H2020 Mobility for Growth
MG-2014_SingleStage_B
Coordination and Support Action
COoperative ITS DEployment Coordination Support
CODECS
Project Number: 653339

Deliverable 2.2

State-of-the-Art Analysis of C-ITS Deployment

Deliverable number:	D2.2
Related to work package:	WP 2 Coordination of initial deployment activities
Related to task:	T2.1 Information sharing on C-ITS deployment initiatives
Due Date:	Month 12 (April 2016)
Submission Date:	01/11/2016
Lead beneficiary of WP:	BASt
Version number:	1.0

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 653339.

Author(s)

Sandro Berndt, Torsten Geißler – Bundesanstalt für Straßenwesen (BASt)
Guillem Bernatallada – ACASA
Suzanne Hoadley – POLIS
Onno Tool, Fred Verweij – Rijkswaterstaat (RWS)
Matěj Malý – INTENS
Paul Spaanderman – Pauls Consultancy
Teodor Buburuzan – Volkswagen AG
Niels Peter Skov Andersen – Anemone Technology
Richard Wisbrun – BMW

Dissemination Level

PU	*Public*	***X***
PP	*Restricted to other programme participants (including the Commission*	
RE	*Restricted to a group defined by the consortium (including the Commission)*	
CO	*Confidential, only for members of the consortium (including the Commission)*	

Disclaimer

Project Coordinator

ITS Automotive Nord GmbH
Dr. Karl-Oskar Proskawetz, Sonja Eickmann
Hermann-Blenk-Straße 17
38108 Braunschweig
Germany

Phone: +49 (0) 531 231721-22
Fax: +49 (0) 531 231721-19
Email: info@codecs-project.eu

Revision chart and history log

Version	Date	Reason	Author
1.0	02.11.2016	Creation of Final PDF file, submission to INEA	Oskar Proskawetz, ITSAN
0.18	27.10.2016	Cross-checking final text, check of picture quality for final version	Sandro Berndt, Torsten Geißler, BASt
0.17	11.10.2016	Update of C-Roads references after technical Kick-Off	Sandro Berndt, Torsten Geißler, BASt
0.16	27.09.2016	Editorial work on 3.8 and 7	Paul Spaanderman, PC
0.15	26.09.2016	Merging of contributions to chapter 3.5 and 4.2, task allocation for corrections	Sandro Berndt, BASt
0.14	15.09.2016	Integration of chapter 3.9	Richard Wisbrun, BMW
0.13	28.08.2016	Updated 2.8; 3.2; 3.4; 3.8	Paul Spaanderman, PC
0.12	26.08.2016	Clean-up document	Sonja Eickmann, ITSAN
0.10	22.08.2016	Integration of chapter 3.8	Paul Spaanderman, PC
0.9	09.08.2016	Integration of chapter 3.6; Update of chapter 2.4, 2.5, 2.8; Editorial changes	Sandro Berndt, Matěj Malý, Suzanne Hoadley, Teodor Buburuzan
0.8	08.08.2016	Integration of chapters 2,9/3.2/3.4/4.5; Changes in sub-chapter 3.11; editorial changes.	Paul Spaanderman, PC
0.7	04.08.2016	Introduction updated; contributions of CODECS partners included [ACASA, INTENS, POLIS, RWS]	Sandro Berndt, Torsten Geißler, Guillem Bernatallada, Matěj Malý, Suzanne Hoadley, Onno Tool, Fred Verweij
0.6	22.07.2016	Enhanced draft distributed	Sandro Berndt, BASt
0.5	21.07.2016	Contribution to chapter 2 and 3	Sandro Berndt, BASt
0.4	08.07.2016	Structure enhanced	Sandro Berndt, BASt
0.3	06.07.2016	Introduction added; shared with partners for contribution	Torsten Geißler, BASt
0.2	27.05.2016	Deliverable Concept	Torsten Geißler, BASt
0.1	31.03.2016	Structure established; empty template	Torsten Geißler, BASt

Abbreviations

Abbreviation	Explanation
3GPP	3rd Generation Partnership Project
5G PPP	5G Infrastructure Public Private Partnership
ANSSI	Agence nationale de la sécurité des systèmes d'information – National Cybersecurity Agency of France
ASECAP	Association Européenne des Concessionnaires d'Autoroutes et d'Ouvrages à Péage – European Association of Operators of Toll Road Infrastructures
ASFINAG	Autobahnen- und Schnellstraßen-Finanzierungs-Aktiengesellschaft – „Autobahn and high way financing stock corporation“ in Austria
BASt	Bundesanstalt für Straßenwesen – Federal Highway Research Institute in Germany
BMVI	Bundeministerium für Verkehr und digitale Infrastrukur – Federal Ministry of Transport and Digital Infrastructure
BSI	Bundesamt für Sicherheit in der Informationstechnik – German Federal Office for Information Security
C2C-CC	CAR 2 CAR Communication Consortium
CAMP	Crash Avoidance Metrics Partnership
C-ITS	Cooperative Intelligent Transport Systems and Services
CEDR	Conférence Européenne des Directeurs des *Routes* – Conference of European Directors of Roads
CEF	Connecting Europe Facility
CEN	Comité Européen de Normalisation – European Committee for Standardization
CENELEC	Comité Européen de Normalisation Électrotechnique – European Committee for Electrotechnical Standardization
CEPT	Conférence Européenne des Administrations des Postes et des Télécommunications – European Conference of Postal and Telecommunications Administrations
CIMEC	Cooperative ITS for Mobility in European Cities, H2020 Coordination & Support Action
CODECS	Cooperative ITS Deployment Coordination Support
D	Deliverable
DAB, DAB+	Digital Audio Broadcast
DG	Directorate General
DITCM	Dutch Integrated Testsite Cooperative Mobility

Abbreviation	Explanation
DSRC	Dedicated Short Range Communication (wireless tolling systems in Europe, operating at 5.8 GHz)
EC	European Commission
ECC	Electronic Communications Committee (at CEPT)
ECo-AT	European Corridor – Austrian Testbed for Cooperative Systems
ETSI	European Telecommunication Standards Institute
EU EIP	European ITS Platform
FOT	Field Operational Test
FTA	Finnish Transport Agency
GNSS	Global Navigation Satellite System
GPRS	General Packet Radio Service
GPS	Global Position System
GSM	Global System for Mobile Communications (2G)
HMI	Human Machine Interface
I2V	Infrastructure-to-vehicle communication
ICT	Information and Communication Technologies
IEEE	Institute of Electrical and Electronics Engineers
IoT	Internet of Things
IP ITS	Implementation Plan ITS
ISO	International Organization for Standardization
ITS	Intelligent Transport Systems and Services
ITSAN	ITS automotive nord GmbH
ITU	International Telecommunication Union
IVI	In-Vehicle Information
IVS	In-Vehicle Signage
KliEn	Klima und Energiefonds – Austrian Climate and Energy fund
LTE	Long Term Evolution, 4th generation of cellular communication (4G)
MTM	Motorway Traffic Management, Dutch system including VMS
OBU	On-board Unit
OEM	Original Equipment Manufacturer
PKI	Public Key Infrastructure
POLIS	European Cities & Regions Network for Innovative Transport Solutions

Abbreviation	Explanation
PVD	Probe Vehicle Data
RSU	Roadside Unit
RWS	Rijkswaterstaat
RWW	Road Works Warning
SDO	Standards Development Organisation
SISCOGA	Sistemas Cooperativos Galicia
SPAT	Signal Phase and Timing
T	Task
TC	Technical Committee
TCC	Traffic Control Centre
TEN-T	Trans-European Network – Transport
TISA	Traveller Information Service Association
TMC	Traffic Message Channel
TPEG	Transport Protocol Experts Group
TS	Technical Specification
UK	United Kingdom
UMTS	Universal Mobile Telecommunications System (3G)
UNECE	United Nations Economic Commission for Europe
VMS	Variable Message Sign(s)
VRU	Vulnerable Road User (e.g. Pedestrian, Bicyclist, Motorcyclist)
V2I	Vehicle-to-infrastructure-communication
V2V	Vehicle-to-vehicle-communication
V2X	Vehicle-to-X, “vehicle to anything” (comprising V2I, I2V, V2V)
WP	Work Package

Table of Contents

List of Tables

List of Figures

Executive Summary

The CODECS Deliverable 2.2 aims at providing a state-of-the-art perspective on the pilots and deployment initiatives for Cooperative Intelligent Transport System (C-ITS) based services. With regard to CODECS, it forms the final element of the inventory phase within Work Package 2 (Coordination of initial deployment activities). The deliverable takes stock of the developments with regard to three perspectives: the different C-ITS pilots and deployment initiatives (chapter 2), the issues to be solved for deployment (chapter 3) and core actors' view on C-ITS deployment (chapter 4). The content of the deliverable is largely backed by the involvement of the authors in several pilots and deployment initiatives as well as coordinating institutions such as the C-ITS Platform and the Amsterdam Group.

The stocktaking of pilots and deployment initiatives has demonstrated that there is a growing interest in Europe to prepare for deployment of C-ITS services in which more than ten European Member States are now active. This forms a coherent basis for the deployment start with a shared view on Day One services making use of smart mix of hybrid communication (involving ITS G5 and cellular communication, potentially also others). The geographical pattern reveals that deployment starts in less challenging operating environments, i.e. on motorways, but involves now increasingly (the interface to) urban environments. In a modal perspective, most of the initiatives have started with focussing on personal transport but more and more also freight and logistics applications are envisaged.

The stocktaking of issues to be solved for initial deployment of C-ITS services has revealed and (re-)confirmed several issues calling for action on European level, amongst others security, compliance assessment, data protection and privacy, radio spectrum and frequency. Expert support is provided by all C-ITS actors and stakeholders into the EC (DG MOVE) coordinated C-ITS Platform (support level). The institutional framework of the ITS Directive will be used for developing legal certainty about the above mentioned core elements of the European-scale C-ITS deployment (policy level). These elements will become part of a future Delegated Regulation on C-ITS. Facilitating C-ITS deployment by sharing knowledge, expertise and lessons learned in a deployment expert community, and strategic alignment of the initial and respectively future phases of the C-ITS deployment, provides a huge value. This knowledge brokerage on implementation level is facilitated by the C-Roads Platform, with the Amsterdam Group overlooking the strategic dimension of C-ITS deployment from the perspective of core deployment partners (i.e. automotive industry and infrastructure organisations).

The stocktaking is complemented by a view of core actors towards the initial deployment of C-ITS services. It makes clear that the actor's motivation is partly congruent when it comes to fulfilling public goals and contributing to Corporate Social Responsibility (CSR) factors. When it concerns aspects related to Customer Relationship Management (CRM) and the ego position in the value network, the motivation of actors is substantially different by nature. Organisational issues, including a high level shared view on corner stones of business models and leaving the details to the actors to make their share of the total benefit, are therefore essential for successful deployment of C-ITS services.

1. Introduction

1.1. Preparation of C-ITS Deployment in Europe

Safe, efficient, reliable and environmental friendly mobility strongly builds on making full use of the potential of Information and Communication Technologies (ICT) in transport. In recent years, maturing technology, testing potential services in the field, and shaping the policy framework, e. g. by the Intelligent Transport Systems (ITS) Directive and related delegated regulations, have stimulated the efforts towards deployment preparation of services that are based on a Cooperative Intelligent Transport System (C-ITS). C-ITS is defined as a subset of overall ITS that communicates and shares information between ITS stations (vehicles, road-side, traffic control centre (TCC), personal mobile devices) to give advice or take actions with the objective of improving safety, sustainability, efficiency and comfort beyond the scope of stand-alone ITS [302 665]. C-ITS deployment is a cross-sector endeavour, with the automotive industry and infrastructure organisations as core actors. The automotive industry plans towards bringing vehicle-to-x communication onto European roads in 2019 [CAR2CAR]. The industry plans are complemented by efforts of road authorities and operators to roll out adequate infrastructure at the roadside and to make TCCs future proof for the next cooperative generation of technologies.

The preparation of C-ITS deployment involves elements of bottom-up- and top-down coordination. Different pilots and deployment initiatives have started from local and regional test beds or living labs, maturing in a mid-term perspective into long distance corridor deployments covering substantial parts of the TEN-T core network. The pilots and deployment initiatives require the support of a policy framework which sets out common elements of the deployment, e. g. common security and certificate policy, recommendations for compliance assessment, privacy framework. These elements will form the basis for a Delegated Act on C-ITS under the framework of the ITS Directive 2010/40/EU. Preparatory work for the Delegated Act has started in May 2016 with a first meeting of Member State experts. The preparatory work builds on the findings of the first phase of the Platform for the Deployment of Cooperative ITS in the EU (C-ITS Platform). The platform has been launched in 2014 and has delivered the final report of its first phase in January 2016 [Platform]. The three-level-approach followed by the European Commission, DG MOVE, is illustrated in Figure 1.

The work of the C-ITS Platform is complemented by the Amsterdam Group which connects the C-ITS pilots and deployment initiatives with the goal of interoperable deployments which is facilitated by sharing information as well as discussing and mitigating possible divergent approaches. The Amsterdam Group was formed in 2011 as a strategic partnership between the automotive industry within the CAR 2 CAR Communication Consortium (C2C-CC) and infrastructure organisations (CEDR, ASECAP, POLIS) as committed core stakeholders in the C-ITS deployment. The interaction between the Amsterdam Group and the (corridor) deployment initiatives is illustrated in Figure 2.

In a wider context, the deployment preparations as described above are stimulated by the “Declaration of Amsterdam” on cooperation in the field of connected and automated driving [DoA]. On European Commission level the efforts towards C-ITS deployment coordinated by DG MOVE are recently complemented by the GEAR 2030 process (under coordination of DG GROW) and the efforts to boost 5G communication technologies for V2X applications (pre-deployment initiative of the Oettinger Round Table, DG CNECT).

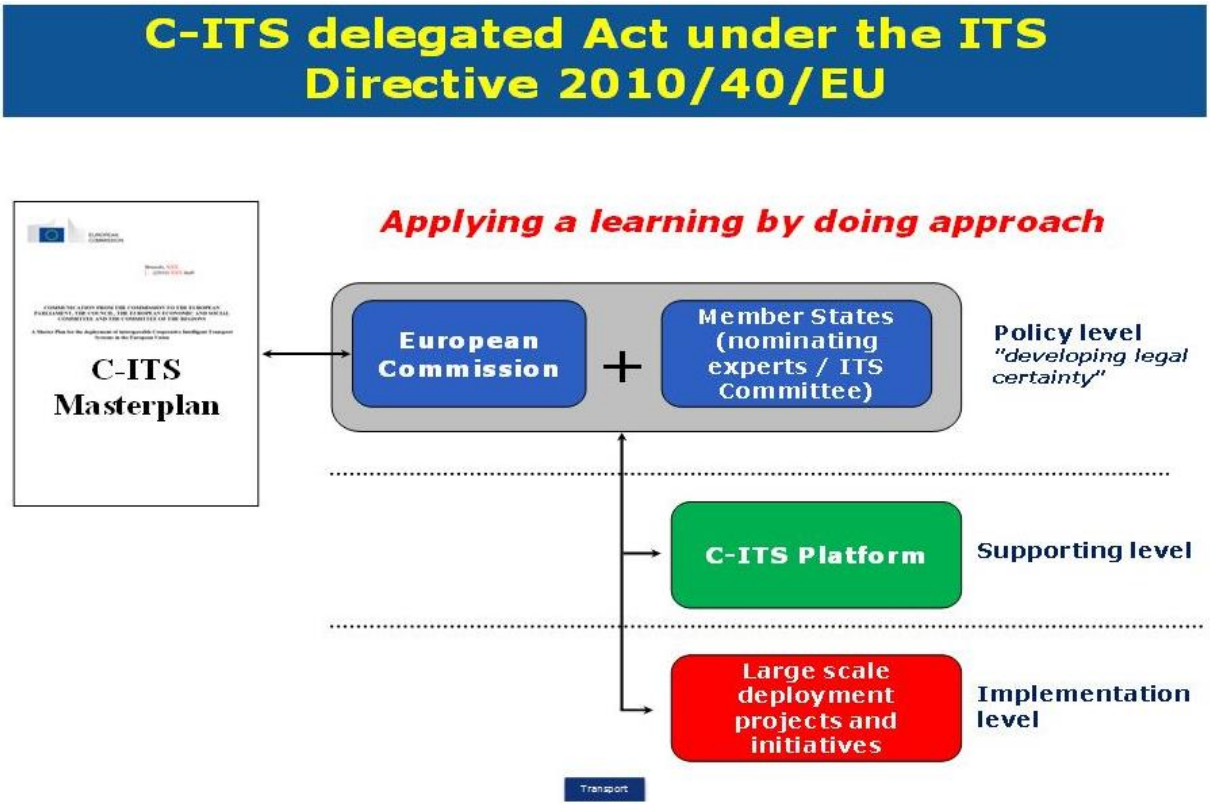


Figure 1: Three-level-approach of DG MOVE for preparing C-ITS Deployment
Source: DG MOVE 2016

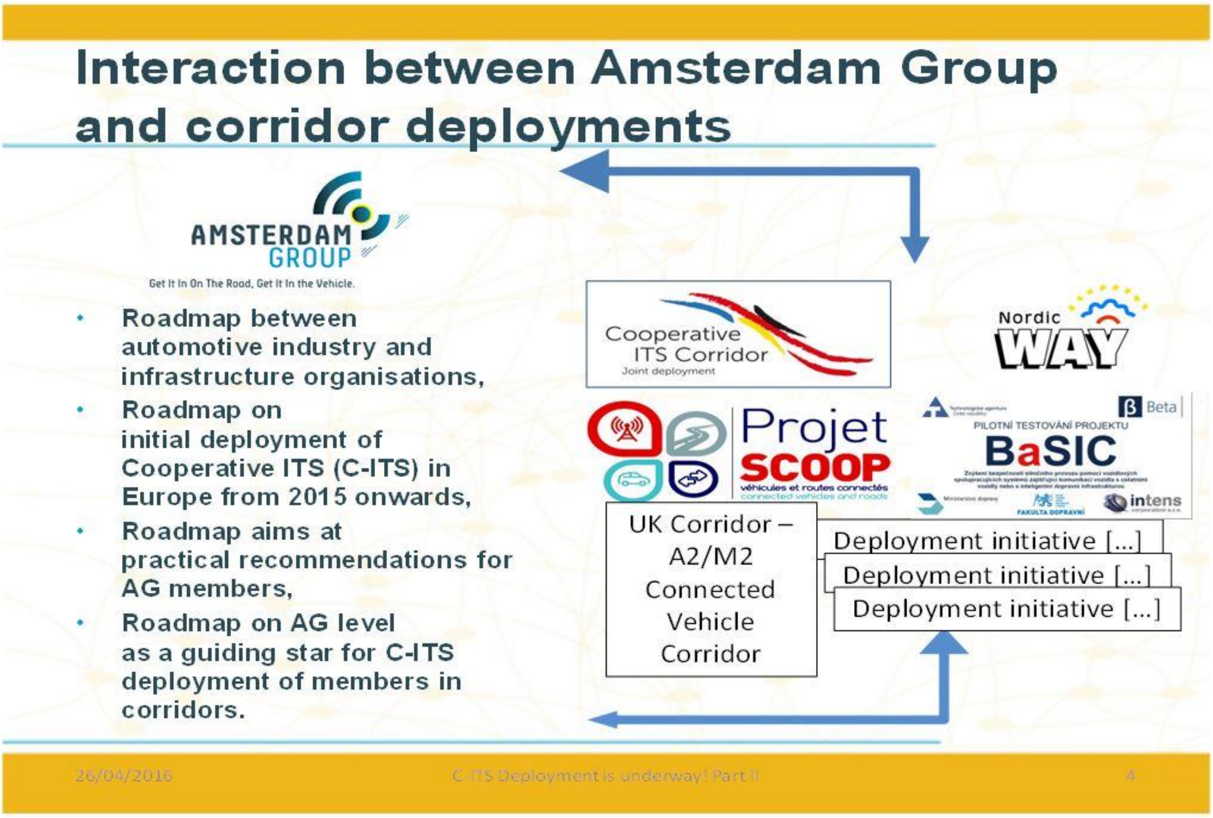


Figure 2: Interaction between Amsterdam Group and C-ITS corridor deployments
Source: Amsterdam Group 2016

1.2. Supporting role of CODECS in C-ITS deployment

The mission of the Horizon 2020 Coordination and Support Action COoperative ITS DEployment Coordination Support (CODECS) is to support the initial deployment of vehicle-to-x communication services in Europe. An agreed list of Day One services targeting at road safety, efficiency and driving comfort is available from the final report of the C-ITS Platform [Platform]. Corridor projects and pilots are today arising all over Europe and form the first examples of real C-ITS deployment. An aligned roll-out of systems and services still remains challenging. To avoid fragmentation, missing interoperability of systems and lacking coherency of services, CODECS acts as a nodal point pooling the interests, preferences and requirements of all C-ITS stakeholders – also of those who might step into the deployment process at a later stage. With this goal setting, CODECS supports the Amsterdam Group, the C-ITS Deployment Platform of the European Commission, Standards Setting Organisations and other key deployment players to come to a concerted C-ITS roll-out across Europe. CODECS is also closely related to the Coordination and Support Action Cooperative ITS for Mobility in European Cities (CIMEC). This is demonstrated in a close collaboration within the Horizon 2020 cluster on ITS and Connected Vehicles as well as with the organisation of common workshops (e.g. CODECS – CIMEC City Pool Workshop, 03.03.2016, London). The idea of leveraging the efforts of the Amsterdam Group – and also the C-ITS Platform – is illustrated in Figure 3.

Figure 3: CODECS – part of a network supporting the C-ITS deployment preparation
Source: Amsterdam Group 2016

1.3. Position of state-of-the-art analysis in CODECS work program

The support to the coordination of deployment is organised around three fundamental work packages of CODECS (WP 2: Coordination of initial deployment activities, WP 3: Roadmapping for Cooperative ITS Deployment in Europe, WP 4: Strategy coordination support). For all of them, a crucial step is the interactive discussion with the stakeholder network – not only for starting the inventory on the technical as well as strategic deployment status, but also for making the consolidated results and developed guidelines available and providing them for discussion by high-level decision makers. This guiding three-step-process represented in all work packages is illustrated in Figure 4.

Figure 4: CODECS work process for all work packages
Source: CODECS

Deliverable 2.2 analyses the state-of-the-art of C-ITS deployment preparation in Europe. The analysis represents the final step of the inventory phase with respect to WP 2. The plan of the deliverable is to report from a three level perspective on the preparation of C-ITS deployment in Europe. The guiding idea of the three level perspectives is illustrated in Figure 5.

In more detail, chapter 2 presents the different C-ITS pilots and deployment initiatives. Chapter 3 takes a different viewpoint towards C-ITS deployment, namely from the issues to be solved for deployment. Chapter 4 subsequently presents the view of core actors for C-ITS deployment. It should be noted that it is not intended to provide a micro-cube perspective as a combination of issue per actor per initiative. Chapter 5 summarises the key findings and provides an outlook towards next steps.

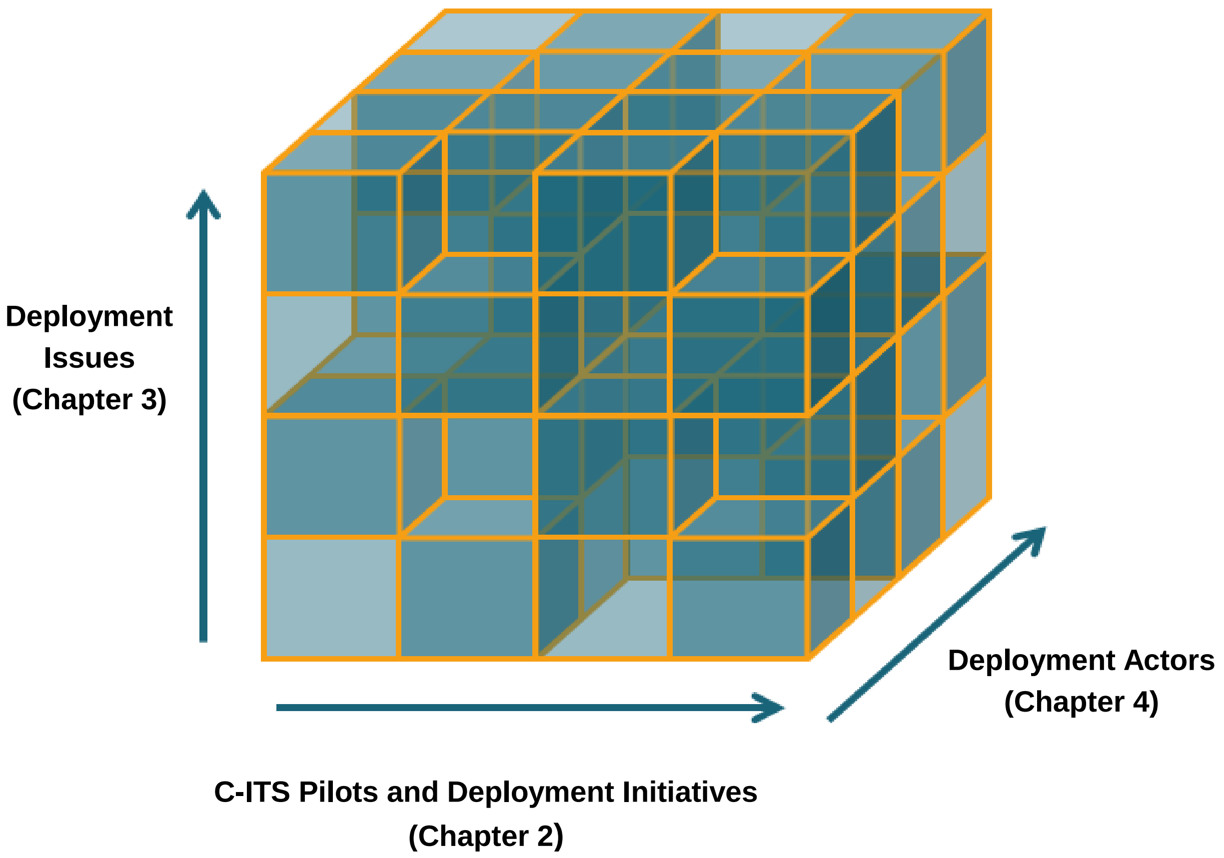


Figure 5: Deliverable concept for CODECS D2.2
Source: CODECS

2. C-ITS Pilots and Deployment Initiatives in Europe

Maturing technology and functional testing in the Field Operational Tests (FOT), together with the shaping of the C-ITS policy framework, have encouraged the efforts towards deployment preparation of services that are based on a Cooperative Intelligent Transport System (C-ITS):

- Roughly ten years ago, a number of cooperative research and development projects were initiated on national and European scale. Automotive industry, road authorities and operators and other key stakeholder have on European scale successfully performed e.g. the Integrated Projects SAFESPOT, COOPERS and CVIS.
- Beyond stimulation of further research, the stock of knowledge which emerged from these projects and studies has also paved the way towards the cooperative FOTs which have been performed in various European Member States during the last five years. Examples include simTD in Germany (Frankfurt), SCORE@F in France (Versailles), Testfeld Telematik in Austria (Vienna), DITCM testsite in the Netherlands (Helmond), SISCOGA in Spain (Galicia). The EU co-funded projects DRIVE C2X and FOTsis have aimed at linking and synchronising cooperative FOTs basically all over Europe.
- The test infrastructure in these areas has formed the nucleus for subsequent large scale pilots and deployment initiatives which have emerged in the past two to three years. On geographical scale, the initiatives aim at providing services along (TEN-T) corridors, with the goal of area wide coverage at a later stage. Meanwhile, more than ten Member States have got engaged in C-ITS deployment initiatives (see Figure 6).

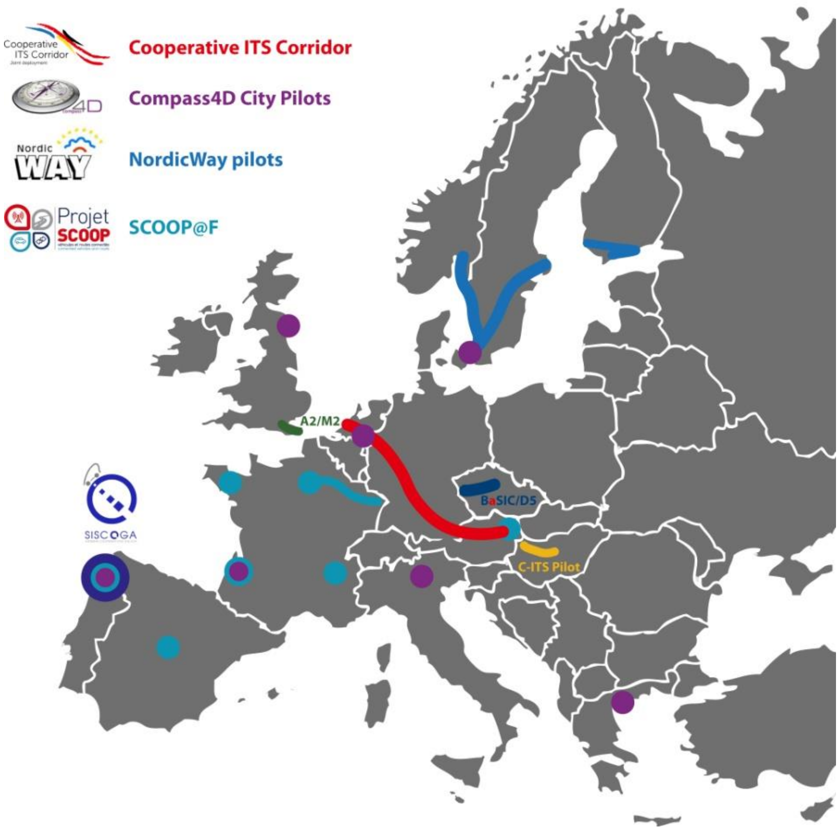


Figure 6: Overview of C-ITS Pilot and Deployment initiatives in Europe
Source: CODECS

Within the following subchapters, all recent activities are described that are relevant for (the preparation of) C-ITS deployment in Europe. For each of the deployment initiatives an overview is given and the selected services are described in more detail.

If a list of standards, that are essential for the services of the respective initiatives, is available, this information can also be found in the subchapters of the individual deployment initiative. For some of these standards, even some specialized profiles are included, that are already in use or still under development.

At the end of the chapter, a summary and overview are given, also providing links to additional sources of information regarding the presented deployment initiatives.

2.1. Cooperative ITS Corridor

The basis for the deployment of C-ITS was laid in June 2013, when the national transport ministries of Germany, the Netherlands and Austria signed a Memorandum of Understanding, in which the ministries agreed [Corridor]:

- to develop a common launch/rollout timetable for the implementation of the first cooperative applications on highways
- to define common conventions that ensure a harmonized interface with vehicles in the three countries
- to implement roadside facilities for the first collaborative applications.

A corridor, extending across the highways from Rotterdam (Netherlands), via Frankfurt/Main (Germany) to Vienna (Austria), was chosen as the route for the first deployment (Figure 7).

Along this so-called Cooperative-ITS Corridor (C-ITS Corridor), German, Dutch and Austrian highway operators, in cooperation with partners from the automotive industry, have launched the gradual deployment of Cooperative Systems to allow for an exchange of traffic-related information between vehicles and the roadside infrastructure as well as to facilitate the information flows among the first vehicles that are equipped with Cooperative Systems.

