoted a press event "Smart cars under winter test – hop on!" 10 media representatives followed the invitation to a press conference and to gain hands-on experience in a driving demonstration. The presented functions were Weather Warning and In-Vehicle Signage.

<u>Opening towards general public</u>

As the technology became more and mature and the project was more visible, DRIVE C2X partners opened-up the test site campaign for the general public as the last remaining target group. Therefore, the third test site event (DRIVE C2X @ TSS) was designed as a two days event: Day one was open for experts and day two for the public. For the expert day, DRIVE C2X stuck on the established concept of driving demonstrations, presentations, panels and exhibition. For the public day, presentations were kept to a minimum and revolved around the benefits of C2X technologies in general and the DRIVE C2X project in particular. The user-oriented DRIVE C2X video clip was shown and participants could join several tours of driving demonstrations where C2X technologies were presented and explained to the visitors by showcasing several DRIVE C2X functions.

The involvement of general public was also used to gather data on user acceptance by conducting interviews (for overview see: DRIVE C2X Cooperative Driving Campaign).

The DRIVE C2X cooperative driving campaign "Making cooperative systems cooperate" proved that experiencing cooperative driving and workshops at test sites is fruitful to foster the integration of the project. Moderated panel discussions initiated a real dialogue among the test sites and different national projects. The opening up for a constant stakeholder dialogue at the events contributed to number of collaboration activities beyond DRIVE C2X. Finally, it was an important means to use the feedback of visitors for open issues and get interview partners for the micro-economic study about business models and deployment strategies.

The events also showed that tangible experiences like driving demonstrations and exhibitions together with dedicated information are more appealing to the press than only press conferences or press releases.

5.3.3 General dissemination and liaison activities

As outlined in the dissemination plan, the task of dissemination in DRIVE C2X was twofold: On the one hand the project aimed at reaching all stakeholders relevant for a fast deployment of C2X technologies and infrastructure on European road systems. On the other hand the future user was in the focus of the project communication: It is only by the support of the general public that a comprehensive deployment of C2X technologies will succeed.

With the strict deployment orientation the project used well known dissemination channels such as the website or a project brochure. But DRIVE C2X went beyond these activities. Road site events with stakeholder panels were a core part of the project dissemination in the project years generating huge interest in the expert community and at user side. During the final event stakeholder perspectives on deployment strategies will be an important part of the event.

Besides, special means such as videos that aim at the general public and are distributed through various internet platforms were used. All material was available at an early stage of the project and could be used from the beginning onwards. DRIVE C2X focused on producing descriptive material accompanying the project (for overview see: The DRIVE C2X dissemination material).

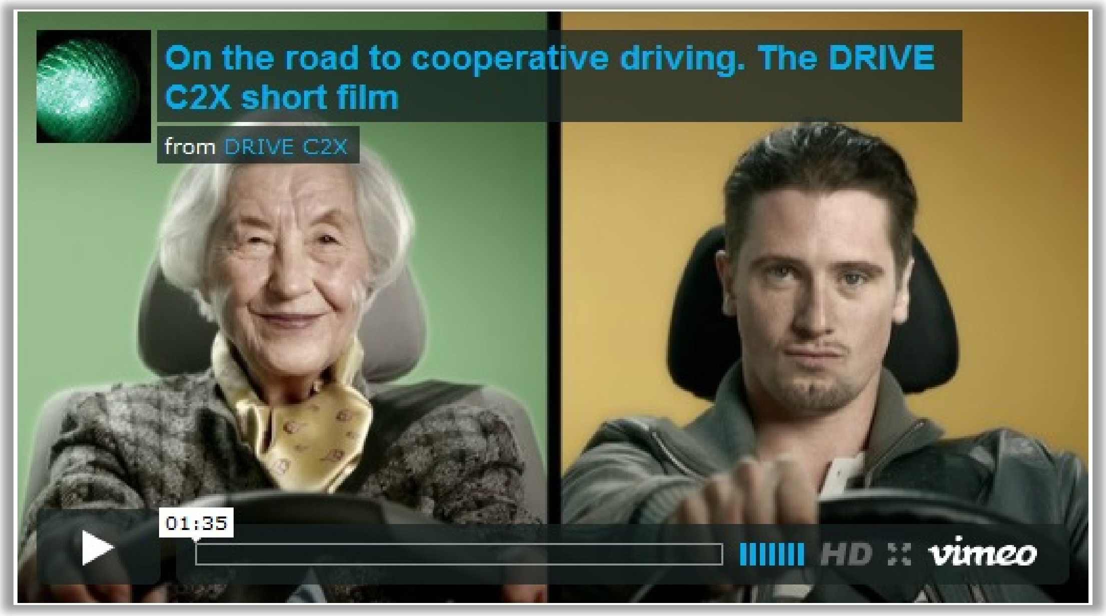


Figure 20: DRIVE C2X short film on cooperative driving

DRIVE C2X actively involved initiatives and other project in its project activities. External projects were invited to conferences and exhibitions during the DRIVE C2X test site events. There also were a number of joint activities – during the test site events, e.g. with simTD as well as other activities, such as the 19th ITS World Congress (for overview see: Participation in ITS World and European Congresses).

DRIVE C2X regularly disseminated results towards initiatives such as FOTnet with newsletter contributions and presentations, EasyWay via common workshops and the Car 2 Car Communication Consortium. DRIVE C2X contributed to the standardisation via ETSI events and working groups.

DRIVE C2X even went beyond European liaison. The consortium built close ties to Japanese partners and to the U.S. Department of Transportation (for overview see Main liaison partners and activities).

As a result, DRIVE C2X could reach its goal of becoming the European reference and integrating platform for national FOTs and European car-2-X communication with regards to test results, standards and deployment strategies.

6 Lessons learnt

6.1 Project management and organisational issues

Even though DRIVE C2X obtained promising results from the traffic safety and a potential to solve environmental issues point of view as well as good prospects for the market introduction of cooperative applications, there were, however, a number of things the project could have done better. These are discussed in the following.

