White Paper on (future) C-ITS Service Implementation – Roles and responsibilities for C-ITS

Deliverable 3 of sub-activity 4.4

Roles and responsibilities for C-ITS: A strategic study

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Preface

This report brings forth a study on views concerning the possible roles and responsibilities for road authorities associated with the deployment of Cooperative Intelligent Transportation systems (C-ITS) and any communications solutions related to the development of what is called Day 1 and Day 1,5 services and applications around the world.

The preliminary aim has been to develop knowledge and guidance regarding a road authorities' possible role in terms of any chosen or planned technical and communicative solutions for C-ITS.

The study is of a strategic nature with a focus on communication solutions not only in terms of technology but also in the form of design, communication, and the use of data such as at a "cloud level". The study attempts to clarify any benefits or limitations associated with the communication solutions looked upon in the study.

It is important to point out that this study focuses on the Day 1 and Day 1,5 related vehicle-to-infrastructure services and applications.

Some of the topics under study can be categorised as being concerned with:

- Data and data sharing
- Cooperation and harmonisation
- Communication technologies
- Liability and regulations

Much of the final recommendations concerning possible roles and responsibilities for road authorities in providing C-ITS are based on the overview presented throughout the chapters 2 to 6 and the interviews and the questionnaire presented in chapter 7 and 11 (Appendix 2).

Summary

Findings from the overview indicate that C-ITS is a worldwide development in which organizational issues related to both technical and organizational standardization is called for by many countries, and interoperability is seen as a major concern. Other issues include security and privacy aspects related to C-ITS with regard to business cases and national roadmaps towards Connected, Cooperative and Automated Mobility.

While many C-ITS related pilot projects have shown that cooperative systems work at a technical level, there is still a need to provide evidence of how real benefits for road authorities and local authorities can be proven, such as how they can contribute to either policy objectives and/or cost-effectiveness (Amsterdam Group, 2013).

The deployment of C-ITS faces many important issues still unresolved, such as legal, organisational, administrative, governing aspects, technical and standardisation issues as well as implementation and procurement issues addressing in particular two types of end-user's services, as those found in the Day 1 and the Day 1,5 services. Cybersecurity, interoperability and collaboration forms is perceived as central and important in C-ITS deployment. The common view is that the C-ITS communicative solutions will not work unless there is a means of ensuring that each connection is a secure connection. Standards are part of this aspect of the interoperability challenge, such as in the work being pursued by C-Roads in Europe. It relates to achieving interoperability between different working groups and actors in which communication and cooperation are "crucial".

Interoperability will be key for a successful introduction of C-ITS systems and services. In this context, standards are one essential tool to achieve interoperability, but standards alone are not sufficient to ensure interoperability. A shared understanding and consistent interpretation of applications and useful standards is necessary to provide benefits to all C-ITS stakeholders.

Communication technologies and strategies for C-ITS still bring forth uncertainty for whether there is a need for special roadside equipment for C-ITS, such as if communication can be handled via ITS-G5, the cellular network, or V2V communication. Related questions become who is responsible for the installation and maintenance of the roadside equipment and the importance of V2I and V2V communication, the availability and provision of digital maps or what associated costs for implementation, particularly by the road administration, if indeed the cost should be connected to them.

Successful C-ITS deployment will most likely require a targeted list of Day 1 and Day 1,5 services and applications that deliver value to end-users. These services and applications

will need their own set of roll-out plans linked to specific roles and responsibilities for their implementation, management and business plans.

While the Day 1 and 1,5 services and applications are not directly linked to a specific communication technology or solution they may require specific technologies and communications solutions to function optimally. The scenarios looked at through the many test pilots being conducted around the world are some of the determinants of what technologies will ultimately be used. It is expected that new technologies will emerge on a regular basis, but the main requirements will still persist for good service provision, such as costs, reliability and safety, latency and speed, to mention some of them. It is also important that the C-ITS applications being used are based on standardised sets for communication and have been tested and validated in relevant field operation tests.

What the road administrator may need to do to support these Day 1 and Day 1,5 services will most likely be defined through the standardisation work and through both national and cross-national test pilots being conducted.

The international overview of C-ITS development around the world indicates a continued need for collaboration on a national and international level, particularly towards a strategy for facilitating the cooperation and sharing of knowledge and experiences concerning a digital infrastructure for C-ITS. Such a strategy would benefit from an increased collaboration with countries outside of Europe such as Japan, Korea, the United States and Australia.

Glossary

Abbreviation	Explanation
ATMS	Advanced Traffic Management System
AVL	Automated Vehicle Location Services
CAM	Cooperative awareness message
CAN	Controller Area Network
CEN	European Committee for Standardisation (https://www.cen.eu/)
C-ITS-S	Central ITS Station (CIS)
CBA	Cost-benefit analysis
C-ITS	Cooperative Intelligent Transport Systems
DAB	Digital Audio Broadcast
DENM	Decentralised Environmental Notification Message
DFCD	Decentralise Floating Car Data
DSRC	Dedicated short-range communications (DSRC)
ETSI	European Telecommunications Standards Institute (www.etsi.org)
FCD	Floating Car Data
GNSS	Global Navigation Satellite System
HMI	Human Machine Interference
ISO	International Organisation for Standardisation (http://www.iso.org/iso)
IVI	In-vehicle Information
IVS	In-vehicle Signage
I2V / V2I	Infrastructure-to-Vehicle and vice versa
ITS	Intelligent Transport System
ITS-G5	A European set of protocols and parameters for V2V and V2I communications based on the IEEE standard 802.11p on wireless access in vehicular environments
LDM	Local Dynamic Map
LTE	Long Term Evolution is a standard for wireless broadband communication for mobile devices and data terminals, based on the GSM/EDGE and UMTS/HSPA technologies.
LZM	Day 1 V2I service to support the driver, fleet manager and road operator in the booking, monitoring and management of urban parking zones specific to freight vehicles.
MAP	Map Data
OEM	Original equipment manufacturer
PKI	Public key infrastructure (PKI) is a set of roles, policies, and procedures needed to create, manage, distribute, use, store, and revoke digital certificates. To facilitate the secure electronic transfer of information for a range of network activities.
PVD	Probe Vehicle Data
PCP	Pre-Commercial Procurement

R-ITS-S	Roadside ITS Station (RIS)
RSU	Roadside unit
RWW	Road Works Warning
SAE	SAE International
SmartR	Traffic information and smart routing C-ITS service
SPAT	Signal Phase and time of traffic light
SRM	Signal Request Message
SSM	Signal Status Messages
SWD	Shockwave damping C-ITS service
TCC	Traffic Control Centre
TSP	Traffic signal priority request by designated vehicles C-ITS service
V-ITS-S	Vehicle ITS Station (VIS)
V2I	Vehicle-to-infrastructure
V2P	Vehicle-to-pedestrian
V2V	Vehicle-to-vehicle
V2X	Vehicle-to-X (X represents any entity capable of C-ITS communications)
VSGN	In-vehicle signage C-ITS service
WLAN	Wireless Local Area Network
WWD	Wrong way driving C-ITS service
ZAC	Zone access control C-ITS service

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1. Introduction

1.1. Background

Cooperative Intelligent Transport Systems (C-ITS) refers to the use of wireless communications between vehicles, infrastructure and personal devices, which enable systems that cooperatively work together to deliver safety, mobility and environmental outcomes beyond what standalone systems can achieve. Cooperative Intelligent Transport Systems (C-ITS) typically involves what is labelled communication between vehicles (V2V), between vehicles and infrastructure (V2I) and/or infrastructure-to-infrastructure (I2I).

There are ongoing worldwide developments related to C-ITS which include state and local transportation agencies, vehicle and device makers, and the public testing and evaluating technology that will enable cars, buses, trucks, trains, roads and other infrastructure, together with other devices to "talk" to one another. According to Menadue and Asselin-Miller (2016) C-ITS has the potential to play a significant role in tackling the increasing problems of congestion, transport energy consumption and emissions. Benefits can be found in areas such as improving road safety, reducing congestion, optimizing transport efficiency, enhancing mobility, increasing service reliability, reducing energy use and environmental impacts, and supporting economic development amongst others.

Connected Vehicle applications are part of the evolution of C-ITS, from information provision for human drivers to safety critical applications for the control systems to act upon. Integrated communication technologies and standards such as ETSI ITS G5 and cellular C-V2X, from the cellular industry, are some of the communication solutions envisioned to provide innovative network structures (e.g., edge, vehicle cloud and service cloud).

C-ITS has the potential to greatly increase the quality and reliability of information being shared through the system. C-ITS facilitates cooperation among the different entities of an ITS by sharing information usually between vehicles, roadside equipment, traffic control centres and nomadic devices via a standardized communication architecture (e.g., an ITS Station Reference Architecture). The aim being to provide road users with better road safety, traffic efficiency, comfort, and more efficient mobility with an increased potential for improving safety, sustainability, efficiency and comfort beyond the scope of stand-alone systems (ERTICO Task Force on Communication Technologies for C-ITS services, 2015).

C-ITS systems and applications may offer a more (cost) effective way of delivering certain traffic management functions than traditional ITS does today, (e.g., traffic data to support adaptive traffic management). According to the European Commission (2016) the success of deployment of C-ITS relies on reaching substantial network effects via the rollout of both

communicable vehicles and infrastructure for C-ITS across a large number of its Member States (“ITU towards ‘IMT for 2020 and beyond,’” 2017).

Japan, as an example, deployed its first C-ITS services in a real-life environment as early as October 2015.

Interoperability will be key for a successful introduction of C-ITS systems and services. In order to provide benefits to all C-ITS stakeholders, it becomes apparent that a stakeholder specific profile concerning roles and responsibilities is needed. Road administrators will need to be informed not only about their own potential roles and responsibilities but also how to be part of a harmonisation between different stakeholders covering the interfaces and overlapping areas of interest (Tool & Verweij, 2017).