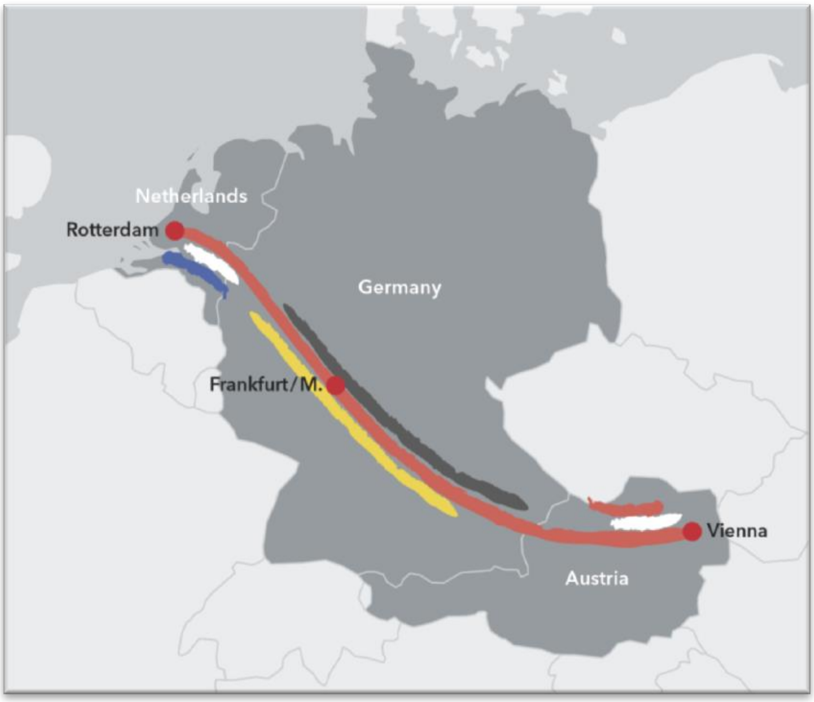


Figure 7: C-ITS Corridor Rotterdam – Frankfurt/M - Vienna
Source: Project Flyer of the Cooperative ITS Corridor [Corridor]

The effective cooperation among the three countries is a particular challenge of the C-ITS Corridor. Differences in their political and legal environment, as well as varying conditions in terms of procurement for cooperative systems result in different procedures for the conception and realization of the C-ITS Corridor. In spite of the individual, national views on the C-ITS Corridor project, the three participating countries rigorously follow the objective of a consistent, cross-border system solution. An effective coordination among the ministries of transport and road operators of the three countries is ensured by strategic and operational level teams, harmonizing the three Corridor parts to the largest possible extent. Moreover, the project works closely with international organisations and other deployment initiatives to support the pan-European harmonization efforts. These include the close cooperation with the European Commission (in particular the C-ITS platform), the Amsterdam Group and international standardization bodies (CEN / ISO / ETSI), but also strong links to knowledge management and dissemination activities like CODECS, the EU EIP and C-Roads.

The Netherlands, Germany and Austria have agreed upon the introduction of two cooperative services to be provided along the whole C-ITS Corridor:

- Road Works Warning (RWW)
- Probe Vehicle Data (PVD) or "Improved Traffic Management by Vehicle Data"

Both are part of the list of Day One services as defined by the Amsterdam Group [AG], an umbrella organisation in which representatives from European public and private road operators (mostly on high level networks) as well as city representatives collaborate with the automotive industry to stimulate deployment of Cooperative ITS. Both applications have been selected because of their present relevance, as there are still many accidents related to road works, and with regard to the further dissemination of C-ITS technology. These first applications should help to pave the way for other services, which could be added at a later date.

- **Road Works Warning**

This service is about providing in-car information about road works, adjusted to the needs of the approaching drivers, whether as immediate warning in the vicinity of the actual road works site or as routing information.

The service can be realized by equipping road works safety trailers or other roadside equipment with an appropriate communication system.

As basis for setting up the RWW service, as described below, a profiling document of the DENM standard ETSI EN 302 637-02 [DENM], called "Message Set & Triggering Conditions" has been written by an expert group within the Amsterdam Group. As of today, the most recent version of the document has been published in 2106 [WhitePaper]. So far short-term road works, e.g. less than 24 hours, are covered in detail, the upcoming version 3.0 will also include a DENM description for long-term road works.

The profile defines the use of certain data elements and reflects a kind of consensus or convention how road works have to be described when using warning message in the DENM format. It does not specify the message down to the very last bit, but leaves room for options, that are necessary due to variations in national road works guidelines, e.g. speed limits and validity times within a construction site.

In the so-called 'stand-alone mode' (without connection to a backend system), the trailer is able to determine its own position, sign configuration and for special road works configurations also lane closures in the road works zone. This information can be transmitted to oncoming vehicles, using an event triggered "Decentralised Environmental Notification Message" [DENM] on the ETSI ITS G5 channel ("WIFIp" using 5,9 GHz).

In the so called "Basic Service", the infrastructure component (road works safety trailer) continuously determines its status (and position via GPS/GNSS), sends this information to the back office, where it is evaluated and enriched with additional background information about the road works (if available). The enhanced information is sent back to the roadside station, which transmits a warning in form of an updated DENM to approaching vehicles via ETSI ITS G5. At the same time, the back office can provide data to a "Single Point of Access", where it is made available for third parties, so that all providers of traffic information services are able to use data to improve their own services and distribute it via additional channels (TMC, DAB+, apps & webservices). Examples for a Single Point of Access are the Mobility Data Marketplace in Germany and the National Data Warehouse in The Netherlands [MDM, NDW].

- **PVD or "Improved Traffic Management by Vehicle Data"**

The "Cooperative Traffic Management" service focuses on improving various services that are already set up by highway operator (e.g variable speed limits, incident detection, temporary hard should running), by improving the data base for the required traffic management decisions. Beyond that, the utilization of vehicle data will also pave the way towards a more individual traffic management, in contrast to the rather collective measures that are available for road operators nowadays.

In order to broaden the data base available in traffic control centres (TCC), cooperative messages that are sent by equipped vehicles, are received by the ETSI ITS G5 unit of the infrastructure components (e.g. gantries, road works safety trailer), pre-processed and then forwarded to the backend systems.

Message formats to be used in Day One scenarios have already been standardized as "Cooperative Awareness Messages" [CAM] and "Decentralized Environmental Notification Messages" [DENM]:

- CAMs are sent continuously with a high frequency and contain information about the current position of a vehicle, its speed, direction and dimensions.
- DENMs are sent event-driven and triggered only in case the vehicle sensors detect events like black ice, traffic jam, broken-down vehicle etc., for example.

By using the information derived from these cooperative messages, the following benefits will be sought:

- Congestion avoidance thanks to optimized routes and network control, including environmental benefits
- Improved traffic safety and incident management
- Proliferation of C-ITS technology to make it usable for further applications

In the future, additional message types might be available and used in TCCs. Even a specialized "Probe Vehicle Data" format is under discussion, a dedicated message for traffic management purposes delivering data sets optimized for traffic measurements and forecasting.

2.1.1. Dutch part of the C-ITS Corridor

The project is carried out by Rijkswaterstaat, the national road operator for highways in the Netherlands and is funded by the Ministry of Infrastructure and the Environment. Working together with suppliers

The Netherlands wants innovative systems for travel information and traffic management to become available on a large scale - both in the Netherlands and elsewhere. This will not only benefit road users and road operators, but also suppliers and therefore the Dutch economy. In the Netherlands, Rijkswaterstaat will undertake the project in cooperation with suppliers who will provide roadside equipment and after-market devices to deliver the services.

Every day, Rijkswaterstaat works on safe mobility in the Netherlands. Not only by building new roads and waterways, but also by using the existing infrastructure more efficiently. Smart technology is helping to realize that. The development of Intelligent Systems (ITS) will continue over the coming years and offer opportunities to road users, road operators and Dutch businesses. Rijkswaterstaat is currently working on the introduction of two cooperative ITS services as part of the Cooperative ITS Corridor project:

- Road Works Warning (RWW)
- Probe Vehicle Data (PVD)

It is important to mention that the C-ITS Corridor initiative is providing the basis for further developments and the introduction of additional services later on.

The goal of the RWW service is to provide timely information to the road user about road works on their trip, such as a lower maximum speed limit and the lane configuration. In the project not only the DENM's via ETSI ITS G5 ("Wifi-p") will be provided, but also forms of in-vehicle information, like the aforementioned lane configuration during road works.

As shown in Figure 8, a combination of messages can be used in the following way:

- First message, at a larger distance (3km), cellular communication
- Second message, more detail about lay-out road works, Wifi-p communication
- Third message, speed limit 90 km/h, Wifi-p communication
- Fourth message, speed limit 70 km/h, Wifi-p communication

In the A16 field operational test, a first trial following this hybrid communication concept has already been implemented and tested.

To make the field test happen, as shown in Figure 9, several parties were asked by Rijkswaterstaat to bundle their specific expertise and work together. C-ITS as a cooperative system requires specific expertise from all parties involved, but also specific collaboration to make the communication between the involved ITS stations seamless.

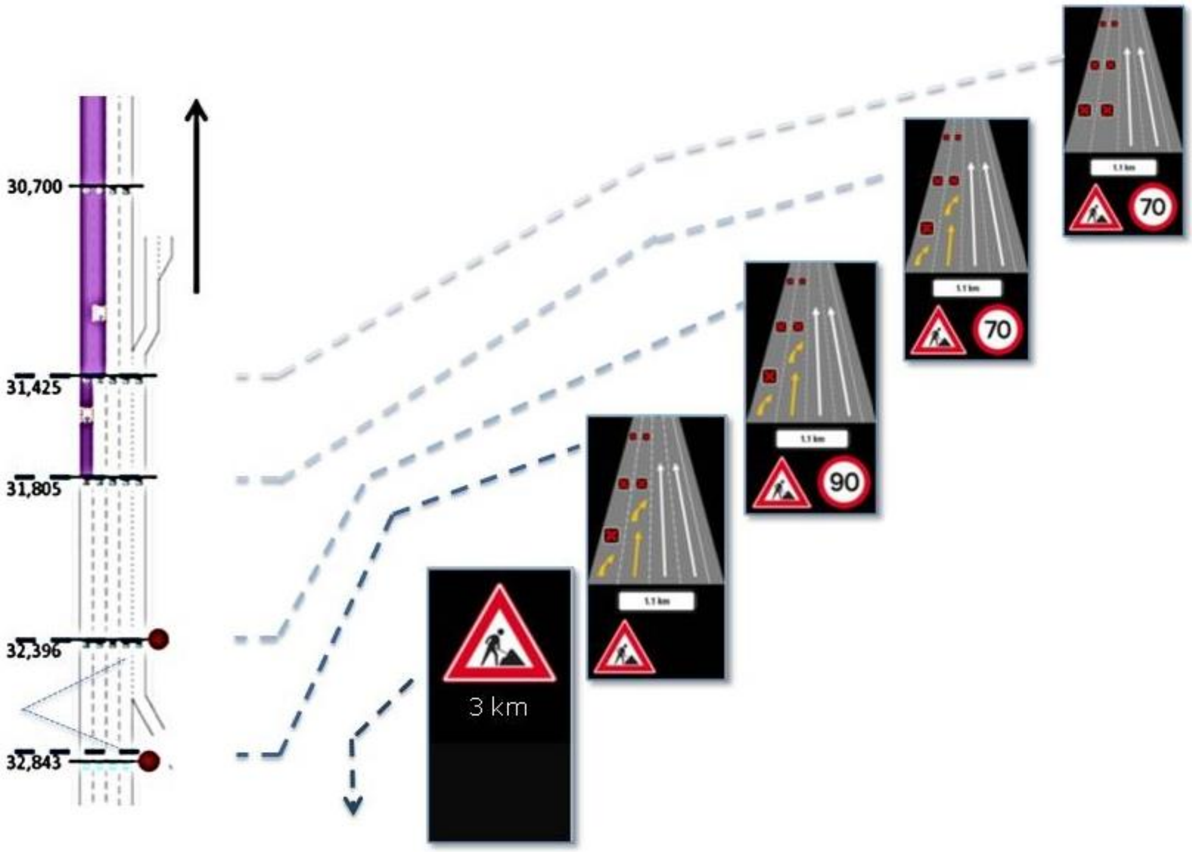


Figure 8: Schematic overview of the C-ITS Corridor Test on motorway A16
Source: Rijkswaterstaat

Figure 9: C-ITS Corridor Test on motorway A16
Source: Rijkswaterstaat

For road works in the Netherlands, two alternatives to support the road works measures are typically used, depending on the infrastructure available:

- On highways that are equipped with the Motorway Traffic Management system (MTM) red crosses are shown on variable message signs (VMS) on the gantries (every 500-800m) in case of lane closures and the VMS will show a lower maximum speed limit, see Figure 9.
- On highways where there is no MTM present, mobile systems are used for stationary road works (safety trailers, mobile lane signaling systems).

The development and deployment in the Dutch part of the C-ITS Corridor will comprise a solution for both situations.

The project is split up in the following phases:

- Research stage (2015 – 2016, finished)
- Pre-deployment: refinement of the specifications and extensive testing (2016-2017)
- Start of the tender process (end of 2017)
- Operational services (2018)

In the first phase the following issues were taken up:

- Architecture, PKI's, standardisation
- Coordination, meetings and determination of arrangements between governmental bodies, market parties and knowledge institutes
- Specifications and pre-commercial market consultation
- Several field tests on motorways A16, A58 and in Germany

The second phase is about all sorts of issues that have to be taken into account during the actual deployment and is considered as a pre-deployment phase. The year 2016 will be devoted to this pre-deployment and to further refine the specifications. The RWW service will be tested in practice at several road sections, over a longer period. Not only in the Netherlands, but also coordinated across the borders. Four elements form the main core of this phase:

- General solution for the situation with gantries
- General solution for the situation without gantries
- RWW and PVD on 3rd party infrastructure
- Impact on road operator processes

During this pre-deployment phase the project team will also work on the possible installation of some on-board units (OBUs) in test vehicles, a central system for providing the information, an evaluation plan and further refinement of the specifications. Results from all the work packages will lead to a set of recommendations for the next phases, the tender process for the actual deployment and the actual deployment itself.

2.1.2. German part of the C-ITS Corridor

In Germany, the partners involved – industry and the public sector – make investment decisions for the launch of Cooperative Systems from different individual perspectives. A specification and launch cannot be coordinated with the industry in the same way as in the Austrian Eco-AT project (see section 2.1.3 below), due to competition rules. These regulations also mean that any party may act only in its own jurisdiction, which requires extensive coordination between the partners to get to common result. As a result, the development and introduction of the two common C-ITS Corridor services is carried out in a multistage, iterative process.

An important aspect for properly operating the overall cooperative system with the two initial services is the definition of roles and responsibilities, and assigning those to the appropriate actors. This might result in changing and/or new tasks for the road works personnel, but also for the operators in the backend systems and other stakeholders. Therefore the elaboration of guidelines, operational procedures and blueprints for handbooks is an essential part of bringing cooperative services into everyday operation, which also includes re-thinking existing value chains and processes. The roles and responsibilities for the German part of the C-ITS Corridor are to a large extent based on already existing standards [ISO], [ITIL].

Another aspect is the integration of adequate IT security measures to ensure integrity, authenticity and availability of the C-ITS system, not only regarding the backend systems of the road operators, but also including messages exchanged between infrastructure and vehicles. This adds a new layer of requirements to the C-ITS system operation, namely the introduction of an information security management system [ISMS], providing an operational framework and best practices, as well as the operation of products that are certified according to the Common Criteria, a freely available ISO standard providing a comprehensive framework of security requirements and measures [CC]. These IT security aspects and the certification of compliance to the aforementioned standards are in the responsibility of the German Federal Office for Information Security (BSI).

The effort of setting up first common applications for regular operation is considerable already on a national level of cooperation, not only across the sectors, but also within the public sector. The Federal Ministry of Transport and Digital Infrastructure (BMVI) is responsible for the overall project coordination, and with strong support of the Federal Highway Research Institute (BASt), which is part of the BMVI, the introduction of cooperative systems is prepared from a perspective of the German road authority. Hessen Mobil, the highway operator of the federal state of Hesse, is carrying out the actual deployment. This comprises developing prototype units for the road works safety trailers and the software modules for enhancements of the TCC, but also testing the new technology and processes in a series of workshops together with car manufacturers and automotive industry partners.

Next step after prototyping and system specification is a six-month pilot phase in Hesse, which will be operational with around 20-30 road works safety trailers (Figure 10) on highways and some major roads in the network of Hessen Mobil. This real-life experience will allow for a fine-tuning and optimizing the technology and processes, before the roll-out will take place in five other German federal states, which are located along the C-ITS Corridor. Subsequently the introduction will take place in the remaining federal states.

Figure 10: C-ITS equipped Road Works Safety Trailer, operated by Hessen Mobil, Germany
Source: BASt

In all steps, sharing knowledge and experiences will be an essential building block for the organisational side of C-ITS operation. This holds true for identifying the right actors for certain roles and responsibilities, adequate change management on different levels (within organisations, across organisations and jurisdictions, cooperative systems in general) and certainly contains also financial aspects of tendering, procurement and service operation.

2.1.3. Austrian part of the C-ITS Corridor

In Austria, the national building block for joint deployment in the C-ITS Corridor is called ECo-AT (European Corridor - Austrian testbed for Cooperative Systems). The Eco-AT project is cofounded by the Austrian Federal Government via the Climate and Energy fund (KliEn).

The project is led by ASFINAG, Austria's national highway and expressway operator, and is split into two distinct phases, a "specification definition and testing phase" and an actual "deployment phase." In the first phase the system specifications are defined and tested in several iterative test cycles. During phase one, the work progress on the specification documents is made publically available through a set of several releases up to the end of 2016. Within each release, a system overview is given, the individual subsystems and component are described and the interfaces connecting them. Moreover use case descriptions and data models, e.g. DATEX II profiles, are published.

In addition to the common use cases of all three C-ITS Corridor partners, ECo-AT is working on the deployment of additional cooperative services like

- **In-Vehicle Information (IVI):** IVI is used to inform drivers about present speed limits and provide other (hazard) information which is shown on dynamic traffic signs.
- **Intersection Safety (ISS):** ISS means that Cooperative Traffic Lights will provide information on the traffic lights status (SPaT – Signal Phase and Timing) and a geographical representation of the vicinity of the traffic light (in format called MAP).
- **Other DENM based applications:** This use case covers the information provision from the TCC to the vehicles and vice versa, one direction of information flow as a service for the road users (including various so-called „cause codes" within the DENM messages), and the other broadening the data base for traffic managers.

Interested parties can get access to the all the specifications and documents of the individual releases by free registration at the Eco-AT homepage [Eco-AT].

In parallel with the finalization of the specifications and in transition from the first to the second phase, a "Living Lab" for testing is set up by ASFINAG, which allows vendors to deploy and test roadside equipment along certain stretches of the road network and check for conformance with the system specifications.

In the second phase, after verifying the results of the first phase, ASFINAG will commence with the actual deployment on the Austrian part of the corridor and further sections of the highway and expressway network from 2017 onwards (Figure 11).

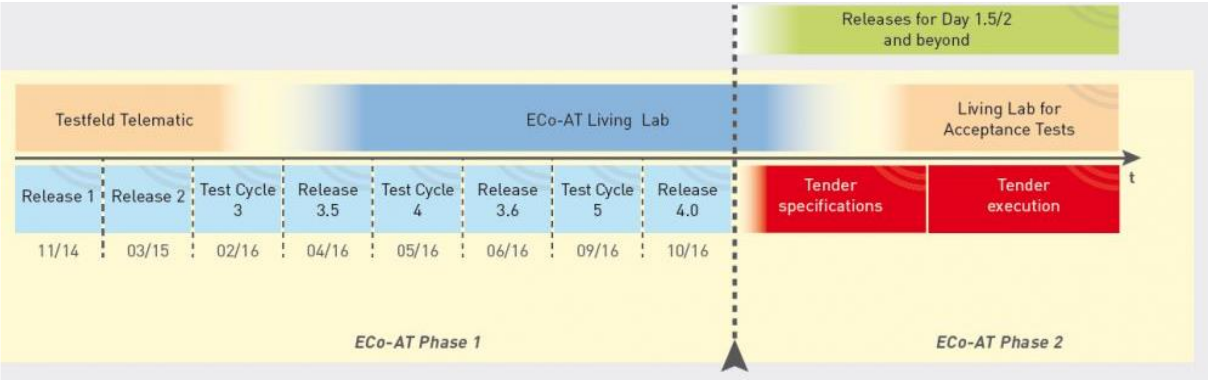


Figure 11: Eco-AT phases specification/testing, followed by tender/deployment
Source: [Eco-AT]

2.2. SCOOP@F

The C-ITS pilot deployment in France is organised via the project SCOOP. The project has been launched by the Secretary of State in charge of transport in 2014. The project goals comprise improving road safety and safety of road operating agents, making traffic management more efficient and contributing to the reduction of emissions, optimising infrastructure management costs, making vehicles fit for the future and developing new services.

In order to do so, vehicles are equipped with sensors to detect events such as slippery road, emergency braking manoeuvers, etc. and with on-board units (OBU) to transmit the information to vehicles in the vicinity (V2V) and to the road operator (V2I) through roadside units (RSU). Road operators can also transmit information (road works warning, etc.) to the vehicles through the vehicle's on-board units (I2V). In total, SCOOP aims at equipping 3,000 vehicles and deploying RSUs along more than 2,000 km of roads. The five pilot sites in France cover Ile-de-France, the motorway between Paris and Strasbourg, Isère, the Bordeaux ring road and Bretagne. Those pilot sites comprise a very different mix of road types and operating environments, involving motorways, major arterial roads in conurbations, bi-directional interurban and local roads, see Figure 12.

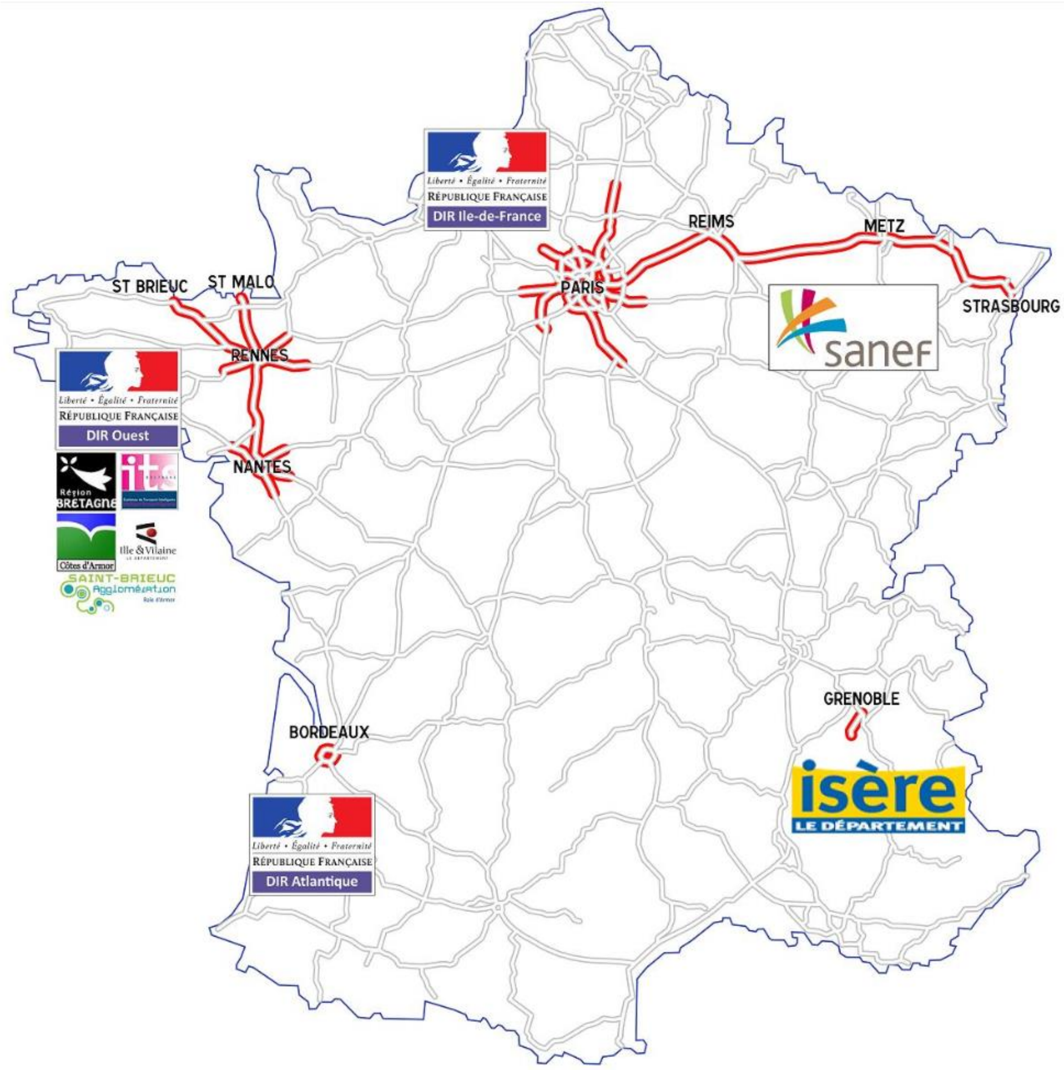


Figure 12: SCOOP@F Pilot Sites
Source: [SCOOP]

The SCOOP pilot deployment is coordinated by the French Ministry of Environment, Energy and the Sea. It comprises numerous public and private partners. The French automotive industry is represented by PSA and Renault. Local authorities and road operators are part of the collaborative team as well as universities and research institutes. SCOOP phase 1 has been carried out in the years 2014 and 2015. With the transition towards phase 2 of SCOOP (2016-2018) new partners have joined the project, amongst others a telecom operator and a trust services provider. In order to address the important issue of cross-testing of services, partners from Austria, Spain and Portugal are now also involved. The SCOOP pilot deployment receives EC co-funding (phase 2: 2014-EU-TA-0669-S, 50% co-funding of 20 Mn EUR eligible costs).

SCOOP brings on the road a number of services congruent with the Day One services of the C-ITS Platform, and more general, in line with the scope of the ITS Directive 2010/40/EU. Key services are hazardous location warnings (on-board signaling of unexpected and dangerous events, see Figure 13), road works alerts and data collection to enable enhanced traffic management. The service concept in general represents a closed loop, and congruent to other initiatives, the elements are transmitting information to road users (downlink) and taking up vehicle data in order to improve the processes for traffic management (uplink).

Documentation of the system development as well as a list of standards applicable to specifications has already been published and is available at the project homepage [SCOOP] It covers standards for the different layers of ITS stations, security, I2I communication (DATEX II) and testing.

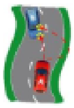
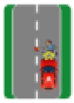
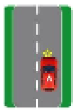
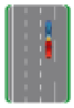
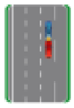
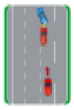
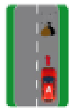
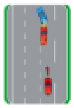
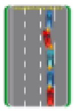
Drawing	Name	Pictogram	Objectives
	Temporarily slippery road warning		• Accident risk reductions
	Animal warning	 	• Accident risk reductions • To provide information as fast as possible and ensure real time update.
	Human presence on the road warning		• Accident risk reductions
	Obstacle on the road warning		• Accident risk reductions
	Stationary vehicle warning		• Accident risk reductions
	Broken vehicle warning		• Accident risk reductions
	Unmanaged accident warning		• Accident risk reductions
	Bad visibility warning		• Accident risk reductions
	Unmanaged blockage of the road warning		• Accident risk reductions • To redirect traffic
	Emergency brake warning		• Accident risk reductions • To avoid multiple braking that could create an early congestion
	Traffic jam ahead warning		• Accident risk reductions • Eventually, to redirect traffic
	Extreme weather condition warning	  	• Accident risk reductions

Figure 13: SCOOP@F On-board signaling of unexpected and dangerous events
Source: [SCOOP]

2.3. NordicWay

NordicWay is a C-ITS pilot in the four Nordic countries Finland, Sweden, Norway and Denmark. It aims at enhancing traffic safety and demonstrating interoperable C-ITS services in Nordic countries while building business model and an ecosystem for the data value chain and stakeholders. The NordicWay project pilots link the major metropolitan regions in the Nordic countries with one v-shaped C-ITS corridor linking Oslo, Gothenburg, Copenhagen, Stockholm and Helsinki (see Figure 14). NordicWay involves approximately 2,000 users on Nordic roads. The general timeframe of NordicWay comprises the period 2015-2017. NordicWay receives co-funding of the Connecting Europe Facility (2014-EU-TA-0060-S).

NordicWay is focused on demonstrating the concept of cellular C-ITS services utilizing 3G and 4G/LTE communication. This preference is motivated by the high availability and performance of cellular communication in the Nordic countries. In addition, the geographical conditions (i.e. large area, sparse population outside the metropolitan regions) and the resulting traffic volumes suggest to use cellular communication as preferred communication channel and to make use of ITS G5 installations only in exceptional cases (e.g. in tunnels) or special service fleets (e.g. road works warning).

Figure 14: NordicWay C-ITS Pilot
Source: [NordicWay]

NordicWay pilots three core Safety Related Traffic Information (SRTI) services:

- Cooperative Hazardous Location Warning,
- Cooperative Weather and Slippery Road Warning,
- Probe Data Services.

Also in NordicWay, the core services are congruent with the list of Day One services of the C-ITS Platform. The national pilots also include services additional to the three core services. An overview of the involved actors is provided in Figure 15.

	Finland	Sweden	Norway	Denmark
Service Provider/OEM	HERE	Scania, Volvo Cars, Kapsch	Volvo Cars	
Traffic Data Provider	FTA/ Infotripla	Ericsson, Swedish Transport Administration	Vegvesen	Danish Road Authority
TMC/Road Authority	FTA	Swedish Transport Administration	Vegvesen	Danish Road Authority

Figure 15: Actor-role mapping in NordicWay
Source: [NordicWay]

More details on national activities are summarized below:

- The Finnish pilot COOP involves the Ministry of Transport and Communication, the Finnish Transport Agency, the Transport Safety Agency (TRAFI), a consortium led by map provider HERE (involving also Infotripla, Nokia, Elisa and Solita) and VTT Research Centre. A fundamental step of the Finnish pilot is the assessment of the technical performance of cellular C-ITS systems. Proof of Concept results are available at [VTT], see Figure 16, showing the round trip times of DENM messages as results of the first test setup. The one year pilot aiming for 1.000 test users has started in May 2016 on E18 (Helsinki – Turku) and Helsinki Ring Roads I and III [FTA]. Final results are expected in September 2017.
- The Swedish pilot involves Trafikverket and the industry partners Scania, Volvo, Ericsson and Kapsch. Services include hazard warning and road works warning. Key to the Swedish pilot are naturalistic trials with a fleet of some 50+ vehicles (not all with sending capability) to be carried out in 2017.
- The Norwegian pilot with a focus on slippery road warnings consists of a fleet of 200 vehicles (already in 2016) with a goal of 500 vehicles at the end of the year. Other piloted services comprise amongst others hazard warning lights and in-vehicle signage.
- The Danish road authority provides safety related traffic information (SRTI) for two pilot applications in DATEX II. The goal is to establish and verify communication and data exchange between the national access point and shared translator by the end of 2016.

A guiding element for architecture and interoperability represents the NordicWay Interchange Server. The Interchange Server is connected to the different clouds from service providers (including OEMS acting as service provider) and interfaces also to all (national) traffic clouds and – where applicable – local TCCs, as it is illustrated in Figure 17. In that respect, this cloud connection manages the information flows and transfers messages between publishers and recipients, based on the established subscriptions and the location of the recipient.

