DRIVing implementation and Evaluation of C2X communication technology in Europe

DRIVE C2X

Accelerate cooperative mobility

Deliverable D11.4

Impact Assessment and User Perception of Cooperative Systems

Version number	Version 1.0
Dissemination level	PU
Lead contractor	TNO
Due date	30/06/2014
Last update	02/07/2014

SEVENTH FRAMEWORK PROGRAMME

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Project funding

7th Framework programme

INFORMATION AND COMMUNICATION TECHNOLOGIES

Objective ICT-2009.6.2: ICT for Mobility of the Future

Large-scale integrating project

Grant agreement no.: 270410

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Executive summary

DRIVE C2X aimed at delivering a comprehensive assessment of cooperative systems functions, providing for instance: warnings about road hazards (road works, weather, traffic jam...) or information to optimise arriving at and passing a traffic light. The assessment used log data resulting from Field Operational Tests (FOTs) carried out on several test sites located in different EU countries. DRIVE C2X addressed four major technical objectives:

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

This deliverable reports the activities carried out as part of the DRIVE C2X sub-project 4: It reports on the impacts and user acceptance of the DRIVE C2X functions, based on driver behaviour and surveys in the Field Operational Tests (FOTs).

The project built on previous and on-going work on cooperative systems and the FOT operations were carried out by a Europe-wide testing community including seven test sites in Finland, France, Germany, Italy, the Netherlands, Spain, and Sweden.

The coordination of the FOT operations was left under the responsibility of the test site leaders. However the FOT organisation followed a common and harmonised methodology, in order to preserve the conditions for combining data from all test sites for the impact assessment and user acceptance analyses. This presented a challenge to the assessments, because the local circumstances needed to be understood in the assessment.

The FOTs were executed in a specific way at each Test Site, for instance running "naturalistic driving" (ND) or "controlled tests" (CT). In the controlled tests, the drivers were called into the test and followed the driving instructions provided by the Test-Site Instructor, allowing the driver to encounter specific test situations, such as a traffic jam. In the naturalistic approach, the test drivers' behaviour were monitored in their daily driving, and the routes and driving times are based on drivers' needs. The tested scenarios comprise both vehicle-to-vehicle (V2V) and infrastructure-to-vehicle (I2V) communication.

A wide set of functions were implemented in the DRIVE C2X reference system: Obstacle warning / Road works warning (OW/RWW), Traffic jam ahead warning (TJAW), Car breakdown warning (CBW), Weather warning (WW), Approaching emergency vehicle warning (AEVW), In-vehicle signage (IVS) and Green-light optimal speed advisory (GLOSA). In addition, the German test site simTD also tested Emergency Electric Brake Light (EEBL).

The impact assessment and user acceptance analyses made use of data collected from drivers participating in the FOT. These data form the basis for the results presented in this report.

Test sites

Six test sites (TSs) operated FOTs and collected data for impact assessment and user acceptance. The test sites were located in Finland, France, Germany, Italy, Spain and Sweden. Each test site determined which functions would be tested. The functions In-vehicle signage/ Speed limits and Obstacle warning/ Road works warning/ Car breakdown

warning were tested at all the test sites. The remaining functions were tested at least one test site.

Methodology

Impact assessment and user acceptance made use of different data and 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 1 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, and then pooled with data from other test sites and locations within test sites and analysed again. These analyses provided input for the assessments on the impact areas safety, traffic efficiency, environment and mobility. Other data and tools supplemented the driving behaviour data. Safety impacts also made use of previous expert assessments found in the literature and expert assessment of DRIVE C2X. Traffic efficiency and environmental impact assessment made use of simulation models. The scaling up of the effects to the EU-level made use of external data. In most tasks, scenarios were used.