Often it is the case that one knows only afterwards how the project should have been optimally run and managed. This is the case with DRIVE C2X too. Here below are identified and discussed some issues that were not anticipated beforehand but solved in the course of the project work causing delay and extra effort to the management and partners overall. This chapter hopefully serves in a small part the following projects.

1st of January is not an optimal start for a project due to Christmas holiday extending in some countries over the mid- January. After the vacation period it takes some weeks until all partners and people are back in the working mode. The first month in DRIVE C2X was over without too much action. Also other vacation periods need to be taken into consideration when doing project work, and especially differences in vacationing across Europe.

One of the most important tasks in the management is ensuring smooth communication between partners. Management motivation to solve issues makes things happen. If emails are not answered, try to call people directly. Calling is overall the best way of getting in touch and making things happen.

Active communication between the management team and sub-project leaders is needed for the management to be aware of the project status, and the same line extends to work package and task leaders. There is never too much communication between the project partners.

Consortium agreement issues have been taking too much time of the project management work. It is imperative that the partners agree well in advance on the issues and open questions listed. It is recommendable that the legal advisors in partner companies keep active contact to one another and the project management.

Work package leaders have to be aware, and in case they are not, made aware of their responsibilities: taking care of all contributions in the project and act appropriately. The actual development & testing work was carried out on the work package/task level. All the focus needs to put on that level.

Concerning low- or non performing partners, early actions are very important to curb the escalation of problems and for the success of the whole project. This is because the duration of many work packages, especially the so called orientation part that needs and requirements represent, is rather short, and the other work packages are dependent on the earlier ones, accumulating the delay easily.

Overall, management responsibilities start already in the project planning phase by making sure that you have a team of capable and committed people, and then later on, taking care of a good team spirit. In a European context with different cultures and ways of handling things, this is a challenging task and needs definitively previous experience in managing European projects.

Test use agreements - or simple consent forms - may limit re-use of data and analyses by 3rd parties, unless specific care is taken when formulating the wording. Test users must agree to share their log data for scientific and collaborative research.

When planning events poses a challenge: Consider vacation period when planning events or trying to get input from universities, and take into consideration possible parallel events.

Liaison with other projects: Even if it is desirable (also from EC point of view) the necessary fit needs to be given such as time plan, technology and commitment of key people. Check carefully whether the partners are capable of organizing big events with about 150-200 international guests. Collaboration concerning events: If you are jointly involved in a major event, make sure that you can perform independently – if problem arise, everyone takes care or their interests – no matter what was agreed.

Concerning dissemination, if you need input for dissemination material (website, brochure) from the technical experts, be aware that your topic comes last in their priority list.

6.2 Common methodology

DRIVE C2X was a Field Operational Test procedure with two very different expertise areas involved, on one hand side wireless communication and mechanical engineers, and then, on the other hand side behavioural scientists having testing experience and statistical thinking on human behaviour in traffic. In the beginning of the project these two or even three different groups were talking 'different languages' in terms of tests planning, and they all were needed in the process. It took time before these different groups fully understood each other. This was to be anticipated but not well enough to get these groups together to discuss with each other face-to-face. Communication by emails and conference calls was not an optimal solution to weld these groups into one.

This was very well seen when different expertise came together to discuss the technical and behavioural requirements of the data logging system, so what was possible to log and what was needed to be logged to indicate given behavioural patterns of subjects. Furthermore, it was not easy to make all parties understand at first common methodological principles like what does it mean when we talk about controlled tests having dedicated control groups or – like here - control measurements (= baseline measurements). This led to different interpretations and caused delays in the project. Furthermore, the importance of acquiring information on the road scene ahead of test vehicles needed a lot of efforts to have a common understanding that is imperative to know what is happening in the environment the test vehicles are travelling along. If this knowledge is missing, it is not possible to interpret the data or draw conclusions from the data. Moreover, the need for an efficient tool to define RQs and measurements was recognized to speed up the process.

The decisions about the needed measurements will be made quite straightforward as soon as the research hypotheses are formulated. Typically, there is a time pressure in this phase of the project; there are several parallel activities going on which are dependent on each other's outcome: fine-tuning of functions, formulating of research hypotheses, defining the indicators and measurements, specification of a reference system and logging needs. This calls for an efficient approach and tools to generate the research hypotheses efficiently. Furthermore, it must be taken care that the research hypotheses are scientifically justified; they reflect the theories of substance areas and that they are consistent for all analysed impact areas.

Concerning the methodology, discussions on methodology details like methods must start very early, especially among function owners, data management and evaluation team to enable rich conclusions from the data obtained. It is also to be noted that it is not possible to provide very detailed information about test designs, but rather give general design principles of applying the principle of control in measurements. Test site specific features define how the actual tests are planned and can be realised. Developing the testing procedure is an iterative process. Test manual like FESTA can't provide with precise answers to testing. It is more like a check-list for pilots when taxiing before the take-off.

Partners responsible for impact assessment were involved in an early phase to contribute in selecting the functions for impact assessment. Criteria for selection were developed. One of them was the expected magnitude of impact. Later the analyses revealed and emphasized the importance of this criterion – if the functions are focused on a limited area (short road section) or a limited problem (rarely occurring circumstances) only limited benefits can be expected. At least the total selection of functions should preferably be such that the functions together address significant problems either in safety, environment, mobility or efficiency.

Originally, the intention was to use the same HMI in all DRIVE C2X. This, however, turned out not to be possible as some national test sites would have missed the opportunity to get user experience in real use context and feedback to test site specific solutions. This resulted in some complexity in user acceptance measures. Therefore, it is strongly recommended that major differences in HMI design should be avoided in field tests. Furthermore, use of different HMIs restricts conclusions by national differences – one cannot decide e.g. whether the differences found depend on HMI or some other cultural or environmental reason.