The European Commission, in its C-ITS strategy, identifies what are called Day 1 services or use cases. These are services that should run seamlessly and interoperable across the EU according to the European Commission (2017). [1]

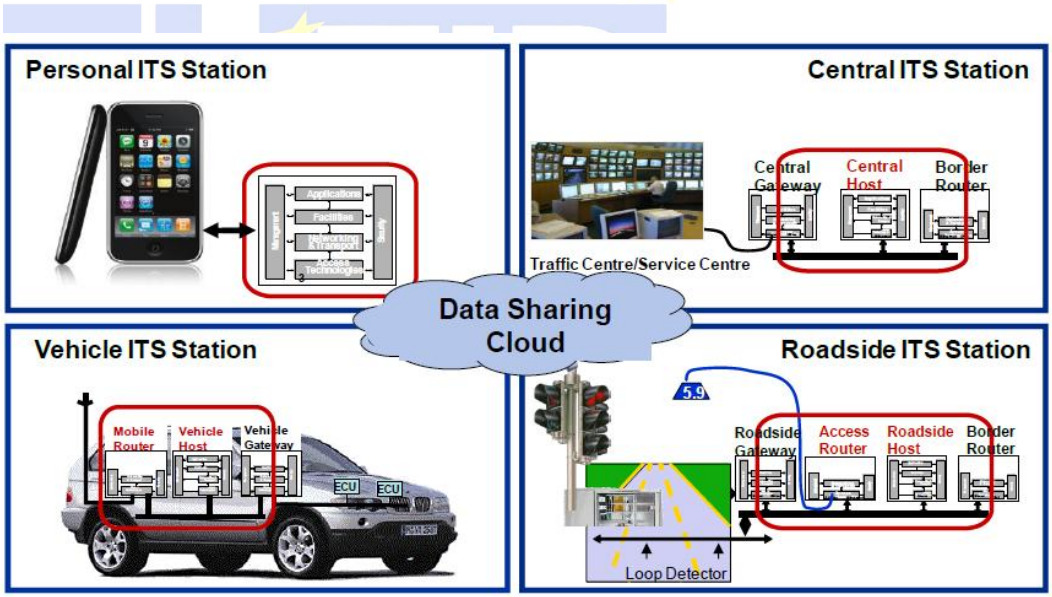


Figure 1 Architecture for C-ITS example ITS Station reference architecture. Source: ERTICO, 2015

[1] Communication ‘A European strategy on Cooperative Intelligent Transport Systems, a milestone towards cooperative, connected and automated mobility ‘ European Commission, 2017. https://ec.europa.eu/transport/themes/its/c-its_en

1.2. Objective

The aim of this study is to give an overview of C-ITS developments and strategies around the world in terms of chosen or planned technical and communicative solutions for C-ITS service provision and in specific addressing two type of end-users' services, i.e. the "Day-1-services" and the "Day-1,5-services". Further, the study aims at clarifying the pros and cons of the communication solution that are being considered for C-ITS together with any associated strategy for its implementation.

Based on this information the study will conclude and make recommendations for road administrators and authorities based on the current state of C-ITS development and the technical solutions being employed throughout parts of the world at the time of this study.

The study assumes a road operator's perspective with a focus on services based on vehicle to infrastructure communication. It has become apparent throughout the study that the field of C-ITS is changing and there is a need to gain insight into the next steps that are being taken moving from the initial Day 1 C-ITS services towards higher and higher degrees of automation. This includes identifications of the technology and regulatory challenges facing road administrators as well as the need for standardization.

Specific aspects looked at in the study as related to Day 1 and Day 1,5 services:

- Security aspects (data security)
- Delay (latency) short range versus long range/cellular systems
- Pros and cons of communication with "cloud solutions"
- Status regarding companies and products
- Any unclear questions related to standards (ad hoc communication vehicle-vehicle)
- The role of the Road Administration / Road Operator in providing services and systems

Road Administrations (authority/operator) views and strategies regarding the use of certain technologies for C-ITS in terms of:

- Connectivity for V2V, V2I (ITS-G5, 5G and other types of cellular network), V2X
- Pros and cons of respective communication solution (such as ITS-G5, Cellular and Hybrid solutions)
- Any delays or similar issues (such as latency and range issues)?

Road authority's strategy related communication solutions for C-ITS, if any, for setting up C-ITS services in terms of:

- To purchase data from company clouds
- To provide data from Company Clouds to the public

- For using data. Such as for handling slippery road, need to send out vehicles to put sand/salt on road, publish slippery road alerts to the public, provide information signs along the roads
- For providing data such as for influencing or complying with legal requirements.
- Regarding open interfaces such as for communication between different “clouds”, communication interchange servers

1.3. Methodology, scope and delimitations

Part of the process has been to select and describe specific C-ITS services. Basis for the selection have been Day 1 services and Day 1,5 services where the road authority can be expected to have a role. The study also involves the current state of communication solutions for C-ITS and their current deployment in some parts of the world related to Day 1 and Day 1,5 services. Further, this study describes a selection of the applications related primarily to V2I (vehicle-to-infrastructure).

Besides the service selection, additional steps have involved:

- Conduct a review of relevant literature and information gathering to describe possible roles that exist in the provision of various C-ITS services and make a theoretical assignment of roles to the road authority.
- Make an interview guide based on the theoretical assignment of roles.
- Make a questionnaire based on the theoretical assignment of roles.
- Send out the questionnaire and interview road authorities in Europe and a selection of countries outside of Europe considering their views on the road authorities’ role in the provision of C-ITS.
  Summarize the interviews and the responses and adjust in the role assignment if appropriate.

Deployment of C-ITS is treated here in terms of strategies, or more specifically technical strategies that are being devised in some parts of the world by road administrators. The study has limited itself to an overview of the communication solution trends around the world in terms of C-ITS development and initiatives in some parts of Europe, USA, Japan, South Korea and Australia.

The focus within the international overview has concerned the status of a service, if any, and what communication solutions strategy is being considered, if any, by the countries Road Administration/Road authority.

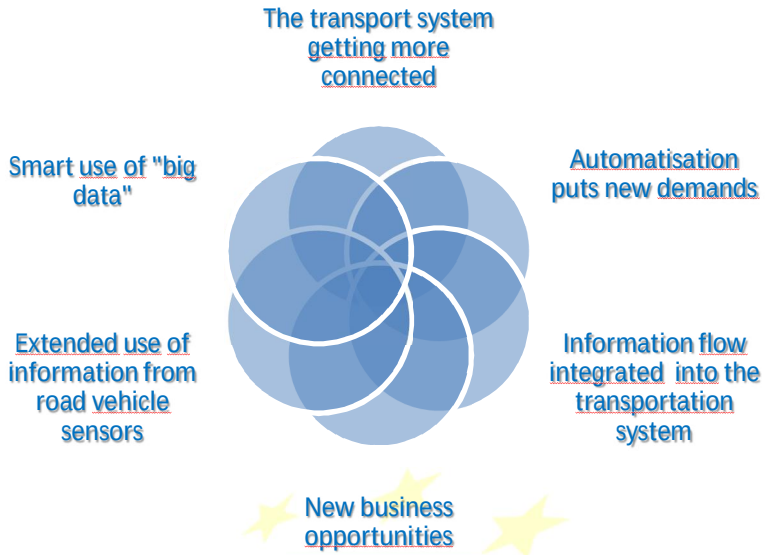


Figure 2 Trends in transportation

The questionnaire on roles and responsibilities for deploying C-ITS was sent to 90 individuals around the world. Mainly to individuals working at, or with, road authorities or assisting them. Answers were received from 17% respondents, which amounts to 20 respondents. Placing the questionnaire in summer time 2017 (vacation period) may have impacted the response rate. However, the responses have allowed for quite good coverage of the underlying developments, both in terms of geography as well as diversity of sectors (e.g. road authority, academia, consultancy).

The interview study concerned the view different road authorities might have on their role in providing Cooperative Intelligent Transportation Systems (C-ITS) in their respective country and their views on different communication solutions for C-ITS. The interview was set up for a duration of 30 minutes (maximum 60 minutes) via Skype or telephone. The ambition was to gain insights about technical communication solutions the Road administrator in their respective country was looking at for C-ITS and any strategy connected to its implementation. Another aspect we wanted to ask was about their view on the role and responsibility of their road administration for providing C-ITS services, systems and infrastructure. Mainly based on the provision of Day 1 and any Day 1,5 services in their respective country. But also, if applicable, concerning any other ideas or future innovative solutions the road administration in their respective country might be considering.

In terms of study scope it has to be noted that the bulk of work represented in this deliverable has been carried out in the second half of 2017 and first half of 2018. Important progress in terms of both, providing legal certainty (Delegated Regulation on C-ITS) as well as ensuring interoperability of C-ITS services (C-Roads releases) has been made throughout the year 2018. These developments have occurred in parallel to this study, in full awareness of the study team. The landmark character of both developments is fully acknowledged.

Some of the initial references on service harmonisation and interoperability (e.g. Amsterdam Group White Papers) are still valuable sources but are superseded today by the C-Roads releases. With respect to the recurrent nature of deliverables in the EU EIP sub-activity 4.4 on C-ITS deployment support, this White Paper should be perceived as a draft of Deliverable 3. Therefore, it is arguable in the light of efficiency reasons that the effort to reflect the latest harmonisation progress of C-Roads has deliberately not been taken now but will be reflected in the final version of the deliverable. The final version of this document, the road map for C-ITS service implementation beyond initial deployment, is scheduled for the year 2020.

Further it must be noted that issues such as communication solutions have also been reported in earlier deliverables of the EIP project family (e.g. EIP+ White Paper on C-ITS services, Berndt et al. 2016). Some of the key features and issues at stake have been included here in order to improve the context awareness for roles and responsibilities with respect to different C-ITS services.

2. Communication solutions for C-ITS

There are a number of potential communication solution related to C-ITS. Many of them are envisioned as being part of an infrastructure that is pervasive, reliable, high-speed, high-volume and provides wireless connectivity with low latency. Another part of such an infrastructure is via large cloud-based data centres where higher-level, big data processing will occur. Wireless connectivity faces the greatest technical challenges but is seen as promising with 5G, whose specification will be released in 2020 by the 3rd Generation Partnership Project (3GPP) who are overseeing the development of 5G, according to Ericsson (2017). [2]

[2] https://www.ericsson.com/assets/local/narratives/industries/intelligent-transportation-systems/connected-traffic-cloud-brochure-161007.pdf

Data sources will be crucial for providing the drivers, vehicles and the general public with relevant information about the road conditions and infrastructure. Once real-time data is available from drivers, vehicle, infrastructure and the general public there is a need for a communication solution (including business models) for access/sharing of data, i.e. mechanisms for exchanging information between different service providers, and between service providers and the Traffic Data provider. [3]
The following sections describe some of the communication standards related to C-ITS being considered at the moment.

2.1. C-ITS standards

Many of the road-based vehicles of today are already communicating wirelessly for over-the-air software and firmware updates, receiving high-definition content for back-seat entertainment, and downloading maps for navigation systems. C-ITS requires standardized often critical services to be in place called Day 1 services and their related functions. Additional services are called Day 1,5 services.

Day 1 use cases and applications are not at this point linked to specific communication technologies. However, applications have different operational and functional requirements, such as different latency requirements which lead to a specific communication technology being used. An example is services based on information exchanged between vehicles and infrastructure which require low latency, reliable short-range communication such as ETSI ITS-G5 technology communicating within the 5,9 GHz band (such as R-ITS-S). When it comes to the early deployment of C-ITS services it is important to use use-cases that are based on standardized message sets that have been tested and validated in field operational tests. It is of great importance that relatively simple and non-complex use cases are prioritized. The cases should be easy to implement with limited costs. High level of end-user benefits can however not be overlooked.[4] [5]

CAM and DENM are considered as a first deployment;

CAM (Cooperative Awareness Message) is a periodic message sent one to ten times per second with data. Data includes information about vehicles position, directions, speed etc.[6]

[3] https://www.ericsson.com/assets/local/narratives/industries/intelligent-transportation-systems/connected-traffic-cloud-brochure-161007.pdf.

[4] ERTICO "Guide about technologies for the future C-ITS service scenarios"

[5] Highly inspired by the presentation *Deployment of connected, cooperative and automated transport: the role of investment opportunities* by Suzanne Hoadley, POLIS, 2016.

[6] ERTICO "Guide about technologies for the future C-ITS service scenarios"

Refers to a message ('I am here') sent by one to ten times per second with data on vehicles. Position, direction, speed etc.