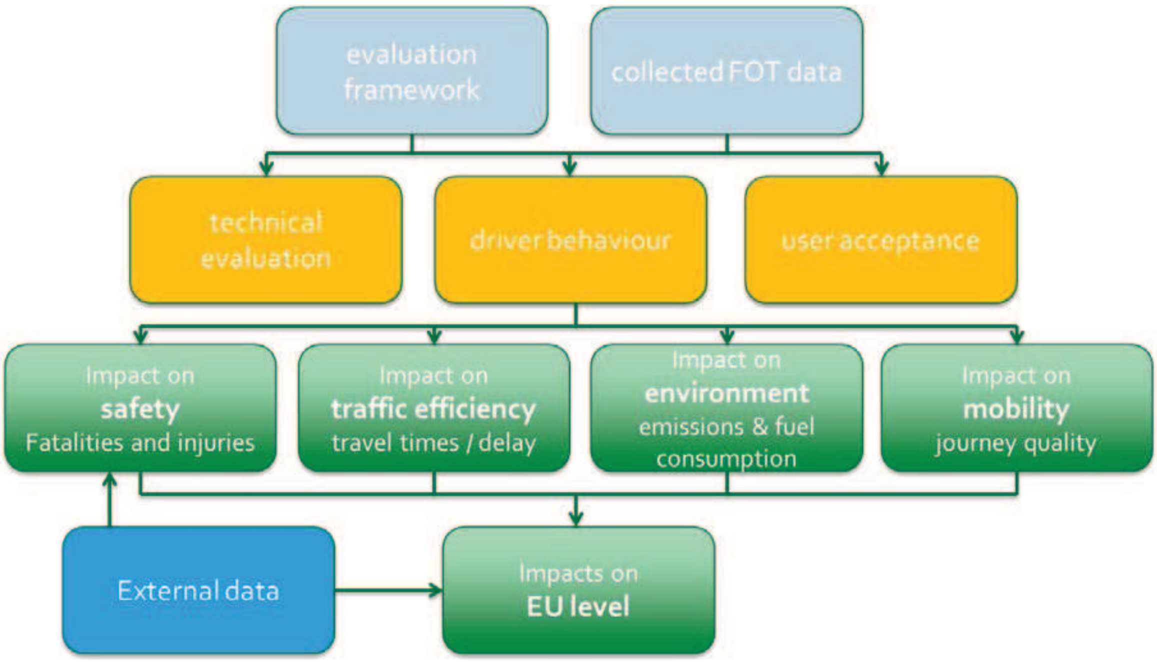


Figure 1: Overview of impact assessment process

The scenarios took into account most important aspects that affect the impacts of DRIVE C2X systems: penetration level of the cooperative system in Europe, road types, traffic composition and traffic demand (peak or off-peak). Scenarios assumed that heavy goods vehicles are not equipped; no DRIVE C2X functions were tested on heavy goods vehicles.

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.

User acceptance of DRIVE C2X technology and the specific functions was measured by a mixed approach of quantitative and qualitative data. The design of data collection and analysis was adapted to the complex settings across five test sites and eight functions. Test site Germany has been excluded from the user acceptance measurement approach as a test-site-specific approach was used.

On each test site the test drivers received an invitation for a measurement of expectation after the briefing sessions and another invitation for measurement of evaluation after the final tests. This offered the option to compare expectation and evaluation after the actual experience. Finally, the mainly quantitative results of these surveys were enhanced by focus groups on every test site, involving the test users again in order to generate more open feedback from the respondents.

Results

The user acceptance results were analysed in descriptive but also in multivariate form. Therefore a Technology Acceptance Model has been defined and calculated.

Generally a high acceptance of the system could be noted. 91% of the respondents stated that they would use the system if it was available in their cars. The willingness to purchase the system as special equipment was comparably low with 42% agreement.

The most preferred functions were Approaching emergency vehicle warning and Green light optimal speed advisory which were also the only functions that exceeded the expectations. All other functions were evaluated slightly less positively, mainly related to reliability aspects.

One main argument for the positive evaluation of Approaching emergency vehicle warning and Green light optimal speed advisory was the innovative character of the functions. Compared to other functions such as In-vehicle signage, the respondents could see a clear benefit that was not offered by existing solutions on the market.

Generally a subjective effect on the own driving style was perceived, even to a higher extent than originally expected by the test drivers. While originally only 32% of the drivers agreed that their driving style would be affected by the use of DRIVE C2X technology, 62% of the test users agreed after the test experience.

The main concern of the drivers is the potential distraction due to information overload, inaccurate information and the need to send their own messages. Even if the pre-prototype development status of the technology caused various malfunctions and limitations related to Human-machine interface (HMI) usability, this aspect is expected to be of essential relevance also in a market-ready solution.