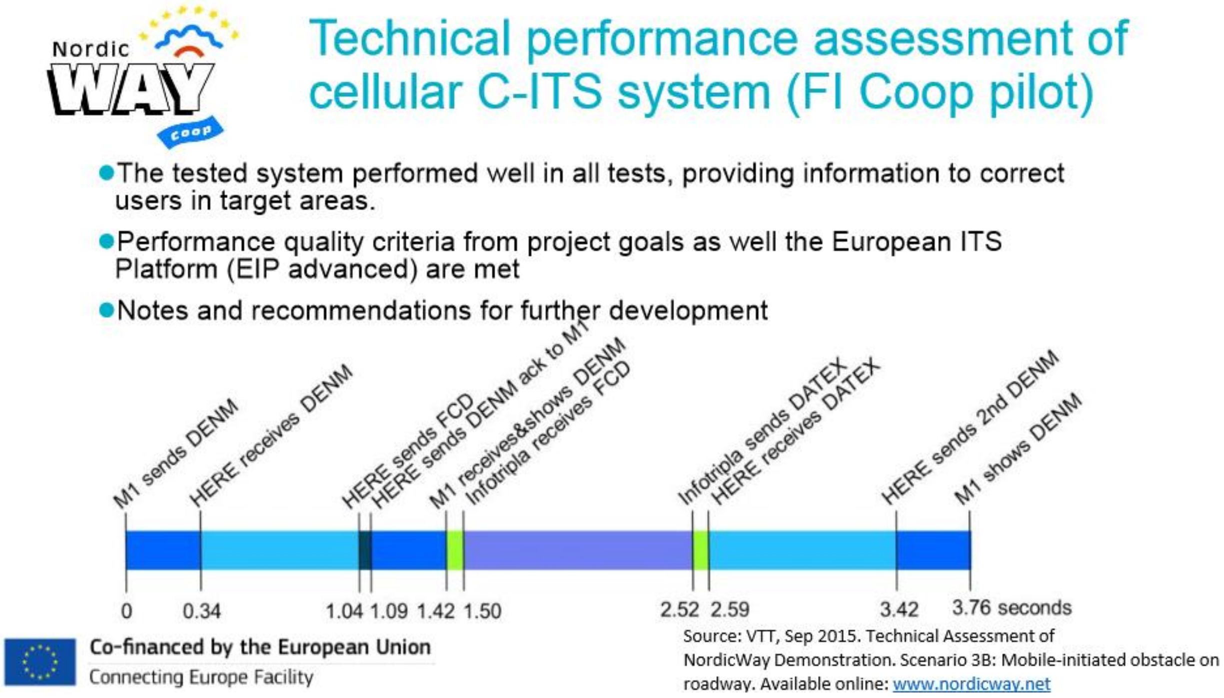


Figure 16: Technical performance assessment of cellular C-ITS system
Source: [NordicWay]

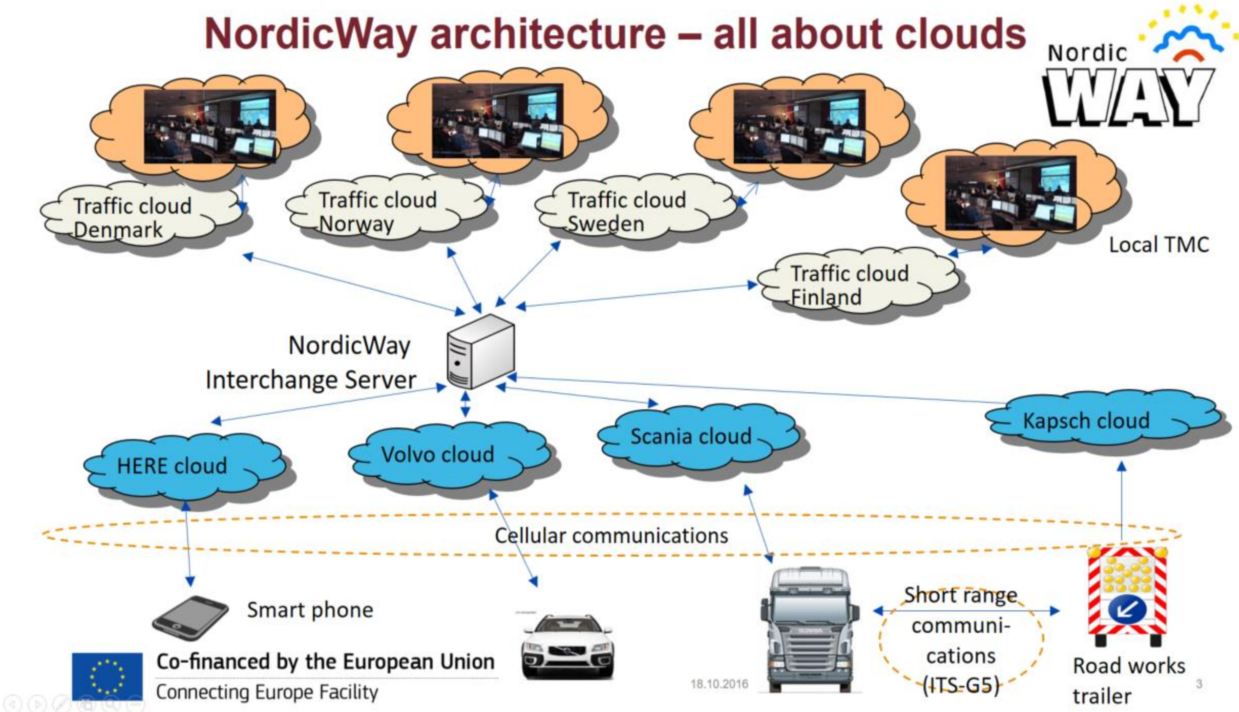


Figure 17: NordicWay architecture
Source: [NordicWay]

2.4. Deployment in the Czech Republic

C-ITS deployment in the Czech Republic is supported by national strategic documents approved by the Ministry of Transport and the Government of Czech Republic. The documents follow and further enhance EU strategic documents (e.g. Directive 2010/40/EU). In particular, the ITS Action Plan implemented by the Government in 2015 specifically defines the need to deploy C-ITS services nationwide until 2020 and to head towards autonomous driving in 2050. The C-ITS deployment is also included in an associated document – The national ITS Implementation Plan which was approved by the Government in June 2016. The Implementation Plan contains a pool of ITS projects that are either under development or yet to be realised in order to fulfill the objectives of the ITS Action Plan. Activities in C-ITS deployment between years 2013-2016 are shown in Figure 18. From this picture it becomes clear, that the deployment is supported by three levels of activities focused on Projects, Strategy documents and Support activities.

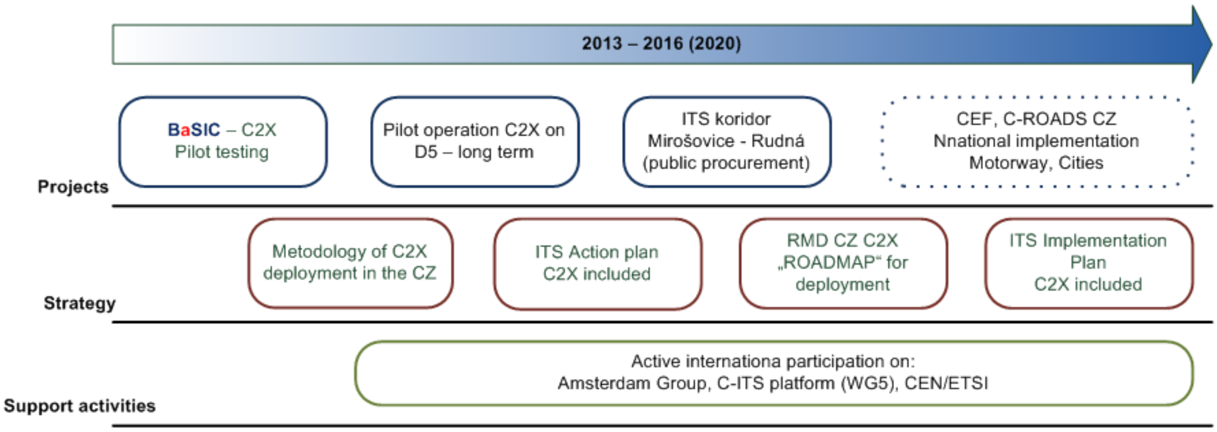


Figure 18: Overview of C-ITS deployment in the Czech Republic
Source: INTENS

Each of these activities is set into a time frame to logically follow previous action and support the following.

Several R&D projects have already been carried out in the Czech Republic that were dedicated to C-ITS pilot testing and verification of theoretical knowledge in real operation. The BaSIC project (2012-2013) was focused on short-term testing of the following applications:

- Slow moving vehicle warning
- Stationary vehicle / trailer information
- Decentralized FCD
- Approaching Emergency Vehicle Warning
- Traffic Jam Ahead Warning
- In-Vehicle Signage (IVS)
    - Highway traffic control by VMS (max. speed, lane allowance)
    - Other information (road works, rain, fog, snow etc.)
- Road Works Warning (RWW)

The communication was based solely on the ITS G5 technology. The tests were carried out on the Prague outer ring road and were a major success. A whole set of technical, legal and operational recommendations for future deployment were developed as a result of the tests.

Another pilot testing is currently in operation on the D5 motorway between Prague and Pilsen. This project is focused on long-term testing of C-ITS in real operation and related deployment issues from the road operator perspective (warranties, responsibilities, duties, operation etc.). Within this project two RSUs were mounted on the highway along with a number of equipped maintenance vehicles and warning trailers. Apart from 'conventional' C-ITS use cases (RWW, SMVW), further applications are being tested, i.e. maintenance monitoring and performance evaluation.

In 2015 the Road and Motorway Directorate implemented a Roadmap for C-ITS Deployment on the Czech road network (Figure 19). The roadmap separates the C-ITS deployment in five stages in terms of geographical coverage, deployed services (use cases) and stakeholders' involvement.

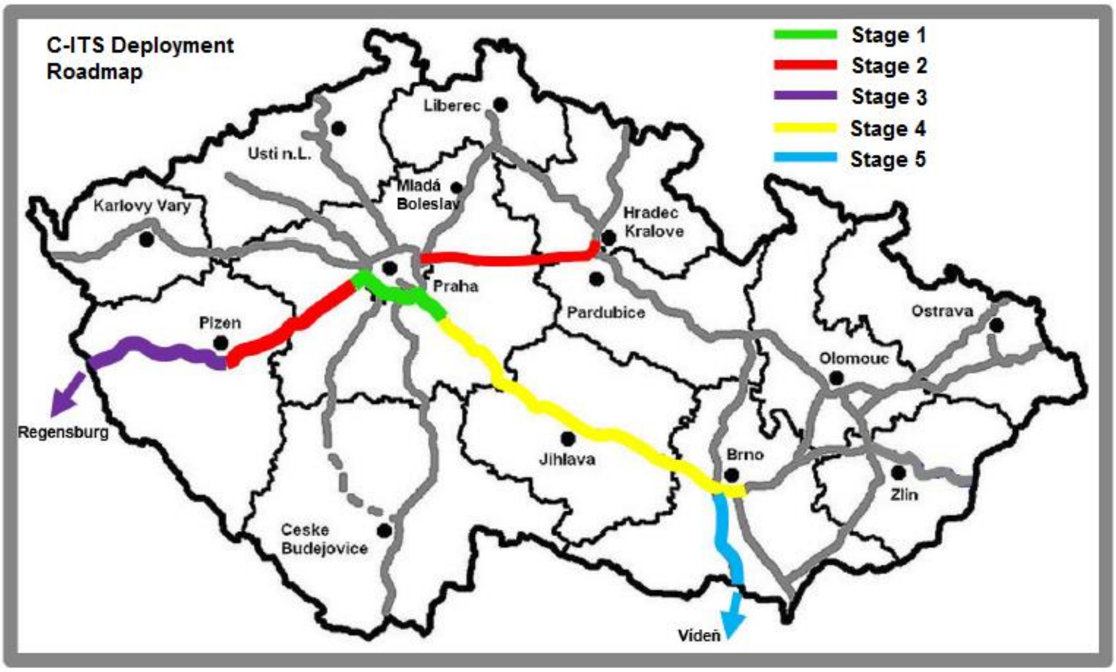


Figure 19: Roadmap for C-ITS deployment on the Czech road network
Source: INTENS

In fact, Stage 1 (also known and Cooperative Corridor Mirošovice – Rudná) is already in the tendering process and to be realized by the end of 2016, as it is included in the ITS Implementation Plan. With parts of the D5 motorway, the D0 Prague Ring Road and the D1 motorway with total length of 50 km, it covers the busiest Czech highway sections. Along with 29 RSUs, more than 150 maintenance vehicles and mobile trailers are to be equipped with hybrid ITS G5 / GSM technology.

The following services are to be deployed within the Stage 1:

- Probe Vehicle Data
- Road Works Warning
- In-Vehicle Information
- Additional traffic data collection (WiFi- and Bluetooth based)

In addition, the Czech national C-ITS back-office platform is to be developed and put into operation as a part of this project. The technical specifications of the Stage 1 closely followed the specifications of the Austrian consortium working on the European Cooperative ITS Corridor (Eco-AT). Hybrid communication of ITS G5 / 3G / LTE is expected to be used for communication with the on-board units (OBUs). The DATEX II profile will be used for communication between the C-ITS back office and the National Traffic Control and Information Centre.

In 2016 Czech Republic has built a strong consortium of infrastructure operators (both road and railway), telco operators, researchers, and ITS consultants, supported by automobile manufacturer SKODA and led by the Ministry of Transport, to join the international C-ROADS initiative within the Connecting Europe Facility (CEF) funding scheme. As a result, the C-Roads CZ project has been approved by the European Commission and commences in September 2016. The ambitions of the project are high – it covers all the remaining stages of the C-ITS Roadmap as the D1 (Prague – Brno), D5, D11 and D52 motorways are to be covered with hybrid ITS G5 / LTE technology, along with additional deployment in the city of Brno, and field testing in the cities of Ostrava and Pilsen. On top of this, C-ITS deployment on railway crossings is to be deployed on 2 railway crossings in the Pardubice region as a part of the C-Roads CZ project. Following the actual deployment, international cross-site tests will be carried between different member states of the C-Roads initiative in order to secure interoperability. The project will be in operation from 2016 to 2020 and covers the following applications:

- Emergency vehicle approaching
- Slow or stationary vehicle(s)
- Traffic jam ahead warning
- Hazardous location notification
- Road works warning
- Weather conditions
- In-vehicle signage
- Probe vehicle data
- Signal violation/Intersection safety

A number of previously defined issues of technical, legal and administrative nature have yet to be resolved within this project in order to proceed to large-scale deployment. Such barriers include interoperability with the 5,8 GHz toll collection system, security aspects, interoperability with neighbouring countries (i.e. Austria and Germany) and clear definition of responsibilities and duties of stakeholders.

2.5. C-ITS Pilot in Hungary

One of the main drivers to foster C-ITS deployment in Hungary was the involvement in the European CROCODILE project. The project objectives were to improve the quality and availability of traffic data, to secure exchange of this data with neighbouring countries in DATEX II format, to improve road safety, i.e. in work zones, and to provide quality traffic information services to the drivers.

In line with the above mentioned objectives, the Hungarian Public Road Company has selected part of its network for C-ITS services deployment. The 136km-long stretch of the M1 motorway between Austria and Budapest has been equipped with 27 fixed- and 20 mobile RSUs towards the end of 2015. The fixed units were mounted on VMS gantries and SOS stations, whereas the mobile devices were put in maintenance vehicles as well as mobile trailers. The communication between RSUs and OBUs is thus far based solely on ITS G5. The following use cases have been implemented within the Hungarian C-ITS pilot so far:

- Traffic jam ahead warning
- Hazardous location notification
- Road works warning
- Weather conditions
- In-vehicle signage (trailers equipped with VMS)

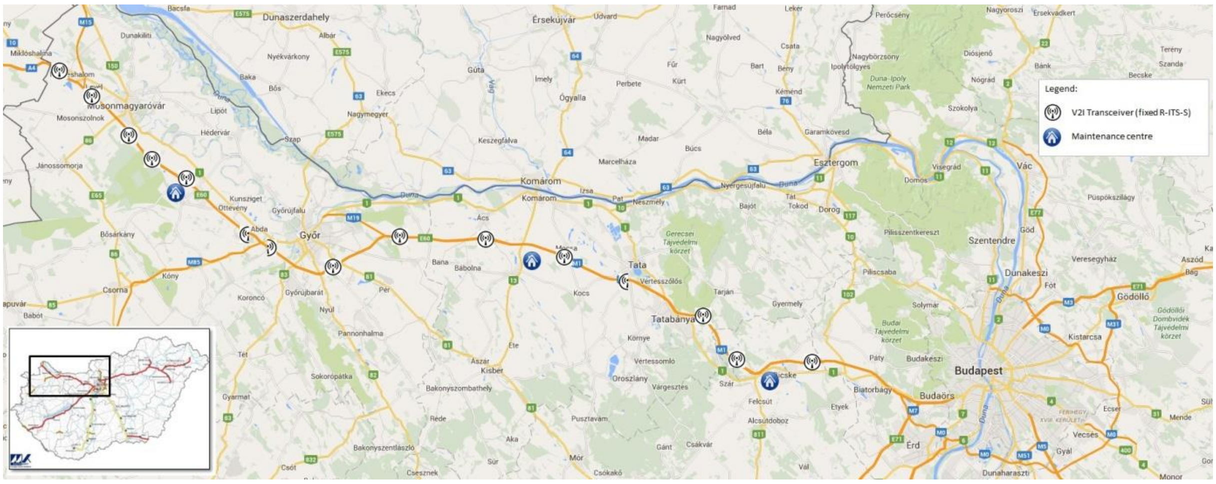


Figure 20: Location of the Hungarian C-ITS deployment activities
Source: Hungarian Public Road Company

The Hungarian Public Road Company intends to extend the C-ITS deployment both in terms of geographical coverage, and offered services. The focus shall be put on urban deployment, in particular GLOSA/Time-to-green as well as intersection safety (signal violation). The upgrade should also concern the communication technology – deployment of hybrid DSRC / cellular technology is envisaged in near future.

2.6. SISCOGA and related initiatives in Spain

The SISCOGA (SIStemas COoperativos GAlicia) cooperative corridor is located in the area of Vigo, Galicia (Spain). The pilot has been established as part of the DRIVE C2X EU Project (Figure 21), and it comprises 120 kilometres of interurban roads – the selected road are AP-9, A-52 and A-55 – but also urban environment along the main streets of Vigo (Figure 22).

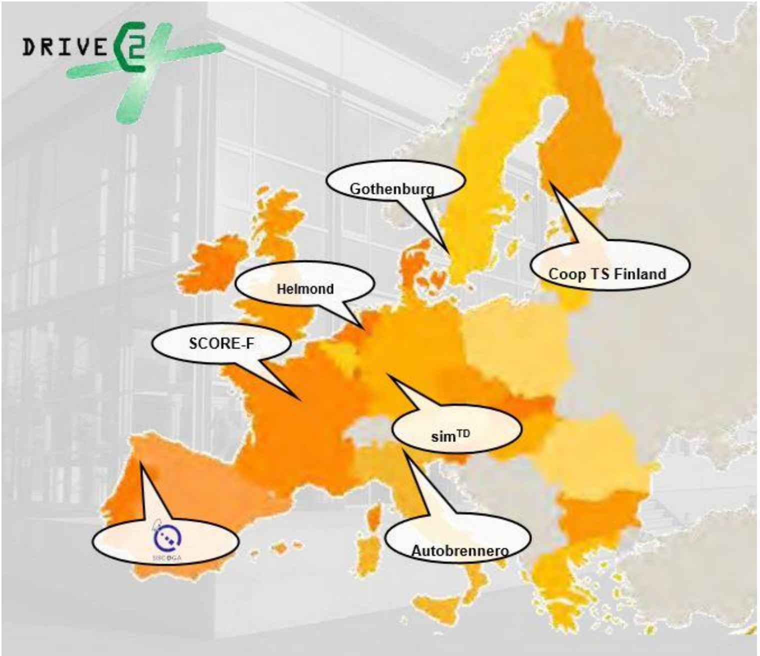


Figure 21: SISCOGA as part of the DRIVE C2X project landscape
Source: DRIVE C2X

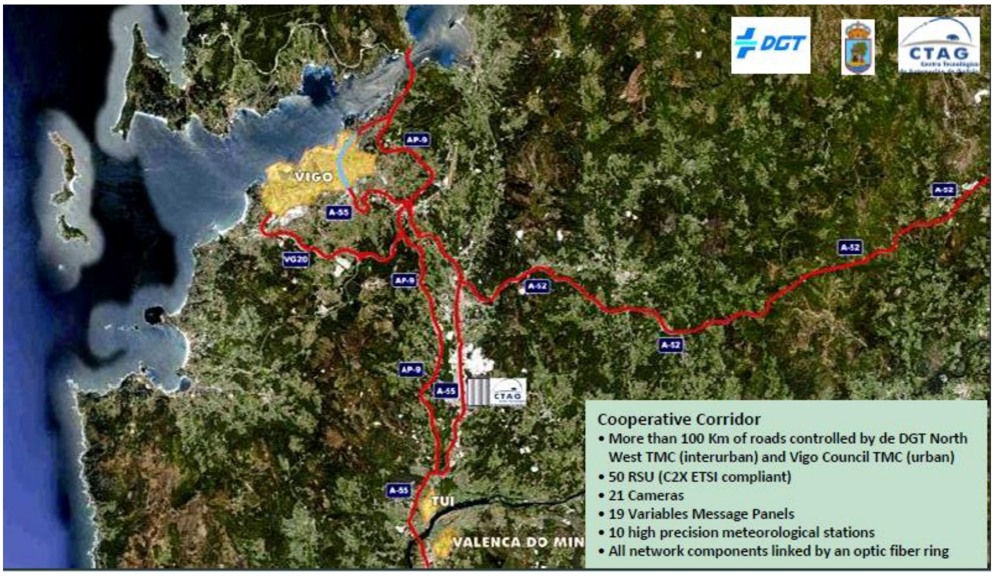


Figure 22: Detailled view of the Spanish project site
Source: CTAG

The connection of roadside equipment to the backend systems was done in a uniform way throughout the whole SISCOGA project, and from a high-level perspective also,the schematic setup looks the same for all parts of the affected network. Due the inclusion of interurban as well as urban environments and use cases, there were some differences in the type of equipment that had to be set up for the motorways and the Vigo area.

Along roads of high-level network the following equipment was deployed

- 30 Roadside Units (C2X ETSI compliant)
- 21 Cameras
- 19 Variable Message Signs
- 10 High precision meteorological stations

All the above-mentioned network components have been linked by a fiber optic ring, allowing traffic information to be provided in real-time by DGT North West Traffic Management Centre.

For the use cases focusing on urban environment, the following equipment was deployed:

- 24 Roadside Units (C2X ETSI compliant)
- 43 Traffic Detectors
- 5 Cameras

Traffic information is provided by Vigo Council Traffic Department. An architectural overview of the pilot is shown in Figure 23:

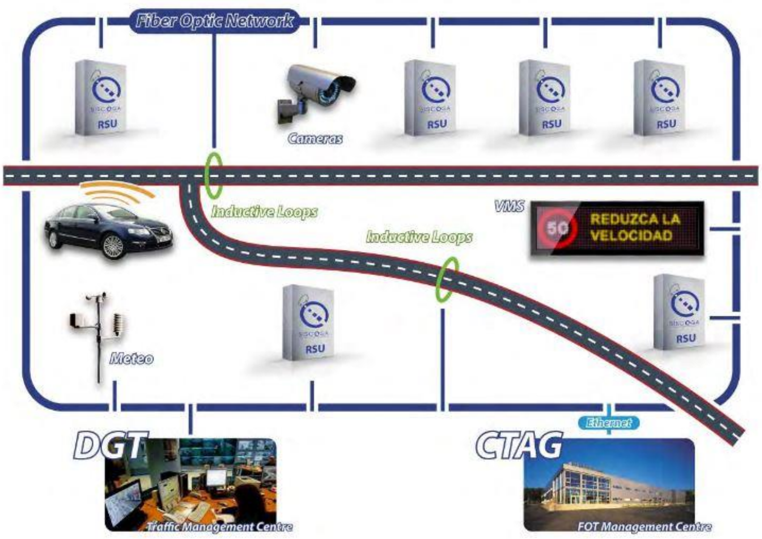


Figure 23: Schematic SISCOGA setup
Source: DGT/CTAG

From the various use cases covered by the DRIVE C2X project, not all of them have been implemented in every European test site. The services initially selected for SISCOGA are:

- Accident / Traffic Jam Ahead Warning
- Alternative Route Information
- Road Works Warning (RWW)
- Cooperative Floating Car Data
- Adverse Weather Warning
- Regulatory and Contextual Speed Limit

Figure 24: SISCOGA services: “RWW” and “Adverse Weather Warning”
Source: CTAG

Beyond the services that had been selected for initial deployment, the SISCOGA initiative has defined a set of future services to be implemented as next steps:

- Priority for public buses at intersections
- Priority for emergency vehicles
- GLOSA (Green Light Optimal Speed Advice) for normal cars
- Cooperative parking management
- Contextual traffic information and alternative route

For the implementation and operation of these services, the use of following communication technology has to be considered for SISCOGA:

- ETSI G5 for cooperative services
- WIFI for OBU-HMI communication
- Cellular link for data logged transmission (planned to be used for non safety related cooperative services as well)
- Wired communication for RSUs network (optic fiber)

The most important standards applied in the project are the following:

- ETSI EN 302 627-2 – CAM
- ETSI EN 302 637-3 – DENM
- ETSI EN 302 636-5 – Basic Transport Protocol -
- ETSI EN 302 636-4 – Geonetworking
- ETSI EN 302 571 – Radiocommunications equipment operating at 5.9 GHz
- ETSI-EN-302-665 – Reference ITS station communication architecture
- ISO-21217 – Reference ITS station communication architecture

2.7. A2/M2 Connected Vehicle Corridor

The A2/M2 (London to Dover) Connected Vehicle Corridor (see Figure 25) is derived from the road investment strategy aiming at providing roadside WiFi capabilities on a number of motorways in England such as M2, M20, M26, M25. The planned Day One use cases which are consistent with the Day One list elaborated by the C-ITS Platform comprise the following:

- Road works information,
- Road works warning data,
- In-vehicle signing,
- Probe vehicle data,
- Signal phasing information (urban C-ITS),
- Freight services.

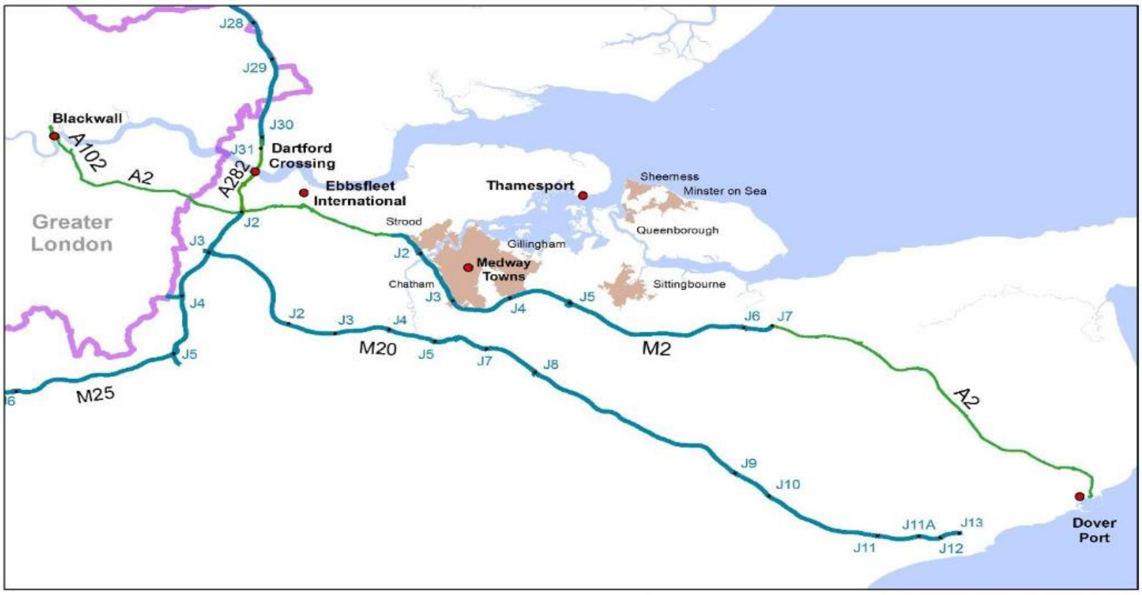


Figure 25: A2/M2 Connected Vehicle Corridor
Source: DfT

The intention is to install a living laboratory for testing and evaluating future technologies. Currently, a series of feasibility studies is already underway (identification of services and infrastructure for the pilot, impact assessment framework, definition of data management requirements/new services) or subject to further studies (framework for industry to test equipment, ITS G5 capability and capacity, retrofitting connecting vehicles). A draft potential core C-ITS data management system is illustrated in Figure 26. The A2/M2 Programme encompasses the years 2016 to 2019.The A2/M2 Connected Vehicle Corridor is now embedded in the INTERCOR project (linking UK with Benelux and France, see chapter 2.9) which has been recommended for CEF co-funding in June 2016.

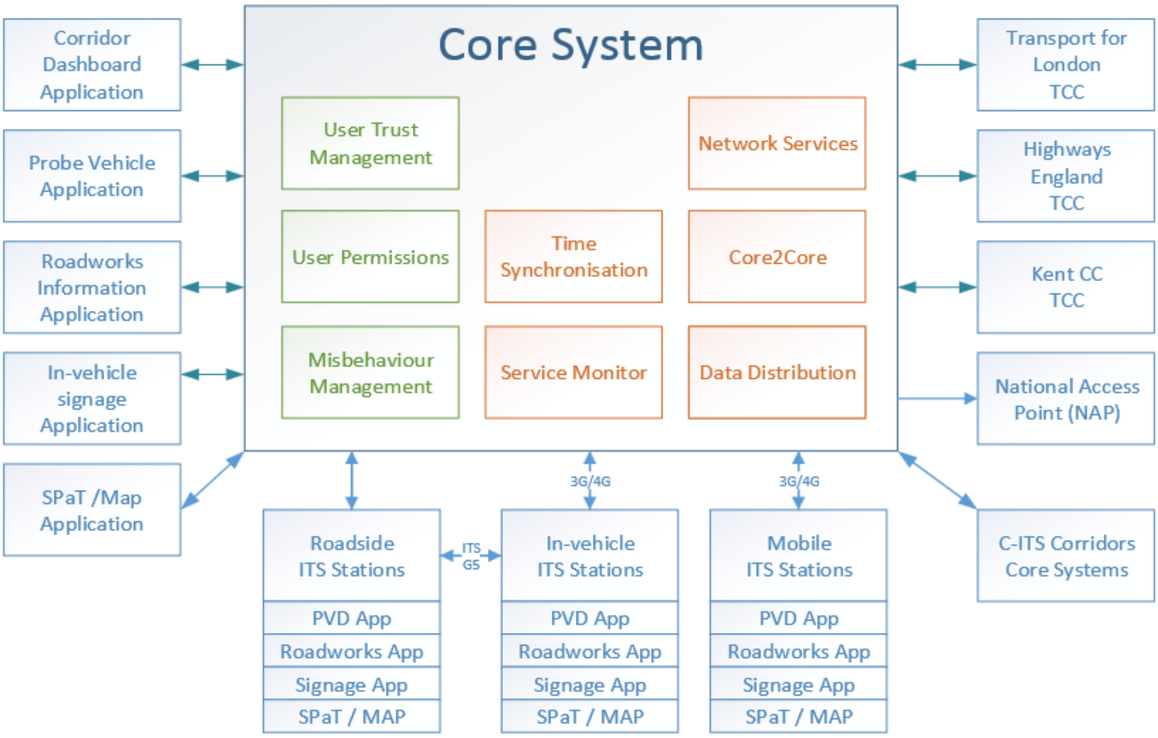


Figure 26: Draft potential core C-ITS Data Management System
Source: DfT

2.8. City pilot deployment (Compass4D)

ITS is not new to cities; it is widely deployed for managing traffic and fleets (eg, buses, public bikes, trucks), providing traffic and travel information, paying for transport services and enforcing traffic rules (parking, access restrictions, etc) among others.

In many cities, there already exists infrastructure-vehicle communication, mainly for fleet priority systems (public transport and emergency vehicles). Such systems make use of a range of communication technologies: GPS, short-range (tag and beacon) and cellular. However, current systems are not using standardised messages (SPaT/MAP, CAM, DENM) nor are they using the dedicated short-range frequency for vehicle-infrastructure communications, ITS G5.

For what concerns mainstream C-ITS (standardised message sets, cellular or ITS-G5), cities are not as advanced as highway authorities with regards to deployment. Nonetheless, some cities are considering deployment and some have piloted a number of C-ITS applications (GLOSA, priority at traffic lights, red light violation, etc) over the years in the context of European and national-funded projects (Compass4D, Freilot, Smartfreight, CVIS, URBAN, etc). Building on the experiences of these demos and pilots, some cities are making plans for deployment and in a small number of cities, the C-ITS services piloted remain post-project, albeit for a small number of vehicles. Compass4D is one such project which is promoting the continuation of C-ITS services post-project.