DENM (Distributed Environmental Notification Message) is different types of warning messages. These messages are sent with high priority and the information is infrastructure based or vehicle based [7] and Refers to a warning message (e.g., slippery road or crash etc.) sent high priority to a vehicle based on information from another vehicle or the infrastructure.

SPaT / Signal Phase & Timing is related to information to the vehicle on traffic light state and future changes.

MAP describes the physical geometry of an intersection.

IVIM (Infrastructure to Vehicle Information Message) contains information about static or variable road signs, virtual signs or free-text information.

2.2. FM broadcast

FM broadcast has been used for traffic information for a long time and most cars are equipped with a FM radio receiver. To receive messages the receiver must support RDS-TMC. The FM radio system is gradually being replaced with DAB radio and which will probably reach very good coverage by 2020. [8] Digital Audio Broadcasting and FM radio are also used to send data to vehicles, and cellular communication solutions can be used also for low-cost broadcast.

2.3. Dedicated Short Range Communications (DSRC)

DSRC is a communications protocol developed to address the technical issues associated with sending and receiving data among vehicles and between moving vehicles and fixed roadside access points. The term DSRC is used for C-ITS communication only in the U.S. DSRC is a specialized form of Wi-Fi, and, as with Wi-Fi, it is a derivative of the basic IEEE 802.11 standard, which is a set of standards developed by the Institute of Electrical and Electronics Engineers (IEEE) for implementing wireless local area network computer communications. DSRC is governed by the IEEE 802.11p and 1609 standards.

[7] ERTICO "Guide about technologies for the future C-ITS service scenarios"
[8] ERTICO "Guide about technologies for the future C-ITS service scenarios"

DSRC also includes the Wireless Access in Vehicular Environments Short Message protocol defined in the IEEE 1609 standard that allows terminals to broadcast messages to all other devices in radio range. This is highly efficient because any given terminal does not need to learn the network identities of any other terminal.
The typical range of a DSRC access point is about 300 meters, although ranges up to about 1 kilometre have been observed.

In 1999, the FCC dedicated 75 MHz of bandwidth at 5.9 GHz to be used for vehicle safety and other mobility applications. DSRC operates in this band and has been developed for more than a decade by a range of stakeholders including automakers, electronics manufacturers, State transportation departments, and the Federal Government. Most work on DSRC has focused on active safety-crash avoidance using driver alerts based on sophisticated sensing and vehicle communications.

Unlike Wi-Fi, DSRC uses a communications protocol that allows each terminal to generate its own IP and MAC addresses. This effectively eliminates the network attach time.

DSRC is also currently the only short-range wireless technology that provides the following: a fast network acquisition, low-latency, high-reliability communications link; the ability to work with vehicles operating at high speeds; the ability to prioritize safety messages; tolerance to multipath transmissions typical of roadway environments; performance that is immune to extreme weather conditions (e.g., rain, fog, and snow); and security and privacy of messages.

2.4. ITS-G5

While 5G refers to next-generation mobile communications, ITS-G5 is local beacon technology. Local (beacon-based) technologies, often referred to as ITS-G5, or simply 'G5' (not to be confused with 5G), DSRC, 802.11p and other names, transmit data between vehicles and infrastructure using special frequencies and protocols designed purely for transport. Because of the specialist and short-range nature of the link, they are more reliable, more secure, and more rapid than existing cellular communications. They require most often special-purpose products to be installed in vehicles and (for C-ITS between vehicle and infrastructure) at the roadside.

ITS-G5 is a short-range WLAN standard developed for ad hoc broadcast communication between vehicles and the road side infrastructure. This technology has been researched

and pre-deployments projects have been performed.[9] Thereby, has the applicability for traffic safety and management related to C-ITS been demonstrated in various projects.[10] When deploying ITS-G5, investment in R-ITS-S are necessary and new backend infrastructure is also needed to handle the incoming data in the existing traffic centres.[11]

Reserved Wi-Fi spectrum for safety applications and other C-ITS services:

- Short-range: 300-500m (up to 1000m) depending on environment.
- Spectrum not (currently) owned by any market player which means free of charge communications.
- Low latency of data transfer, which is critical for safety applications (e.g., emergency braking) but less relevant for urban applications.
- Traffic efficiency-oriented communication technology

When deploying ITS-G5 financial, maintenance and legal aspects must be considered and the cooperation with the private sector need to be determined. There is a need for extensive discussion and agreements among all stakeholders when deploying this communication technology. Uniformity and business models must be determined, especially since there is a need for ensuring that the R-ITS-S can contribute effectively to the overall C-ITS system.

Regarding the legal aspects, the stakeholders must agree upon a security system which can ensure private policies and that the received information can be trusted.

2.5. Cellular networks

Cellular technologies refer most often to 3G, 4G, LTE and, when available, 5G and is based on mobile phone/data services. The key advantage of cellular technologies is that it is already widely used, having networks continuously improving while being sustained by external business cases. They can be used in any vehicle, old or new, and by pedestrians, cyclists, and so forth. Existing user devices (smartphones) are easily complemented by apps, and the investment needed on the infrastructure side is most often made by the industry, and in many cases in line with national communication infrastructure plans, and not, as yet, by road administrators or operators.
The coverage of the cellular network will vary depending on the cellular operators, technology, country and region. For mobile communication, there is a need for standardization of the cooperative function. The development of connected car services will

[9] ERTICO “Guide about technologies for the future C-ITS service scenarios”
[10] European Commission “Study on the Deployment of C-ITS in Europe. Final Report”
[11] ERTICO “Guide about technologies for the future C-ITS service scenarios”

probably result in such attractive service in new vehicles, and it will probably reach close to a 100 % in a few years. These vehicles can thereby support V2X services based on DENM-messages.[12] At this stage, the cellular network and service already offer many ITS connected services and are expected to offer many more in the future. Especially when it comes to coverage and technical performance.[13]

V2X has emerged from the cellular industry. Called C-V2X, it is designed to complement and extend existing cellular capabilities. Like 802.11p, C-V2X direct communications support active safety and enhance situational awareness by detecting and exchanging information using low-latency transmission in the 5.9-GHz ITS band for vehicle-to-vehicle (V2V) as well as V2I and V2P scenarios. C-V2X can function without network assistance and has a range that exceeds one mile, even in areas where mobile network connections aren't available.[14]

C-V2X can combine the capabilities of roadside units (RSUs) and the cellular network to help improve safety and support autonomous driving. RSUs are radio base stations installed at intersections or along the side of the road (they can be on lamp poles, traffic light poles, and electronic toll collectors) that allow communications between vehicles (V2I or I2V) within a localized area. The roadside units will use a high-throughput connection with other cars on the road to build local, dynamic HD maps using camera and sensor data, and distribute them as needed.[15]

C-V2X aims at providing:

- The ability to use all features provided by the existing cellular LTE network.
- The ability to connect the car to all types of objects that either have sensors or cellular connectivity (including people via their smartphones).
- Both device-to-device (V2V, V2I, and V2P) and device-to-network (V2N) services.[16]

[12] ERTICO "Guide about technologies for the future C-ITS service scenarios", 2015
[13] European Commission "Study on the Deployment of C-ITS in Europe. Final Report", 2016
[14] Slovick, Murray. http://www.electronicdesign.com/automotive/dsrc-vs-c-v2x-looking-impress-regulators, 2017
[15] Slovick, Murray. http://www.electronicdesign.com/automotive/dsrc-vs-c-v2x-looking-impress-regulators, 2017
[16] http://www.electronicdesign.com/automotive/dsrc-vs-c-v2x-looking-impress-regulators, 2017

Irrespective of the outperforming claim of any newcomer against incumbent technology, it remains to be seen whether and to what extent these promises can be fulfilled. The picture as of now does not support a unanimous conclusion on superior performance.[17] [18] The different stages of maturity for deployment also make comparisons still difficult.

When deploying cellular communication technology in a C-ITS context the financial aspects need to be determined. As for today cellular communication is driven by the private sector, but when implementing it on a C-ITS scale it may require that the road authorities take a more active role. However, the contribution may differ among countries since financial and policy conditions vary throughout Europe and most probably as well as in other countries. The road administrators might need to also support the establishment of C-ITS infrastructure via cellular operators, if that is the only way to have the necessary coverage and bandwidth of communications. Additionally, issues concerning the integration of cellular communication, in terms of data roaming and devising strategies to handle conflicting information that may arise through different communication channels, would need to be addressed. The responsibility for handling these issues could rest both on the private sector and the road authorities, since there are in both parties' an interest to solve this issue.

[17] C-ITS: Three observations on LTE-V2X and ETSI ITS-G5: A comparison, Andrew Turley, Kees Moerman, Alessio Filippi, & Vincent Martinez, 2018, https://www.nxp.com/docs/en/white-paper/CITSCOMPWP.pdf

[18] Accelerating C-V2X commercialization, Qualcomm Technologies Inc., 2017 https://www.qualcomm.com/media/documents/files/accelerating-c-v2x-commercialization.pdf

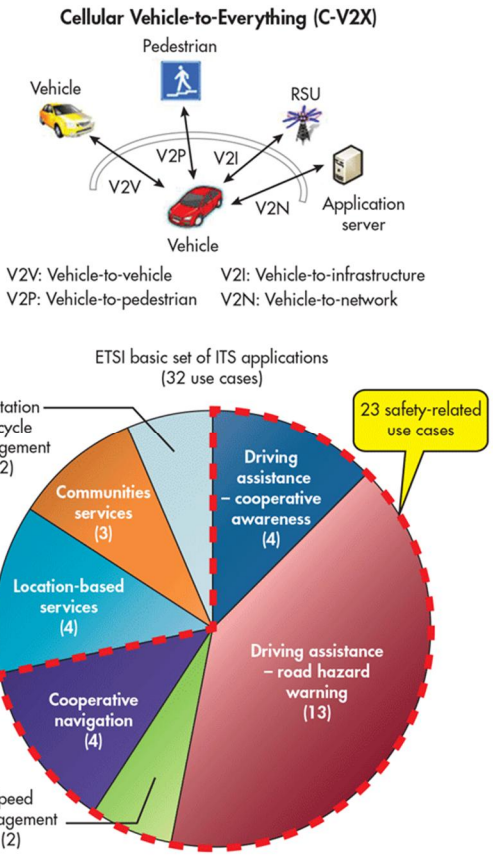


Figure 3 C-V2X uses wireless connectivity to enable connected vehicles to achieve "Cooperative Awareness" for the realization of the "Basic Set of ITS Applications" as defined by ETSI, the European Telecommunications Standards Institute. Source: Hong Kong telecommunications service provider PCCW-HKT.

2.6. 5G networks

5th generation mobile networks or 5th generation wireless systems, abbreviated 5G (not to be confused G5 that is an abbreviation of ITS-G5 where the G5 refers to the use of the 5 GHz band) , are the proposed next telecommunications standards beyond the current 4G/IMT-Advanced standards.[19] 5G planning aims at higher capacity than current 4G, allowing a higher density of mobile broadband users, and supporting device-to-device, more reliable, and massive machine communications.