For further comments on the methodology part, please see Chapter 5.3 "Lessons learned" of Deliverable D11.4 "Impact of cooperative systems and user perception".

6.3 Building upon previous work

DRIVE C2X was in practise a direct continuation of PRE-DRIVE C2X work and taking cooperative driving applications to field tests with so called naive subjects. Even though the various functions developed in PRE-DRIVE C2X were successfully demonstrated at the final event, it was still a long way to go to mature cooperative driving applications for field conditions. The amount of work needed to make a functioning reference system and communication equipment interoperable between different OEMs and suppliers was much more laborious than could be estimated in advance. Furthermore, too few face-to-face meetings at the system test site were held to make all the technical staff to get together with test vehicles. Usually, when all the testing staff got together, the problems were solved rapidly. Eventually, the reference application software development problems were too much tried to be solved by mailing causing unnecessary delays.

6.4 Piloting

The issues discussed above ate up time from piloting when testing the whole FOT was needed. This is a crucial phase for ensuring that data collection in the field tests can be realised precisely as planned. That time was too short practically on all test sites. The time for piloting was mainly used to eliminate errors still found in the reference system. In these kind of large-scale FOT the time needed for piloting would be ideally approximately six months; this time that period was cut down to some weeks only. Piloting consists of having naive subjects to test the system with functions implemented along the test route, recording the data and analysing it, going through the subjects' interviews, so ensuring the whole test system functionality. Usually there are a number of issues arising that needs to be handled to have the complex testing process function perfectly. Frequently, this time need the system for testing-ready is underestimated in practically all FOTs.

Piloting should be able to proceed so that the first data is sent as soon as possible for the analysts to carry out the first estimate on the success of the tests overall and test designs in particular.

6.5 Data management and handling

The DRIVE C2X project was about very much dealing with acquiring data and processing it for the analysis. For this reason, here the challenges and issued faced are treated in a more detail manner to provide the following projects with concrete advice on how to address issues in data management.

DRIVE C2X application developers received a list of logging and information requests from a group of analysts. The application developers also chose to log various messages for debugging and technical assessment purposes. Initially, they had too much freedom to design logging - and more than 10 people were developing logging separately. The result was that many application/component developers suggested unconventional logging styles which would have made analyses difficult (hundreds of message types). Some also accidentally spammed the joint log files with high-frequency messages of little value (e.g. engine temperature logged at 20 Hz, GPS was logged repeatedly by many). After Data Task Force was formed, it required an effort of many months before logging became more harmonized and key content was validated. As a lesson learnt, a tight control over logging development is necessary from the project start and a small group in control. Logging could have been a separate component controlled by the Data Task Force.

A single and unique logger should be used on all test sites to decrease the complication resulting from checking the features of different logging systems.

On a positive note, this project succeeded in logging very rich information content to enable many analyses.

Validation of logging is an important part of FOT preparations. It can also bring about bugs in the system itself - we noticed problems e.g. in handling situations where GPS fix was lost. DRIVE C2X created dedicated SW for validation purposes, which effectively supported manual checking. During FOT execution, the same validation SW allows for frequent and detailed checking of collected data. The SW can detect missing information and indicate system failures. Such problems are important to act on as early as possible, to avoid losing data and having to repeat expensive tests. Dedicated software for log file validation can be considered as a best practise. It was suggested also by the TeleFOT and euroFOT projects.

In integrated projects, where many partners collaboratively analyse FOT data, there are several benefits of using a common storage for log data and related test documentation. A central storage enables easy access to data and monitoring that all necessary documentation becomes available. It serves also as a final storage, where tests are documented in detail - including study designs, test execution diaries, contact details and also statements on future data sharing. It enables harmonized post-processing and analysis of data. A central storage was considered a best practise already during the TeleFOT project.

Compiling metadata documentation is absolutely necessary if FOT data is to be easily shared with other organizations. Test sites need to document several topics also for their own use, when e.g. dates, times and test details are still remembered. Data sharing hasn't been a main topic in previous ITS projects, unlike e.g. in medical testing, so the engineers need to be trained about data sharing practises.

Harmonizing data post-processing enables analysts to more easily cover several tests in collaborative projects. Common post-processing such as map matching and calculation of indicators reduces individual analysis work and it also ensures comparability of indicators across test sites. A few professional programmers can implement key indicators based on analyst wishes. Summarized content also gives an index into raw data. In FOTs, size of the raw data can reach terabytes and analyses may prove to be unpractical without aggregation steps.

7 Conclusions

DRIVE C2X completed successfully extensive road tests on upcoming cooperative V2I and V2V applications serving totally eight different functions most of which were safety-related. The results clearly showed the great potential cooperative systems have based on both user behaviour and preference measurements. Transportation systems with vehicles included are joining the connected world, which is witnessing a huge technological change happening at the moment. This megatrend is changing the world rapidly making also travel safer and more convenient for all of us.

It is forecasted that over the next 10 years billions of connected devices will converge into intelligent and programmable systems that will have the potential to improve lives in a vast number of areas: time and availability, transportation and resource consumption, learning and work, health and wellness, and many more [7]. Automotive industry will play an important role in this change that can be compared to the advent of Internet 20 years ago.

Not only people become connected but vehicles and devices and with the precision that even a light bulb can have an IP address. This all means that information can be received and transmitted by quantities and for needs never been anticipated before. For drivers this means better situational awareness and a possibility to be prepared hazards that were unanticipated earlier. For infrastructure operators and fellow drivers on roads this means that vehicles become intelligent sensors that collect, transmit and receive information for safety and fluency of traffic as well as enable the planning and changing routes and driving styles at a short notice.

Compared to early safety systems that were at first passive only and reactive at the point of impact and later developed towards active systems intervening a few moments before the driver lost control and followed by Advanced Driver Assistance Systems providing information 150 – 200 ahead of the vehicle, cooperative systems can assist the driver even minutes ahead of a potential harm. The safety systems are in a sense taking control of the space further ahead of the driver than ever before. This all means greater safety and more relaxed driving.