2.8.1. Compass4D

The Compass4D project, which ended in December 2015, has piloted cooperative services in seven European cities: Bordeaux, Copenhagen, Helmond, Newcastle, Thessaloniki, Verona and Vigo. As of January 2016, Compass4D is continued as a self-funded activity supported by the ERTICO Partnership [C4D].

Until now, nearly 300 roadside units have been installed, more than 600 vehicles have been equipped with C-ITS capability and over 1200 drivers have been involved in the pilots, which focus on three cooperative services:

- Energy efficiency intersection service (EEIS)

  EEIS provides advice to optimise the way vehicles pass through an intersection. Information on the traffic light status is transmitted from the traffic light control unit to the oncoming vehicles. Inside the vehicle the driver receives information on when the traffic light ahead will change, either in the form of a time countdown or as a speed advice.

- Road hazard warning (RHW)

  RHW provides a variety of safety warnings to vehicles where there is an upcoming, and possibly dangerous, event. Such an event may include road works, a pedestrian crossing, an accident, an end of queue or an emergency vehicle approaching, among others.

- Red light vehicle warning (RLVW)

  RLVW aims to improve safety at signalised intersections by detecting and/or predicting dangerous situations at intersections, such as conflicting turns across a junction or a vehicle violating a red light.

City	C-ITS services			Infrastructure	Users
	RHW	EEIS	RLVW		
Bordeaux	x	x	x	21 RSU, 3G/4G, ITS-G5	87 buses, 2 hydrogen cars, 17 HGVs, 330 drivers
Copenha-gen		x		21 RSU, ITS-G5	87 buses, 2 hydrogen cars, 17 HGVs, 330 drivers
Helmond	x	x	x	24 RSU, ITS-G5	2 buses, 2 electric cars, 4 cars, 8 trucks, 10 taxis, 12 emergency vehicles, 52 drivers
Newcastle		x		20 RSU, ITS-G5	2 electric cars, 11 ambulance service vehicles (non- emergen-cy), 20 drivers
Thessaloni-ki	x	x		7 RSU, LTE, ITS-G5	350 taxis, 1 car, 600 drivers,
Verona		x		3 RSU, ITS-G5	10 buses, 30 cars, 50 drivers
Vigo	x	x		37 RSU, ITS-G5	20 buses, 13 cars, 10 taxis, 2 emergency vehicles, 77 drivers

Table 1: European cities' deployment initiatives overview

Showing the status of C-ITS deployment in a selection of Compass4D cities and complementing the general overview of Compass4D, more detailed information is given for the cities of Helmond and Copenhagen.

2.8.2. Helmond

Helmond is continuing the Compass4D services in 2016 and has also become involved in a number of initiatives to upscale the current services to more users and to more cities. One such initiative is the ITS Agency BrabantStad, which started its activities in 2016. This agency is a cooperation of 5 cities in southern Netherlands (Tilburg, Den Bosch, Breda, Eindhoven and Helmond), the Province of North-Brabant and Rijkswaterstaat (national highways authority), which will work together on sharing good practice and knowledge about ITS as well as the implementation of ITS services in order to achieve economies of scale.

This cooperation will ensure that the C-ITS services become available in more cities. For example, the city of Tilburg will invest in ITS-G5 infrastructure in 2016 and 2017 at approximately 20 intersections. In 2017, the ITS Agency BrabantStad will take charge of the cost and installation of a hybrid communication testbed running from Helmond to Eindhoven to Tilburg, hence including both urban as well as interurban/highway roads.

Besides investing in more C-ITS infrastructure in more cities, the city of Helmond and the region will involve more (professional) users. From 2017 onwards, more buses will be equipped with ITS G5 or hybrid OBUs. Furthermore, a number of new European projects will see the number of equipped trucks and emergency vehicles increase to more than 100 in the next two years.

Finally, the Compass4D services RHW and RLVW, which have not been piloted to a full extent within Compass4D, will be piloted again and improved as part of the new projects. Application of C-ITS for increasing road safety is very important for Helmond too.

2.8.3. Copenhagen

Compass4D is the first *large* C-ITS project for the city of Copenhagen. Some 33 intersections, mainly on the city's ring road, have been equipped to run EEIS and RHW directed at 87 buses and 30 trucks using ITS-G5 communication technology. This experience has been most useful as it has revealed a number of key C-ITS deployment issues that are valid for most cities, including:

- Need for new procedures and technical developments to integrate C-ITS in existing traffic systems infrastructure and operating environment
- Lack of C-ITS awareness among local traffic system providers
- Absence of backward compatibility with existing communication systems
- Need for guidance on which communication technology to use under which circumstances and for which C-ITS service
- Need for collaboration with many players to ensure wider roll out of a service

By way of next steps, Copenhagen plans to upgrade the RSUs to the latest EU standardised protocols in the latter part of 2016 and to install the following year an additional 16 RSUs on other parts of the ring-road and 30 OBUs. The new implementation will also include a cloud based solution using 3G/4G, thus making it possible to use the system without a specialised OBU, but just a Smartphone. A request for additional funding has been made in order to roll out C-ITS on the entire ring road.

2.9. Emerging initiatives – C-Roads / INTERCOR

With regard to the three level approach of DG MOVE (policy development – support – implementation, see Figure 1), the EC has called for proposals to pilot and deploy C-ITS services. The CEF call was launched November 2015 and was closed in February 2016. This call resulted in the acceptance of most notably the C-Roads "family" and INTERCOR proposals. Nearly all of the proposals are recommended to receive CEF co-funding. It is expected that the projects will start either end of 2016 or beginning of 2017.

2.9.1. C-Roads

C-Roads consists of a family of national pilots within the C-Roads Member States. Figure 27 (stemming from the proposal phase) illustrates the geographical extension of the planned C-ITS pilots . A related mapping of planned services per pilot is illustrated in Figure 28. The list of services is again congruent with the list of Day One Services from the C-ITS Platform.

The C-Roads family consists of C-Roads Austria, C-Roads Belgium/Flanders, C-Roads Czech Republic, C-Roads France, C-Roads Germany and C-Roads Slovenia. All C-Roads pilots will contribute to a harmonization effort labeled as C-Roads Platform. It is expected that also other pilots (e.g. INTERCOR) and existing ones (e.g. NordicWay) will contribute to the C-Roads Platform (managed by Austria). The harmonization efforts comprise Working Groups on pilot tracking, organisational aspects, technical aspects as well as evaluation and assessment.

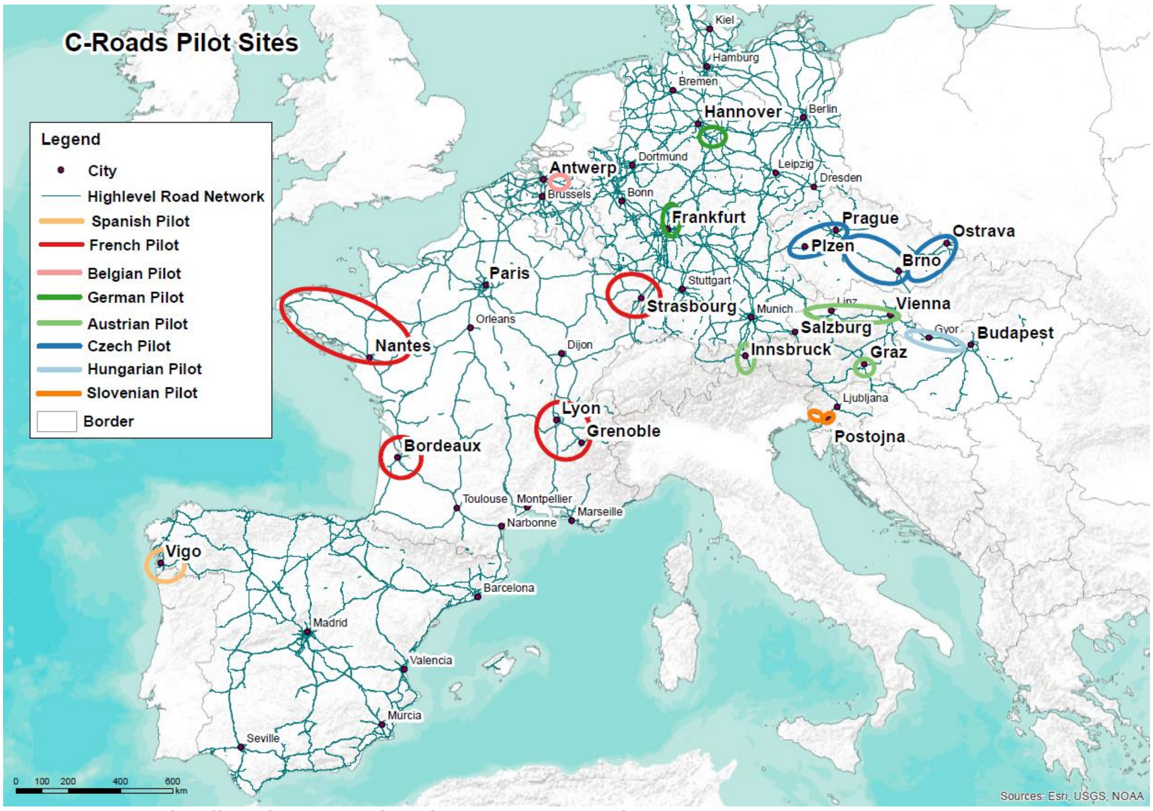


Figure 27: C-Roads pilot sites covering the TEN-T network.
Source: C-Roads

	Austria	Belgium	Czech Republic	France	Germany	Hungary	Slovenia	Spain
Communication technologies used								
ETSI G5	x		x	x	x	x	x	x
Cellular Communication	x	x	x	x	x		x	x
DAB					x			
RDS							x	
WiFi and Bluetooth				x				
Day-1-services covered								
Emergency electronic brake light								x
Emergency vehicle approaching			x					x
Slow or stationary vehicle(s)	x	x	x	x	x			x
Traffic jam ahead warning	x	x	x	x	x	x	x	x
Hazardous location notification	x	x	x	x		x	x	x
Road works warning	x	x	x	x	x	x	x	x
Weather conditions	x	x	x	x		x	x	x
In-vehicle signage	x		x	x	x	x	x	x
In-vehicle speed limits	x					x	x	x
Probe vehicle data	x		x	x	x		x	x
Shockwave damping		x			x			x
Green Light Optimal Speed Advisory (GLOSA) / Time To Green (TTG)	x			x	x			x
Signal violation/Intersection safety	x		x					x
Traffic signal priority request by designated vehicles								x

Figure 28: Services and technologies covered by C-Roads
Source: C-Roads

2.9.2. INTERCOR

INTERCOR stands for “Interoperable Corridors” linking the C-ITS corridor initiatives of the Netherlands, i.e. the Dutch part of the C-ITS Corridor NL-DE-AT, the French SCOOP@F project and extending to the United Kingdom and C-ITS initiatives in Belgium. INTERCOR aims for achieving a sustainable network of corridors providing continuity of C-ITS services and offering a testbed for beyond Day One C-ITS service development. INTERCOR is a 3 year study that seeks to enable vehicles and the related road infrastructure to communicate data through cellular, ITS G5 or a combination of cellular and ITS-G5 (hybrid) networks on a road corridor through the Netherlands, Belgium/Flanders, UK and France to achieve safer, more efficient and more convenient mobility of people and goods.

The objectives of the INTERCOR study are:

- Demonstrating a large-scale interoperable deployment of C-ITS through the Netherlands, Belgium / Flanders, UK and France to achieve safer, more efficient and more convenient mobility of people and goods.
- Foster four member states cross border interoperability by ensuring *interoperability testing*, *security* and *certification*, *seamless continuity of service*, *operation* and *maintenance*.
- Provide C-ITS services on a broader scale by specifying, using and fostering a *hybrid communication* approach to utilise a combination of cellular and ITS-G5 communication.
- Extend the strategic cooperation between C-ITS front running countries and assist other member states to step-in in a cost-effective and future-proof way to develop and apply the common deployment framework through a consistent and cohesive network of corridors.
- Evaluate through a common evaluation framework the cumulative, real-life benefits of C-ITS applications towards increased safety, efficiency, flexibility, user acceptance, sustainability of road transport, to support public and private stakeholders to invest in C-ITS.

This study supports the ambition of the Dutch EU-Presidency (2016) on Smart Mobility which aims to ensure a smooth and effective transition from navigation of vehicles to truly connected, cooperative, and automated vehicles on European roads. The study will help to achieve the C-ITS communication deployment on European roads and ensure new V2V, V2I and V2X services and systems are compatible and interoperable on a EU level.

These studies also support the EU ambition to share best practices by providing large scale cross border test possibilities in Europe. One of the aspects facilitated is the exchange of best practices between and within Member States. This emphasises the added value of a coordinated approach amongst all stakeholders on investments along a common European roadmap and the shared learning among these stakeholders.

Through the C-ITS project “SCOOP@F”, the French Ministry of ecology, sustainable development and energy (MEDDE) has already gained very important experiences on how to deploy C-ITS services, in all phases from specification to interoperability testing between its five pilot sites. A particular focus is the security challenge of such data exchanges and the C-ITS services, also in terms of privacy and further use of the data. In addition, MEDDE has already quite extensive experience in collaborative initiatives regarding interoperability solutions for the freight sector through its ITS Taskforce.

The Dutch Ministry of Infrastructure and the Environment (Rijkswaterstaat) and the Province of Noord-Brabant contribute their extensive knowledge of traffic management approaches, also regarding the freight specific services that the consortium wants to explore together. Rijkswaterstaat also gained important experiences and learning via its work with Germany and Austria on the respective C-ITS Corridor, the “Shockwave Damping” project on the A58 and Pilot Project Amsterdam (Praktijkproef Amsterdam) [PPA].

Both the Dutch Ministry as well as the Flemish Ministry pursue a strategy of optimising freight logistics for smarter and more efficient transports to offer a better use of existing (road) capacity, security and added value services to its freight transporters and logisticians, but also to other road users. Flanders so far gained little knowledge on the deployment of C-ITS services and will take advantage of the proposed collaboration.

The United Kingdom’s Department for Transport, along with its road authority partners, have extensive knowledge of C-ITS trials from their involvement in Compass4D, CVIS, MOBINET and other EU projects. This experience will be applied to deliver C-ITS solutions that mitigate common traffic problems all partners are facing, whether related to road safety, congestion, or emissions - in particular freight logistics around TEN-T ports and strategic road tunnels, such as the Blackwall Tunnel in London.

ERTICO will utilise the communication expertise and channels set-up for all ERTICO Partnership activities ensuring a maximum outreach of the results, functionalities and take-up of the INTERCOR study.

Lastly TTP/i-Trans, specifically through its team at the freight specialized i-Fret innovation platform, is active in sensibilisation actions on ITS for transport and logistics companies in Northern France [TTP].

- The four countries have agreed on a common set of standards, profiles and specifications for C-ITS and will bring these results to the C-ITS platform whereas wider adoption will be promoted through close cooperation in C-ROADS platform study.
- Multiple communication media can be used, in particular ITS-G5 and cellular networks, so end users can benefit from the continuity of C-ITS services via a communication technology implementation strategy which provides complementary features.
- Security measures are in place, so an end user can access all services at all corridors within the limitations of the local security provisions.
- Logistic services related to traffic management are available at relevant areas across the network of corridors.

This study supports European, national and regional policies and ambitions regarding road transport in general (i.e. safety, efficiency, sustainability, competitiveness) with a specific additional focus on freight and logistics.

Figure 29: INTERCOR network coverage - connecting Belgium, The Netherlands, France and UK, also towards C-Roads and existing Deployment initiatives.
Source: INTERCOR project proposal

2.10. Current Activities – Summary

Chapter 2 as an overview of pilots and deployment initiatives has demonstrated that there is a growing interest in Europe to prepare for deployment of C-ITS services. An interim conclusion would have to highlight the following facts:

- More than ten European Member States are active now in C-ITS pilots and deployment initiatives. This forms a coherent basis for the deployment start with a shared view on Day One services making use of smart mix of hybrid communication (involving ITS G5 and cellular communication, potentially also others).
- Including the projects from the CEF Call 2015 (i.e. C-Roads, INTERCOR) pilots now reach out to each of the nine TEN-T corridors.
- The deployment starts on motorways but involves now increasingly (the interface to) urban environments. Most of the initiatives have started with focussing on personal transport but more and more also freight and logistics applications are envisaged.
- Facilitating C-ITS deployment by sharing knowledge, expertise and lessons learned in an expert community, and strategic alignment of the initial and respectively future phases of C-ITS deployment, provides a huge value. This knowledge brokerage is facilitated by the C-Roads Platform, with the Amsterdam Group overlooking the strategic dimension of C-ITS deployment from the perspective of core deployment partners (i.e. automotive industry and infrastructure organisations).
- In terms of functional alignment of Day One applications the community of experts active in the Amsterdam Group have worked out a series of White Papers which contain functional descriptions, message sets and triggering conditions. The White Papers for Road Works Warning (RWW), In-vehicle Information (IVI), Signal Phase and Timing (SPaT) and MAP data (MAP) are available for download [WhitePaper]. Further evolution of these White Papers – towards applications with richer functionalities – is encouraged.
- The resources that are necessary to drive the interoperability and harmonisation process are leveraged mostly via Horizon 2020 Coordination and Support Actions (e.g. CODECS, CIMEC) and CEF studies (EU ITS Platform, perspectively C-Roads).

Many of these key findings will reappear and be addressed in the following chapters 3 and 4, since the aforementioned aspects can be seen either as relevant issues for all of the deployment frontrunners (e.g. security), or issues that arise from a certain perspective (e.g. legal framework versus business models).

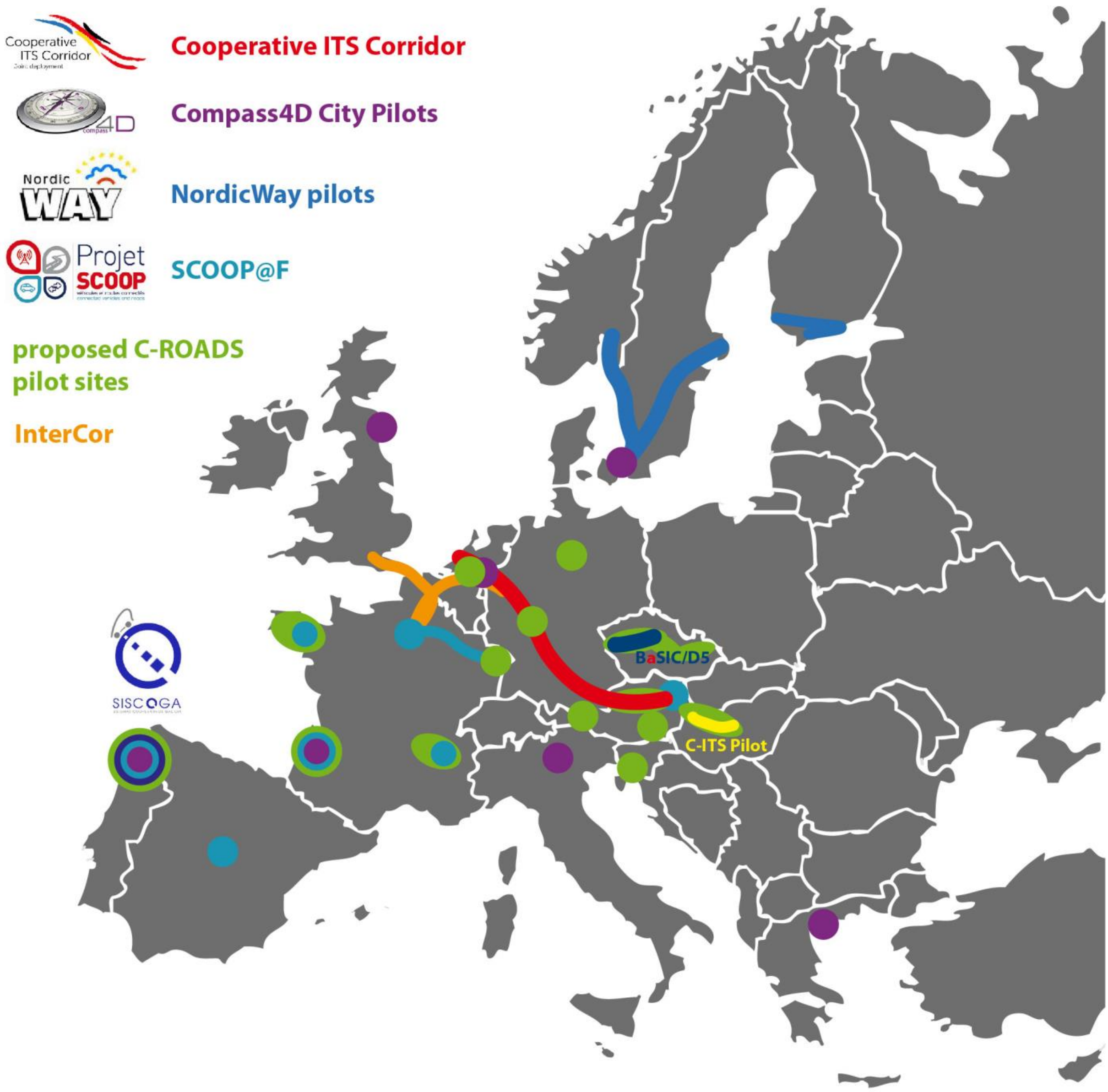


Figure 30: Overview of C-ITS Pilot and Deployment initiatives in Europe
Source: CODECS

Deployment Initiative	Link to (English) project information or presentations available at CODECS library
C-ITS Corridor Germany	http://www.c-its-korridor.de/?menuId=1&sp=en
C-ITS Corridor Austria	http://eco-at.info/home-en.html
C-ITS Corridor Netherlands	https://itscorridor.mett.nl/default.aspx
SCOOP@F	http://www.scoop.developpement-durable.gouv.fr/en
NordicWay	http://vejdirektoratet.dk/EN/roadsector/Nordicway/Pages/Default.aspx
Czech corridors	http://www.codecs-project.eu/fileadmin/user_upload/pdfs/Workshop_C-ITS_Deployment_underway_II/Volny_Czech_Republic.pdf
Hungarian corridor	http://www.codecs-project.eu/fileadmin/user_upload/pdfs/Workshop_C-ITS_Deployment_underway_II/Tomaschek_C-ITS_pilot_Hungary.pdf
SISCOGA	http://ec.europa.eu/transport/sites/transport/files/themes/its/events/doc/2012-06-07-workshop/1.5-national-pilot-siscoga.pdf
UK corridor	http://www.codecs-project.eu/fileadmin/user_upload/pdfs/Workshop_C-ITS_Deployment_underway_II/Hanson_InterCor_UK.pdf
Compass4D	http://www.compass4d.eu/ http://www.compass4d.eu/en/results/
C-Roads INTERCOR	http://www.c-roads.eu/

Table 2: Deployment initiatives overview

3. Issues to be solved for C-ITS Deployment

Taking stock of the C-ITS pilots and deployment initiatives, as it has been done in chapter 2, it becomes clear that all initiatives have to solve a similar set of open issues in order to enable the deployment of initial services. An inventory of issues has been compiled part of the CODECS Deliverable 4.1 on the strategy for C-ITS Deployment. This inventory is grouped into technical, functional, organisational, legal, security, privacy, business case, financial risk, evaluation, roadmap and other issues. This collection of issues matches well with the set of open issues of the Amsterdam Group Roadmap, which is also used in this chapter to highlight the issues to be solved.

In this view the chapter contains stocktaking of the following issues:

- Security,
- System Specification Profiling,
- Legal considerations,
- Radio spectrum and frequency,
- Deployment – roll-out of day one applications,
- Roadmap beyond day one applications,
- Conformance assessment,
- Hybrid communication concept,
- Backend services,
- Use cases and applications,
- Defining roles and responsibilities.

3.1. Security

Cooperative ITS is based on sharing information, and the various types of data might be used for purely informative, but also for safety related applications, or in the future even directly impacting a vehicles’ behaviour. Therefore securing the available communication channels is an important building block in order to ensure a reliable and trustworthy system.

Connecting many different stakeholders and ecosystems via different technologies poses several challenges on all parties involved, not only technically, but also from an organisational point of view.

Different technologies provide different features to users, but they also come with certain restrictions, e.g. latency, data rate, availability, dependency on infrastructure. Therefore security implementations that are designed for specific technologies might not be applicable to other channels. One example is the “security handshake” that is used in common network protocols to establish a trustworthy connection. Whether wired or wireless, the usual way is to exchange information in various steps (basic information, certificate exchange and acknowledgement, agreement on security credentials for a session) before a trustworthy connection is established. This handshake mechanism allows for even more “background checks”, but only as long as a relatively stable type of connection is available.

Although this takes only fractions of a second and is done billion times a day by every PC, laptop, tablet or smartphone, this mechanism takes much too long to be implemented in highly dynamic environments like “vehicle to vehicle” or “vehicle to infrastructure” communication. By the time the individual steps are completed, the communication partner might be out of the connectivity range already, even before a secured information exchange has started. The logical conclusion is, that this multi-step process is no viable solution for a secured V2X communicate concept based on ETSI ITS G5. As stated before, the security scheme for other technologies than ITS G5, e.g. cellular networks, needs to evaluated for highly volatile networks and might differ.

A different mechanism to ensure that the communication partners are authentic, which also works in highly volatile networks, is to broadcast the information without knowing the individual recipient, and attach certificates to the broadcasted messages.

This allows for skipping the time-consuming handshake, which also means that the number of messages, that need to go back and forth just to establish a connection, can be reduced.

Instead of establishing the trustworthy connection beforehand, the receiver of a message can evaluate the certificate after the successful reception – even if the sender is out of range already. If the certificate is valid, this proves the sender’s authentication and the message can be regarded as trustworthy.

Signing a message with a certificate before sending it allows the recipient of the message to check the validity and trustworthiness of any received message by checking the certificate first. Of course the introduction of certificates only shifts the security problem to another domain, because there has to be a trusted and secure way of managing (obtaining, issuing, monitoring, deleting) the certificates for the messages.

This is where the so-called Public Key Infrastructure (PKI) comes into play. The PKI provides a trust framework, and with its common “security policy” the rules are set for all participants within that network of trust. This policy comprises details like key length, algorithms, curves and other cryptographic and organisational aspects – the baseline requirements for the participants. Such a network of trust, as depicted in Figure 31, is commonly used in many domains, e.g. internet, healthcare, banking etc., and provides a mechanism to securely communicate with trusted partners.

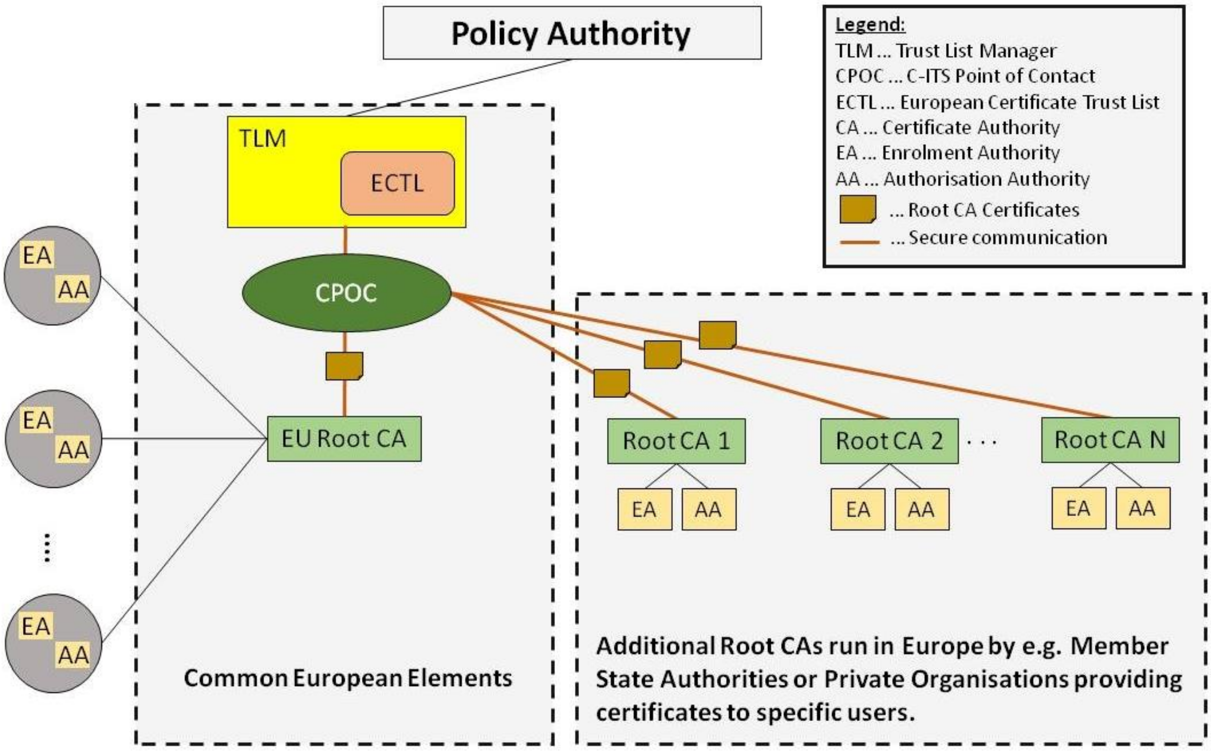


Figure 31: Possible scheme of a European PKI for C-ITS
Source: Draft Security Policy from Drafting Team C-ITS Deployment Platform

Only users that meet certain requirements are allowed to obtain certificates from the respective CA, and only CAs that obey the Security Policy are entitled to act as a part of the PKI. Since many different types and rules for PKIs are possible, there has to be a so called root authority, which is the trust anchor of the system and is responsible for the PKI's internal rules but also for the relation with other networks of trust. This external trust relation is a so called "cross certification" which can be set up in different ways.

Comparable to an official issuer of "traditional" identity cards, the Certificate Authorities (CA) hand out cryptographically signed certificates for the users, so that they can prove their authorisation to others. Different types of CAs might be part of a PKI, dependent on the type of certificates to be used and also linked to the functionality and purpose assigned to those certificates. This is why there are so-called Enrolment Authorities (EA), which provide long-term certificates to C-ITS stations, and Authorization Authorities, that provide short-term credentials for the actual message signatures.

For the European C-ITS system, the PKI is under discussion within the Security Working Group of the C-ITS Platform. For this important building block of the C-ITS deployment in Europe, a scheme close to the one depicted above is likely, but the details are not finalized yet. In parallel, a special drafting team with experts from public authorities and industry has been established to draft the common security policy for the European PKI. The aim of the group is to provide a stable draft until the end of 2016, which might then become part of a revised ITS directive by the European Commission.

3.2. Systems Specification Profiling

In order to ensure seamlessly working services and applications in Europe, interoperability and conformity need to be granted between the different systems and processes owned and managed by various entities (users, service providers, system suppliers, technology providers, authorities) – for all different use cases. Standards therefore provide the main basis, however, they require profiling: Relevant specifications must be commonly agreed, realized, checked by compliance and ensured by certification for a final acceptance by all involved stakeholders. Such a set of specifications needs to cover both functional and technical aspects. Moreover, test specifications have to be covered to satisfy the normal "V" model development process (see Figure 32), which ensures the seamless operation of functions among the stakeholders.