Concerns related to data privacy and security could not be broadly noted. 88% of the drivers would agree to provide their data in anonymous form for traffic related issues. Still, many concerns are present regarding commercial use of driver data. Only 27% of the drivers would provide their information in order to have access to commercial services.

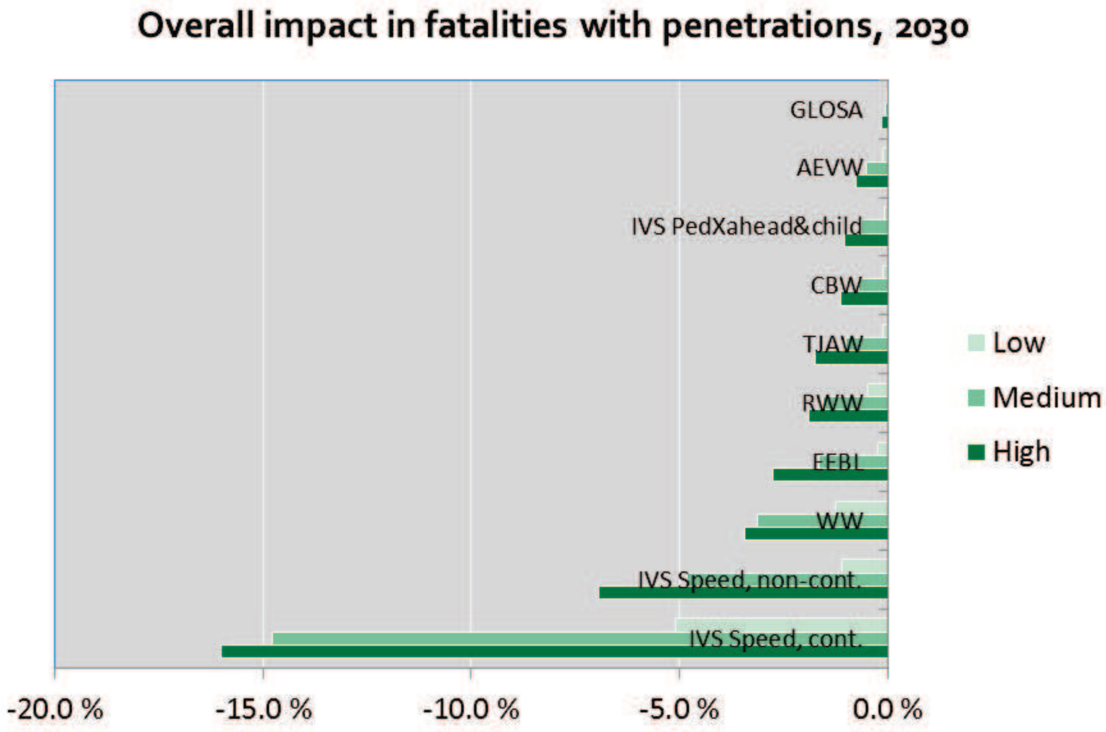
The Technology Acceptance Model supported the importance of the usability of the system and showed a high influence on the perceived usefulness of the system. Furthermore the Technology Acceptance Model showed a positive influence on perceived usefulness by the individual driving style and technological affinity.

Group comparisons based on the cluster analysis of driver types indicated that the acceptance of DRIVE C2X technology is also differing between various driver segments. While the segment of fast, dynamic but generally safe drivers as well as Considerate Drivers do not show major differences in acceptance, it could be noticed that the segment of 'carefree drivers' that is less interested in driving and also less bound to traffic rules shows lower acceptance. It can be assumed that this can be explained by a reactance against any limitation of self-determination during driving.

The driver behaviour results showed that for most of the functions, changes in driving behaviour were observed that were in line with the intended changes. The functions were primarily safety functions, and the impacts, when found, were mostly changes in speed, and its derivatives. No changes in strategic behaviour (route choice, mode choice) were found due to the nature of the functions. The data was successfully pooled over test sites to strengthen the statistical significance of the tests. Relevant and statistically significant results were found for In-vehicle signage / speed limits and some of the other signs, Obstacle warning, Road works warning and Car Breakdown warning, Green light optimal speed advisory and Approaching emergency vehicle. Furthermore, the objective driving behaviour results were in line with the self-reported driver behaviour.