[19] ITU "ITU towards 'IMT for 2020 and beyond,'" 2017

5G research and development also aims at lower latency than 4G equipment and lower battery consumption, for better implementation of the Internet of things. There is currently no standard for 5G deployments.[20]

The Next Generation Mobile Networks Alliance defines the following requirements that a 5G standard should fulfil:[21]

- Data rates of tens of megabits per second for tens of thousands of users
- Data rates of 100 megabits per second for metropolitan areas
- 1 Gb per second simultaneously to many workers on the same office floor
- Several hundreds of thousands of simultaneous connections for wireless sensors
- Spectral efficiency significantly enhanced compared to 4G
- Coverage improved
- Signalling efficiency enhanced
- Latency reduced significantly compared to LTE

In addition to providing simply faster speeds, they predict that 5G networks also will need to meet new use cases, such as the Internet of Things (internet connected devices), as well as broadcast-like services. Telecom providers, the automotive industry (OEM's) and many other stakeholders have been preparing for this next-generation (5G) wireless standard, as mobile systems and base stations will require new and faster application processors, basebands and RF devices.

The U.S. Federal Communications Commission (FCC) approved the spectrum for 5G, including the 28 Gigahertz, 37 GHz and 39 GHz bands, on 14 July 2016.

As cars advance in capability, the US, and many other parts of the world, envisions that 5G networks will be needed to accommodate the vast data requirements. One scenario in particular, vehicle communication with everything (V2X), will require a means of enabling drivers to obtain real-time warnings on traffic conditions, obtain information on the vehicles around them which may further enable collision avoidance (among other things), and geographically relevant information.[22] To further support the global expansion of the C-V2X ecosystem the 5G Automotive Association (5GAA), a cross-industry organization is working towards supporting C-V2X direct and network communications. The 5GAA has grown to over 70 member global companies according to the group which includes automakers and their suppliers, mobile operators, semiconductor companies, test

[20] ITU "ITU towards 'IMT for 2020 and beyond,'" 2017

[21] Next Generation Mobile Networks Alliance. https://www.ngmn.org/, 2017

[22] https://www.ericsson.com/assets/local/narratives/industries/intelligent-transportation-systems/connected-traffic-cloud-brochure-161007.pdf.

equipment vendors, telecom network suppliers, and ITS equipment and software suppliers.[23]

2.7. Hybrid communication

In the evaluation of these communication technologies it has been concluded that neither ITS-G5 nor cellular systems as of today can provide a full range of necessary services for C-ITS. A hybrid communication concept, such as a combination of ITS-G5 + cellular 3G/4G, is thereby presumed highly needed when deploying C-ITS. Consequently, the different technologies can be complementary to each other.[24]

2.7.1. DEPLOYING HYBRID COMMUNICATION: STRATEGIES FOR ROAD ADMINISTRATORS

When deploying a hybrid communication there are different possible areas of responsibility for the road authorities to undertake. Areas of responsibility will most probably differ depending on which type of communication technology that will be used; ITS-G5 or cellular communication.

An aspect when deploying hybrid communication is, who will have the responsibility to decide when ITS-G5 or when cellular network is to prefer once deploying a certain C-ITS service. Different areas and countries have different prerequisites which must be considered, such as varied cellular coverage. Assurance that the suitable communication technology is used might become the road authorities' area of responsibility since the road authorities most often are viewed as having the main responsibility for the road network and the safety of it, a responsibility that needs to be looked upon closer. The responsibility will most likely not include services that the road authorities may not have any clear areas of responsibility for; such as for loading zone management. The road authorities would thereby demand that the communication technology must work around the clock and the quality must be up to standard. Another key aspect when deciding which type of communication technology that will be used is the cost. If the road authorities will have the main responsibility they can decide to use the most affordable technology without jeopardizing the quality, additionally the road authorities' responsibility may quicken the private sector to deliver good enough cellular coverage.

[23] https://www.groupe-psa.com/en/newsroom/corporate-en/le-groupe-psa-accelere-dans-le-deploiement-des-vehicules-connectes/, February, 2018

[24] European Commission "Study on the Deployment of C-ITS in Europe. Final Report", 2016

2.8. Cloud based solutions related to C-ITS

In the Cloud, users are in most cases entrusting their data and computation to a third-party infrastructure (e.g., interchange server). Some of the more common issues at hand concern accountability to facilitate transparency and trust in the cooperative system. Further on, mechanisms for accountability to maintain the integrity of distributed, cooperative computations are some of the issues that need to be addressed when looking at accountability within cloud-based solutions. Cooperation and trust play an increasingly important role in today's information systems. For instance, peer-to-peer systems are powered by resource contributions from participating users while federated systems like the Internet should respect the interests, policies and laws of participating organizations and countries (Druschel, 2012).

2.9. Deploying C-ITS: Security related issues and potential solutions

Current research indicates that the use of a public key infrastructure (PKI) security system, involving the exchange of digital certificates among trusted users, can support the need for both message security and appropriate anonymity for users. PKI is a set of roles, policies, and procedures needed to create, manage, distribute, use, store, and revoke digital certificates and manage public-key encryption. The purpose of a PKI is to facilitate the secure electronic transfer of information for a range of network activities such as e-commerce, internet banking and confidential email. It is required for activities where simple passwords are an inadequate authentication method and more rigorous proof is required to confirm the identity of the parties involved in the communication and to validate the information being transferred.

2.9.1. Service Provision: Issues that need to be addressed

When deploying C-ITS services which is based on real-time data, there is a need to identify the responsibility for the access/sharing of the data (standardization, security and privacy). Countries have different prerequisites (for example public funds and state interference) and approaches regarding this. Probabilities to agree upon on an architecture and specifications will increase if all the stakeholders are involved in development phase. A possible area of responsibility is to ensure interoperability (see figure 5 for an example on an architecture for a traffic information system). Since prerequisites and approaches differ among countries, the responsibility will also vary depending on these circumstances.

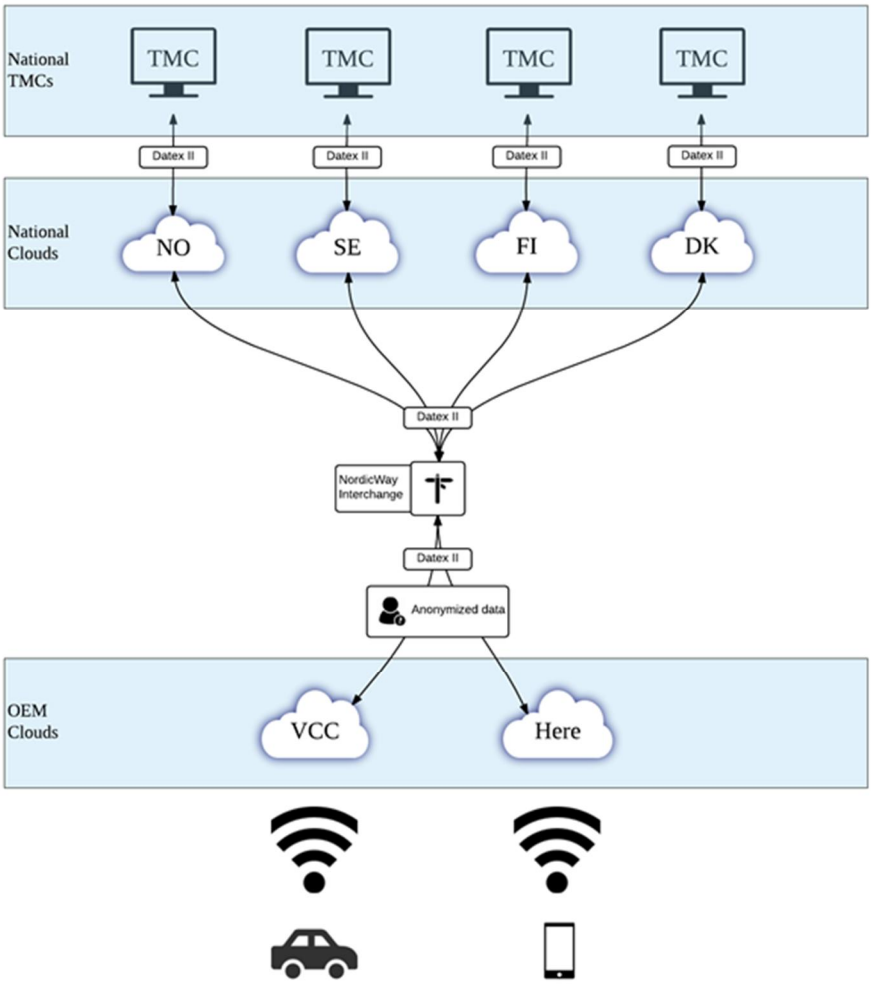


Figure 4 NordicWays' architecture regarding a traffic information system

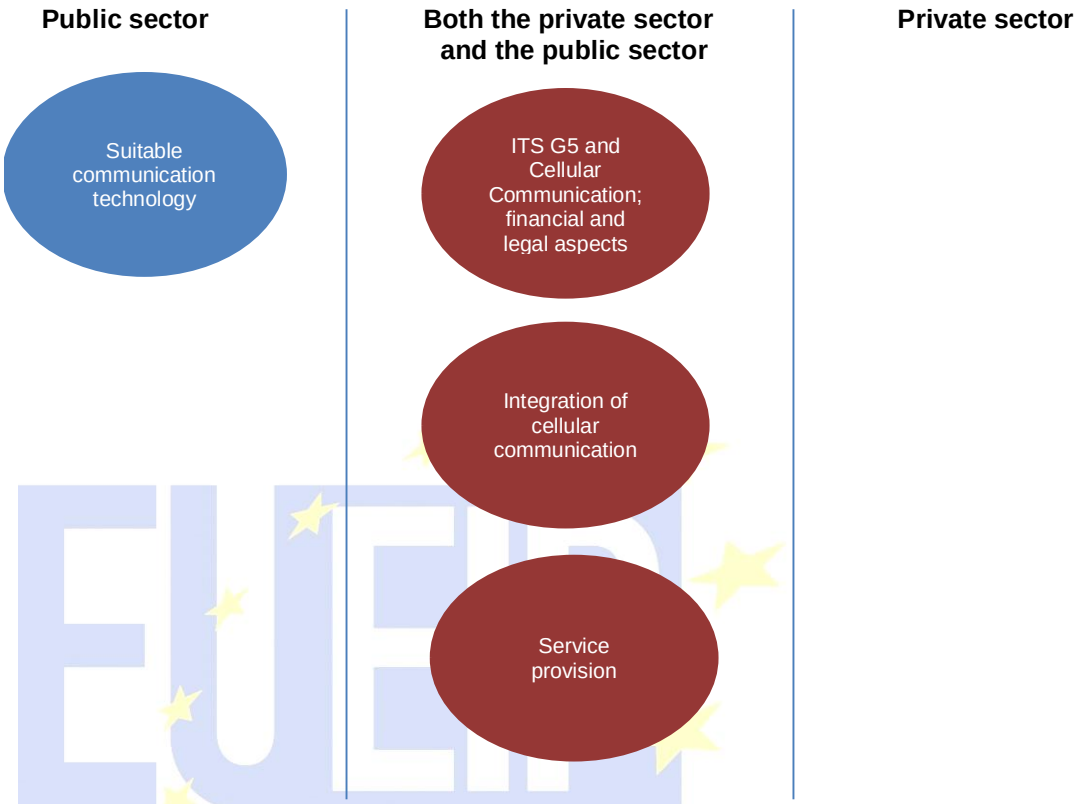


Figure 5 Possible areas of responsibility (hybrid communication) based on an analysis by the authors of this report

3. Day 1 services and applications

C-ITS services are expected to provide increased road safety, new means of optimizing traffic flow and thereby improving the functionality of the entire transport system. Day 1 services and applications (i.e. hazardous location notifications and signage applications) constitute an important development of the road transport system. Day 1 services and their applications provide information and warning services which support foresighted driving with a potential to provide noticeable effects on traffic safety, efficiency and travel comfort.