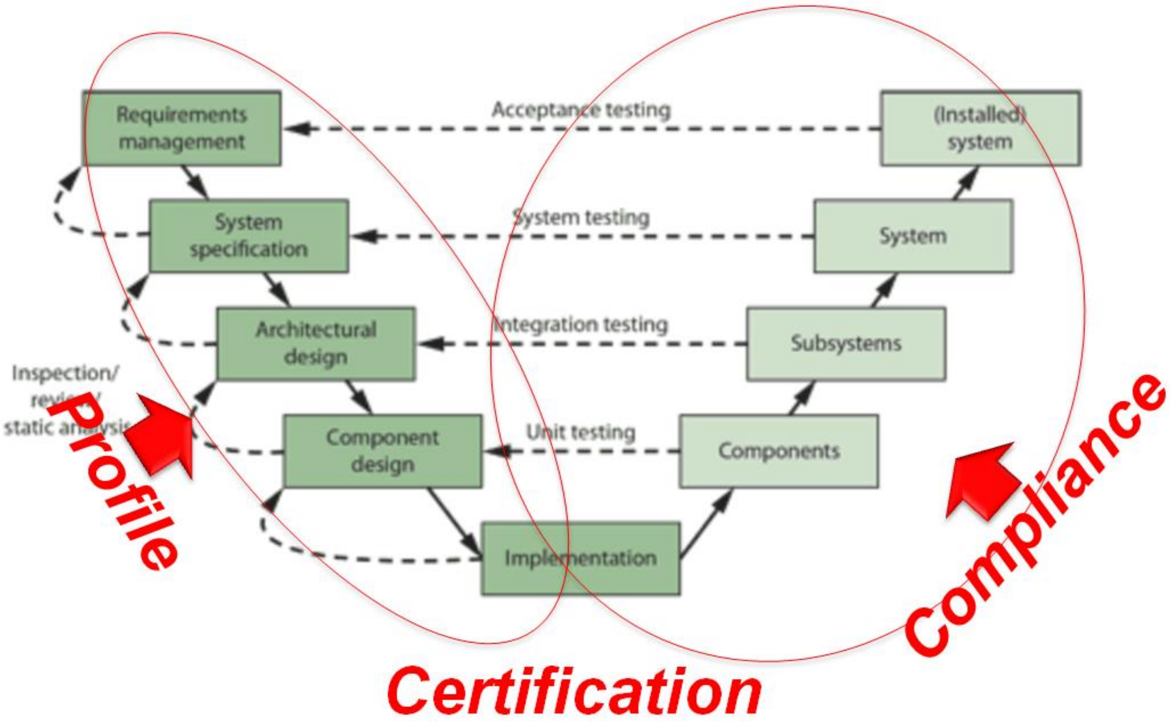


Figure 32: The "V" model process
Source: CODECS, Profiling presentation Glasgow 2016.

While profiling focuses towards the functionality specifications, it can be recognised that compliance focusing on the testing specifications is an additional aspect to cover.

In many cases interoperability is market specific. Interfaces between the market players are easily defined within standards and managed by the related stakeholders from out of their role such as the network providers and technology providers in the mobile market. There is a simple and clear model for roles and responsibility, stating that the profiling is done at one level by standardisation and by the operators for further differentiation in the market.

In the case of C-ITS, there are many different stakeholder groups, systems and technologies. At the end of the day, ITS stations need to be able to understand each other, they need to speak the same language, use the same words and construct known sentences while using the same media. Standards provide the bases for this; they are enabling and need to be open to allow future innovation. The ITS standards defined are as much as possible generic. To realize interoperable solutions they still need to be profiled and commonly agreed use by all stakeholders. For example, in the Cooperative Awareness Message (CAM) standard, the sentence format and many possible information elements (words) are formulated. But the sentences to be exchanged are not defined, and how/when they are sent is not fixed.

In general an ITS system consists of two or more ITS Stations (ITS-Ss). The interoperability end to end, from one application on one station to another application on another station, needs to be guaranteed. To ensure that this is possible and considering that information flows through all layers of the system, all layers need to be checked for their Interoperability and compliance (see Figure 33).

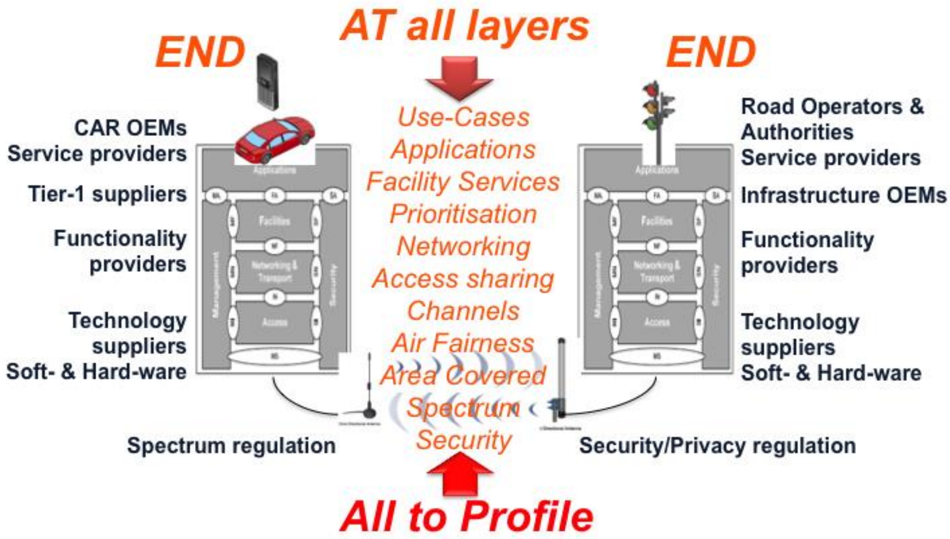


Figure 33: End2End Interoperability
Source: CODECS, Profiling presentation Glasgow 2016.

Functional Data exchange for current non-safety related ITS use cases are covered by existing standards, industry specification and business cases. For current non-safety applications in general, the interoperability requirements with regard to the aforementioned networking aspects are covered by use of generalized IP based protocols, since these are point-to-point communication interoperable by design.

When Hybrid Communication (see section 3.8) approaches become applicable for non-safety use cases, possible interoperability issues may occur. C-ITS information exchange based on ITS G5 however is not based on a point to point communication principle, and therefore the general IP based protocol architecture is not applicable. In contrast, C-ITS information exchange is based on a broadcasting mechanism. The goal is to make others aware of the situation an ITS station (vehicle or other road user of road system) detects, without really knowing if the information is received correctly by other ITS stations around or knowing how others deal with that information. It must be seen as sensor network in which ITS stations share their information freely to allow others to improve their decision-making within a defined and limited area. This sharing is provided in the expectation of also receiving this information from others. For this reason, ITS safety related applications require quite some more profiling tof the standards, so that the information can be assessed correctly based on a common understanding and an agreement on certain triggering conditions.

In Europe there are a number of growing profiling activities and actors regularly taking part in dedicated meetings organised by various initiatives or stakeholder groups. Some examples, besides the C-ITS Platform (working towards a European framework and recommendations for legislation) are the

- Amsterdam Group (use cases, applications towards deployment),
- CAR 2 CAR Communication Consortium (full automotive profile and compliance),
- Cooperative ITS Corridor (as driver of a DENM-based RWW profile), accompanied by Eco-AT (covering additional use cases) and the Dutch Profile by DITCM (generalized Dutch approach supporting all Dutch projects including additional use cases),
- SCOOP@F (for RWW functional and additional use cases),
- Czech Republic ITS deployment (RWW use case),
- Nordic Way (Cellular based, use cases, specific technical profile),
- Connected Corridor A2/M2 (cellular based, use cases, other technical profile).

Additional projects are invited to join this process. Except for the C2C-CC Profile (vehicle focussed), most others activities in that field concentrate mainly on functional specifications and not on the technical. The need for this has been recognized and initial work is started at country or project level.

For local and governmental road operators it is important to maintain country specific profiles to ensure interoperability at national level, as every country has its specific ICT infrastructure, traffic safety and efficiency challenges as well as organisational structures. Based on these, and on the market (vehicle) profiles, border crossing and market sharing should be realized by comparing and aligning all the existing profiles in a European profile. Such a European profile, containing the vital aspects of an interoperable C-ITS system, can be seen as the common core of the various specific profiles, as depicted in Figure 34.

The European Commission has accepted the two CEF project proposals INTERCOR and C-Roads (see chapter 2) to commonly make a first step towards a European Profile. This would have to be followed by a process to maintain the European profile to allow improvements, extend the coverage and foster the growth of services.

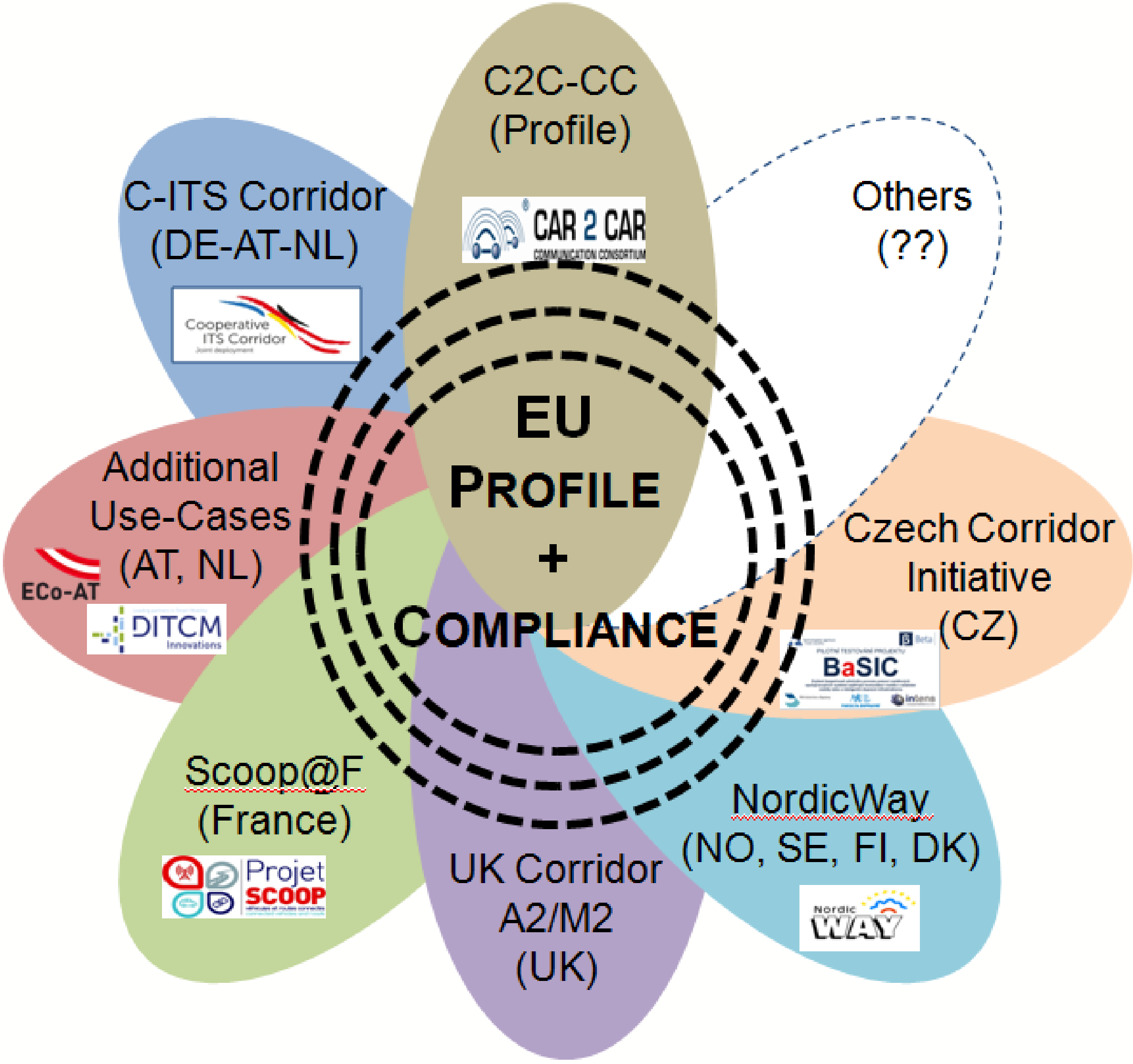


Figure 34: From Country specific profiles to a European interoperability profile
Source: CODECS, Profiling presentation Glasgow 2016.

3.3. Legal Considerations

The introduction of C-ITS opens the question of what is the legal framework the C-ITS deployment has to fit in. This section aims at identifying the key areas of EU and national laws and regulation that is influencing the deployment strategies for C-ITS.

Some examples of impacts on C-ITS deployment and functionality of legislation would be:

- Liability for the different actors
- Data protection and privacy aspects
- Traffic legislation (Highway Code) – both international and national
- Vehicle type approval
- Radio Equipment Directive

Considering the above mentioned examples it quickly becomes clear that there is no guarantee that the different laws and regulations are coordinated seen from a C-ITS perspective. Further the legislation in many cases have not even foreseen the technical advances that allows the implementation of C-ITS

3.3.1. Liability

Different studies including the report of the first phase of the EU C-ITS deployment platform comes to the conclusion that implementation of the identified Day One services, that basically are warning services would not have an impact on the liability as these services have active interactions with the vehicles and this the driver is still in full control.

However, the situation will different for services beyond Day One when the C-ITS information received in the end might be a part of the information used to perform active intervention in the driving. In such cases the liability will potentially be dependent on capability to prove to the cause of the accident. E.g. was it the road operator that provided wrong information about the traffic light status (Green versus Red), was it the car that interpreted the information wrongly or had a software bug or was it the driver who overruled the on board systems in the vehicle. It is clear that current legislation and regulation have not yet foreseen such scenarios as it in general places the responsibility on the driver.

It seems therefore clear that before C-ITS can move forward to the more advance stages that includes active intervention, regulation and legislations needs to be in place that allows the different stakeholders to assess their risks and responsibilities. E.g. it might be necessary to require ‘black boxes’ in vehicles and roadside equipment that will allow investigation of the real cause of accidents in order to place the responsibility and the associated liability.

3.3.2. Road traffic regulation

The road traffic regulation typically consists of several elements on different levels – an international element like the Vienna Convention on Road traffic, a national element, e.g. the Highway Code, and in some cases even a regional or local element. Example of the latter could be parking and environmental regulations.

With respect to the Vienna Convention, it appears that the amendment of article 8 paragraph 5 adopted by UN on 23 September 2015 (see quotation in *italics*) will be sufficient to allow the Day One C-ITS deployment

5. Every driver shall at all times be able to control his vehicle or to guide his animals.

5.bis. Vehicle systems which influence the way vehicles are driven shall be deemed to be in conformity with paragraph 5 of this article and with paragraph 1 of Article 13, when they are in conformity with the conditions of construction, fitting and utilization according to international legal instruments concerning wheeled vehicles, equipment and parts which can be fitted and/or be used on wheeled vehicles.

Vehicle systems which influence the way vehicles are driven and are not in conformity with the aforementioned conditions of construction, fitting and utilization, shall be deemed to be in conformity with paragraph 5 of this article and with paragraph 1 of Article 13, when such systems can be overridden or switched off by the driver.

However, it might be premature to conclude how far along the steps towards fully automated driving this amendment is sufficient.

When it comes to the national Highway Code and associated legislation, part of it might leave room for interpretation. Often the legislation will include elements with the spirit such as "It is not allowed to encourage and/or tempt the driver to disobey the regulations", e.g. exceed speed limits. In some cases, those aspects have been made concrete with explicit legislation, e.g. a ban on the provision of the phase and timing of the traffic lights as this in certain cases can be seen as an encouragement to exceed speed limits.

When moving beyond the C-ITS services of Day One deployment towards the different steps of automation the need for alignment of the national highway Codes will most likely be required. One simple example of these differences is that currently the rules for merging between the oncoming traffic to a motorway and the traffic on the motorway varies between the different European countries – in some countries the traffic on the motorway entrance shall give way to the traffic on the motorway, in other countries the rules state that a vehicle with its front behind the front of another vehicle shall give way to the other vehicle, irrespectively of whether or not it is on the motorway or at the motorway entrance. Even though such cases theoretically could be handled by location dependent algorithms, aligning certain national traffic regulations clearly has the potential to reduce the complexity of the systems and reduce the risks of errors that might be caused by differences in legislation. The Declaration of Amsterdam, signed by the EU transport ministers in April 2016, provides the framework for harmonisation in the context of connected and automated driving [DoA]. The initiated High Level Structural Dialogue is an appropriate means aiming at a coherent regulatory framework for road traffic. .

3.3.3. Data protection and Privacy

The newly approved General Data Protection Regulation (GDPR) sets down the data protection framework in the EU. Without going in detail the GDPR can be said to define personal data as any information that can be linked to a specific person independently of whether the linking is can be done directly or indirectly. The consequences of this is that irrespectively of the in C-ITS build-in measures to remove all possibilities of a direct linking of C-ITS data and an individual the information might still be deemed as personal data. This, according to the phase1 of the EU C-ITS deployment platform, because in certain scenarios, e.g. on a road with light traffic it might be possible associate the transmitted data with a specific vehicle/person. The consequence of this would be that the GDPR applies.

If the GDPR applies it basically means that the data subject (the driver - still subject for discussions as several stakeholders believe the data belongs to the owner) will have to give consent to the data controllers usages of the data except in certain justified cases. Such justified cases would be

- Vital interests of the data subject
- Public interests

Up front the average person would think safety would qualify as vital interest, however this for the identified Day One applications this is being contested by privacy experts as these applications only include warning services, despite the receiver now or in future phases might choose to use the information in the decision process for active intervention.

For the part of public interests, it appears that most of the relevant use cases for a road operator to optimise traffic follow etc. would fall in this category. However, when third parties would like to use this information to provide optimised route guidance it is not likely to qualify as public interest.

The obvious question would then be how the data subject can then grant the potential data controllers consent to use the data. The unfortunate situation is that C-ITS is quite different from other data sharing systems. In general, the GDPR assumes that there exists a one to one relation between the data subject and the data controller. This would be true in the cases where a true per to per connection exists, but in the case of C-ITS each ITS station broadcasts its information to be received by all other C-ITS stations within range – The radio studies of the Decentralized Congestion Control shows that the maximum limit of ITS – Stations. in range would be 400-700. It is obvious that a peer to peer consent in such case is not practical achievable, discussions are currently focusing on how to solve this.

One approach would be to move forward identifying the applications that would qualify for vital interests or public interests and allow the user to indicate if his information can be used for other purposes.

An identified drawback of such an approach is that if the users can choose whether or not to share data independently of their potential benefits of receiving information, there is a high risk that users opt out of sharing but will still want to benefit, which might slow down the uptake of the system which would be dependent on that there is information to share and to enable the applications.

All in all the data protection and privacy aspects are the legislative part which is most critical for the initial deployment of C-ITS.

3.4. Radio Spectrum & frequency

The present chapter provides an insight into the current situation on radio spectrum and frequencies in relation to ITS as well as connected ITS, cooperative ITS and automation use cases and applications. To consider what spectrum and frequency aspects are of relevance, the deployment initiatives described in chapter 2 and the following additional reports have been evaluated:

- "Final report" of the C-ITS Deployment Platform, established by the European Commission, DG MOVE [Platform]
- "Empowering Vertical Industries" by the initiative on 5G PPP, supported by the European Commission, DG CONNECT [5GPPP]
- "5G Automotive Vision" by the initiative on 5G PPP, supported by the European Commission, DG CONNECT [5G-AV].

As outlined for some of the use cases described in chapter 3.5 and 3.10 of the present document, many connected ITS, cooperative ITS and automation use cases are initiated by varying stakeholder groups. They sometimes carry the same title while pursuing different objectives and showing highly varying communication and business requirements. The CODECS work package 3 "Roadmapping for Cooperative ITS Deployment in Europe" and 4 "Strategy Coordination Support" are looking into the possibilities to clarify this ambiguity, and to come to a more common approach.

Discussions at European level within the C-ITS Deployment Platform and initiatives such as the Amsterdam Group or the C2C-CC have led to the common understanding that – for functional and business reasons – the deployment of ITS use cases can't be supported by one single communication technology. Instead, a co-existing framework of communication technologies, in Europe called "Hybrid Communication approach", is needed [Platform, p. 101ff.] and it is expected to be defined in more detail during the second working phase of the C-ITS Deployment Platform (see also chapter 3.8 of the present deliverable).

(Future) ITS systems are therefore supposed to support multiple communication protocols and include several radios, e.g. ITS-G5, WIFI, cellular 3G, 4G and future 5G, DAB+ and maybe others.

The development of connected services is based on internet protocol(s), making use of standard General Packet Radio Service (GPRS) and 2-4G communication cellular protocols. Those connected services based on existing cellular networks are furthermore supported by basic B2C (Business to Consumer) and B2B (Business to Business) models, and the related standard spectrum legislation and according allocation for these non-safety related traffic and efficiency oriented use cases. In contrast to the cooperative use cases, which have particularly more stringent requirements (for safety related reasons) and varying business models. Research and Innovation for more than 10 years have led to the specific traffic safety and efficiency spectrum allocation, along with related standards specifying functional and physical layer, in order to accommodate the C-ITS use cases ready for deployment.

In order to support the specific C-ITS functional communication needs via the different technologies, various spectra are used. Many of them are allocated for general usage with no specific or restrictive reservation for traffic services, except for the 5 GHz band being allocated for cooperative ITS services. A lot of ITS services are non-safety oriented and can use normal consumer oriented business models and communication schemes so allocations for general use which do not provide any restrictions nor priorities for traffic safety and efficiency services can be considered for those services.

In an early stage of ITS research, more than 10 years ago, the ITS communication requirement analyses resulted in the need to allocate a spectrum for cooperative ITS traffic safety and efficiency as well as non-safety use cases. At that point in time, the allocation has been formulated in a conservative way, but with the vision towards expanding the spectrum. The bands allocated in Europe are the same as in the USA. Figure 35 provides an overview of the ITS spectrum as currently legislated.

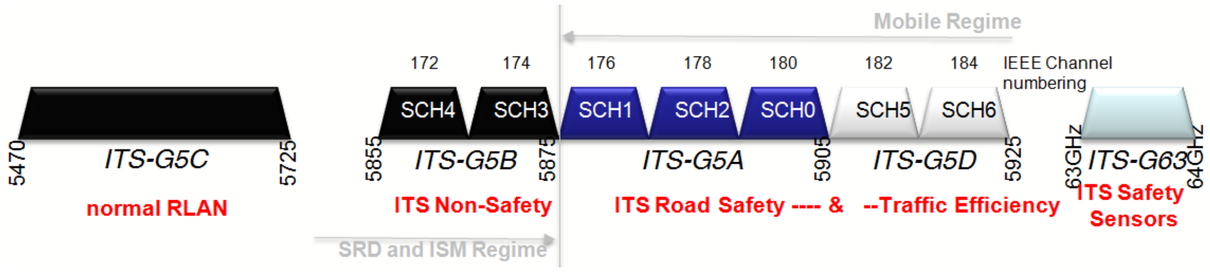


Figure 35: European recognized ITS spectrum and related bands
Source: Car2Car-Workshop 2015

As outlined in Figure 35, the cooperative ITS spectrum is divided in a number of bands (subdivided into channels) with different functional possibilities:

The ITS-G5A and ITS G5D bands fall under a mobile regime, which provides priority to the transport safety and efficiency services in these bands. Other services in these bands are operating in a different radio environment (satellite communication) and are not expected to interfere. For those bands, the ECC at CEPT gave a recommendation [ECC/REC] and based a decision on it [ECC/DEC], which differs for the ITS-G5A and the ITS-G5D band:

While the ITS-G5A bands are *designated*, which means ITS traffic safety and efficiency information exchange have definite priority (independent on the technology used), the ITS-G5D bands have just been *allocated*. Therefore the channels 182 and 183, as shown in Figure 35, are recognized as ITS safety related bands, but in order to ensure priority in these bands, they still need to get the designated stage. A change of their designated/allocated status could be supported by arguments provided by an overall ITS Roadmap and an application analysis. The same applies to the ITS band above 63 GHz, having the ITS allocated status for specific usage in line of sight, and requiring a designated status.

At the same time, the aforementioned ECC/CEPT decision supports non-safety related applications in the ITS-G5B and ITS-G5C bands, which are not protected by any special status. It must be noted that the ITS-G5C bands are making use of normal WiFi spectrum and consideration for ITS services is difficult since priority cannot be ensured.

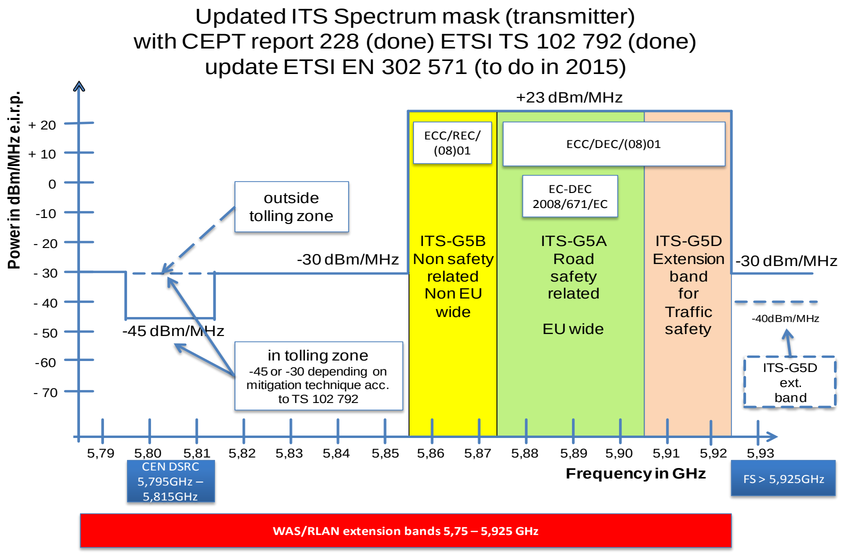


Figure 36: ITS 5.9 GHz spectrum mask
Source: Car2Car-Workshop 2015

For the correct operation of services in the ITS-G5 5.9 GHz spectrum and services such as tolling in the 5.8 GHz spectrum, agreements have been realized with regard to interference and co-existence. A specific spectrum mask as shown in Figure 36 has been agreed, which is now covered by an update two European standards. The norm on spectrum usage by radiocommunications equipment operating in the 5.9 GHz band [302 571] and the standard on co-existence of C-ITS and tolling systems [102 792].

Besides the cooperative aspect, there has been a growing interest in automated vehicle use cases in the last years. The widespread introduction of those use cases is expected to be falling into the same timeframe as the start of 5G cellular and RLAN technologies development. For those automation related applications, that are considering the use of 5G communication technologies, other specific spectrum may need to be considered, besides the currently allocated 5.9 GHz band for ITS traffic safety and efficiency related information exchange. In that sense 5G related protocols need to be seen and evaluated as part of the normal innovation process. It is expected that 5G cellular and RLAN (extensions of WiFi and ITS-G5) will provide additional support for new C-ITS and automated use cases when they become available. However, this should not hamper today’s deployment of technologies which enable ready-for-deployment-traffic safety and efficiency use cases.

It can be concluded that the increase of use cases needs to be supported by making more spectrum available for C-ITS in general. A growing need for spectrum can be seen for other communication schemes as well, e.g. cellular 5G and broadcasting technologies such as DAB+. A detailed analysis of the various use cases is needed to identify the specific needs. Only for traffic safety and efficiency, some early investigations have been started, but conclusions are not available at the time of the development of the present report.

3.5. Deployment / roll-out, Day One

When C-ITS services become available on European roads, it is important that road users can get a consistent user experience, independent from when and where they actually drive. The automotive industry sells vehicles and provides services on worldwide scale. In contrast to that, road authorities and operators are responsible for a road network on national or regional level. The services they offer can be characterized as non-tradeable goods or services. Drivers however do not care about jurisdictional borders. They simply expect a seamless and continuous service on their journey. Hence, it is very important to base the initial deployment on services which are commonly agreed among the key deployment partners and which are mature for deployment. This includes that those services have been extensively tested in Field Operational Tests (e.g. simTD, SCORE@F, SISGOGA, Testfeld Telematik on national level, DRIVE C2X and FOTsis on European level) and that the initial deployment is based on agreed message formats (i.e. CAM and DENM).

The consensus building on this list of Day One services has started already some years ago in the automotive industry and in the infrastructure organisations. The Amsterdam Group roadmap on initial C-ITS deployment in Europe (2013) enumerates the following criteria for including a service in the shortlist for initial C-ITS deployment:

- Simple and non-complex services that provide end user benefit and are supported by a solid business model,
- A balanced mix of services that support all environments of C-ITS (urban, rural, interurban (all V2I2V) and V2V) which can be regarded as minimum set of services for Day One,
- Services that are feasible with low/minimum risk to avoid a first day bad image hampering further user acceptance,
- Services that provide credibility to C-ITS,
- Services that support a fast penetration and offer a platform for further deployment of other services.

With respect to the criteria mentioned above, the Amsterdam Group roadmap lists Hazardous Location Warning, Slow Vehicle Warning, Traffic Jam Ahead Warning, Stationary Vehicle Warning, Emergency Brake Light, Emergency Vehicle Warning and Motorcycle Approaching Indication as typical V2V services, whereas Road Works Warning, In-Vehicle Signage, Signal Phase and Time as well as Probe Vehicle Data are listed as typical I2V/V2I services.

The C-ITS Platform has achieved – in terms of shared view and stakeholder acceptance – an even broader consensus on Day One applications. The Final Report of the C-ITS Platform (Phase 1, January 2016) lists a total of 25 initial services, see Figure 37. It distinguishes between 14 Day One Services with the highest maturity for deployment and 11 further services that likely will be deployed in a next phase (labeled as Day 1.5 services).

#	Day 1 Services	#	Day 1.5 Services
1	Emergency electronic brake light	1	Off street parking information
2	Emergency vehicle approaching	2	On street parking information and management
3	Slow or stationary vehicle(s)	3	Park & Ride information
4	Traffic jam ahead warning	4	Information on AFV fuelling & charging stations
5	Hazardous location notification	5	Traffic information and smart routing
6	Road works warning	6	Zone access control for urban areas
7	Weather conditions	7	Loading zone management
8	In-vehicle signage	8	Vulnerable road user protection (pedestrians and cyclists)
9	In-vehicle speed limits	9	Cooperative collision risk warning
10	Probe vehicle data	10	Motorcycle approaching indication
11	Shockwave damping	11	Wrong way driving
12	GLOSA / Time To Green (TTG)		
13	Signal violation/Intersection safety		
14	Traffic signal priority request by designated vehicles		

Figure 37: List of Services for Day One and “Day 1.5”
Source: Final Report of the C-ITS Deployment Platform, [Platform]

The list of Day One Applications provides orientation and guidance to the C-ITS pilots and deployment initiatives, see also the mapping of the C-Roads pilots against the list of Day One Services (Figure 28 in chapter 2.9). Starting from this basis, it is helpful to dispose of agreed service specifications. They provide guidance to interested parties how to deploy when considering deployment. The White Papers agreed on Amsterdam Group level and published in April 2016 (Road Works Warning, In-vehicle information, SPAT-MAP) may serve as a guiding star in this respect. In addition, specifications from the pioneering deployment initiatives are also available on the respective websites (e.g ECo-AT, SCOOP@F). The set of specifications will be enlarged when more and more C-ITS services will be deployed on European roads.

With a view to a broader portfolio of services, there is an emerging need for establishing and maintaining a C-ITS service catalogue. Such a catalogue can be set up to provide several helpful insights, e.g. contain the description of the services, the value proposition or the expected benefits, the level of service mapped against quality criteria, the geographical and the temporal (e.g. 24/7, daytime, weekends etc.) service availability.

Since the service provision is connected to the fulfillment of distinct roles, responsibilities have to be named. It has to be sorted out which concrete actors are responsible for roles like service manager and service operator and more specific sub-roles. With regard to different jurisdictions or entities involved in service provision, one seamless service (in end user perception) will have multiple responsible actors involved. It is expected that the harmonisation of C-ITS pilots and deployment initiatives will take up this issue. The C-Roads Platform, coming into action end of 2016, has taken provision of a Working Group on Organisational Issues which turns to be the most logical place to come up with proposals for practical solutions.

3.6. Roadmap beyond Day One

One of the most prominent advances in the past months and years is the continuous improvements the automotive industry has made in the area of automated driving. Although these developments are not seen by all experts in a direct relation with C-ITS, most of the automotive industry has a complementary view towards a future when automated and connected driving unites the best of both trends to cooperatively improve the traffic flows and reduce the number of accidents in the future. With the advent of automated and connected driving functions, especially with the broad availability of vehicles capable of supporting higher automation levels (3-5), the need for cooperation and coordination between the various traffic participants becomes a necessity.

Currently, most automated vehicles rely on the premise that they continuously plan their trajectories and, based on the observed environment, select one or another as the current driving trajectory. Today, this requires considering a major overhead for unpredictable behavior of other traffic participants, since it is not 100% certain what another vehicle, or another pedestrian, will do in the next several seconds. This is why relatively large “buffers” have to be included in these trajectories, especially when planning them around other moving vehicles. If these other vehicles would share, or even constantly disseminate their own intentions, other vehicles could use this information to reduce the uncertainties and so minimize the buffers within their trajectories. This would enable automated driving vehicles to drive closer to each other (and so increase the capacity of roads and cities), react more quickly to external maneuvers (fewer traffic jams and congestions), be better controlled (a significantly increase in comfort and travel time), and avoid collisions (reduce accidents).