The main safety results showed that the functions affected traffic safety in a positive way by preventing fatalities and injuries. The most effective functions from the safety point of view were In-vehicle signage/ Speed limit and Weather warning. The next were Electronic emergency brake light, Traffic jam ahead and Road works warning functions. However, even the GLOSA function developed primarily for improvement of environmental impacts enhanced safety slightly.

Figure 2 shows the estimated percentage reduction in fatalities and injuries in 2030 for the low, medium and high passenger car penetration rates due to the DRIVE C2X functions in the EU-28. The findings are based on equipping only passenger cars. It is expected that equipping heavy goods vehicles will result in a larger percentage improvement in safety.


Overall impact in fatalities with penetrations, 2030
GLOSA
AEVW
IVS PedXahead&child
CBW
TJAW
RWW
EEBL
WW
IVS Speed, non-cont.
IVS Speed, cont.
Low
Medium
High
-20.0 %
-15.0 %
-10.0 %
-5.0 %
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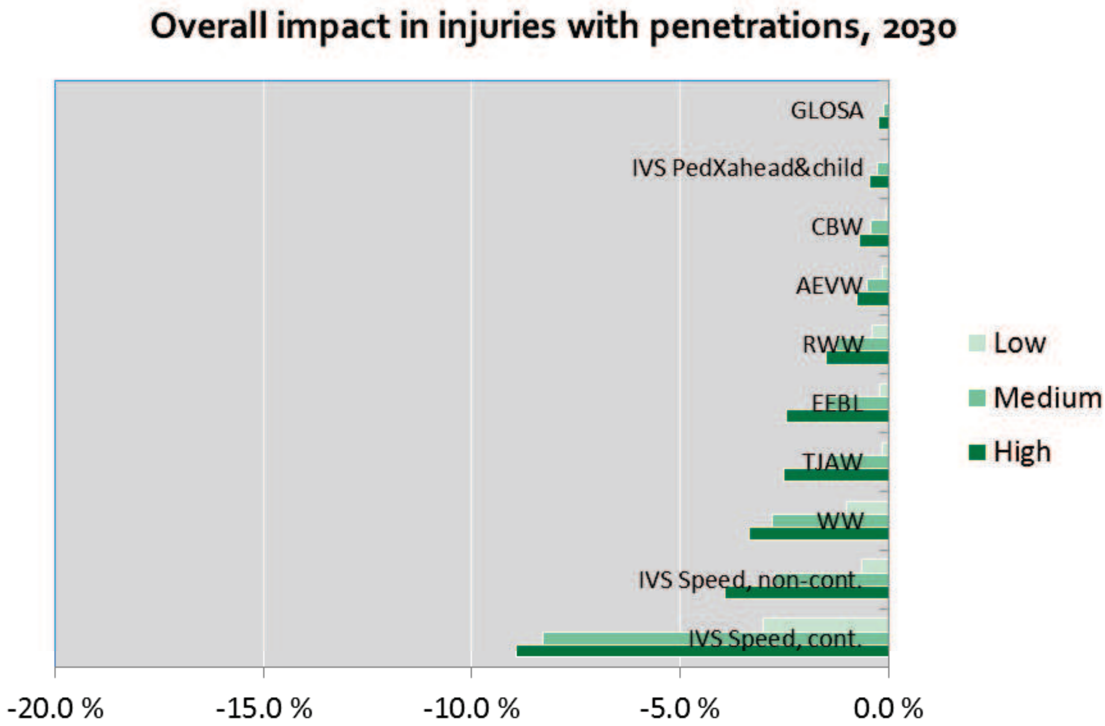
Overall impact in injuries with penetrations, 2030
GLOSA
IVS PedXahead&child
CBW
AEVW
RWW
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TJAW
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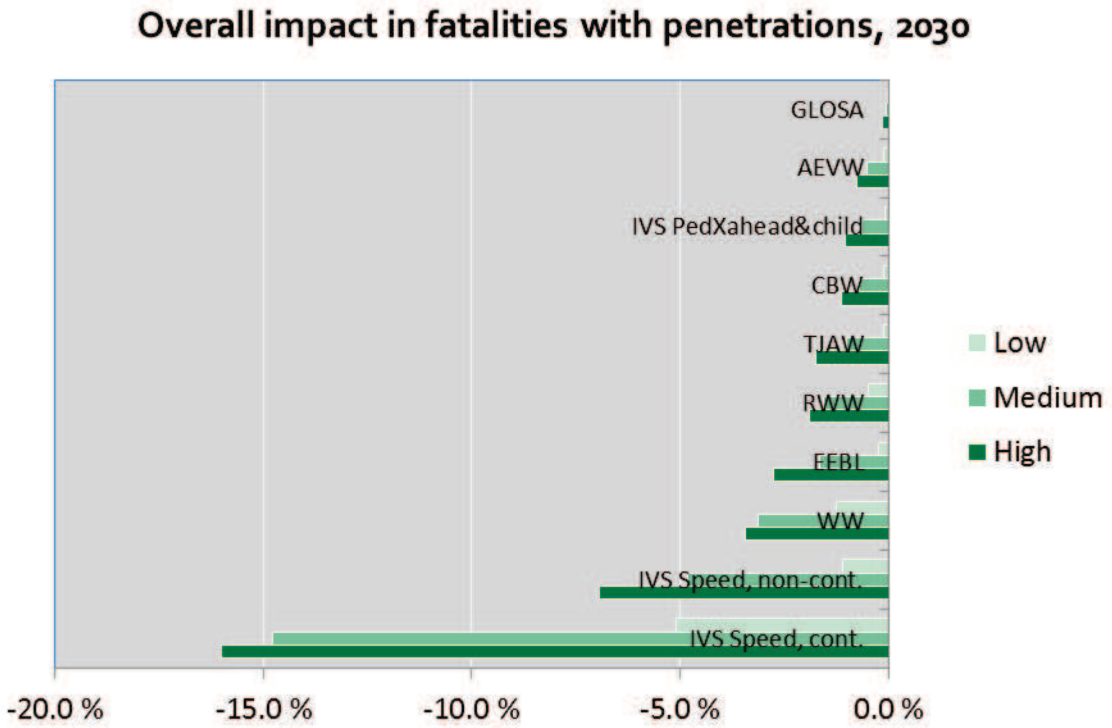