The results of the DRIVE C2X project show that most drivers had a positive attitude towards all functions tested. They especially welcomed functions which allowed them to receive warnings well in advance before an event or obstacle to be able to avoid it, especially of on the road and causing traffic to slow down. Users mentioned Car Breakdown Warning, Approaching Emergency Vehicle, Green Light Optimal Speed Advisory and Speed Alert as helpful and/or bringing added value. Car Breakdown Warning and Approaching Emergency vehicle warning were perceived as novel applications by many users. These warnings helped drivers to stay alert.

Dynamic events were considered fundamental for the DRIVE C2X system since they can help raising attention to variations from the normal conditions. Vehicle-to-vehicle communicating functions were considered more innovative and appealing than infrastructure-to-vehicle functions.

Negative feedback from all test sites was that the system gave too many warnings, especially on speed violations. They would prefer continuous information of the current speed limit and to receive warnings only in especially dangerous places. Drivers also wished for local dynamic speed advice e.g. in curves or during adverse weather. The timing of messages was considered mostly too late. Drivers wanted to receive the warnings well in advance in order to be helpful in making decisions.

Concerning the way Field Operational Tests are carried out, there are doubts how cost effective they are in providing results needed. With a wide variety of partners with different readiness for the FOT preparation and methodological differences in data collection and handling, test design and timing of activities, a lot of resources are wasted when trying to bind together diverse efforts under common methodological principles. Rather, instead of large-scale FOT with a great number of partners, it is worthwhile considering whether the same results could be obtained with a smaller consortium observing strictly the same methodology and test design all the way from logging to HMI and timing of activities.

However, there were no doubts about the effectiveness of the dissemination activities performed in DRIVE C2X. The strong and ever increasing participation in the three DRIVE C2X test site events and the feedback that was received after the events proved that interest in new technologies can be fostered with a well-designed communication campaign, which breaks new ground by using communication means different to the ones chosen by other projects.

8 Glossary

Abbreviation	Meaning
AEV	Approaching emergency vehicle
API	Application Programming Interface
AU	Application Unit
BCR	Benefit-cost ratio
CBA	Cost benefit analysis
CBW	Car Breakdown Warning
CCU	Car Communication Unit
CEN	The European Committee for Standardization (CEN, French: Comité Européen de Normalisation)
CIS	Central ITS Station
CODAR	Monitoring tool (not an acronym)
CT	Controlled test (having reference measurements)
CTI	Centre for Testing & Interoperability
C2C	Car-to-Car communication
C2I	Car-to-Infra communication
DB	Data base
DENM	Decentralized Environmental Notification Message
DGT	Spanish Ministry of Traffic
DITCM	Dutch Integrated Testsite Cooperative Mobility
DP	Data processing
DRIVE C2X	DRIVing implementation and Evaluation of C2X communication technology in Europe
EEBL	Emergency Electronic Brake Light
EC	European Commission
ETSI	European Telecommunications Standards Institute
FESTA	Project Field opErational teSt supporT Action
FOT	Field Operational Test (Field trial, Field test, Field experiment)
ftp, FTP	File Transfer Protocol
FTS	Functional Test site
GLOSA	Green Light optimal speed advisory
GPS	Global Positioning System
HDD	Hard Disk Drive
HMI	Human Machine Interface (or interaction)
HW	Hardware
IP	Internet Protocol
ITS	Intelligent Transport Systems
ICT	Information and Communication Technology
ITS	Intelligent Transport Systems
IVS	In Vehicle Signage
LogPro	Log procurement and inventory management software
ND	Naturalistic test (non-controlled test)
OEM	Original Equipment Manufacturer
OSGi	Open Service Gateway initiative
OW	Obstacle Warning
PCW	Post-crash Warning
PIS	Personal ITS Station

Abbreviation	Meaning
PKI	Public Key Infrastructure
POTI	Position and Time
RIS	Roadside ITS Station
RSU	Roadside Unit
RWW	Road Work Warning
SCORE@F	Système COopératif Routier Expérimental Français (French field operational test for cooperative systems)
simTD	Sichere, intelligente Mobilität, Testfeld Deutschland
SP	Sub-project
SST	Small-scale test site in DRIVE C2X
SVW	Slow Vehicle Warning
TCP	Transmission Control Protocol
TE	Test execution
TJAW	Traffic jam ahead warning
TMC	Test Management Centre
TOC	Test Operator Client
TS	Test Site
USB	Universal Serial Bus
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
VIS	Vehicle ITS Station
VDP	Vehicle Data Provider
VsFs	Versuchsflottenstützpunkt – eng.: Test fleet base
WebScE	Web Scenario Editor
WP	Workpackage
WW	Weather Warning

9 Partner list

The main source of information about the project is the public website http://www.drive-c2x.eu/project.

Ben ef. no.	Beneficiary name	Short name	Country
1	Daimler AG	DAI	DE
3	Audi AG	AUDI	DE
4	Volvo Personvagnar AB	VCC	SE
5	Centro Ricerche Fiat S.C.p.A.	CRF	IT
7	Renault s.a.s. represented by GIE REGIENOV	REN	FR
8	Peugeot Citroen Automobiles S.A.	PSA	FR
9	Ford Forschungszentrum Aachen GmbH	FFA	DE
39	HITACHI Europe SAS	HIT	FR
11	NEC Europe Ltd.	NEC	UK
13	Renesas Electronics Europe GmbH	REE	DE
14	PTV Planung Transport Verkehr AG	PTV	DE
16	Facit Research GmbH & Co. KG	FACIT	DE
17	Inria	INRIA	FR
18	Bundesanstalt für Strassenwesen	BAST	DE
19	Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek	TNO	NL
20	Deutsches Zentrum für Luft- und Raumfahrt e. V.	DLR	DE
21	Valtion Teknillinen Tutkimuskeskus	VTT	FI
22	Technische Universität Graz	TUG	AT
23	Karlsruher Institut für Technologie	KIT	DE
24	Universitatea Tehnica din Cluj-Napoca	UTC	RO
25	Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V. FOKUS	FHG	DE
26	Interuniversitair Micro-Electronica Centrum VZW	IMEC	BE
27	University of Surrey	UNIS	UK
28	European Center for Information and Communication Technologies GmbH	EICT	DE
29	European Road Transport Telematics Implementation Coordination	ERT	BE