Figure 6 Day 1 Services and applications as an example of categorization "service" and "application". Source: Böhm, 2017a.

The C-ITS Platform has agreed on a list of Day 1 services which are expected to be deployed in the short term because of their expected societal benefits and their technological maturity. The platform further agreed on a list of Day 1,5 services which are expected to be the next step in the C-ITS deployment. These services do not have the technical maturity as the ones for Day 1 services and applications.

EU EIP European ITS Platform

Table 1 List of Day 1 services

#	Day 1 Services		
1	Emergency electronic brake light	V2V	Safety
2	Emergency vehicle approaching	V2V	Safety
3	Slow or stationary vehicle(s)	V2V	Safety
4	Traffic jam ahead warning	V2V	Safety
5	Hazardous location notification	V2I	Motorway
6	Road works warning	V2I	Motorway
7	Weather conditions	V2I	Motorway
8	In-vehicle signage	V2I	Motorway
9	In-vehicle speed limits	V2I	Motorway
10	Probe vehicle data	V2I	Motorway
11	Shockwave damping	V2I	Motorway
12	GLOSA / Time To Green (TTG)	V2I	Urban
13	Signal violation/Intersection safety	V2I	Urban
14	Traffic signal priority request by designated vehicles	V2I	Urban

The hazardous location notification contains six different services, see the list below:

- Emergency electronic brake light (V2V)
- Emergency vehicle approaching (V2V)
- Road works warning (V2I)
- Slow stationary vehicle (V2V)
- Traffic jam ahead warning (V2V)
- Weather conditions (V2I)

Out of these only road works warning is entirely an infrastructure to vehicle service.

This study focuses on the vehicle-to-infrastructure services and especially the following list of services and applications.

Day 1 services and applications

- Signal phase and time of traffic lights (GLOSA, TSP and TTG) (not listed)
- Traffic signal priority request by designated vehicles (TSP)
- Road works warning
- In vehicle signage (VSGN)
- Probe Vehicle Data
- Shockwave damping

At this point the list of Day 1 services are not linked to specific communication technologies. However, it has been realized that applications have different operational and functional requirements, such as different latency requirements which lead to a specific

communication technology or technologies. An example is services which is based on exchange of information between vehicles and infrastructure which require ETSI G5 technology within the 5,9 GHz band, such as R-ITS-S. For the early deployment of C-ITS services it is important to use standardized message sets and communication technologies which have been tested and validated in field operational tests. It is of great importance to focus on relatively simple and non-complex use cases. The services should be easy to implement with limited costs.[25]

CAM and DENM are considered as a first deployment:

3.1. Signal Phase and time of traffic lights (SPAT)

Signal Phase and time of traffic light (SPAT) is an identified Day 1 V2I/I2V service. The service's function is to inform the driver about the current status and change of the traffic signal ahead, as well as when the next signal stage is going to change. Information about approaching traffic will also be provided to the driver.[26]

3.1.1. FUNCTIONAL DESCRIPTION

The traffic light is connected to a roadside unit (RSU), and via this connection the traffic light can broadcast information to nearby vehicles. Information about the topology of the intersection and the phase schedule of each traffic signal is provided to the approaching vehicle. Thus, the approaching vehicles can calculate the optimal approaching speed. To concretize this C-ITS service an example can be made; if a vehicle is approaching a currently red traffic light the vehicle can calculate the approaching speed based on the traffic light´s phase schedule. The driver is presented with the calculated approaching speed so that the driver can arrive to the signal at the beginning of the next green phase. Avoidance of an unnecessary stop is thereby possible.

SPAT is addressed through the exchange of information between the traffic signal controller and the approaching vehicles.

The composition of SPAT is based on different messages;

- *Signal Phase and Timing (SPAT);* describes the signal state of the intersection and how long this state will persist for each approach and lane that is active.

[25] ERTICO "Guide about technologies for the future C-ITS service scenarios", 2015

[26] Amsterdam Group "Signal Phase and Time (SPAT) and Map Data (MAP)", 2015

- *Map Data (MAP);* describes the physical geometry of one or more intersections. *Signal Request Message (SRM);* requests pre-empt or priority services for selected user groups.
- *Signal Status Messages (SSM);* describes the internal state of the signal controller. Provides a more complete summary of any pending priority or pre-emption events.[27]

As for today, different architectures are in usage. One of the differences is the usage of fixed time or adaptive traffic control systems. An adaptive system can alter the green time for each movement, while fixed systems have a pre-set green time to each movement in the intersection and it applies a pre-set cycle time. Another difference is a Centralized system and a Stand-Alone system. The centralized system communicates with a central system in order to calculate and decide the next signal phase, while a Local Stand-Alone system makes the decision based on local information. Local control and communication via R-ITS-S are classified to be a Day 1 application. A centralized monitoring and using mobile communication network need further consideration, especially due to the cost-saving aspect this method probably will enable in a future scenario.[28]

3.1.2. STATUS OF THE SERVICE

Current signal control systems are already quite sophisticated and each of them are suited to the specific city context and the different signal control strategies the European countries have. Accordingly, these prerequisites will influence how SPAT will be integrated in an optimal way. The main challenge when deploying this service is not the technical aspects, rather how to finance, organize and maintain this as a permanent service. Additional, challenges concerning driver distractions, legal issues, political focus and standardizations is relevant. However, it seems to be an easier start-up if the cities already are planning for other Day 1 applications. [29]

3.1.3. ROAD AUTHORITIES' POSSIBLE AREAS OF RESPONSIBILITY

There are several areas of responsibility which need to be determined regarding the deployment of SPAT. First, determine which actor have the responsibility to finance, install and maintain the service. These areas are primarily associated with the infrastructure, which is commonly the road authorities' responsibility. The responsibility to finance, install and maintain this service will therefore most likely become the road authorities. The provision of supporting infrastructure is also stated in EIP + study "C-ITS deployment

[27] Amsterdam Group "Signal Phase and Time (SPAT) and Map Data (MAP)", 2015
[28] Amsterdam Group "Signal Phase and Time (SPAT) and Map Data (MAP)", 2015
[29] Amsterdam Group "Signal Phase and Time (SPAT) and Map Data (MAP)", 2015

preparation for road authorities and operators", which further motivates an area of responsibility.

Secondly, the legal aspects need to be determined, for example who is responsible for an accident caused by a wrong message delivered by the HMI. The road authorities might have to become an active partner in this process. However, the private sector is an important actor as well since they are also involved in the application.

The quality assurance of the information towards the driver is another issue, assurance that the information is reliable and exact. The private sector will probably have a great interest to provide their customers high quality services, such as GLOSA. Therefore, they may be interested to get access to this information, which means that the road authorities will most likely not have to finance this part.

Deciding when appropriate to deploy SPAT and which type of SPAT will be deployed will most likely be the road authorities' responsibility, regarding how active role the road authorities should undertake based on test studies examining the service's impacts and possibilities. This would indicate that they will most likely be willing take on a co-active role when deploying C-ITS, especially when it comes to test studies and similar pilot activities.

3.2. Traffic signal priority request by designated vehicles (TSP)

Traffic Signal Priority (TSP) is a system which facilitates a faster movement of transit at signalized intersections. When implementing TSP designated vehicles experience less delay at intersections due to increase in green time or reduction in red time. The TSP can thereby improve schedule adherence and travel time efficiency. An example of usage of this system is buses or emergency vehicles who can be given priority at traffic signals either all the time or under specific conditions.

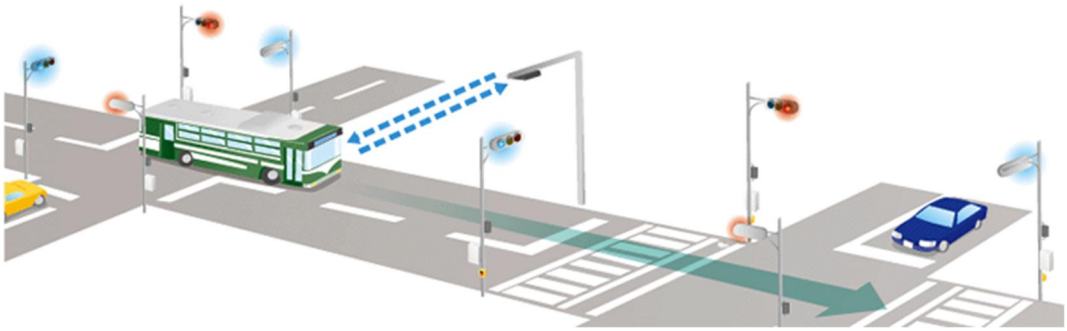


Figure 7 Traffic signal priority. Source: http://global-sei.com/its/products/utms.html

3.2.1. FUNCTIONAL DESCRIPTIONS

TSP is based on a detection system which delivers vehicle data, including time to arrival. The communication technology that likely will be used will be ITS-G5 according to a study ordered by the European commission and reported in 2016.[30] The detection system requests priority from the traffic control system via a priority request generator. Priority control strategies are then used when deciding whether to grant the priority or not. Granted priority is given to vehicles that meets certain conditions based on the deviation of the vehicle from the schedule or time elapsed since last awarded priority.

3.2.2. STATUS OF THE SERVICE

As for today, the service is available. TSP is most suitable for urban environments and it is applicable for all vehicle types apart from passenger cars. The service is expected to rely on ITS-G5 communication, but several projects are also considering possibilities to demonstrate the effectiveness via high speed cellular networks.[31]

3.2.3. THE ROAD AUTHORITIES' POSSIBLE AREAS OF RESPONSIBILITY FOR URBAN C-ITS SERVICES

Possible areas of responsibility when deploying these services is the responsibility for the installation, maintenance and the financial aspects. The question is if the road authorities should undertake all the responsibility regarding these areas or if this should be handled in cooperation with the private sector. The need for providing supporting infrastructure motivates the responsibility even further.

[30] European Commission. "Study on the Deployment of C-ITS in Europe. Final Report", 2016
[31] European Commission. "Study on the Deployment of C-ITS in Europe. Final Report", 2016

Furthermore, when deploying this service there is a question if the road authorities should be able to demand that vehicles such as busses are equipped with systems compatible with TSP. Since the road authorities would invest resources to deploy the service it seems reasonable that they should have the ability to demand that certain vehicles be equipped with systems that are compatible with the service in question.