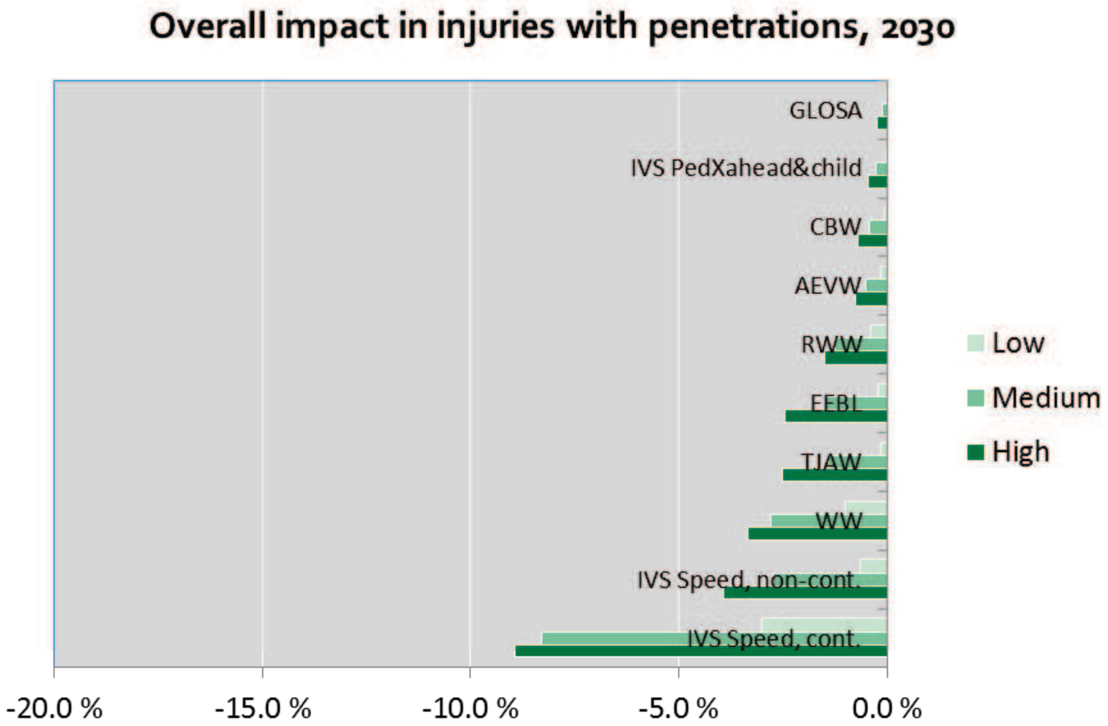

Figure 2: The overall safety impacts of cooperative functions in 2030 with vehicle penetration scenarios: low, medium and high

The traffic efficiency impacts examined three functions for which effects at the traffic flow level could possibly be observed. Traffic jam ahead warning, Green light optimal speed advisory and In-vehicle signage/ Speed limits were analysed with traffic simulation. The main results showed that delay increased for Green light optimal speed advisory and In-vehicle signage/ Speed limits, due to reduced vehicle speed caused from either the speed advice or to stricter enforcement of speed limits. The Traffic jam ahead warning did not show any statistically significant changes in traffic efficiency. 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.

The environmental impact assessment of the functions Green light optimal speed advisory and In-vehicle signage/ Speed limits showed reasonable reduction potential for energy consumption and emissions. For Green light optimal speed advisory the reductions resulted mainly from the optimisation of the speed to avoid unnecessary braking and acceleration manoeuvres. For In-vehicle signage/ Speed limits, the influences on emissions resulted from a general reduction of the velocity. The Traffic jam ahead warning function had only very local effects since it influences mainly the deceleration area upstream of a traffic jam. The influence on fuel consumption and CO_2 emissions from TJAW is rather positive due to an earlier speed reduction.

The main results of the mobility impact assessment showed positive implications for the quality of travel. The cooperative functions did not have implications for the amount of travel or travel patterns on the personal level, except for In-vehicle signage/ Speed limit which lead to such a decrease in average speed resulting in an increase in duration of the journeys.

Conclusions

The DRIVE C2X project investigated Day-one cooperative functions which are primarily focused on improving road safety. The analysis revealed that the safety results are promising for the DRIVE C2X functions individually. When the cooperative systems are brought to the market, they will be offered in bundles of systems on vehicles. That is, multiple systems will be offered in a package. Because all functions contributed in safety the safety impacts of the bundles will be larger than the impacts of the individual systems analysed, however, lower than sum of individual effects because the targeted accidents are partly the same,.

The DRIVE C2X functions achieved safety improvements with some adverse effects on traffic efficiency and slight positive effects on fuel consumption and CO_2 for the environment. It is assumed that greater improvements to traffic efficiency and the environmental can be achieved with modifications to the DRIVE C2X function implementation. The eCoMove project (eCoMove, 2014) showed that the combination of addressing driver behaviour and the traffic control algorithm leads to significantly larger environmental effects. Furthermore, the DRIVE C2X user survey revealed that the optimization of traffic flow is as important to drivers as safety issues. Addressing traffic flow as well as safety in cooperative functions would expand the system experience and make the functions more attractive to consumers.

The qualitative mobility assessment revealed positive impacts. Specifically, journey quality was improved in terms of user stress, user uncertainty, feeling of safety and comfort.

The impact assessment findings provide lower bounds on the impacts for environment and safety for the given penetration rates. Only passenger vehicles were equipped in the analyses. It is assumed that if heavy goods vehicles were equipped, the impacts would be positive for this class of vehicles, too, which represent a significant amount of CO_2 and other emissions.

User acceptance indicated a huge potential for the market introduction of DRIVE C2X technology. Still, it can also be noted that major improvements are needed related to the implementation towards the driver. Information accuracy needs to reach a clearly higher level in a market-ready solution. At the same time, innovative concepts are needed to provide appropriate HMI solutions that do not lead to distraction of the driver.