	scrl		
30	Chalmers Tekniska Hoegskola AB	SAFER	SE
31	Autostrada del Brennero SpA	BRE	IT
32	Hessische Straßen- und Verkehrsverwaltung	HLSV	DE
33	Delphi Deutschland GmbH	DEL	DE
34	Adam Opel AG	OPEL	DE
35	Fundación para la promoción de la innovación, investigación y desarrollo tecnológico de la industria de automoción de Galicia	CTAG	ES
36	French institute of science and technology for transport, development and networks	IFSTTAR	FR
37	Neavia technologies SAS	NEAVIA	FR
38	YGOMI Europe GmbH	YGOMI	DE

No.	Support partner name	Short name	Country
1	Honda R&D Europe (Deutschland) GmbH	HONDA	DE
2	Robert Bosch GmbH	BOSCH	DE
3	Continental Teves AG & Co. OHG	CONTI	DE
4	Denso Automotive Deutschland GmbH	DENSO	DE
5	City of Tampere	TAMPERE	FI
6	Nokian Renkaat OY	NOKIAN	FI
7	Vector Informatik GmbH	VECTOR	DE
8	Hochschule für Technik und Wirtschaft des Saarlandes	HTW	DE
9	Rijkswaterstaat Centre for Transport and Navigation	RWS	NL
10	BMW Forschung und Technik GmbH	BMW	DE
11	Testing Technologies IST GmbH	TT-IST	DE
12	ETSI Centre for Testing and Interoperability	ETSI-CTI	FR
13	Yamaha Motor Co., Ltd.	YAMAHA	NL

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1. Dinguis, TA., Neale, VL., Sudweeks, JD., Ramsey, DJ. (2006) The impact of driver inattention on near-crash risk: An analysis using the 100-Car naturalistic driving study data. Journal of Neuroscience Research. 91 (3) 321-334.

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4. Krajzewicz D., Bieker L., Erdmann J., 2012, Preparing Simulative Evaluation of the GLOSA Application, ITS World Congress.

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10.1 Standards: general references

[G1] European Commission, Enterprise and Industry Directorate-General: "Standardization mandate addressed to CEN, CENELEC and ETSI in the field of information and communication technologies to support the interoperability of co-operative systems for intelligent transport in the European community", Mandate M/453, October 2009, URL: http://www.etsi.org/WebSite/document/aboutETSI/EC_Mandates/m453%20EN.pdf

[G2] CEN TC 278, ETSI TC ITS: "Joint CEN and ETSI Response to Mandate M/453", April 2010, URL: http://www.etsi.org/WebSite/document/Technologies/First_Joint_CEN_and_ETSI_Response_to_Mandate_453.pdf

[G3] European Commission, Enterprise and Industry Directorate-General: "Joint CEN and ETSI Response to Mandate M/453 – EC Comments", June 2010, URL: http://www.etsi.org/WebSite/document/Technologies/EC_Commments_June_2010.pdf

[G4] CEN TC 278, ETSI TC ITS: "1st joint CEN/ETSI-Progress Report to the European Commission on Mandate M/453", Version 2-06, April 2011, URL: http://www.etsi.org/WebSite/document/1st_Joint_CEN_ETSI_Progress_Report_Mandate_453.pdf

10.2 Published ETSI standards

[P1] ETSI ES 202 663 V1.1.1 (2010-01): “Intelligent Transport Systems (ITS); European profile standard for the physical and medium access control layer of Intelligent Transport Systems operating in the 5 GHz frequency band”

[P2] ETSI TS 102 867 V1.1.1 (2012-06): “Intelligent Transport Systems (ITS); Security; Stage 3 mapping for IEEE 1609.2”

[P3] ETSI TS 102 636-4-1 V1.1.1 (2011-06): “Intelligent Transport System (ITS); Vehicular communications; GeoNetworking; Part 4: Geographical addressing and forwarding for point-to-point and point-to-multipoint communications; Sub-part 1: Media independent functionalities”

[P4] ETSI TS 102 636-5-1 V1.1.1 (2011-02): “Intelligent Transport Systems (ITS); Vehicular Communications; Part 5: Transport Protocols; Subpart 1: Basic Transport Protocol”

[P5] ETSI TS 102 637-2 V1.2.1 (2010-04): "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 2: Specification of Co-operative Awareness Basic Service"

[P6] ETSI TS 102 637-3 V1.1.1 (2010-09): “Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 3: Specifications of Decentralized Environmental Notification Basic Service”

[P7] ETSI TS 102 941 V1.1.1 (2012-06): “Intelligent Transport Systems (ITS) Security Identity, Trust and Privacy Management”

10.3 Draft ETSI standards

[D1] ETSI EN 302 636-4-1 V0.2.0 (2012-12): “Intelligent Transport System (ITS); Vehicular communications; GeoNetworking; Part 4: Geographical addressing and forwarding for point-to-point and point-to-multipoint communications; Sub-part 1: Media independent functionalities”

[D2] ETSI EN 302 636-5-1 V0.0.4 (2012-12): “Intelligent Transport Systems (ITS); Vehicular Communications; Part 5: Transport Protocols; Subpart 1: Basic Transport Protocol”

[D3] ETSI EN 302 637-2 V0.0.13 (2013-01): “Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 2: Specification of Co-operative Awareness Basic Service”

[D4] ETSI TS 102 636-4-2 V0.0.10 (2012-10): “Intelligent Transport Systems (ITS); Vehicular Communications; GeoNetworking; Part 4: Geographical addressing and forwarding for point-to-point and point-to-multipoint communications; Sub-part 2: Media dependent functionalities for ITS-G5A media”

[D5] ETSI TS 103 097 V0.0.6 (2012-12): “Intelligent Transport Systems (ITS); Security; Security header and certificate formats for ITS G5”

11 Annex

An overview of the work to disseminate targets and results of DRIVE c2X is given in the tables below.