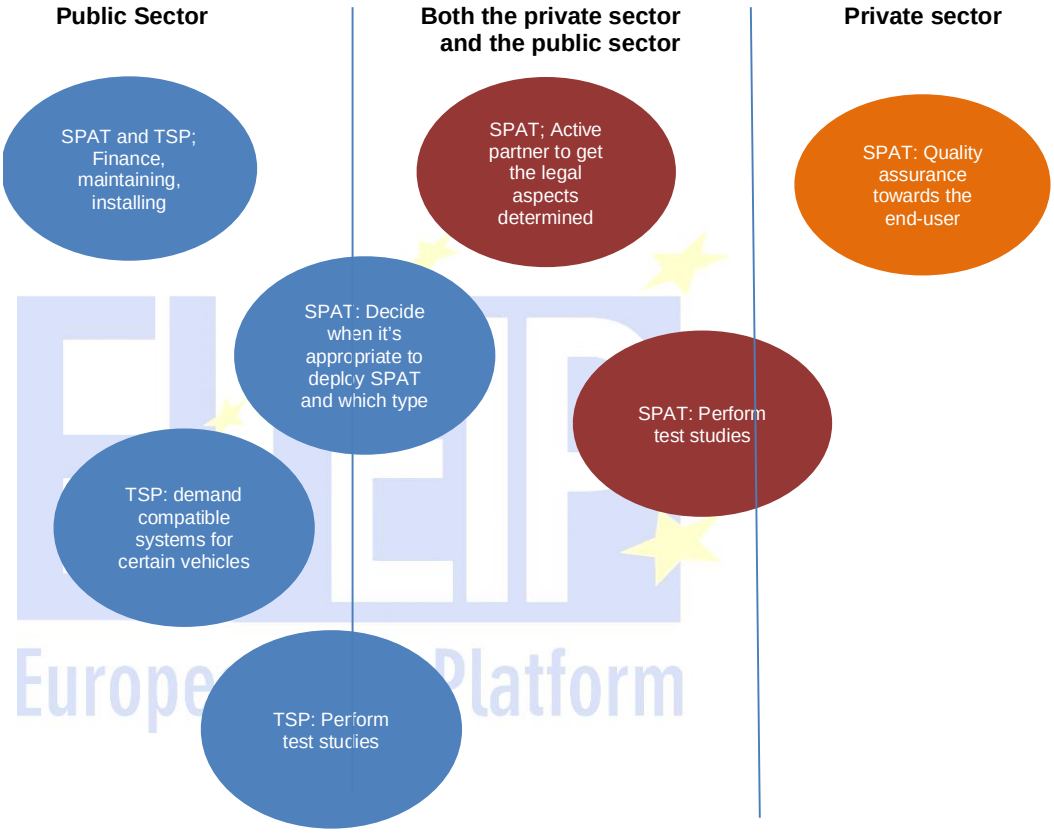


Figure 8 Possible areas of responsibility (Urban C-ITS services) based on a scenario in which GLOSA/SPAT/TSP is implemented via ITS-G5 and not cellular solutions. Analysis by the authors of this report

3.3. Road works warning (RWW)

Road works warning purpose is to inform drivers about road works; the corresponding parameters and associated obstruction on the route ahead. To increase awareness, the driver will be informed of potentially dangerous conditions within a given timeframe. When information about the road work is available the driver can thereby adapt the speed to the situation. The service is expected to improve road safety and the traffic flow around the area of the worksite. Additionally, the road works warning is expected to improve the road workers' safety and prevent damages on the road work property.[32]

3.3.1. FUNCTIONAL DESCRIPTION

As for today, there are various distribution channels for the service; Trailer in a "Stand-Alone" mode, Basic service, Network-Wide and Strategic and Information by other services.[33] The service is based on hybrid communications concept, either cellular network or ITS- G5.[34]

Trailer in a "Stand-Alone" mode the driver's vehicle HMI presents a warning to the driver when it approaches a stationary or a mobile road works site. In practice, the road operator parks a road works safety trailer per national regulations and as soon as the warning sign opens the transmission of road works warning is started. Information which can be transmitted to the vehicle is only the information available in the road works safety trailer or information entered manually by the staff on-site. The transmission stops when the sign closes.[35]

[32] Amsterdam Group "Road Works Warning Service – Functional Description", 2016
[33] Amsterdam Group "Road Works Warning Service – Functional Description", 2016
[34] European Commission "Study on the Deployment of C-ITS in Europe. Final Report", 2016
[35] Amsterdam Group "Road Works Warning Service – Functional Description", 2016

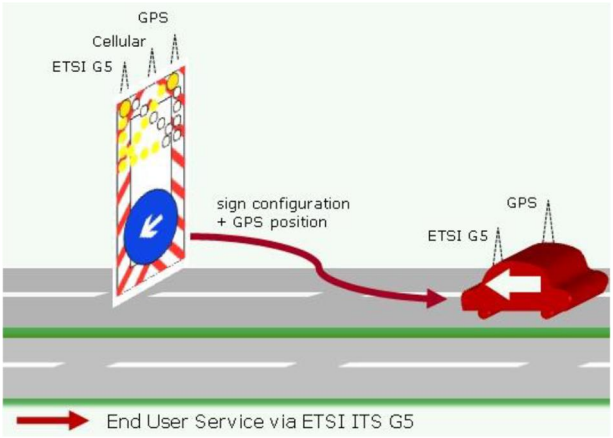


Figure 9 Figure 7 Road works warning in a Stand-Alone mode. Source: Amsterdam Group "Road Works Warning Service – Functional Description"

The function of *Basic Service* is that the vehicles HMI presents a warning to the driver. Information, such as closed lane, can be augmented by further information from the Traffic Control Centre (e.g. complementary attributes of the road works). The additional information can be transmitted to the driver on request. In practice this means that the road operators park a road works safety trailer. When the sign opens, the trailer transmits its position and the arrow sign configuration to the Traffic Control Centre. The Traffic Control Centre thereby complement the received information with additional information.[36]

[36] Amsterdam Group "Road Works Warning Service – Functional Description", 2016

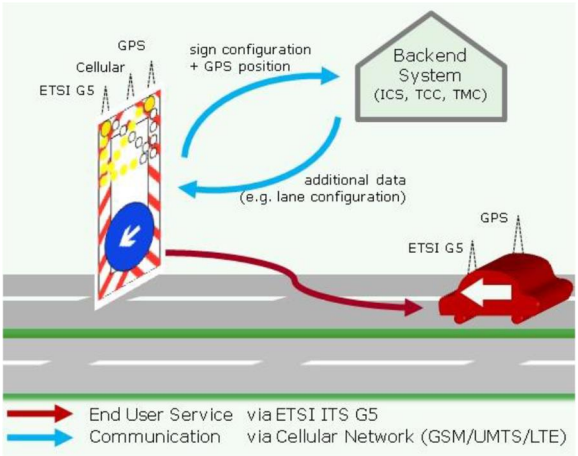


Figure 10 Road works warning is "Basic Service" mode. Source: Amsterdam Group "Road Works Warning Service – Functional Description"

When, *Information via roadside stations – network-wide and strategic,* are implemented the driver receives information about the current road works when the vehicle passes the R-ITS-S. The road works information is distributed through the vehicle HMI to the driver. Through the road operators' perspective this means that the Traffic Control Centre provide the road operators with all road works information. The information is delivered to the R-ITS-S based on geographic relevance. The messages are repeatedly transmitted to ensure that vehicles receive all messages. [37]

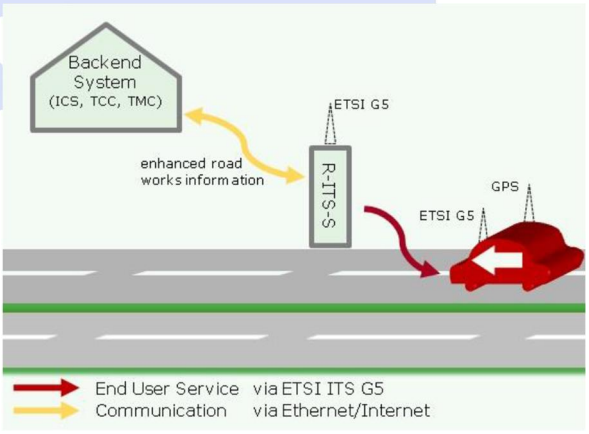


Figure 11 Distribution of network-wide Road Works Warning. Source: Amsterdam Group "Road Works Warning Service – Functional Description"

[37] Amsterdam Group "Road Works Warning Service – Functional Description", 2016

Regarding, *information by other services,* the information might serve as an input for others C-ITS services.

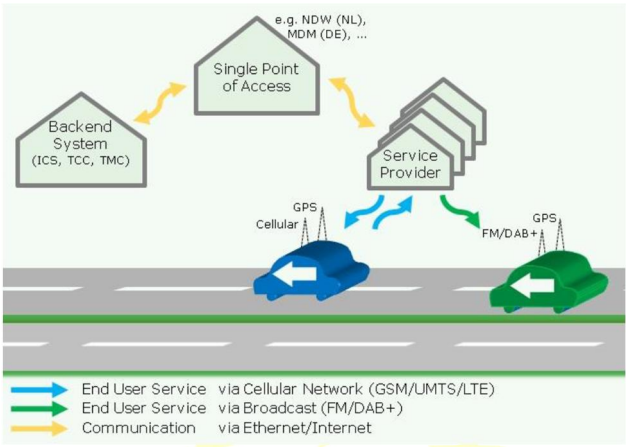


Figure 12 Information by other services. Source: Amsterdam Group "Road Works Warning Service – Functional Description"

There are three types of road works;

- *Mobile short-term* include road works where the activity is moving, such as renewing lane markings. A slowly moving trailer is thereby used when securing these types of road works.[38]
- *Stationary short-term* is the most common type of road work. These types of road work have a fixed start and endpoint.[39]
- *Stationary long-term* are not always secured by a road works safety trailer. However, R-ITS-S will transmit information about the road works to the approaching vehicles.[40]

3.3.2. ROAD AUTHORITIES' POSSIBLE AREAS OF RESPONSIBILITY

Since this service has several distribution channels there is a need for identifying areas of responsibility for each distribution channel. The road authorities already have the primarily responsibility for the road network, and therefore it seems given that the road authorities should undertake the responsibility for the infrastructure. The other distribution channels

[38] Amsterdam Group "Message Set and Triggering Conditions for Road Works Warning Service", 2016
[39] Amsterdam Group "Message Set and Triggering Conditions for Road Works Warning Service", 2016
[40] Amsterdam Group "Message Set and Triggering Conditions for Road Works Warning Service", 2016

who have the same conditions; basic service and distribution of network-wide road works warning, the responsibility for the infrastructure should be the same.

Regarding the distribution channel, information by other services. The road authorities should not have the main responsibility when it comes to technology which will not require any infrastructure deployment, such as Probe Vehicle Data. The reason being, that the areas of responsibility associated with these types of services are primarily the private sectors. For example, the private sector is more involved than the road authorities in the deployment of Probe Vehicle Data.

Furthermore, there is a need to get the legal aspects determined, such as who will be responsible when the wrong message is shown at the HMI. Due to difficultness to identify who is to blame when problems such as these occur the road authorities should be an active partner to make sure these legal aspects are determined. This being said does not rule out the possible need for the private sector to also take on an active role in this matter.