Based on the initial deployment of the IEEE 802.11p technology, the members of the C2C-CC, representing the large part of the automobile industry, have created a staged deployment strategy using a development roadmap structuring the past, current and future research and standardization work in the field of communicating and cooperative vehicles. The main principles around this cooperation are: firstly that every individual vehicle independently plans its trajectory based on the collectively gained environment information, and secondly that every vehicle continuously disseminates information which might help the other traffic participants complete their view of the environment and better assess its future intentions.

The C2C-CC applications roadmap, presented in Figure 38, envisions the four deployment phases for direct V2X communication. Each subsequent phase extends the previous one by allowing vehicles to exchange more information, thus enabling new applications and classes of use cases to be realized.

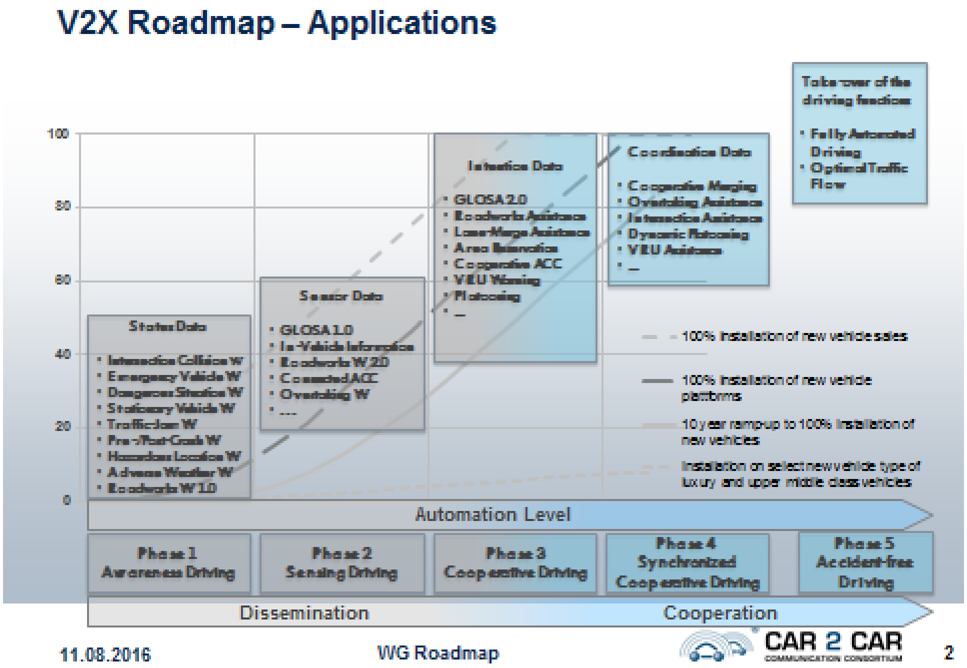


Figure 38: V2X Applications Roadmap
Source: C2C-CC WG Roadmap (11th August 2016)

Each new phase is characterized by the new type of information it allows traffic participants to disseminate and share between themselves:

- The first, initial phase, as described in the previous chapters, will enable vehicles to disseminate their *status* information, thus allowing other vehicles to become aware of their presence and of eventual hazards detected on the road.
- The second, sensing driving phase will allow various traffic participants to provide additional information, namely information gained from the various on-board *sensors* such as cameras and radars. This additional information enables vehicles to "see with the eyes of others" and so detect otherwise hidden objects (e.g. around a corner), or get a more accurate view on what is happening within their environment (e.g. an intersection with various vehicles and pedestrians).
- The third, cooperative driving phase will allow vehicles to share their *intentions* with other traffic participants, and so provide them with a glimpse into the individual future of each vehicle. Information such as trajectories or planned manoeuvres will be used by automated driving algorithms to enable vehicles to accurately predict what other traffic participants will do in the near future and so allow them to optimize their own decisions and manoeuvres.
- The last, *synchronized* driving phase is where vehicles are autonomously driven through almost all situations (levels 4 and 5 in Figure 38) and are able to exchange and synchronize driving trajectories among each other and thereby achieve optimal driving patterns.

3.7. Compliance Assessment – Context and Framework

When it comes to the framework for Compliance Assessment of C-ITS equipment, it is necessary to understand what other regulations might influence the equipment. In this document the primary consideration is equipment containing a communication interface that allows communication with other C-ITS equipment over an open radio interface. Thus in this section the interface internal to an road operator are not considered as they might vary from operator to operator due to the need for integration with already existing equipment.

Starting with the radio interface it will generally irrespectively of the technology in question be subject to the Radio Equipment directive (RED) in Europe [RED]. The RED imposes some minimum requirements allowing the equipment to be using the radio spectrum. There will typically be one or more Harmonized Standards that translate the RED requirements to explicit requirements for a given access technology's access to a given portion of the spectrum. In short this regulation sets the minimum requirements for the radio access part of the C-ITS equipment and any specific C-ITS compliance assessment cannot make exemptions to this.

When looking at (new) vehicle assessments they are in general subject to type approval. This type approval is based on the UN 1958, 1997 and 1998 agreements [UNECE]. This is under the responsibility of UNECE WP29 with the purpose of providing a harmonized regulatory framework supporting innovations for safe and environmental friendly vehicles. This allows the market introduction of vehicle technologies and is facilitating cross-border trade, since provisions established under the 1958 Agreement include the reciprocal acceptance of approvals of vehicle systems, parts and equipment issued by other Contracting Parties (other signing country).

Clearly the C-ITS compliance assessment cannot and should not interfere with the UNECE agreements. It is however not always understood what the implications of this will be. Especially as the first phase of C-ITS generally is considered to only include mostly warning services for the driver, not intended to directly impact the car's driving behaviour. However, a vehicle might consider the input from the build-in C-ITS station as just another sensor data it uses in its decision processes and thus this input might be used for applications that are regulated by UNECE and others that are not. With this in mind it might therefore be recommendable to separate the compliance assessment for the communication system from any potential assessment of the applications. So an appropriate way to set up a C-ITS compliance assessment must be found, and a common argument is that this compliance assessment is needed to ensure interoperability.

It is worth mentioning, that in general communication systems have to pass a compliance assessment and an interoperability testing, because the compliance assessment will only define the "minimum requirements to be tested in order to be a participant in the communication system", while the interoperability testing checks the actual compatibility with other components. Since it is unrealistic to test all potential configurations in an emerging European C-ITS system, the selected compliance test criteria will only cover a subset of potential interoperability scenarios. Therefore, compliance assessment needs to be complemented by Interoperability Testing.

3.7.1. Why Compliance Assessment

While the argument often is to ensure interoperability, the primary reason for compliance assessment might be in other areas. Firstly, it is to protect against misuse of the system and its resources. One can of course argue the RED gives some elementary protection, but when getting to the higher level of the protocol the RED will not provide any significant protections of the resources and the system. Secondly, the compliance assessment of at least the transmitting side has to be setup to allow a certain level of trust in the transmitted data.

This later argument is one of the reason why the Phase 1 Report of the EU C-ITS Deployment platform are proposing to put the passing of the compliance assessment as a precondition for the enrolment in the trust model (security model). Why this linkage is introduced might not be obvious, however if one considers that one of the key goals of compliance assessment is to ensure that the data transmitted - and thus received by the participants – are trustworthy. It is clear that the signing of messages which is intended to allow validation of the source would provide little value – unless the basic functionality of the sender has been verified a priori to the enrolment.

3.7.2. Current status

The Phase 1 Report of the EU C-ITS Deployment platform came with some recommendations for the overall model, which is summarised in Figure 39, linking the trust model (Security) with the compliance assessment as described above.

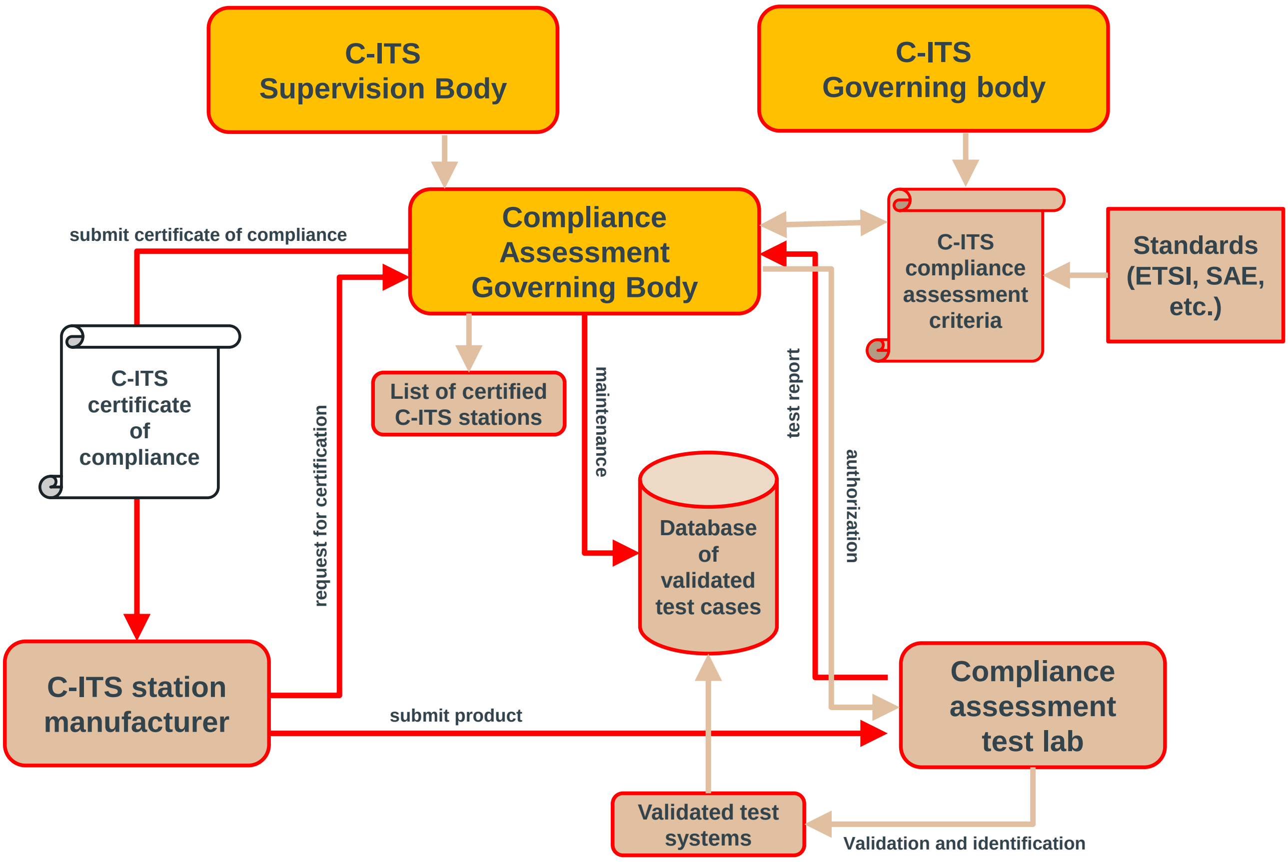


Figure 39: Overview of Compliance Assessment Model
Source: Final Report of the C-ITS Deployment Platform [Platform]

In the Phase 1 Report of the EU C-ITS Deployment platform defines the following stakeholders, roles and responsibilities

- **C-ITS Governing Body:** Defines the requirements to the C-ITS Station, that fulfil the policy needs. The C-ITS governing body defines the operational and security requirements, which drive the definition of the compliance assessment test and procedures, which are coordinated by the compliance assessment governing body.

- **Compliance Assessment Governing Body:** The central governing body in the compliance assessment process, defines the Common Criteria (if this process is accepted by the C-ITS community) for the compliance assessment labs and the governing rules and procedures for the compliance assessment tests and procedures. It issues the C-ITS certificates of compliance.
- **Trust Model Manager:** This is the entity responsible for managing the trust model infrastructure (e.g., PKI) according to the requirements of the C-ITS Governing Body.
- **C-ITS Supervision Board:** Is responsible for the detection of problems in the deployment phase, which can be reported to compliance assessment governing body for further analysis and action.
- **Standardization Bodies:** Responsible for drafting the standards for communication and testing (e.g., EN ISO/IEC 17065:2012).
- **Compliance Assessment Lab:** Executes the compliance assessment tests and procedures. At current no decision is taken on whether the C-ITS station manufacturer may fulfil this role or whether it has to be performed by an independent body.
- **Workshop for mobile C-ITS Stations:** For the setup and decommissioning of the mobile C-ITS station.
- **Workshop for roadside C-ITS Stations:** For the setup and decommissioning of the roadside C-ITS station.
- **Manufacturer of the C-ITS Station:** Responsible for production and performance of the compliance assessment procedure for the single C-ITS stations in the related market segment.
- **Enrolment Authority:** This entity is responsible to perform the enrolment of a C-ITS station based on a positive test outcome of a compliance assessment lab. The enrolment is related to the recording of the ID and features of a C-ITS station before deployment in the field.
- **Authorization Authority:** This entity is authorized to perform the authorization of a C-ITS station. This is a security function in comparison to the enrolment authority, which is specific to the recording of the ID and features of a C-ITS station before deployment in the road.
- **Member State Authority:** Responsible for the distribution of cryptographic material for public safety related C-ITS station network, if required by security policy.
- **Operator of the C-ITS Station:** For example vehicle manufacturer or road operator.
- **Workshop for mobile C-ITS Stations:** For maintenance and periodic inspection.
- **Workshop for roadside C-ITS Stations:** For maintenance and periodic inspection.
- **User:** This is the driver of the C-ITS vehicle or user of another (mobile) C-ITS station.
- **Service Provider:** This is the servicing entity of C-ITS stations for regular tasks on behalf of users, operators, manufacturers or other organisations.
- **Law Enforcement Organization:** Represents a law enforcer organization, which must ensure conformance to the regulations and to the specific public policies of the C-ITS governing body.

It is recognized that not all of these stakeholders and roles have to be fully defined at the beginning of the C-ITS roll-out, but respective tasks should be defined by the stakeholders involved and be planned to allow for upcoming phases of C-ITS.

3.7.3. Scope of Compliance Assessment

While the definition of different roles might already be clear to some extent, even though it has not been decided who will have to fill them, the scope of compliance assessment is still up for discussion at the time of writing (9/2016).

Where the car industry in general believes the need for compliance assessment is to ensure that received data can be trusted, some EU member states want to go further and not just ensure this, but also ensure that the receiver utilises the provided information correctly. This latter requirement is primarily put forward as it is believed that it can be used to justify the investment on the infrastructure side. However, as currently neither transmission of certain data nor any specific applications are mandated, it appears it would be difficult to justify requirements going much further that the correctness of the transmitted data and their triggering, plus some basic performance requirements on the receiving side such as general radio receiver performance, protocol reaction time (Data processing latency) and resilience to reception errors. On the other hand, there are no hard requirements for road infrastructure or regarding the underlying traffic management structure, so vehicles have to deal with similarly unreliable situations all the time.

It has to be stated clearly that at the time of writing (9/2016), the overall role of compliance assessment in the initial C-ITS deployment is still open. It can be expected that the respective working group at the C-ITS Platform will help forming a consensus among all stakeholders and clarify the scope of C-ITS compliance assessment; although the aforementioned aspects and the ongoing discussions indicate that this will not be achievable without compromises.

3.8. Hybrid Communication

The communication needs of C-ITS broad, as C-ITS covers very different scenarios. In general, the communication needs can be split in two main categories – communication of tactical information and communication of strategic information:

- **Tactical information** is the type of information that is needed to perform imminent actions, e.g. collision avoidance.
- **Strategic information** is the type of information that would allow planning ahead e.g. change of route based on traffic information, traffic management.

It is clear the communication requirements for tactical information and strategic information might differ. Tactical information will typically only have a value within a short range, but require a low latency. For this type of information, short range direct device to device communication such as ETSI ITS G5 would be suitable. On the contrary, strategic information will typically require a longer range but would on the other hand have less stringent requirements to latency. So for strategic information, wide area communication such as Cellular, FM (RDS), DAB+ would probably be able to fulfill the communication requirements.

Non-safety related use cases already utilize cellular technologies to exchange information, while other pilot deployments show that short range communication via ITS G5 is ready to use and – at least for traffic safety related use cases – is an essential technology to guarantee very low latency.

So when appropriate cellular technologies are ready, It can be envisioned that the combination of different technologies will increase an open market with same or similar ITS information being exchanged via different communication protocols.

With 5G cellular technologies currently being developed, aiming for deployment by 2020. these considerations have led to interests in combining multiple communication means, e.g. ETSI ITS G5 and cellular, a combination known as ”Hybrid Communication”.

In some scenarios, the introduction of ”Hybrid Communication” will provide redundancy of information, which means that a .

3.8.1. Outline / Concept

The concept of “Hybrid Communication” is described in a report commissioned by RWS in 2014 [RWS], in which it was recognized that there are in the first place many different C-ITS use cases ranging from traffic information to traffic safety, all having their own specific communication requirements, for which today a case-by-case choice of technology has to be made. With new ITS use cases, there is a rising interest and need in sharing information and obtaining high-quality information, while at the same time the complexity increases since different cars, devices and applications are using the available technologies.

Beyond that, the exchanged information will be required with high reliability and quality, in order to guarantee secure operation for prospective advanced systems supporting high levels of automation. To tackle this issue, fulfill the situation specific requirements and provide access to trusted information matching certain quality criteria, which can hardly be judged prior to any driving decision, is a real challenge.

Many business cases can be envisioned and should be enabled to support an open market, ideally numerous sources of information will then become available. Two approaches can be imagined to enhance the quality and reliability of the information provided:

- **Improving** the data of a single source, whether this is a sensor or a data provider.
- **Increasing** the amount of data sources, basically by increasing the number of sensors, data providers and others.

While improving the data of a single source is always desirable and typically achieved by technological progress (new sensor types or improved performance), the concept of “Hybrid Communication” also aims at system redundancy. This is an important step toward resilient systems, which is crucial for automation and safety related ITS use cases.

A system supporting hybrid communication is equipped with more than one radio (and more than one communication protocol), with each communication protocol having its own characteristics. Those characteristics, which can be statically specified or dynamically changing during operation, could be the basis for selecting different communication protocol at a specific time or in a specific situation. This means that the same type of data can be provided by the same or by different data providers, while the exchange of this data can go via different communication protocols. Hybrid communication also supports the realisation of these use cases via many business cases, including various systems, which is important for the creation of interoperable applications, services and systems provided by a variety of actors.

A rather complex hybrid communication scenario would include several data providers or sources. In that case merging and/or verifying data is challenging, since there might be slight variations in the data, e.g. location precision, time offsets due to system/channel latency, different sensors etc. For example the speed of a vehicle can be measured by its GPS locations, radar, wheel sensors or loop detectors, all based on different technologies and operating with varying accuracy. Moreover, there would be no identifier available for (near) real-time data coming from different sources. So the algorithms in a vehicle for merging various sets of data, that are describing one situation in slightly different ways, must be rather sophisticated.

A less complex hybrid communication concept would be one single data provider supplying data statically through multiple communication protocols simultaneously. In such a system, the receiver can merge the data more easily, since there should be no conflicting information. The data provider might even use a unique identifier, so that data sets can be matched the device receiving data via various channels, even with large latency variations.

3.8.2. Implications

This paragraph identifies and describes generic functions, interfaces and specific groups of functional requirements to be further investigated, since a discussion of the implications of “Hybrid communication” on ITS use cases has just started within Europe.

Use cases are realized by means of applications and services active in a defined, specific, system. These use cases can be multi stakeholder dependent, whether in a purely ITS traffic safety and efficiency related use case based on the architecture defined by ETSI [302 665], or as part of an IoT system supporting different architectures. A general representation of such environment can be found in Figure 40, where four different Communication methods are represented: cellular, ITS-G5, DAB+ and WLAN.

Such an environment supports back-office or cloud services, broadcast and peer to peer communication via a mixture of short, mid and long range communication methods – for simplicity, it is not depicted that, depending on the country or region, providers may also offer several combined services.

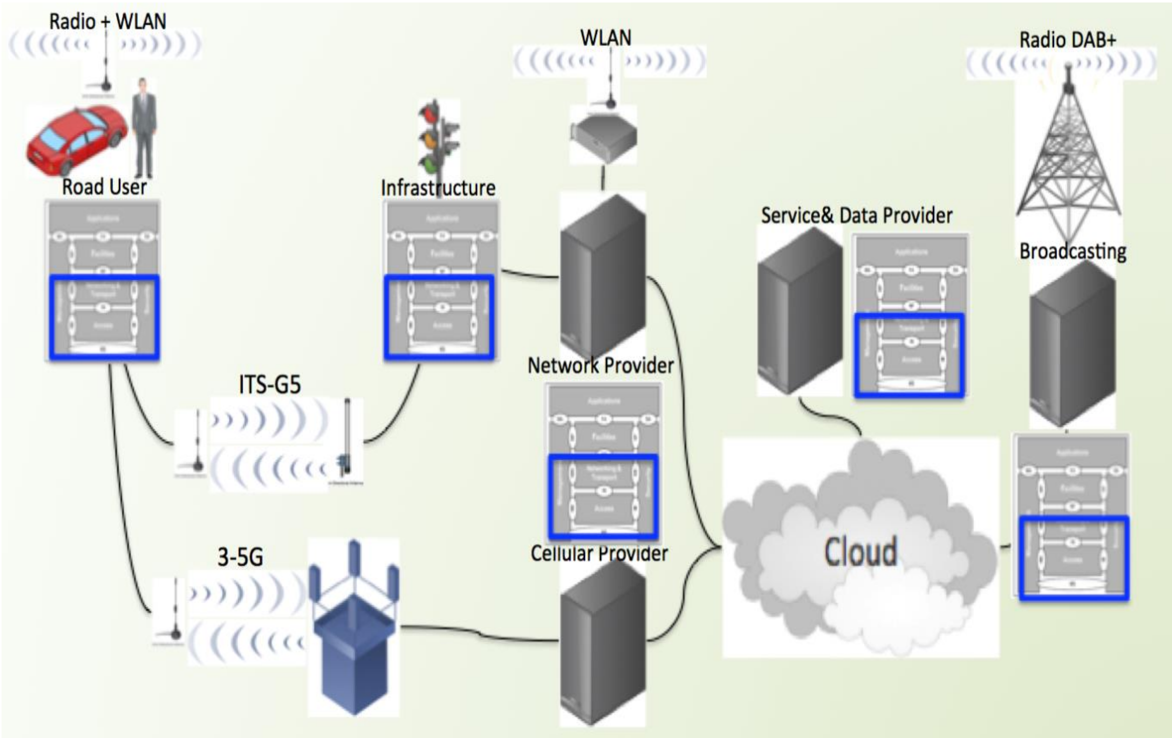


Figure 40: Communication layers in Hybrid Communication Environment
Source: MITCM Hybrid Communication workshop NL (13th September 2016)

When discussing such a hybrid communication system, one approach would be to assume that all aspects regarding the communication protocols do not need to be part of hybrid communication specification – as they are commonly available "just as they are" – and that interoperability has to be ensured by the specific market itself. In Figure 40, blue frames are highlighting these communication layers in each of the participating ITS systems

Within the definition of Hybrid Communication however, communication requirements may also be part of the specification, at least to some extent. One of these requirements could be that the dynamic performance of a specific protocol is provided to a service, which then manages which protocol to use under which conditions. Typically, this kind of services will reside in the facility layer. The facility layer of any ITS system supporting hybrid communication needs to have at least awareness of the static capabilities of each of the communication methods supported, in order to realize predictable and interoperable behavior in the ITS system. For ITS systems supporting traffic safety and efficiency related ITS use cases, this will probably result in extended awareness of dynamic communication behavioral aspects.

Bearing these aspects in mind, another challenge for a "Hybrid Communication Concept" is the simultaneous use of more than one communication protocol and the envisioned support for the concurrent operation of one or more applications and facilitating services in the same system/environment. So a special focus will be on the complex situation that arises from applications, which may be owned and/or developed and/or operated by different stakeholders and are running in a system owned by the same or other stakeholders – which on top of that are making use of various data services, which may be operated/developed/owned by another set of stakeholders.

As long as the communication protocols are specified well within their context, and information is provided to the facility about their specific capabilities, the main other requirements concern especially the service/application providers, as depicted in Figure 42.

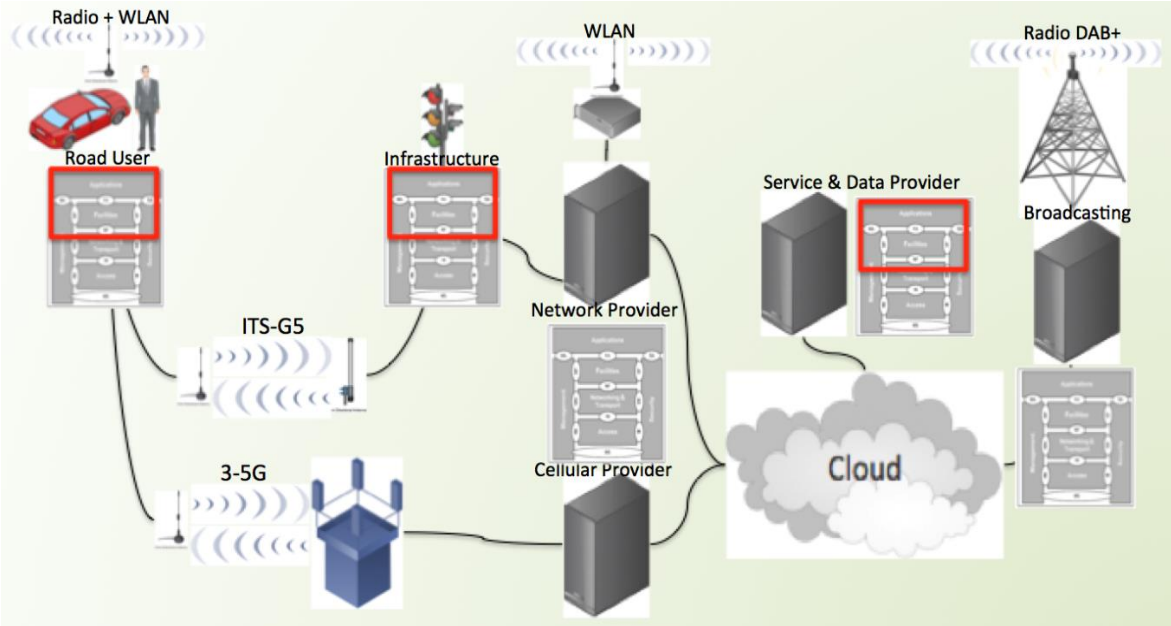


Figure 41: Application and Facility layers in a Hybrid Communication Environment
Source: MITCM Hybrid Communication workshop NL (13th September 2016)

Within the ITS and C-ITS environment, information providing applications and decision-making applications can be recognized. For each of these two groups, which consist of multiple and potentially different stakeholders, a different set of specific as well as some common behavioral requirements maybe identified (Figure 42).

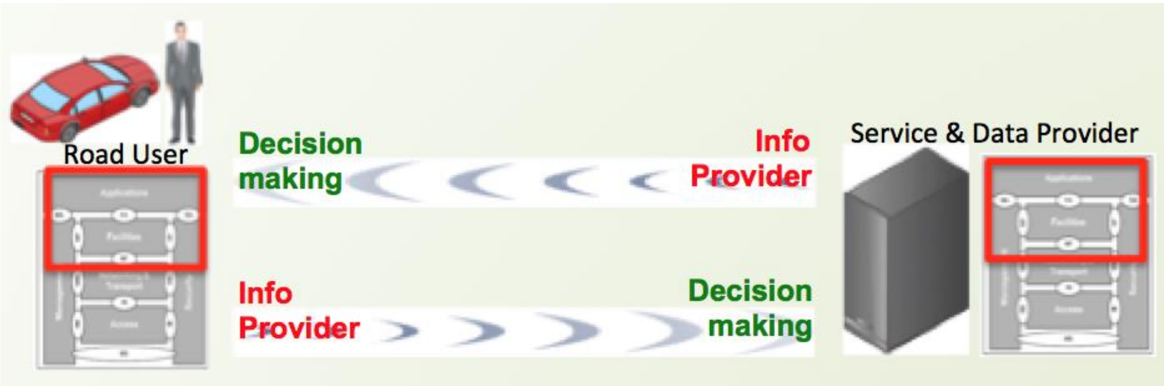


Figure 42: Different and or/common transmitting and receiving requirements
Source: MITCM Hybrid Communication workshop NL (13th September 2016)

As Authorities, non-commercial and commercial stakeholders are active, functional receiver, transmitter and general behavioural requirements depend also on legal, security and business related aspects. For each of the interfaces within the systems and their environment, these aspects need to be taken into account, which may result in adding additional aspects into the protocols, e.g. allowing payments, misbehavior detection, ensuring liability etc.

To enable the realisation of hybrid communication systems, a number of the available standards may need to be updated and new ones created. As it is likely that some updates will be based on IoT developments, updates of C-ITS standards might also be required, for instance the ETSI Architecture [302 665] or application and facility standards based on the basic set of applications [102 638]. It is expected that the development of these new and updated standards will also be monitored and supported by the European commission.

3.9. Backend services

Availability of relevant data, which can be provided in time, is crucial for the improvement of mobility digitalization. Information such as maps, traffic flow, traffic strategies, traffic lights, parking lots, public transport and real-time sensor data can provide new insights, enable several ITS services and thereby help customers to make better mobility decisions. With a powerful cellular network access, all this data can be brought to the ITS customers with little effort.

The more open the data infrastructure is to everyone, the more value might be created from it. Nevertheless there are differences, data assets in the digital data infrastructure may be in the completely closed or open parts of the data spectrum, or somewhere in the shared or licensed area in between [ODI]. For some types of data that are processed by public or private institutions, there might be privacy concerns, which may limit the use or even prohibit an open access to the data.

It is as crucial to protect data that needs to be kept private, as it is to openly publish data that should be open for everyone to use. In that respect both aspects, privacy and openness, help to create trust.

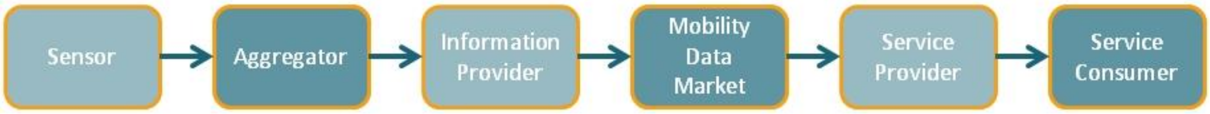


Figure 43: Example of a traffic data value chain
Source: CODECS, based on TISA value chain [TISA]

Figure 43 can be seen as a blueprint for the value chain of an ITS service, real-life examples of such a “Data Market” are the German “Mobility Data Marketplace” or the Dutch “National Data Warehouse for Traffic Information” [MDM, NDW].

From the process chain it is obvious, that the information has to be transferred along the whole chain in any step and between different actors with a quality, speed and bandwidth according to the desired overall service quality.

Another obvious need is that either the location based data has to be stable for the duration of a certain time period or a reliable prediction for the moment when the vehicle passes the point of interest for the information has to be transferred.

For data relevant in time scales of milliseconds, that architecture is not appropriate, e.g. the information needed to start an automatic break process in a car due to an unforeseeable event, like an accident or a person stepping on the drive way just in front of it.

For communication between TCCs and ITS information consumers the existing protocols DATEX II or TPEG commonly are used, but several other protocols are possible. Cellular technologies networks with IP based UMTS or LTE are already deployed in high quality. Range limitations and signal shadowing are known topics in the business of the wireless communication technologies. Due to other needs of the business model drivers, those very local issues are potentially solved much faster and better for mobile devices than it can be expected for ITS-G5 which is expected to be driven to a large extent by public authorities, which often have to manage insufficient funding. Privacy reliability and scalability are common solved issues and aware in the legislative for that industry. Cellular network quality is improving and costs are declining due to the competition of mobile network offers worldwide. Backend technologies for services are evolving with all the big data business models of the internet commerce. Communication units are already an integrated part of all cars, at least with the regulations around introduction of the eCall in EU in 2018 [eCall].