11.1 Main liaison partners and activities

Dissemination and liaison partner	Activities
EU US ITS COOPERATION	• Meetings initiated • Focus on US Model deployment during third test site event DRIVE C2X @ TSS
EU★US★JAPAN ITS COOPERATION	• Japanese associated partners • DRIVE C2X presentation at 20th ITS World Congress in Tokyo, JPN via Japanese partners
MLIT Ministry of Land, Infrastructure, Transport and Tourism	• Visit from Japanese MLIT at • DRIVE C2X system test site in Helmond, December 2012 and simTD DRIVE center in Frankfurt, February 2013
CAR 2 CAR COMMUNICATION CONSORTIUM	• Showed posters at Car 2 Car Forum • Invited to DRIVE C2X SIS during ITS WC 2011 • Multiplier of news
EasyWay	• Common workshops • Invited to DRIVE C2X SIS during ITS WC 2011
FOT-NET	• Contribution to newsletter • Joint dissemination channels e.g. at iMobility stand at ITS WC • Best practice fact sheet delivered
Rijkswaterstaat	• DRIVE C2X specification made available for procurement of IRS • Active support membership and collaboration in several WPs

Dissemination and liaison partner	Activities
EUCAR	• Participation in annual conferences • Contributions to poster book
ETSI	• Intense collaboration via WP 55 "standardisation" • Common workshops – Plug-tests
PRESERVE	• Joint workshop at General Assembly 2012 • Several test meetings • Joint demonstrations at 19th ITS World Congress 2012 • Integration meeting at NEC Europe 2013 • DRIVE C2X VIS and RIS reference systems successfully integrated with PRESERVE security module
COMeSafety2	• Partner involvement via WP55 • Contribution to webinar "European International and National FOTs for Cooperative ITS evaluation" • Contribution to newsletter • Common presentation during IAA motor show, Frankfurt/Main 2014
eCoMove	• Participation in eCoMOve events • Integration into DRIVE C2X panel discussions and events
FOTsis	• Interoperability of DRIVE C2X system and infrastructure side developed by FOTsis - possibly via CTAG on Spanish test site • Exchange of deliverables • Integration into DRIVE C2X events and conferences
TeleFOT	• Continuous exchange on FOT methodology

Dissemination and liaison partner	Activities
	• Participation in final event
	• Continuous exchange on FOT methodology • Participation in final event
	• Joint demonstration during third test site event DRIVE C2X @ TSS
	• Exchange on roadmap about initial deployment of Cooperative ITS in Europe • Interview partners for deployment strategies
	• Contribution to test site event DRIVE C2X@TSS • Continous exchange on project results • Exchange on city deployment strategies and stakeholder interviews
	• Stakeholder intervies about the impact of C-ITS on energy efficiency
	• Stakeholder intervies about technology improvements of C-ITS regarding positioning, reliability and user acceptance

11.2 Participation in ITS World and European Congresses

Event	Location, date	Contents
10th ITS EUROPEAN CONGRESS Helsinki, Finland | 16-19 June 2014	Helsinki, Finland June 16-19, 2014	• Contribution to SIS • Technical paper
20th ITS WORLD CONGRESS TOKYO 2013	Tokyo, Japan October 15-18, 2013	• Proposal "Field Operational Testing of Cooperative Systems - A Comparison between Europe and U.S.A." integrated into a Stakeholder Workshop with SIS from Asia Pacific and the Americas regions. • Date Management in Field Operational Tests, Sami Koskinen, VTT • User Evaluation of Cooperative C-ITS, Cécile Barbier, REN, et al
9th ITS EUROPEAN CONGRESS Dublin, Ireland | 4-7 June 2013	Dublin, Ireland June 4-7, 2013	• Contributions to FOTsis SIS • Technical Evaluation of CS – Experience from DITCM Test Site, Bart Netten, TNO et al