3.4. In vehicle signage IVS

In Vehicles signage's (IVS) purpose is to present relevant information about the road signs to the road user through the HMI in the vehicles. The in-vehicle signage alerts the driver about present speed policy/advises and other relevant hazard information, which includes recommendations and contextual regulations. Whether the signs are static, dynamic, virtual or mandatory the in-vehicle signage can provide a wide range of traffic information. However, not every physical sign will necessarily be presented in the vehicle, since some signs, as an example, are only relevant for specific vehicles. Expected benefits from this service is to enable the driver to partake in all the relevant information continuously and on time. The information can either be presented automatically or on request. Thus, the service will improve the awareness of the road users since drivers gain access to relevant information at the right location and time. Additional expected benefits are; reduced number of accidents, increased road safety, improved understanding of difficult contextual signs, better traffic efficiency and improved environmental and sustainable efficiency (Amsterdam Group, 2016). [41]

3.4.1. FUNCTIONAL DESCRIPTION

[41] Amsterdam Group "Draft Functional Description of Day One Applications (In-Vehicle Information" from the point of view of the Amsterdam Group", 2016

From a road operator's perspective; the in-vehicle service can enable the road operators to inform the drivers about road information and rulings. The usage of R-ITS-S is a possibility, the station will broadcast the information to the passing vehicles. There are different cases of R-ITS-S; Stand-Alone R-ITS-S, R-ITS-S which are part of dynamic stand-alone system and R-ITS-S which are part of dynamic network (centrally), online controlled by the road operator. All these different systems are available at this time.[42]

From a user's perspective it involves a situation in which the vehicle, when approaching a traffic sign or a specific area, receives an in-vehicle information message through either ITS-G5 or cellular network.[43] The messages are announced via the HMI and when the message occurs on the HMI they are adjusted to time, speed and distance. As long as the sign is relevant for the driver the sign will be available at the HMI. [44]

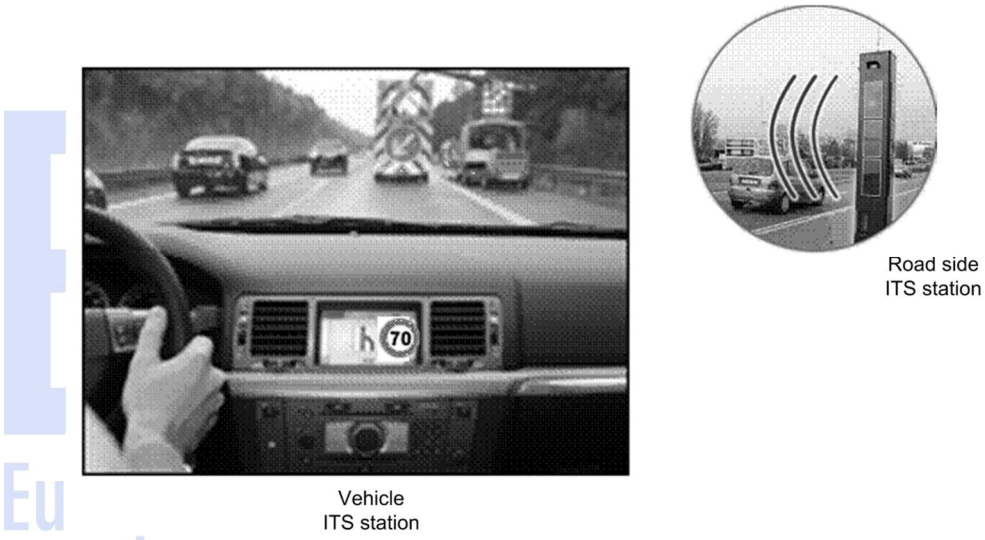


Figure 13 IVS from a user's perspective. Source: Amsterdam Group, "Draft Functional Description of Day One Applications (In-Vehicle Information" from the point of view of the Amsterdam Group"

[42] Amsterdam Group "Draft Functional Description of Day One Applications (In-Vehicle Information" from the point of view of the Amsterdam Group", 2016

[43] European Commission. "Study on the Deployment of C-ITS in Europe. Final Report", 2016

[44] Amsterdam Group "Draft Functional Description of Day One Applications (In-Vehicle Information" from the point of view of the Amsterdam Group", 2016

When a *Stand-Alone R-ITS* is implemented the R-ITS-S transmits for example the speed limit to the passing vehicles. In order to deliver the information to driver at the right time a R-ITS-S is placed in the area prior to the maximum speed area.[45]

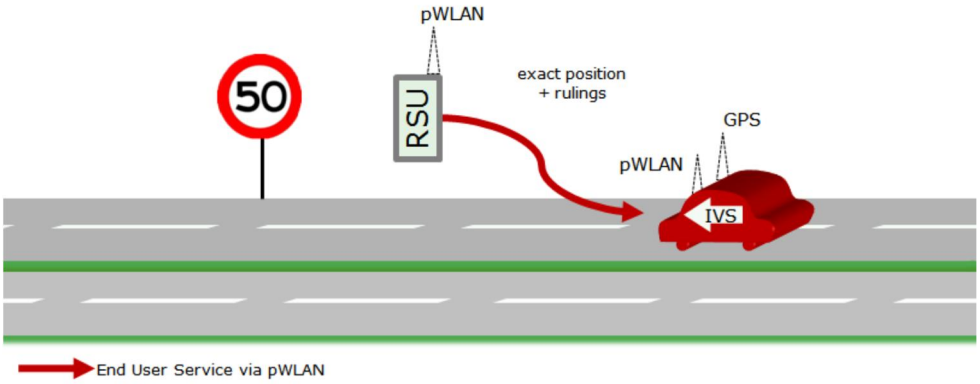


Figure 14 Stand-Alone R-ITS-S. Source: Amsterdam Group, "Draft Functional Description of Day One Applications (In-Vehicle Information" from the point of view of the Amsterdam Group"

R-ITS-S (as a part of a dynamic stand-alone system) is a system which can contain weather stations, roadside units combined with variable message signs and loop detectors with sub-centres. If an incident occur the system automatically lowers the maximum speed limit by means of matrix signs above the road. Thus, the regulated speed limit is transmitted via R-ITS-S to the vehicles.[46]

[45] Amsterdam Group "Draft Functional Description of Day One Applications (In-Vehicle Information" from the point of view of the Amsterdam Group", 2016

[46] Amsterdam Group "Draft Functional Description of Day One Applications (In-Vehicle Information" from the point of view of the Amsterdam Group"

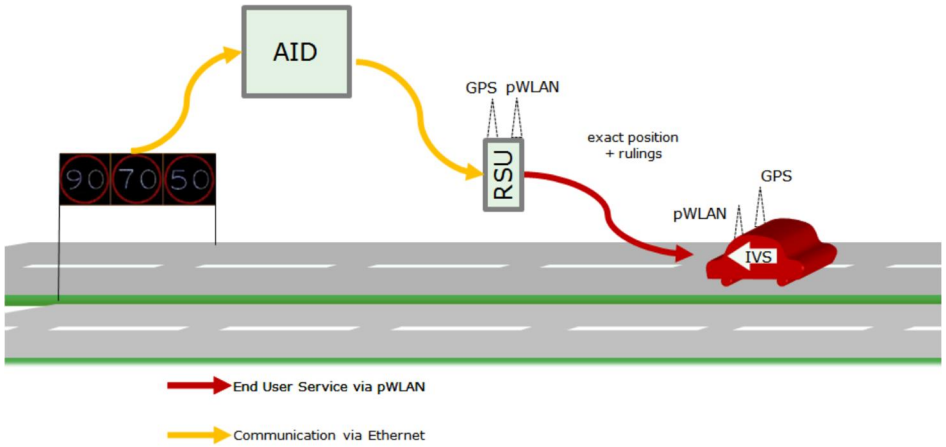


Figure 15 Road units which are part of a dynamic stand-alone system. Source: Amsterdam Group, "Draft Functional Description of Day One Applications (In-Vehicle Information" from the point of view of the Amsterdam Group"

R-ITS-S (as part of a dynamic network, centrally TCC) is a R-ITS-S system which can be controlled directly by the road operators in the TCC. The road operator can online change the ruling and the information which is transmitted to the vehicles.[47]

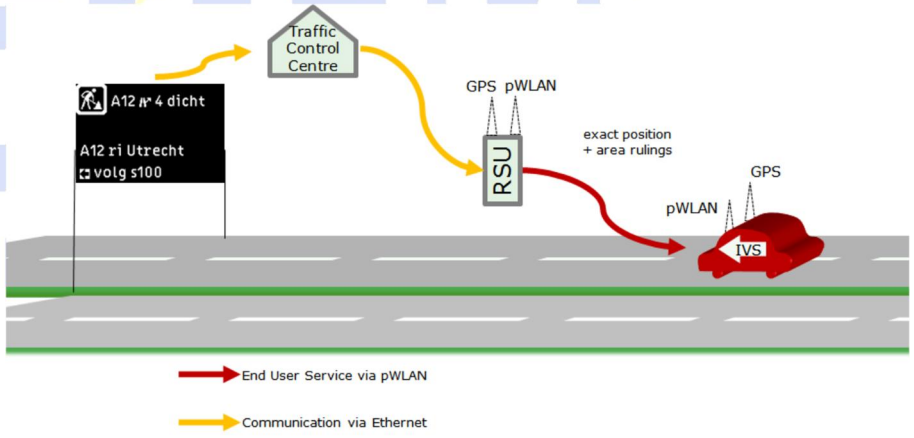


Figure 16 Road side units which are part of a dynamic network. Source: Amsterdam Group, "Draft Functional Description of Day One Applications (In-Vehicle Information" from the point of view of the Amsterdam Group"

3.4.2. STATUS OF THE SERVICE

[47] Amsterdam Group "Draft Functional Description of Day One Applications (In-Vehicle Information" from the point of view of the Amsterdam Group", 2016

The service is applicable to all road types and vehicles, but specifically relevant for motorways due to the expected benefits on this road type.[48] Available data regarding impacts which is related to in-vehicle signage is limited.[49] When implementing this service, in terms of complexity, highways are classified as a Day 1 application. Higher level of information at the same time are required in the urban areas and rural roads. These implementing phases are classified as being within Day 2 development.[50]

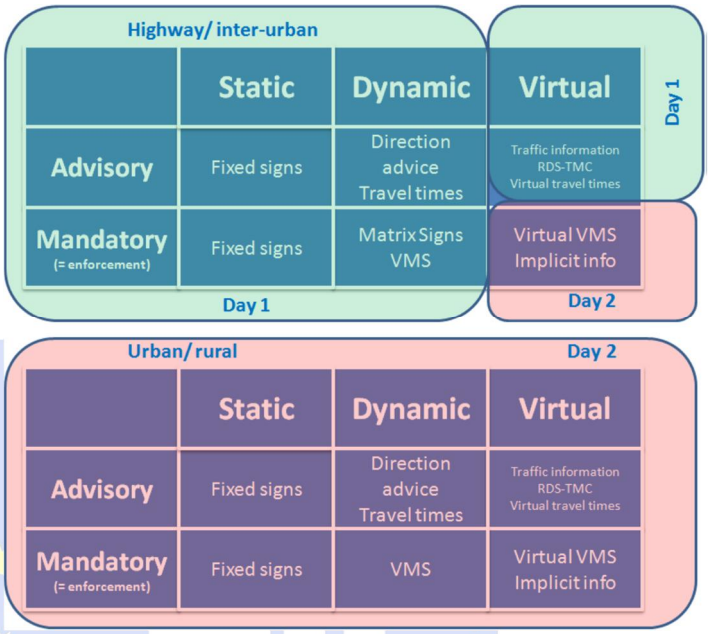


Figure 17 Day 1 applications (Highway/inter-urban) vs Day 2 applications (urban/rural). Source: Amsterdam Group, "Draft Functional Description of Day One Applications (In-Vehicle Information" from the point of view of the Amsterdam Group"

3.4.3 ROAD AUTHORITIES' POSSIBLE AREAS OF RESPONSIBILITY

Since this service has different systems (Stand-Alone R-ITS-S, Road units which are a part of a dynamic Stand-Alone system and Road side units which are a part of a dynamic network) there is a need to identify responsibilities for each system. The same will apply for the other systems. Both the private sector and the road authorities have an interest to get this determined. Hence, both the private sector and road authorities should play an active role for providing the service.