Several of the applications listed in sections 3.5 and 3.10 or the Final Report of the C-ITS Deployment Platform [Platform], are already implemented today with a backend service architecture. Even the services with very high latency requirements might be realized with the upcoming 5th generation cellular network the respective ad-hoc, device-to-device communication.

For example the GLOSA service is being announced to be brought into a big number of cars via backend service by two more OEMs. Real time traffic and local hazard warning information is already widely integrated in vehicles with a backend-based architecture.

Many of the abovementioned applications will have to be reviewed in connection with the further development of highly automated driving. Of higher relevance will probably be only those use cases which will also be necessary on a machine to machine base e.g. since decisions in the vehicles have to be based on more concrete triggers than a “warning”, which is intended to raise awareness, several types of warnings might become irrelevant in the future, due to the fact that there is no driver in charge.

3.10. Use-Cases, Applications

Different bodies have been active in collecting and structuring a multitude of C-ITS applications and use-cases. Among the recent and most complete such lists are the ones provided by the C-ITS Platform (see section 3.5 of this document), as well as the roadmap of the C2C-CC, presented in more detail in section 3.6. They sum up pretty well a number of ITS and C-ITS use-cases tested over the past years in a huge number of research and deployment projects such as Eco-AT, SimTD and SCOOP@F. Trying to aggregate all these lists together, the C2C-CC maintains by itself a co-called "living document", which is basically a matrix of ITS-use-cases and ITS-messages which is constantly updated by its members. Besides listing around 35 use-cases (as of 31st of August 2016) as seen below in Table 3, the list also includes short descriptions, references and the foreseen deployment phase.

ID	Name	Category	Phase
EEBL	Electronic Emergency Break Light Warning	Safety	Phase 1
EVAW	Emergency Vehicle Approaching Warning	Safety	Phase 1
HLN	Hazardous Location Notification	Safety	Phase 1
PVD	Probe Vehicle Data		Phase 1
RWW 1.0	Road Work Warning 1.0	Safety	Phase 1
SSVW	Slow or stationary Vehicle Warning	Safety	Phase 1
SV	Signal Violation	Safety	Phase 1
SWD	ShockWave Damping		Phase 1
TJAW	Traffic Jam Ahead Warning	Safety	Phase 1
TSPR	Traffic Signal Priority Request/Preemption		Phase 1
AEC	Available E-Charging		Phase 1.5
CCRW	Cooperative Collision Risk Warning	Safety	Phase 1.5
CN	City Navigation		Phase 1.5
LZCM	Load Zone Control Management		Phase 1.5
LZM	Loading Zone Management		Phase 1.5
OffSPI	Off Street Parking Information		Phase 1.5
OnSPM	On Street Parking Management		Phase 1.5
PRI	Park & Ride Information		Phase 1.5
VRU	Vulnerable Road User	Safety	Phase 1.5
WWDW	Wrong Way Driving Warning	Safety	Phase 1.5
C-ACC	Connected ACC	Efficiency, Safety	Phase 2

ID	Name	Category	Phase
GLOSA 1.0	Green Light Optimum Speed Advisory 1.0	Efficiency	Phase 2
IVI	In-Vehicle Information		Phase 2
MAI	Motorcycle Approaching Indication	Safety	Phase 2
C-ACC 2	Cooperative ACC	Efficiency, Safety	Phase 3
GLOSA 2.0	Green Light Optimum Speed Advisory 2.0	Efficiency	Phase 3
Platoon	Platooning	Efficiency, Safety	Phase 3
CoDriv	Cooperative Driving/Maneuvering	Efficiency, Safety	Phase 4
AAD	Automatic Accident Detection	Safety	
CGR	Co-operative glare reduction		
CMA	Co-operative merging assistance	Efficiency, Safety	
ETC	Electronic toll collect		
IVS	In-Vehicle Signage		
LCA	Lane change assistance	Safety	
OVW	Overtaking vehicle warning	Safety	
PCSW	Pre-crash sensing warning	Safety	

Table 3: C2C-CC List of Use-Cases

The same living-document also provides a complete list of currently known ITS-messages, this second list being then used to match individual use-cases to their required ITS-messages and. This matrix, which can also be seen in Table 4 provides an accurate indication on the enabled use-cases which any ITS stakeholder will be providing when disseminating one or another specific ITS-message (or a combination of several ITS-messages).

	CAM 1.0	CAM 2.0	DENM	SPATEM	MAPEM	IVIM	CPM	IM	SREM	SSEM
EEBL	x		x							
EVAW	x		x							
HLN	(x)		x							
PVD	x	x								
RWW 1.0			x							
SSVW			x							
SV	x		x							
SWD				x	x					
TJAW			x							
TSPR			x?	(x)	(x)				x	x
AEC										
CCRW	x									
CN										
LZCM										
LZM										
OffSPI										
OnSPM										
PRI										
VRU										
WWDW										
C-ACC		x	(x)							
GLOSA 1.0				x	x					
IVI						x				
MAI	x		(x)							
C-ACC 2										
GLOSA 2.0				x	x					
Platoon										
CoDriv							x			
AAD										
CGR										
CMA										
ETC										
IVS										
LCA										
OVW										
PCSW										

Table 4: Use-Cases to ITS-Messages matrix

Even though many of the Day-1 applications are being put into operation in different deployment sites across Europe, large-scale roll out of the services is still limited due to number of reasons:

- Insufficient specification – a task that is also addresses by CODECS as a Coordination and Support Action. Apart from few Day-1 services that have been covered by the European C-ITS initiatives (White paper on RWW by the AG, IVI and PVD by Eco-AT), most of the use cases have not yet been clearly specified on international scale. Different deployment sites handle the use cases differently which may result in problems with future interoperability.
- Standardized messages – the messages used in ITS G5 technology are standardized and provide limited options for transfer of various kinds of data. As new use cases are being developed, the standardized messages sometimes turn out to be insufficient for certain types of applications. In such cases either new types of messages have to be developed or the old ones need to be revised – both options require a considerable amount of work and time.
- Low penetration rate – one of the major obstacles for the C-ITS applications deployment, as many of the services' efficiency is highly dependent of the penetration rate (PVD, TJAW, EEBL etc.).
- Competition with other technologies – some of the C-ITS applications can also be provided with other types of technologies. Applications like signal violation, traffic signal priority request, probe vehicle data or traffic jam ahead warning are to a certain extent currently being provided with the use of conventional ITS technologies which puts more pressure on justifying the C-ITS's effectiveness and finding the right business models.

Especially the last two bullet points sum up the debate about C-ITS technology via cellular communication or based on ITS-G5. For all the aforementioned use-cases to be deployed, there will be separate scenarios. Much effort has been invested in the scenario development of the C-ITS use cases based on ITS-G5 – which suffers from low penetration rates so far. On the other hand there is already a huge amount of information transferred to the backend systems of OEMs and/or service providers and back into (other) vehicles - based on cellular communication, utilizing existing infrastructure. So for non-time-critical services, information providers are already able to deliver location based content and prognosis data with latency times comparable to common internet data transfer. For instance an on-street parking information service has been announced for the end of 2016 [INRIX], which enables vehicles to find an on-street parking lot easier by obtaining information from a backend system via a cellular link, and GLOSA service via LTE will go live at the same time in selected cities in the USA [GLOSA].

3.11. Defining roles & responsibilities

Compared with conventional ITS, the growing Cooperative ITS requires much more interaction among various stakeholders. In this context, the word “cooperative” does not only refer to interacting technical components, but also to stakeholders behind the technology, so Cooperative Systems require new levels of stakeholder cooperation and demand a certain “spirit of cooperation”. This is quite a challenge for stakeholder groups that, up to now, used to work in rather isolated domains, but for smooth operation, closely networked and meticulously coordinated cooperation is required.

Cooperative Systems will also result in changing roles and responsibilities:

- On the one hand, there are established actors and stakeholders, who have to find a new position in the emerging overall cooperative structure.
- On the other hand, there will be new roles, for which appropriate actors have to be identified, or new organisations will need to be created in order to take responsibilities and fulfil tasks that have not existed before.

In their traditional roles, there might have been only very limited contact between them, e.g. road operators and the automotive industry, since there was a clear separation between the ones building and operating the road networks, and the others building the vehicles to use them. In the future, in order to reach a successful deployment and ensure seamless interoperability, national public operators have to cooperate with private organisations and deal with international interests. Actors, who were previously in no relation to one another, might become partners because of common objectives, service providers on the one end will become service recipients in other respects.

These aspects are already covered to some extent by existing roles and responsibility concepts and standards, whether from a specifically IT related perspective [ITIL], or in a specialized C-ITS approach [ISO]. Moreover, the C-ITS perspective on roles and responsibilities has to take the ETSI ITS-G5 architecture [302 665] into account, but there is also a huge overlap with existing “traditional” ITS actors and processes, for example in relation to the ITS Deployment Guidelines [ITSDG] and the concept of the TISA value chain [TISA].

The international dimension makes this change of roles and responsibilities even more complex since many roles and responsibilities can no longer be sufficiently defined at the national level. In the C-ITS deployment projects and the whole European C-TS arena, close cooperation between road operators, vehicle manufacturers and service providers takes place. This requires a major change for all the stakeholder groups involved, and the impact of this should not be underestimated for the C-ITS deployment in Europe.

A few concrete examples of international tasks that have to be taken care of are

- the definition of a common security policy,
- change management, and
- release management,

all of which get quite complex in an European C-ITS system, compared to the challenges that these processes pose on a single organisation.

4. Actor based view on C-ITS Deployment in Europe

In this chapter, an analysis of the perspectives of several major stakeholder groups within the C-ITS arena is given. The presented insights were derived by consulting experts from the field, within the CODECS core team and the CODECS stakeholder network.

Not only single expert's opinions have been collected as input for the sections within this chapter, but the findings have been circulated and revised by various representatives of the respective groups.

The different views on C-ITS have been clustered into the following groups of actors:

- Road Authorities and Road Operators
- Automotive industry
- Cities
- User Perspective
- Standardization bodies
- Service Providers
- Mobile communication operators (Network Infrastructure)

Those seven main actor groups are reflected by the structure of this chapter.

Although the individual stakeholder groups might have different motivations to engage in the "C-ITS Pilots and Deployment Initiatives in Europe" as described in section 2, and to tackle the "Issues to be solved for C-ITS Deployment" as outlined in section 3, they have to agree on the proper definition, deployment and operation of a common European C-ITS system, in order to reach the common goal of a safer, sustainable and more efficient traffic system. Therefore the challenge is to emphasize the commonalities of all involved parties and take that as the basis for the development of a truly cooperative system, rather than sticking to the historical approach of "isolated silos", in which every stakeholder group is mostly focusing on its very own concerns.

In order to allow for a comparison of the various views given as input to this chapter, a structured approach was necessary. Therefore all stakeholder groups were asked to address at least the following questions as the common denominator of all sub-chapters:

- What is the role of the actor in deployment?
- What does C-ITS mean to the actor role?
- What will the actor get by deployment?
- What are the main issues the actor is concerned with?

4.1. Road Authorities and Road Operators

National, regional and local road authorities provide essential rules for the traffic system in general, and a framework for the road operators and the entire traffic infrastructure.

Whether at a CEDR level where rather high-level agreements are of interest or down to the very detailed regulations and processes in a traffic control centre (TCC), the road authorities and operators are a crucial part of the whole traffic information value chain.

In that respect, they act as an initiator of ITS projects and deployments, but also have to manage those projects and take care of the respective information flows. Traditionally, road operators are seen as manager of a large share of the traffic information chain, or as provider of information to others. With the emerging cooperative systems and services, changing roles and responsibilities, new value chains and value networks open for other stakeholder groups, the road operators will become more of collaborative partner. Instead of solely providing traffic information coming from loop detectors or other (stationary) sensors, C-ITS will allow road operators to be service provider and receiver at the same time and to benefit from the data that is gathered and/or processed elsewhere, enabling them to better monitor and manage traffic. Depending on the type of service considered, road operators value C-ITS for the potential to improve traffic efficiency on European roads, increase road safety and reduce the environmental impact. Eventually C-ITS may even reduce road operator’s costs, e.g. because the number of costly road sensors can be reduced, if reliable data can be obtained and validated from various sources, or due to optimized maintenance processes, if potholes can be detected and reported by vehicles.

So road authorities and operators, e.g. the Conference of European Directors of Roads (CEDR), are strongly supporting an accelerated deployment of cooperative ITS and stating the need to do so together with other strategic stakeholders [CEDR].

Since several aspects of a large scale C-ITS deployment cannot be accurately assessed in the pre-deployment phase, some effects still have to be measured and evaluated – but all of the aforementioned benefits are expected to bring significant improvements for European road traffic. Besides this interest in C-ITS and the expectations associated with C-ITS deployment, there are several issues that road authorities and operators are concerned with.

One major challenge is to solve organisational issues like roles and responsibilities, tendering and operation, update the process descriptions etc.

Road operators are traditionally working on building/maintaining roads and bridges and have a strong focus on those labour-intensive and costly processes – which they control themselves or contract to partners. The deployment of cooperative systems on the other hand require new and other skills, e.g. the setup and operation of IT centered systems, availability and analysis of various data sets, collaboration with new stakeholders, shared responsibilities etc. Main challenge for road authorities and road operators is how to provide a proper framework and how to adapt the processes and (re-)organise these aspects in the most effective way. Besides the aforementioned aspects, which are considered as “internal” to the road authorities/operators, there are others, which are also dependent on other stakeholder groups and therefore highlight the necessary cooperative approach.

One prominent topic among these is IT security, which is currently discussed at the according work group of the C-ITS Platform. In that process, several road authorities, together with the experts from the C2C-CC, automotive industry and security experts, e.g. from the German BSI, discuss how to evolve the initial solution that has been proposed by the C2C-CC.

Another issue is conserving the privacy of road users, while access to more detailed data might be the key to new opportunities for road operators. At the moment the result is, that data from vehicles is seen as personal data and current privacy rules stipulate that data collection is in proportion to the objectives, but nevertheless road operators are staying on the safe side and not using the full potential of vehicle date so far. Moreover, there is still some more analysis on the exact use of data in (road operator's) processes necessary, but major improvements in traffic safety and efficiency could be unlocked by better traffic management and optimized road maintenance processes, enabled by the use of a special Probe Vehicle Data (PVD) format.

This also touches the issue standardization – not only regarding the roadmap for the development of future message formats, like PVD. Also the interpretation of essential standards, i.e. the profiling of those standards, is of importance, since actual (physical) testing still brings up slight differences in interpretation, e.g. with respect to the already existing RWW profile that has been driven by (road authorities and operators within) the Amsterdam Group.

Besides the profiling, the correct use and interpretation of the various message types is not fully specified. DENMs for example are meant to send a limited amount of safety related data and provide a warning. The question remains, what data can to be put into a DENM, and/or what information needs to be added into other messages, because not only in case of RWW, road operators want to send the same data as is shown already on (variable message) signs, in order to provide consistent information via various channels.

This issue is again linked to another topic in question, the Human Machine Interface (HMI) in the car. While not being in the responsibility of road authorities/operators, the HMI is essential for the functioning of the whole chain, since this is where the information is presented to the road user. So far, there has been no discussion among the different stakeholders at the practical level, but this topic should be discussed as a common interest of road operators, automotive sector and service providers.

4.2. Automotive industry

The automotive industry, grouped inside the C2C-CC, will play the leading role by supporting a large number of V2X Day-1 services. These services are based on the CAM and DENM messages which will be disseminated over ITS-G5. In the following years, as increasingly more V2X-vehicles and V2X-infrastructure will become available, additional services will become available, this evolution being described in sections 3.6 and 3.10 of this document. Those OEMs outsides the C2C-CC will be responsible for building up and running a backend service platform to communicate with the vehicles and transfer the relevant and consumable location based information to the control units down in the vehicles and up through backend to the infrastructure providers, where it is in public or in the interest of the driver. For all security and quality issues, the service provider to the vehicles is in duty.

C-ITS represents one of the most important technology developments the automotive industry is currently foreseeing when aiming for a reduced number of accidents and increases in traffic efficiency. When combined with other important technology trends, C-ITS will also play a central role, although it is not fully clear to what extent e.g. future automated driving functions will rely on information from external sources. For instance awareness information that is currently important for a driver will not be necessary for certain automated processes and decisions based on (onboard) sensor fusion. In such a scenario external information might even be more complicated for a system that is design to act autonomous, like Google's prototype cars that are currently only relying on visible and radar sensor interaction

Nevertheless C-ITS will be the basis for enabling automatic driven vehicles to communicate with each other, with other traffic participants and with the smart infrastructure and so enable a fully cooperative traffic flow. This aspect of C-ITS will certainly contribute to a further increase in road safety and traffic efficiency and hence pave the way towards an optimally managed and accidents-free future.

- What will the actor get by deployment?
    - Increased safety and efficiency benefits for our customers
    - Cooperative behaviour for automatically driven vehicles
    - Optimal management through traffic
    - Direct communication with smart infrastructure (Roads and Cities)

Besides the expected advantages that C-ITS will bring, there are some of the issues mentioned in section 3, which are most prominent from the perspective of the automotive industry. Among them is the need for broad availability of ITS-infrastructure, especially in urban areas, which will be crucial for the success of certain (urban) C-ITS use cases.

Another aspect is a potential over-regulation by too detailed legislation, which might lead to an even increased complexity of the cooperative systems and services and/or limit innovative solutions and developments. This aspect is not always mentioned explicitly, but can be read between the lines of various ongoing expert discussions, for example regarding compliance assessment criteria and access to in-vehicle data.

Besides that, the privacy concerns must be taken care of in order to maintain and ensure a high level of user acceptance, which can already be stated on the basis of FOT based survey, e.g. DRIVE C2X deliverable D11.4 [DRIVEC2X].

4.3. Cities [POLIS]

As traffic manager, infrastructure owner and operator, transport operator (e.g. buses, trams) and information service provider, city authorities are important users and therefore buyers of ITS. C-ITS can certainly add to the existing ITS mix. However, cities will only invest in cooperative technology where they see a benefit. ITS deployment in cities is increasingly policy-responsive, which is why the last decade or so has seen a significant growth in ITS investments to promote public transport (bus priority at traffic lights, bus countdown information) and multimodality (Smartcards and journey planners), among others.

It is important to underline that urban areas are very different to the motorway environment. A motorway is by definition a home for vehicles whereas city roads play host to diverse functions and multiple modes. Furthermore, city authorities themselves are comparatively complex structures – strongly policy driven and generally risk-averse.

When discussing C-ITS with cities, the typical questions and comments that are raised time and time again tend to be of a strategic nature:

- "How will C-ITS help me deliver my policies?"
- "Why is a C-ITS solution better than the ITS I have already?"
- "How much will it cost to install, operate and maintain?'
- "How can C-ITS build on existing investments?"
- "Who is liable if technology failure leads to an accident?"
- "C-ITS is for car drivers and highways"

As C-ITS developments have been driven largely by the car manufacturers and technology providers, many of the Day One C-ITS services (as agreed by the Amsterdam Group) are not necessarily aligned with the urban transport policy goals of modal shift, multi-modal transport, safety of all road users and mobility efficiency (as opposed to traffic efficiency), rather they are more suited to the motorway environment for vehicles running at high speed and for which safety and traffic efficiency are paramount. The C-ITS community seems to have acknowledged this and is now in the process of developing new services that do respond to some urban transport priorities (public transport and vulnerable road user safety).

While ITS may be widely used in cities to monitor and manage traffic, locate and manage fleet movements and provide travel information among other functions, there are some application domains which C-ITS may be better equipped to deliver for efficiency, quality and/or cost reasons.

One key application is traffic data (to support traffic management), which today is typically gathered from embedded loops and supplemented by other data sources such as ANPR or third parties (probe vehicle, GSM or GPS data). In some European cities, loops are no longer replaced once they break down due to the expense. A future whereby traffic managers can obtain traffic data directly from the vehicles (aggregated CAM) is indeed very appealing for cities. This particular case describes how C-ITS can respond to a specific problem/need, of which there are many in the urban transport and ITS domain. Such an approach will certainly aid the broader deployment of C-ITS in cities.

Despite the reservations held by cities generally, C-ITS deployment is starting to happen in a number of cities across Europe. In many cases, EU funding for demonstrations and pilots has been instrumental. While this is not a sustainable business model for the rest of Europe, EU projects are valuable in terms of raising awareness of C-ITS and in understanding the main issues surrounding deployment – e.g. Copenhagen's experience of implementing the Compass4D services, from which emerged a number of technical and organisational challenges, is a good case in point (see chapter 2.8.1).

4.4. User Perspective

Along the whole value chain, the actors who have greater influence in enhancing the massive development of C-ITS systems are public administrations and other private actors such as automakers but the end users will be one of the main beneficiaries of the C-ITS deployment in the future. At this end of the value chain, the involvement and influence of this stakeholder group is relatively low, but obviously, as C-ITS deployment will increase, end users will be of major importance for the success of C-ITS.

Drivers or road users in general will be the users of the systems and ultimately be the largest recipients of the benefits that C-ITS development can bring. Therefore they will be the ones to decide which services are of interest and for which of these services they might be willing to pay – hence their interests will heavily influence the definition of business models. Additionally, the end-users must participate in the future development, contributing with their vision in terms of usability, definition of requirements (both technical and business model) and participating in the validation process of the services.

Finally, end-users have the key to promote the deployment of C-ITS by acquiring vehicles and requiring roads properly equipped with the systems needed for the C-ITS services.

So the main challenge is to get this actor group interested and involved in C-ITS, ideally by understanding the road users' needs and requirements and supporting those.

For users the C-ITS is an opportunity to gain major benefits when driving:

On the one hand, the development of C-ITS systems is presented as a, if not the only, opportunity to continue working on improving road safety. In recent years all countries throughout Europe have made great efforts to reduce road fatalities. One example of this is the evolution of the number of death road users in Europe in recent years, along with the definition of new policies, done by the administrations, with the ultimate goal of the "Vision Zero", i.e. to reach a number of zero victims on the roads. So far policies have mostly addressed the driver's behaviour, but a point of stagnation in the improvement of accident figures has been reached, which makes it necessary to consider alternatives to continuously get closer to the zero target. C-ITS deployment is a clear response to this need. The selection of primary Use Cases related to road safety is a clear demonstration of this objective.

So as a main benefit, road users will get an improvement in road safety as a first and foremost benefit. Looking at the longer term, the development of C-ITS also offers very important benefits while driving for drivers, and society in general, such as a more efficient, economical and sustainable transport.

Finally, the development of C-ITS is the prelude to autonomous driving that will provide an exponential increase in driver comfort, especially on long trips and interurban environment. This anteroom will provide value-added services that gradually will increase comfort and driving pleasure for users.

On the other hand, there are also some issues that definitely have to be taken care of, since they might severely limit the road user's enthusiasm for cooperative systems and services. The main concerns that end-users have with regard to C-ITS deployment are:

- Security: C-ITS systems and services should guarantee the security of the communications and, in general, of all services that users would get. This especially holds true when looking at the future automated systems and the coexistence of different vehicles with different technologies sharing the road network.

- Privacy: Privacy of the user's data is one of the main concerns about C-ITS (and future automated) systems; and the main topic in which end-user associations are concerned and focussing their efforts (e.g. FIA). All end-user data used in the different applications should be anonymized and end-users must have knowledge and control about which data is generated by the car, to whom it is sent, for which purpose et.c Also the user must have the possibility to manage all these aspects in an easy and efficient way.
- Reliability: C-ITS offers a set of different applications that are based on information, usually generated by third parties. In order to achieve that end-users will be adopters of C-ITS applications and demanders of the C-ITS deployment from the beginning, it is very important to guarantee the quality and reliability of all information.

4.5. Standardization bodies

Standards are tools to enable conformity and interoperability between services and systems. Standardisation and profiling, as outlined in chapter 3.2 of the present document, include both functional and technical specification in which mandatory aspects (shalls) as well as optional aspects of implementation are presented. For those aspects not begin mandatory, the C-ITS stakeholders need to jointly decide how the standards will be used.

The present chapter provides an overview of the role of standards setting organisations and other standardisation bodies in the deployment of ITS with focus on Hybrid Communication (see chapter 3.8). There are three main European standards development organisations (SDOs): ETSI (European Telecommunication Standards Institute), CEN (European Committee for Standardization) and CENELEC (European Committee for Electrotechnical Standardization). Beyond, there are also non-European SDOs of importance. For cooperative ITS, the following SDOs, their Technical Committees (TCs) and other bodies occupied with standardisation are relevant:

- ETSI
  - TC ITS
  - TC ERM
  - TC BRAN
  - TC RT JTFIR
  - TC IOT
- 3GPP / 5G PPP
- ISO/CEN
  - TC204: WG14 (Automation), WG16 (CALM),
  - TC204-WG18/CEN TC278-WG16
  - CEN TC278-WG17 Urban ITS (aligned with ad-hoc coordination group in TC204 called “Intelligent Mobility”)
- IEEE
  - 802.11
  - P1609
- SAE
  - J2735
  - J2945
- Standardization related initiatives and industry standards
  - DATEXII, TISA and others

A detailed overview of the SDOs and standardisation bodies, their TCs, their thematic focus, decision processes, white papers and standards they are working on, is provided at the end of this document [Annex]. Additionally, the European H2020 project HIGHTS realized a complete report on ITS standards and legislation organisations [HIGHTS]. SDOs are somewhat different than the other stakeholder groups, since they are essential to provide a kind of toolbox for others who are aiming at a consistent deployment of C-ITS, but SDOs themselves are not involved in the actual operation or use of cooperative systems and services.

4.6. Service Providers

Several types of organisations are included when it comes to “Service Providers“, navigation systems manufacturers, traffic information providers, automotive industries and OEMs, broadcasting agencies and (toll) road operators, but also data processing can be bought as a service – just to name a few examples. Although the term “Service Providers” comprises a rather diverse stakeholder group, they are still all expecting huge benefits from the introduction of C-ITS for regular operation. One way of clustering the aforementioned examples would be to draw a (blurry) line between the

- **Traditional** service providers (related to maps, roads, navigation etc.)
- **New** service providers (IT background, communication oriented, data analysis etc.)

For some of the **new** actors, which are often established in and expanding from other domains than traffic, C-ITS will open up a whole new playing field. For actors with a different background than e.g. road authorities or car manufacturers, C-ITS will be an opportunity to bring in their set of skills into the traffic sector and grow into a new market segment. Data mining and the development of algorithms for example might provide answers to the most pertinent questions of other stakeholders, like in navigation or traffic management. Those new actors might be the ones who allow the traditional stakeholders in the traffic sector to provide higher service levels and/or increase the number of services more easily. For those actors, the complex traffic domain will probably be difficult to tackle all on their own, since a certain understanding of processes and dependencies is essential – and this might differ for countries or even regions. So for those new players, cooperation will be key in order to quickly set up and operate successful services.

On the other hand there are the rather **traditional** service providers, for whom C-ITS is offering “just another tool” to tackle their already existing tasks, like traffic management or navigation services. Ideally C-ITS improves the cost-benefit ratio by enabling them to raise the level of service they can provide, or lower their costs when offering services – ideally both at the same time. Using C-ITS as a new tool might require only very little changes a be introduced in existing processes rather easy. Beyond that, additional information generated by a cooperative approach can also enable them to set up additional new services. Maybe those new services have already been drafted before, but could not be realized yet. The introduction of new (and substantially different) services will certainly require modifications of existing procedures and maybe even a changed mindset regarding the actors’ traditional roles and responsibilities. In that respect, some flexibility regarding business models and cooperation with other actors helps, since contracting some very specialized (sub-)service, e.g. data mining, is a lot easier than building up all types of expertise in each and every organisation.

These extending playing fields for the various service provider groups, as described above, are also depicted in Figure 44, which is taken from a recent McKinsey report coming to similar conclusions [CCR]

The cooperative aspect of C-ITS systems and services is still an issue regarding the definition of appropriate **business models**. By focussing on core services and contracting other actors for sub-services, some existing and straightforward value *chains* might transform into more complex value *networks*. Also the integration of stakeholder groups, who are extending their activities into new playing field like the traffic domain or the automotive sector, will lead to the formation of new alliances, but also to increased competition.

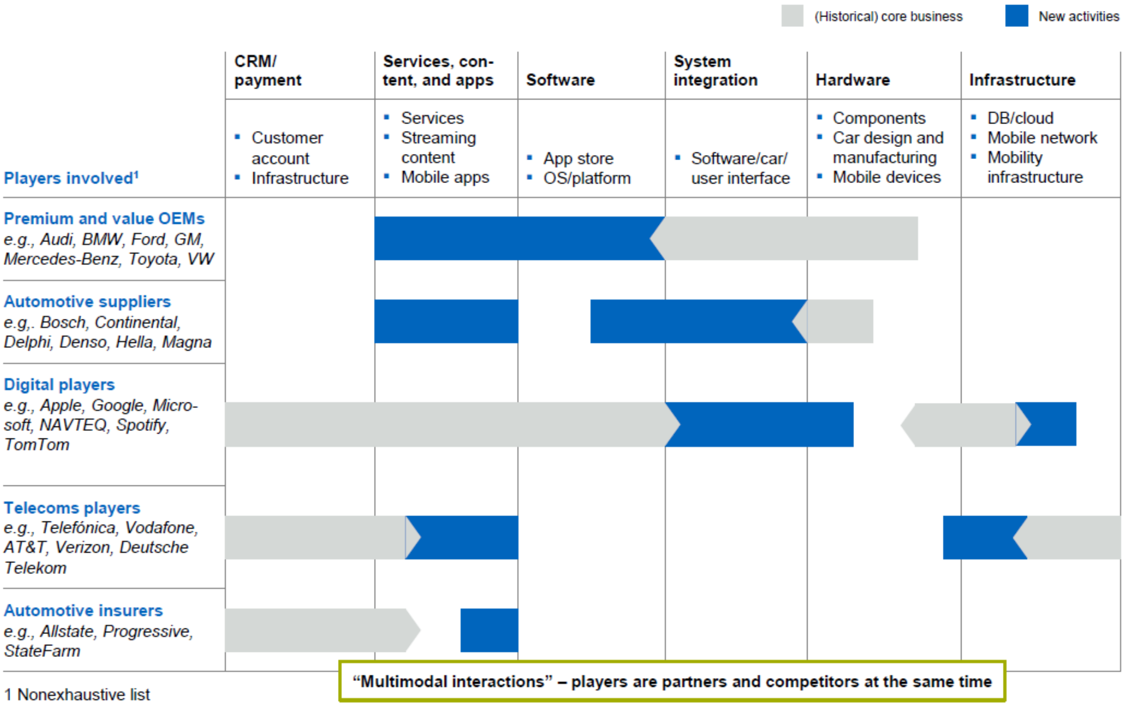


Figure 44: Traditional and nontraditional players extending their activities
Source: Report "Connected car, automotive value chain unbound", McKinsey [CCR]

Instead of controlling the whole chain or big shares, core actors will turn into service providers and service recipients at the same time.Contractual relations to others, e.g. regarding content provision, who again might cascade parts of the job down to others and share responsibilities, require appropriate models for (guaranteed) levels of service.

Also the proper definition of suitable (open/proprietary) **interfaces** might enable or hinder the flexible development and introduction of new services. One possible approach to solve this issue is the agreement on industry standards, for example the proposed SENSORIS interface for vehicle related data [HERE].

As for other stakeholder groups, also the service providers are concerned about the ongoing discussions regarding **privacy** and IT **security**.

Privacy aspects might turn out to be key factors when it comes to user acceptance. Guaranteed confidentiality by trusted companies might even be a selling argument, but privacy breaches might also severely damage the image of services, companies or even technologies. Finding the right compromise when granting access to personal data (and to in-vehicle data), while at the same time limiting the number of identifiers and/or their linkability is still a challenge and an ongoing discussion.