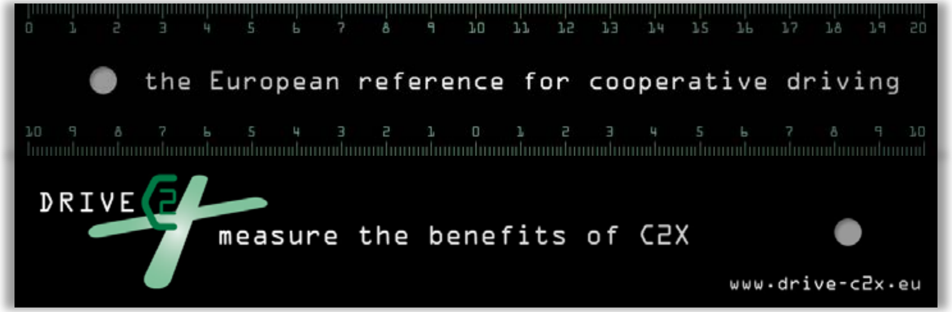
Event	Location, date	Contents

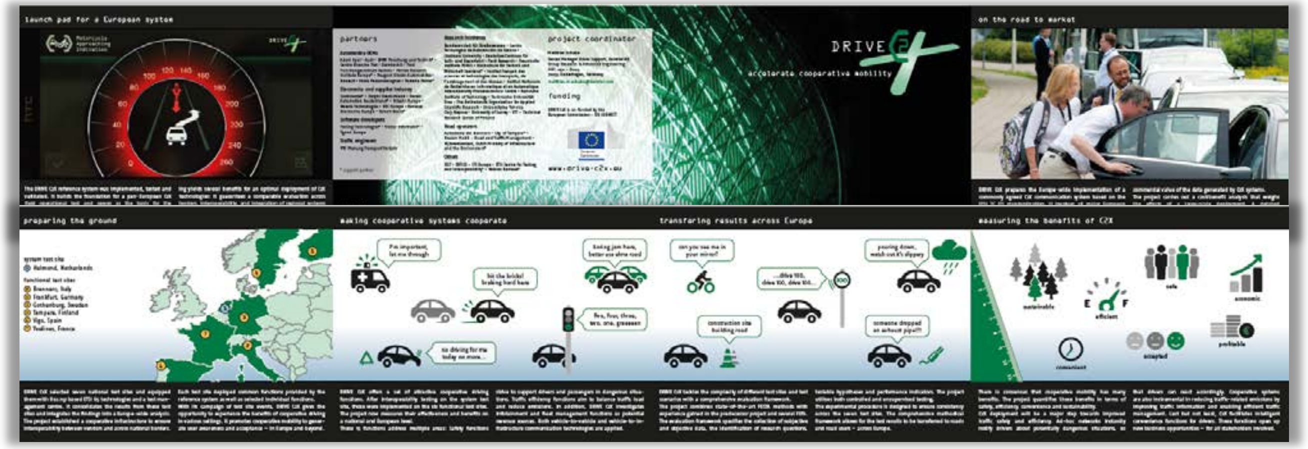
19th **ITS World Congress**
Vienna, Austria
22 to 26 October **2012**
smarter on the way
	Vienna, Austria
	October 22-26, 2012
	
	(also part of Cooperative Driving Campaign)
		• Driving demonstration
		• Posters
		• 2 Special Interest Sessions
		    • SIS38 – Business models and revenue sources for C2X communication with about 60 participants
		    • SIS68 – Global deployment of Car-2-X communication technology – A technical perspective on commonalities and similarities with about 75 participants
		• 7 technical papers released
		• Press release for joint driving demonstration of C2C Communication Consortium and Testfeld Telematik
		• Press conference for booth "Cooperative Driving" with Austrian Ministry for Transport, Innovation and Technology, Doris Bures

18TH ITS World Congress
2011
ORLANDO
	Orlando, FL, USA
	October 17-20, 2011
		• Technical session "V2V Communication: Evaluation and Assessment"
		    • Presentation "Using EuroFOT Operational Experience in DRIVE C2X"
		    • Presentation "Starting European Field Tests for CAR-2-X Communication: The DRIVE C2X Framework"
		• DRIVE C2X SIS "Field operational tests as enabler for cooperative mobility in Europe?" with speakers from DAI, HIT, C2C-CC, EasyWay, AustriaTech and about 50 participants
		• Presentation at SIS "Vehicle-IT Convergence for the Fully Networked Car", organised by Korea Transport Institute
		• Presentation at SIS "FOT: moving ahead towards ITS

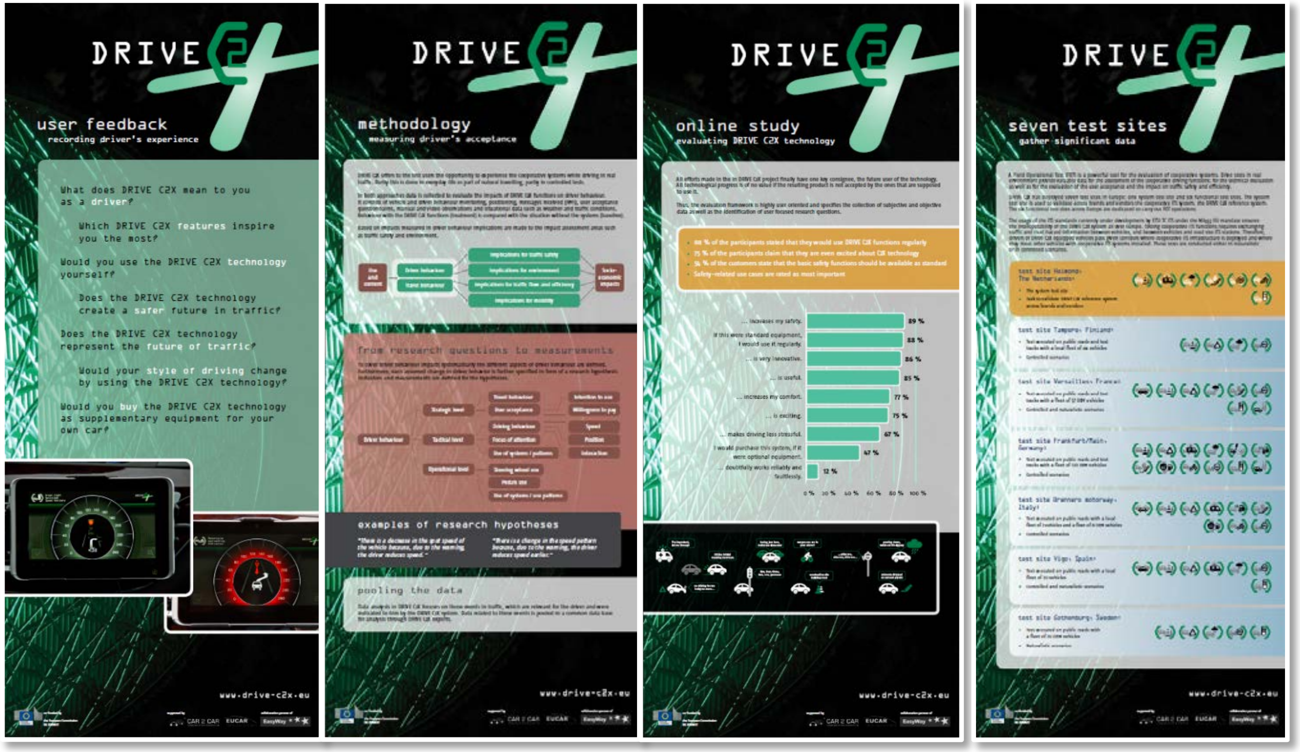
Event	Location, date	Contents
		deployment, organised by FOT-Net • Starting European field tests for Car-2-X Communication: the DRIVE C2X Framework Rainer Stahlmann (Audi AG); Andreas Festag (NEC Laboratories Europe); Andrea Tomatis (Hitachi Europe); Ilja Radusch (Fraunhofer FOKUS); François Fischer (ERTICO - ITS Europe) • Using EuroFOT Operational Experience in DRIVE C2X Maxime Flament (ERTICO - ITS Europe)
	Lyon, France June 9, 2011	• 90 minutes session with 5 presentations and about 50 participants • FOTs as a means for enabling cooperative mobility - the EC's perspective, Eva Boethius (European Commission DG INFSO) • The DRIVE C2X approach to create a Europe-wide platform for C2X technology, Cornelius Menig (Audi AG) • The DRIVE C2X system test site in Helmond, the Netherlands, Peter-Paul Schackmann (TNO) • SISCOGA one of the functional test sites of DRIVE C2X in Galicia, Francisco Sánchez (Centro Tecnológico de Automoción de Galicia) • The FOTsis approach towards cooperative systems for highway operation, Federico García-Linares (OHL Concesiones)