Secured communication is of course an essential part to most businesses and especially to C-ITS, vehicle and user data, but it is also a complex issue with several challenges. Finding (or building up) expertise is difficult and costly. In case of many different security solutions, the number of service providers, and therefore attractive services, in specific markets might be very limited. As for privacy, flawed security systems might cause whole business models to fail, once the trust is lost – even worse if it has negative impact on the safety of the road users.

4.7. Mobile communication operators (Network Infrastructure)

The key role of telco operators in the C-ITS deployment is in providing infrastructure for transfer of data in hybrid or solely cellular-based cooperative systems. So far, mobile operators have not been very active in C-ITS since many of the deployment activities have been rather ITS G5 oriented. However, there are other projects like NordicWay, which underline that cellular communication is also one of the technologies to be used in C-ITS, and that there is a potential for mobile operators in future deployment.

For telco operators, there are the following opportunities in C-ITS deployment:

- **Data transfer:** There is potential of millions of vehicles moving across the network, as well as thousands of pieces of roadside equipment, transferring data non-stop between each other or with the back office. Even if only a small part of this data transfer is performed through cellular networks, it is an enormous market the mobile operators are highly interested in. Unlike the ITS G5 broadcast technology, the cellular-based data transfer can be – and most likely will be – charged.
- **Data source:** By being part of the C-ITS system, the operator receives real time data about large number of end users / vehicles. Such information is of a high value to mobile operators and might substantially improve their big-data-based applications.
- **Service providers:** Telco operators might easily take over the role of a service provider in C-ITS. For some non-safety use cases, it might be sufficient to use the driver's mobile phone as an on-board unit and HMI device, and to provide various complex services through dedicated apps (traffic info, adaptive route planning etc.).

The opportunities for the telco operators in entering the C-ITS market are clear, and they have been establishing their position in deployment roadmaps across Europe over the past years. However there is also still a number of issues and threats in the field of C-ITS, that the operators are facing:

- **Technology:** Even though the cellular networks development is rapid and there is a new generation of mobile communication technology every few years, the mobile networks still cannot compete with DSRC in terms of latency or operation in high speeds. Therefore the operators are not able to guarantee the strict requirements for safety applications with the current available technology. This is expected to change with the coming 5^{th} generation of mobile network standards, but the according specification and standardization (and subsequently the large-scale deployment of a new generation network and devices) will certainly take some more years.
- **Interoperability:** The ITS G5 technology is somewhat ahead in C-ITS deployment compared to the cellular technology, at least in a direct device-to-device communication scenario. ITS G5 has been standardized years ago, and is currently working on vast majority of C-ITS sites across Europe. The standardisation for the use of cellular networks in C-ITS is in its infancy, and at the time of writing (09/2016), there is neither a platform nor a concept for securing interoperability between different operators, countries, as well as between cellular and ITS G5 technologies.
- **Security:** There are numerous aspects to be looked at, especially with regard to trustworthyness in (future) safety-related systems and automated driving functions. Similarly to road managers and operators, the mobile operators have yet to resolve how to secure C-ITS data transfers and guarantee the end users' privacy.

5. Conclusions

The CODECS Deliverable 2.2 is designed to provide a state-of-the-art analysis of the European Cooperative Intelligent Transport System (C-ITS) deployment. This is done with an approach providing three-dimensional perspectives on the pilots and deployment initiatives for C-ITS based services. The content of the deliverable is largely backed by the involvement of the authors in several pilots and deployment initiatives as well as coordinating institutions such as the C-ITS Platform and the Amsterdam Group, Moreover the CODECS networks has strong ties with industry partners, road user organisations, standardisation bodies and various other expert networks which are relevant also in the wider context of C-ITS.

With regard to CODECS, Deliverable 2.2 forms the final element of the inventory phase within Work Package 2 (Coordination of initial deployment activities), see Figure 4.

The deliverable takes stock of the developments with regard to three different perspectives, that are entagled in various ways, as explainend in section 1.3 and depicted in Figure 5:

- First the C-ITS pilots and deployment initiatives in Europe are considered (chapter 2).
- Next are the issues to be solved for deployment (chapter 3).
- Finally there are the core actors' views on C-ITS deployment (chapter 4).

As a conclusion and summary to the document, the core findings for each of these dimsensions and their relation to each other are condensed in the following short wrap-ups

5.1. C-ITS Pilots and Deployment Initiatives in Europe

The stocktaking of pilots and deployment initiatives in chapter 2 has demonstrated that there is a growing interest in Europe to prepare for deployment of C-ITS services. After several years of trials, studies and field operational tests, more than ten European Member States are now active in the actual deployment preparations.

With the advent of the C-Roads pilots and INTERCOR in the course of the 2015 CEF call and funding, each of the nine major TEN-T corridors is now (partially) covered and part of the emerging pan-European C-ITS network, This forms a coherent basis for the deployment start with a shared view on Day One services, covering many different constellations regarding roles and responsibilities and making use of smart mix of hybrid communication (involving ITS G5 and cellular communication, potentially also others).

The geographical pattern reveals that deployment starts in less challenging operating environments, i.e. on motorways, but involves now increasingly (the interface to) urban environments. In a modal perspective, most of the initiatives have started with focussing on personal transport, but now more and more freight and logistics applications are also envisaged, mirroring the economic factors and business model considerations that will contribute to a more comprehensive C-ITS deployment in Europe.

5.2. Issues to be solved for C-ITS Deployment

The stocktaking of issues to be solved for initial deployment of C-ITS services in chapter 3 has revealed and (re-)confirmed several aspects that are calling for action on European level. Surely the most frequently mentioned issues are security, compliance assessment, data protection and privacy, radio spectrum and frequency, which are consequently also highlighted by the C-ITS Platform activities. Besides those most prominent aspects, there are other issues considered more or less crucial, varying with the stakeholders' point of view, e.g. legal framework versus business models.

Regarding the numerous questions still to be answer for European-wide deployment of C-ITS, expert support is provided by all C-ITS actors and stakeholders into the EC (DG MOVE) coordinated C-ITS Platform (support level, see Figure 1).

The institutional framework of the ITS Directive will be used for developing legal certainty about the above mentioned core elements of the European-scale C-ITS deployment (policy level). These elements will become part of a future Delegated Regulation on C-ITS.

Facilitating C-ITS deployment by sharing knowledge, expertise and lessons learned in a deployment expert community, and strategic alignment of the initial and respectively future phases of the C-ITS deployment, provides a huge value. This knowledge brokerage on implementation level is facilitated by the C-Roads Platform, with the Amsterdam Group overlooking the strategic dimension of C-ITS deployment from the perspective of core deployment partners (i.e. automotive industry and infrastructure organisations).

The resources that are necessary to solve these issues and drive the interoperability and harmonisation process are leveraged mostly via Horizon 2020 Coordination and Support Actions (e.g. CODECS, CIMEC) and CEF studies (EU ITS Platform, perspectively C-Roads).

5.3. Actor based view on C-ITS Deployment in Europe

The stocktaking is complemented in chapter 4 by providing a view of core actors towards the initial deployment of C-ITS services. Considering the reasoning behind those various positions, it becomes clear that the actor's motivation is partly congruent when it comes to fulfilling public goals and contributing to Corporate Social Responsibility (CSR) factors. On the other hand, the motivation of actors is substantially different by nature in other respects, at least when it concerns aspects related to Customer Relationship Management (CRM) and the ego position in the value network.

Organisational issues, including a high level shared view on corner stones of business models and leaving the details to the actors to make their share of the total benefit, are therefore essential for successful deployment of C-ITS services.

5.4. Outlook

The main task in the consolidation phase within Work Package 2, a further elaboration of experiences made in the deployment initiatives by the various actor groups and regarding the crucial aspects, will result in Deliverable 2.4, the draft version of the "Deployment Guidance" document. Eventually, at the end of the concluding phase of CODECS Work Package 2, the updated and finalized "Deployment Guidance" in Deliverable 2.6 will also contain a structured overview of the lessons learned and most successful and recommendable ways to engage in C-ITS deployment, with respect to the different stakeholder's needs and ambitions.

6. References

[102 638] ETSI TR 102 638 V1.1.1: Vehicular Communications; Basic Set of Applications; Definitions – http://www.etsi.org

[102 792] ETSI TS 102 792 V1.2.1: Mitigation techniques to avoid interference between European CEN Dedicated Short Range Communication (CEN DSRC) equipment and Intelligent Transport Systems (ITS) operating in the 5 GHz frequency range – http://www.etsi.org

[302 571] ETSI EN 302 571 (draft V2.0.0 currently for approval): Radiocommunications equipment operating in the 5 855 MHz to 5 925 MHz frequency band; Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU – http://www.etsi.org

[302 665] ETSI EN 302 665 V1.1.1 (2010): Intelligent Transport Systems (ITS); Communications Architecture – http://www.etsi.org

[3GPP] 3rd Generation Partnership Project, http://www.3gpp.org/news-events/3gpp-news/1787-ontrack_5g

[5G-AV] White Paper "5G Automotive Vision", https://5g-ppp.eu/wp-content/uploads/2014/02/5G-PPP-White-Paper-on-Automotive-Vertical-Sectors.pdf

[5GPPP] Brochure "5G Empowering Vertical Industries", https://5g-ppp.eu/wp-content/uploads/2016/02/BROCHURE_5PPP_BAT2_PL.pdf

[5G-V] Brochure „5G Vision", https://5g-ppp.eu/wp-content/uploads/2015/02/5G-Vision-Brochure-v1.pdf

[AG] Amsterdam Group homepage, list of Day One services and roadmap, http://www.amsterdamgroup.eu

[AIOTI] "IoT Large Scale Pilots (LSP) Standard Framework Concepts" and report on Smart Mobility, https://ec.europa.eu/digital-single-market/en/news/aioti-recommendations-future-collaborative-work-context-internet-things-focus-area-horizon-2020

[CAR2CAR] European vehicle manufacturers work towards bringing Vehicle-to-X Communication onto European roads, https://www.car-2-car.org/..../Press_Release.pdf

[CAM] ETSI EN 302 637-02 in Version1.3.2 (2014) – Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications;Part 2: Specification of Cooperative Awareness Basic Service, www.etsi.org

[C4D] Compass4D homepage, http://www.compass4d.eu

[CC] Common Criteria for Information Technology Security Evaluation, also ISO/IEC 15408, http://www.commoncriteriaportal.org/

[CCR] Report "Connected car, automotive value chain unbound", McKinsey, https://www.mckinsey.de/files/mck_connected_car_report.pdf

[CEDR] Position Paper on ITS Action Plan and Directive, April 2014, http://www.cedr.fr/home/fileadmin/user_upload/en/Thematic_Domains/Strat_plan_3_2013-2017/TD3_Network_management/N7_ITS_for_NRAs/N7_public_folder/Published_ITS_Position_Paper_April_2014.pdf

[CODECS] CODECS project homepage, http://www.codecs-project.eu Presentations in section "Library"

[Corridor] Cooperative ITS Corridor – Joint Deployment; Project Flyer, http://www.c-its-korridor.de/?menuId=26&sp=en

[DENM] ETSI EN 302 637-03 in Version1.2.1 (2014) – Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 3: Specifications of Decentralized Environmental Notification Basic Service, http://www.etsi.org

[DoA] Dutch EU Presidency document, "Declaration of Amsterdam", http://english.eu2016.nl/documents/publications/2016/04/14/declaration-of-amsterdam

[DRIVEC2X] http://www.drive-c2x.eu and http://www.drive-c2x.eu/publications

[eCall] Announcement of mandatory introduction of eCall in vehicles from April 2018 on, https://ec.europa.eu/digital-single-market/en/news/ecall-all-new-cars-april-2018

[ECC/DEC] ITS EU spectrum regulations: ECC Decision (08)01 for the ITS-G5A & ITS-G5D bands covering Traffic Safety and Efficiency and for the ITS-G5B and ITS-G5C bands for non-safety usage, http://www.erodocdb.dk/docs/doc98/official/pdf/ECCDec0801.pdf

[ECC/REC] ITS EU spectrum regulations: ECC Recommendation (08)01 for the ITS-G5A & ITS-G5D bands covering Traffic Safety and Efficiency and for the ITS-G5B and ITS-G5C bands for non-safety usage, http://www.erodocdb.dk/docs/doc98/official/pdf/REC0801.pdf

[Eco-AT] Homepage (English site) of the Austrian ECo-AT, http://eco-at.info/home-en.html

[FTA] Road users on the Ring Roads and the Helsinki-Turku Motorway: Participants wanted for trial aimed at improving traffic safety, May 2016, http://www.epressi.com/tiedotteet/logistiikka-ja-liikenne/road-users-on-the-ring-roads-and-the-helsinki-turku-motorway-participants-wanted-for-trial-aimed-at-improving-traffic-safety.html

[GLOSA] Audi announces GLOSA service via LTE, https://www.audiusa.com/newsroom/news/press-releases/2016/08/audi-announces-first-vehicle-to-infrastructure-service

[HERE] http://360.here.com/2016/06/28/here-standard-for-shared-car-data-wins-pan-european-backing/

[HIGHTS] H2020 RIA High precision positioning for Cooperative-ITS applications (HIGHTS, Grant Agreement No. 636537): D7.1 Worldwide Standards and Regulation Landscape for Cooperative ITS Systems http://hights.eu/?wpfb_dl=12

[INRIX] INRIX and BMW press release for on-street parking service, http://inrix.com/press/drivers-can-find-parking-faster-with-new-inrix-on-street-parking-2/

[ISMS] ISO/IEC Standards 2700x; especially ISO/IEC 27001, Information security management systems

[ISO] ISO/TS 19427 (2014) Intelligent transport systems -- Cooperative systems -- Roles and responsibilities in the context of cooperative ITS based on architecture(s) for cooperative systems

[ITIL] IT Infrastructure Library, https://www.axelos.com/best-practice-solutions/itil

[ITSDG] ITS Deployment Guidelines (2012), https://dg.its-platform.eu/DGs2012

[MDM] German “Mobilitätsdatenmarkplatz” (Mobility Data Marketplace), http://www.mdm-portal.de/en

[NDW] Dutch “National Data Warehose”, http://www.ndw.nu/en

[NordicWay] NordicWay, Presentation by Ilkka Kotilainen, Amsterdam Group - CODECS Workshop on C-ITS Deployment, 26.04.2016, http://www.codecs-project.eu/index.php?id=42

[ODI] “Open Data Initiative” on data spectrum, http://theodi.org/data-spectrum

[oneM2M] http://www.onem2m.org

[Platform] European Commission - Final Report of the C-ITS Deployment Platform, http://ec.europa.eu/transport/themes/its/doc/c-its-platform-final-report-january-2016.pdf

[PPA] Dutch Pilot Project “Practical Trial in Amsterdam”, http://www.praktijkproefamsterdam.nl/default.aspx

[RED] Directive 2014/53/EU of the European Parliament and of the Council of 16 April 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of radio equipment and repealing Directive 1999/5/EC Text with EEA relevance

[RWS] Report “Overview of standards for first deployment of C-ITS”, (Spaandermann, Broeders, van den Dries), 2014, http://connectingmobility.nl/Rondetafels+Smart+Mobility/Bibliotheek/downloads_getfilem.aspx?id=490876

[SCOOP] Project homepage of SCOOP@F including service descriptions, standards and functional specifications, http://www.scoop.developpement-durable.gouv.fr/en/

[TISA] TISA Value Chain Concept for Traffic Information Services (2012), http://1hqs3nr4u8a1fb7cd3gnb8h1.wpengine.netdna-cdn.com/wp-content/uploads/documents/EO12013TISADefinition-ITS-value-chain20121018.pdf

[TPEG] TISA link on Transport Protocol Experts Group http://tisa.org/technologies/tpeg/

[TS278] “Prestudy UrbanITS - Final Report” as PDF download: http://www.itsstandards.eu/files/Prestudy%20Urban%20ITS%20Full%20Report.pdf

[TTP] L’association Transports Terrestres Promotion and i-Fret Platform, http://www.i-trans.org/association-ttp/fr-association-ttp.html

[UNECE] UNECE “1958” Type approval, http://www.unece.org/trans/main/wp29/wp29regs.html

[VTT] Technical Assessment of NordicWay Coop Demonstration, Kimmo Kauvo and Sami Koskinen, Tampere, September 2015

[WhitePaper] White Papers written by the Amsterdam Group, e.g. DENM profile “Message Set & Triggering Conditions”, https://amsterdamgroup.mett.nl/White+papers/

7. Annex

This section gives an overview of Standards Development Organisations (SDOs) and standardisation bodies relevant for cooperative ITS, their Technical Committees (TCs), thematic focus, decision processes, C-ITS related white papers and standards they are working on.

7.1. ETSI (European Telecommunication Standards Institute)

As communication-oriented SDO, ETSI is well known for its communication standards especially for 3-4G mobile phone technology, for frequency spectrum related standards, M2M standards and others. The ETSI standards may have direct relation with spectrum regulation and are often referenced to by the regulatory bodies.

ETSI in general is driven by contribution of industrial stakeholders mostly. Contribution is based on payment as a portion of the income of telecommunication equipment sales, and linked to voting rights. Vehicle OEMs have one to three votes, research organisations and others in general have one vote.

7.1.1. ETSI TC Intelligent Transport Systems (ITS)

The Technical Committee ETSI TC ITS covers Intelligent Transport Systems, in particular within the 5.9 GHz band, and has direct relationship with ETSI TC ERM, related to spectrum issues. This Technical Committee addresses all ITS-related aspects from application down to the lower communication layers. As ITS are highly relying on location-based service principles, geolocation referencing is an essential element and especially geolocation requirements can be derived from ETSI TC ITS specifications.

The European Commission mandate M/453 assigned ETSI TC ITS to be responsible for the realisation of all C-ITS technical communication standards, safety-related functional standards and C-ITS architecture covered by ITS-G5. CEN was charged with being responsible for all the infrastructure related functional specifications.

The ETSI-standards have a European focus, but based on the success of the ETSI TC ITS standards, they are recognized worldwide. Interest for C-ITS standards has been expressed by Japan, and Australia has adopted these standards for deployment of C-ITS in Australia. In Europe, ITS-G5 is currently used as basis for all short-range safety and traffic management related C-ITS use cases. This is also stressed in the European Commission Mandate M453.

7.1.2. ETSI TC ERM (EMC and Radio Spectrum Matters)

All spectrum related standards are handled within ETSI TC ERM, therefore, all spectrum related communication with the European Conference of Postal and Telecommunications Administrations (CEPT) and the European Commission goes through this technical committee.

For C-ITS, ERM TG37 is of great importance. At the moment, the European NORM EN 302 571 which is specifying how to use the ITS spectrum, is being updated and is currently in common resolution status expected to be finalised after the summer of 2016.

7.1.3. ETSI TC BRAN (Broadband Wireless Access)

The TC BRAN is of importance in the European context. As normal RLAN (WiFi) specifications are covered by IEEE 802.11, BRAN covers the specific European aspects. One of which is the co-existence between normal WiFi and ITS-G5. Contributions by the ITS-G5 community are required to ensure that interference by WiFi devices will not occur.

7.2. CEN/ISO

There is a close cooperation between the European Committee for Standardization (CEN) and the International Organization for Standardization (ISO) with regard to ITS, resulting in many mirror working groups in each of the organisation. ISO is therefore equally important for Europe as CEN, however, specific European aspects or the usage in a specifically European context are driven by CEN.

7.2.1. ISO TS 204-WG14

The WG 14 focuses on automated driving and has the following standardisation in process:

- Traffic congestion assist systems (TCA).
- Divided highway assist systems (DHAS).
- Partially Automated Lane Charge Systems (PALS)
- Cooperative adaptive cruise control (CACC)
- Road Boundary Departure Prevention Systems (RBDPS)

7.2.2. ISO TC 204-WG18 / CEN TC278-WG16

ISO TS 204-WG18 / CEN TC278-WG16 is the working group responsible for the development of standards linked to C-ITS use cases according to mandate M/453, which are non-safety related use cases with infrastructure involvement. CEN has agreed to develop related standards in direct cooperation with ISO, although the business models are different. All related standards will be categorized as world standards and be distributed by ISO.

ISO TC204-WG18 / CEN TC278-WG16 is key for a limited set of specific facility layer related service standards such as SPAT and MAP for traffic light information exchange, IVI for sign information exchange and PROBE DATA standards for the support of additional traffic related information exchange. For PROBE DATA standardisation, the developed standards in ISO TC204-WG16 are also important.

7.2.3. ISO TS 204-WG16

Besides this CEN/ISO group, there is the ISO TC204-WG16, in which early ITS standardisation started and which is the so-called “CALM working group”. “Communications access for land mobiles” (CALM) has been used within CVIS and other projects at that time. It is IP-based and does not allow managing liability properly. This is the reason why it is seen as insufficient for safety related use cases.

7.2.4. CEN TS 278-WG17

CEN TC278-WG17 Urban ITS (aligned with the ad-hoc coordination group in TC204 called “Intelligent Mobility”) is currently being established based on the “Prestudy Urban ITS – Final Report” [TS278]. The initial start of the group is planned for end of 2016. This group is not specifically expected to develop standards, but to setup strategies for it and to give direction to other CEN working groups.

7.2.5. DATEX II

The DATEX II standard is a CEN/ISO standard especially fitting to exchange data among (road) traffic centres and between (road) traffic centres and service-providers. It is mostly used for provision of traffic information, traffic analysis as well as large area traffic management and control. Based on the large packet size of DATEX II data, it is not well suited for short range ITS-G5 communication. Further investigation is needed to identify the exchange of data between the local and inter-local traffic management layers of the ITS system. Some questions, e.g. to what extent information provided by ITS-G5 communication needs to be translated into DATEX II and how this information will be used, still need to be answered.

7.3. IEEE

The Institute of Electrical and Electronics Engineers (IEEE) covers many different areas of electrical and electronics engineering standardisation. In the following section, only the ITS related standards IEEE P1609 and IEEE 802.11p are highlighted:

7.3.1. IEEE P1609 – source: [HIGHTS]

IEEE 1609 is the set of standards used for ITS deployment in the USA in combination with the SAE ITS standards. IEEE 1609 is also referred to as the WAVE standards. These standards define architecture and a complementary standardised set of services and interfaces that collectively enable secure wireless vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications. The family of standards includes the following documents:

- **IEEE 1609.0:** IEEE Guide for Wireless Access in Vehicular Environments (WAVE)--Architecture
- **IEEE 1609.2:** IEEE Standard for Wireless Access in Vehicular Environments - Security Services for Applications and Management Messages. An OER encoding is used and the last version includes several new features
- **IEEE 1609.3:** IEEE Standard for Wireless Access in Vehicular Environments (WAVE) - Networking Services. Major update to the WAVE Short Message Protocol and significant update to the WAVE Service Advertisement was established including adoption of Ether Type Protocol Discrimination (EPD)
- **IEEE 1609.4:** IEEE Standard for Wireless Access in Vehicular Environments (WAVE)--Multi-channel Operation
- **IEEE 1609.11:** IEEE Standard for Wireless Access in Vehicular Environments (WAVE)-- Over-the-Air Electronic Payment Data Exchange Protocol for Intelligent Transportation Systems (ITS)
- **IEEE 1609.12:** IEEE Standard for Wireless Access in Vehicular Environments (WAVE) – PSID Identifier Allocations
  In the last version a few additional PSID's have been added, e.g. WAVE security, CAM, DENM, Vulnerable Road User (VRU), Misbehaviour Report, Certificate Revocation List. The IEEE Registration Authority Committee (RAC) has published an allocation list not including all EU required PSID's yet.

7.3.2. IEEE 802.11

IEEE 802.11 is the RLAN (WiFi) communication standard. The IEEE 802.11p derivative of standard provides the underlying standard regarding the lower layer (MAC-PHY) used within C-ITS communication in Europe, Australia, parts of Asia and the USA.

In Europe, the ITS-G5 protocols run on top of the IEEE 802.11-2012 version including the 11p amendment (specifically required for ITS-G5). As these standards are the basis for proper operation of ITS-G5, they are essential to the deployment of C-ITS in Europe. In the USA, the IEEE 1609.x standards run on top of IEE 802.11-2012. Harmonisation of this WAVE standard with ITS-G5 has been done, but there are still some (regional) differences.

With respect to security aspects, there is agreement between CAMP from the USA and the European-based C2C-CC on the security hardware. Experience built-up during this process shows that more harmonisation may be possible and required in future.

7.4. SAE

The standardisation activities of the Society of Automotive Engineers (SAE) are of importance in the USA. They are the SDO to establish the higher layer protocol standards such as message service standards and minimum set of requirements. Direct alignment on related definitions at ETSI TC ITS and CEN TC278-WG16/ ISO TC204-WG18 in order to harmonise the standards is in place. Monitoring their activities is relevant to make sure that developments in Europe are not blocked by their efforts, for instance, alignment with regard to vulnerable road user standards requires attention and cooperation. Their related ITS standards are J2735 and J2945.

7.4.1. J2735 – source: [HIGHTS]

J2735 defines the Dedicated Short Range Communications (DSRC) Message Set Dictionary, which includes the Basic Safety Message (BSM) as well as related warning messages such as Emergency Vehicle Alert (EVA). Probe Data Management (PDM) and other message types. Harmonisation efforts between SAE members, ETSI and ISO have led to an alignment of these standards with those used in Europe such as CAM DENM, IVI and SPAT/MAP.

A recent update of the BSM includes now also a first version of the Personal Safety Message (PSM) to be used by Vulnerable Road User (VRU) applications.

7.4.2. J2945

The J2945 is a collection of standards, including the following:

- **J2945/1:** On-board system requirements for V2V safety communication
- **J2945/2:** DSRC requirements for V2V safety awareness for other vehicles than cars
- **J2945/6:** Performance requirements for Cooperative Adaptive Cruise Control (CACC) and Platooning
- **The J2945/9:** Performance requirements for safety communications to VRUs

7.5. 3GPP

The 3rd Generation Partnership Project (3GPP) unites seven telecommunications SDOs from different regions around the globe and develops standards for cellular telecommunications network technologies, including radio access, the core transport network, and service capabilities. Those mobile broadband standards are developed within 3GPP, ranging from 2G (GPRS), 3G (UMTS), to 4G (LTE and LTE-Advanced), and in the future 5G. 3GPP has recently started working on C-ITS for LTE-Advanced and 5G [3GPP].

Currently, 3GPP is working on the definition of the next generation mobile standards to be part of 5G (5th Generation of communication standards, including WiFi and ITS-G5 communication). Especially the Technical Specification Group (TSG) SA is of interest as here, the next generation standards are initiated. For the purpose of ITS, the working groups Services (SA1), Architecture (SA2) and Security (SA3) are of particular relevance. 5G will support more use cases then earlier generations. Where current mobile technologies provided communication for general traveling information and routing, next generation(s) will be able to provide more real-time related services and therefore will enable more time and location critical applications.

7.6. ITU C-ITS

Efforts of the International Telecommunications Union (ITU) with regards to C-ITS have not yet resulted in worldwide standards, though this may change and these could be of influence in a later stadium. So far ITU only provided reviews and produced comments on the C-ITS standards as provided by the other SDOs.

7.7. Standardization related initiatives and industry standards

7.7.1. 5G PPP for 5G networks – source: [HIGHTS]

To stimulate and accelerate the achievement of the evolution towards 5G networks, the European Commission and the European ICT industry, through the 5G Infrastructure Association, have launched the 5G Infrastructure Public Private Partnership, in short 5G PPP, as part of the Horizon 2020 Research Programme. Its objective is to rethink the infrastructure and to create the next generation of communication networks and services. The 5G PPP is aiming at securing Europe's leadership in the areas where Europe is strong or where there is potential for creating new markets such as smart cities, e-health, intelligent transport, education or entertainment & media, as outlined in the paper "5G Vision" [5G-V]. The 5G PPP will deliver solutions, architectures, technologies and standards for the ubiquitous next generation communication infrastructures of the coming decade. Next generation of communication covers communications generically and is not cellular specific. 5G may also include WiFi relates aspects as well as broadcasting aspects etc.

The 5G PPP has also published a white paper on C-ITS, "5G Automotive Vision" [5G-AV], in which representatives from both the automotive and the telecom industry commonly provide their 5G vision – how it will enable new mobility services to support the realisation of next generation connected, cooperative and automated ITS use cases by means various wireless technologies. The paper also describes key research and innovation areas that need to be explored and advanced in order to realize this automotive vision [HIGHTS].

7.7.2. TISA

The standardisation of the Traveller Information Services Association (TISA, supported by ERTICO) is traffic information oriented [TPEG], however, new versions cover some safety related elements. Main interest is currently on non-time critical aspects as TPEG messages can be large and quite complex, which means that they are not very useful for information exchange with high latency requirements. This protocol, besides DATEX II, is recommendable for IP based, non-safety and bulk data related Information exchange, for use specifically in broadcasting networks such as DVB-T.

7.7.3. Dynamic Location Referencing, OpenLR™

TomTom launched OpenLR™ as royalty-free technology and open industry standard in 2009, and it invites the ITS Industry to join and adopt it. It provides a dynamic location referencing method, which enables reliable data exchange and cross-referencing using digital maps of different vendors and versions.

7.7.4. oneM2M

The industry is organized within oneM2M, a global standards initiative for Machine to Machine Communications and the Internet of Things [oneM2M]. Related specifications are standardized at SMARTM2M at ETSI. OneM2M concentrates on a scalable architecture with focus on interoperability for allowing the deployment of industrial grade solutions.

At the moment, this is not of major importance to the current ITS-G5 air interface deployments or cellular based communication, but it is of importance to infrastructural architecture definitions. First implementations are available and of interest for ITS related infrastructural implementation.

7.7.5. AIOTI – source: [HIGHTS]

The "Alliance for the Innovation Internet of Things" (AIOTI) can be seen as a tool launched for supporting policy making and the dialogue within the Internet of Things (IoT) ecosystem and with the European Commission.

The near-term objective is to support the large-scale pilots (LSP), which are planned in the H2020 work program. There are two working groups within AIOTI relevant for C-ITS:

- **WG03:**_Focus on standardization
- **WG09:** Focus on smart mobility (smart transport/smart vehicles/connected cars)

WG03 published the report on "IoT Large Scale Pilots Standard Framework Concepts" and WG09 published a "Smart Mobility" report, considering the applications of the IoT in the mobility domain ("Internet of Vehicles") [AIOTI].

The action of WG03 is completed by an ETSI Specialist Task Force (STF 505) on "IoT Standards landscaping and IoT European LSP gap analysis".

7.7.6. SENSORIS

SENSORIS is HERE's proposed industry standard for shared car data. Vehicle sensor data exist in many different formats in the vehicle, varying with brand and type of vehicle. Efficient creation of autonomous vehicle applications will require a common approach on how vehicle sensor data is gathered by connected cars and sent to the cloud for processing and analysis. To that end, HERE published the first open specification and initiated SENSORIS in June 2015 (Figure 45). Comparing the current SENSORIS specifications with existing standards, many elements are already provided by ETSI message formats [CAM], [DENM]. Further monitoring of this development, which is supported by ERTICO and envisioned to be standardized, is however of interest.

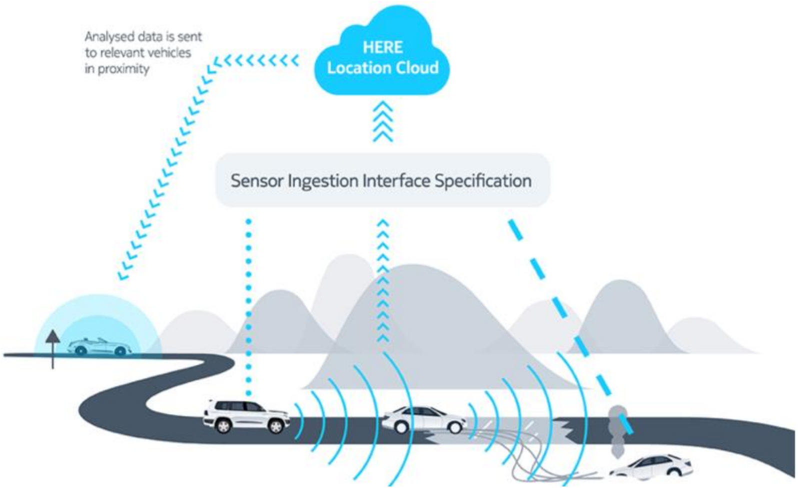


Figure 45: The SENSORIS interface
Source: [HERE]