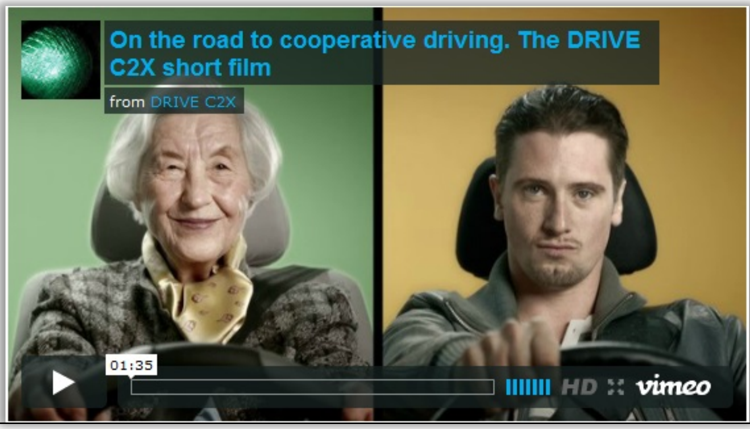
11.3 The DRIVE C2X dissemination material

Means	Purpose
	• Ruler as give-away, e.g. with conference maps
	• Lenticular flyer introducing DRIVE C2X as follow-up of PRE-DRIVE C2X

Means	Purpose
	• Image brochure format A5 addressing experts and non-experts • Explaining functions

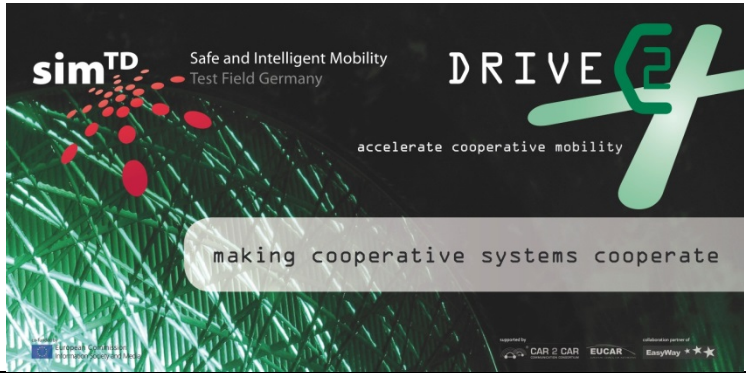
Means	Purpose
	• Seven DRIVE C2X branded overview posters

Means	Purpose
	• Four posters with intermediate results used during DRIVE C2X @ TSS and during final event

Means		Purpose
		• Conference set used during the test site campaign: o folder o notepad o ruler o lanyard and o badges with agenda
		• Short film with real characters illustrating the benefits of DRIVE C2X systems in a funny way • Shown during DRIVE C2X test site events, final event, ITS World Congress 2012 and published on website

Means	Purpose
	• Short animated film featuring functions and use cases • Shown during DRIVE C2X test site events, final event, ITS World Congress 2012 and published on website

Means	Purpose
	• Individual flyer for each event of the cooperative driving campaign counting 16 pages each. • The flyers outlined the respective milestone and contents of the events.

Means	Purpose
	• A4 flyer with four pages in preparation of 19th ITS World Congress, 2012
	• Banners for all test site events

11.4 DRIVE C2X Cooperative Driving Campaign

Event	Location, date	Contents
DRIVE C2X @ simTD	Friedberg, Germany October 13, 2011	• Driving demonstration • Conference with panel discussions • Exhibition • Posters
DRIVE C2X @ DITCM	Helmond, The Netherlands July 5, 2012	• Driving demonstration • Conference with panel discussions • Exhibition • Posters • Press release
DRIVE C2X @ TSS	Gothenburg, Sweden June 13-14, 2013	• Driving demonstration • Conference with panel discussions • Exhibition • Posters • Press release
Winter test event “Smart cars under winter test – hop on!” 	Tampere, Finland December 11, 2013	• Driving demonstration dedicated to press • Press conference • Press release

Event	Location, date	Contents

ITS World Congress	Vienna, Austria
	October 22-26, 2012
		• Driving demonstration
		• Posters
		• 2 Special Interest Sessions
		  • SIS38 – Business models and revenue sources for C2X communication with about 60 participants
		  • SIS68 – Global deployment of Car-2-X communication technology – A technical perspective on commonalities and similarities with about 75 participants
		• 7 technical papers released
		• Press release for joint driving demonstration of C2C Communication Consortium and Testfeld Telematik
		• Press conference for booth "Cooperative Driving" with Austrian Ministry for Transport, Innovation and Technology, Doris Bures

Final event 	Berlin, Germany July 16-17, 2014	• Conference with panel discussion • Business game deployment strategies • Driving demonstration • Exhibition • Posters • Press release