[48] European Commission "Study on the Deployment of C-ITS in Europe. Final Report", 2016
[49] European Commission "Study on the Deployment of C-ITS in Europe. Final Report", 2016
[50] Amsterdam Group "Draft Functional Description of Day One Applications (In-Vehicle Information" from the point of view of the Amsterdam Group", 2016

Moreover, the control over the messages which is provided to the end-user via the HMI is a relevant issue. In practice this means a responsibility to provide a database with images, signs, communication languages and similar. If the road authorities want to quicken the process and assure that the quality of the messages is up to standard the road authorities could provide a database or traffic sign images as open data.

3.5. Probe Vehicle Data

The Probe Vehicle Data services' purpose is to collect and collate anonymized vehicle data, which can be used for a variety of applications, such as traffic management. [51]

The expected benefits are that the road network will be used more effectively as the road users and the road mangers will receive additional information. The Probe Vehicle Data are predicted to be a viable means to monitor traffic flow, deliver both speed and travel-time information to enable advanced traffic management systems and advanced traveller information services applications. As well as supporting other transportation agency requirements, such as monitoring the impacts of construction activities and planning. [52] Reducing number of traffic jams is thereby a possible effect. Additionally, the sensor data from the vehicles will provide information about road conditions to the road managers. [53]

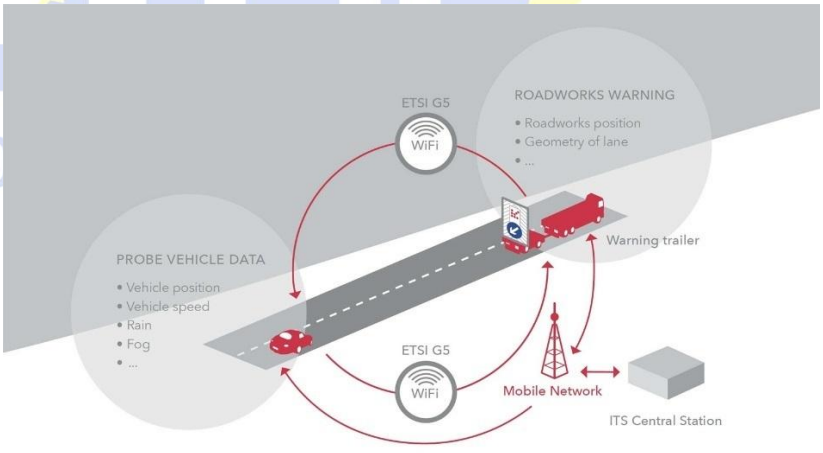


Figure 18 Illustration of Probe Vehicle Data- Source: http://itscorridor.mett.nl

[51] Rijkswaterstaat. Cooperative ITS Corridor "Probe Vehicle Data", 2017
[52] Young, S. "Real-Time Traffic Operations Data Using Vehicle Probe Technology", 2007
[53] Cooperative ITS Corridor "Probe Vehicle Data, 2016

3.5.1. FUNCTIONAL DESCRIPTION

The service will be based on a hybrid communication technology, either ITS-G5 or cellular communication depending on the infrastructure equipment.[54] Each Probe Vehicle technology possess unique characteristics and the Probe vehicle technology differs in concept in several aspects.[55]

Key aspects of cell phone and AVL probe technology

- *Vehicle travel time is measured directly.*
- *Only a sample of all vehicles is monitored.*
- *Speed is inferred from travel time.*
- *Volume is inferred from sample size.*
- *Speed estimates are space-mean speed (as opposed to point speed or time-mean speed)*
- *Roadside infrastructure is minimized or eliminated.*
- *Quality of data is based on the percent of vehicles monitored.*

Cell Phone Probes is a method used to infer the location of the vehicles through the cell phones and their associated infrastructure. The method varies but falls within two broad categories; Signal information (such as tower hand-off timing) and embedded assisted GPS technology within the user's phone, where the signal information is the most prevalent category. Both methods however require a partnership with a cell phone carrier within the region. This reliance has proven to be a risk factor.

Automated Vehicle Location Services (AVL) is system where information is gathered by commercial businesses. These systems rely on GPS receivers to track vehicles, and locations are periodically reported via satellites, radios or cellular data services. The growth of available AVL services through GPS data is estimated to 60% to 100% per year. The quantity of traffic information depends on the quantity and distribution of vehicles reporting through AVL systems, and these distributions differ.

Toll-Tag Technology have the same attributes as AVL and cell phone and probes. However, in the deployment process there is a need for additional Toll-Tag readers. As for

[54] European Commission. "Study on the Deployment of C-ITS in Europe. Final Report", 2016

[55] Young, S. "Real-Time Traffic Operations Data Using Vehicle Probe Technology", 2007

today, the Toll-Tag systems are owned and maintained by the road authorities or by organizations which is aligned with transport management.

Probe-based Technology Market are for now not leaning towards a single market technology. It is often a merge between data from multiple sources and the data is collected via their own proprietary collection methodologies, and possibly with data from partners who can amplify data collection about specific regions or roadways.

Key aspects of Fixed-Point Speed Sensors;

- *Traffic volume and occupancy is measured directly.*
- *Traffic speed is inferred from occupancy based on an average vehicle length.*
- *Travel time is inferred from a network of sensors.*
- *Quality of travel time data is dependent on the density of the sensor network.*
- *Equipment in the right-of-way is required.*
- *Cost of deployment has historically been high.*
- *The technology has been historically maintenance-intensive.*

Fixed-Point sensors are emerging, and these are based on radar, acoustics and other sensing concepts. These sensors have enabled new business models which are introduced by vendors. Outsourcing of the road authorities is thereby possible since the road authorities can purchase only the data inscription, and in that way, avoid the responsibility for installations and maintenance.[56]

3.5.2. STATUS OF THE SERVICE

Probe Vehicle Data is already available and has been available the recent years. There is an increasing demand for comprehensive traffic monitoring from both travellers and transport agencies. Gathering of traffic data is declining from a cost point of view due to the proliferation of technology and the emergence of businesses dedicated to traffic data collection and dissemination. The current method for collection traffic data is being replaced by comprehensive traffic monitoring across the entire roadway system, which means that the application-specific and geographically constrained can merge into one. However, such an approach requires legacy applications and methods who supports the growing demand for advanced traveller information services data. Demonstrations of probe technology have shown to be successful for freeway applications. The pressure on road authorities to consider Probe-based technologies are increasing. The main pressures are

[56] Young, S. “Real-Time Traffic Operations Data Using Vehicle Probe Technology”, 2007

the cost of owning and maintaining, reasonability for the construction and preservation of the travel way and lastly the consumers demand for real-time travel data and timely reports regarding the highway system.

3.5.3. ROAD AUTHORITIES' POSSIBLE AREAS OF RESPONSIBILITY

The possible areas of responsibility for deploying each technology need to be determined, which areas the private sector should undertake, which areas the road authorities should undertake, and which areas should be a co-responsibility. Concerning Cell Phone Probes, the service provider should gather the data and quality assurance should also be the service providers' responsibility. This solution will probably be more efficient and cheaper for the road authorities. These areas of responsibility should be applied to Automated Vehicle Location as well.

Regarding Toll-Tag technology, it is highly likely that the road authorities will need own and maintain the system since the system is infrastructure based. Furthermore, the private sector will be responsible for the fixed-point sensors. The private sector will probably handle this without the involvement of the road authorities which is to prefer since cost can be rather high. The road authorities will thereby only subscribe the data.

Another issue that needs to be resolved are the legal aspects, such as data protection and privacy rules. Both the private sector and the road authorities need to be an active partner since both parties have an interest in solving these legal issues.

As mentioned before the road authorities should only subscribe to the data and not gather the data via own methods. The reason is mainly based on costs which could be limited when the private sector will be responsible for all the areas associated with the data gathering, such as installing, maintenance and technical matters.
Additional responsibilities beyond the gathered data, such as traffic restrictions, policy goals, information about the road and infrastructure etc., should be the road authorities' responsibilities since these areas are more related to the road network as a whole.

3.6. Shockwave damping (SWD)

The purpose of the service, shockwave damping, is to smooth the flow of traffic through damping traffic shockwaves. To smooth out speed variations real-time traffic data is used to give advisory speeds to cars.[57]

3.6.1. FUNCTIONAL DESCRIPTION

The service is based on hybrid communication concept, either with cellular network or ITS-G5. Shockwave damping are particularly relevant on motorways and the information could be delivered through RSUs or cellular network.[58]

3.6.2. STATUS OF THE SERVICE

There is very little data available regarding SWD. Nevertheless, a recent study in Holland indicates that the service can have a positive effect on traffic jams since the travellers approach the jam more calmly.[59]

3.6.3. ROAD AUTHORITIES' POSSIBLE AREAS OF RESPONSIBILITY

When deploying shockwave damping the responsibility for the installation, maintenance and the financial aspects needs to be determined. The installation and maintenance should be the road authorities' responsibility when the areas are associated with infrastructure. Since other services in need of infrastructure should be the road authorities' responsibility this service will be no exception. Relevant infrastructure is R-ITS-S. The financial aspects of other areas, excluding infrastructure, could be the private sector responsibility, for example the deployment of the communication technology or VSGN (see chapter hybrid communication and In Vehicle Signage).

Additionally, the responsibility for the quality assurance towards the end-user need to be established. Since this mainly is related to the HMI it seems given that the OEM: s/service provider should have the main responsibility for the quality assurance.

Furthermore, the private sector and the road authorities should have a co-responsibility to perform test studies. Since the private sector and the road authorities both are active partners in the deployment, they should have a co-responsibility to exam the service's impacts and possibilities. Based on EIP + study "C-ITS deployment preparation for road authorities and operators", most of the countries road authorities see themselves as front runners. This would indicate that they will be willing to take on a co-active role when deploying C-ITS, especially when it comes to test studies and so on.

[57] European Commission "Study on the Deployment of C-ITS in Europe. Final Report", 2016
[58] European Commission "Study on the Deployment of C-ITS in Europe. Final Report", 2016
[59] Province of Noord-Brabant for Rijkswaterstaat, "Shockwave Traffic Jams A58", 2017

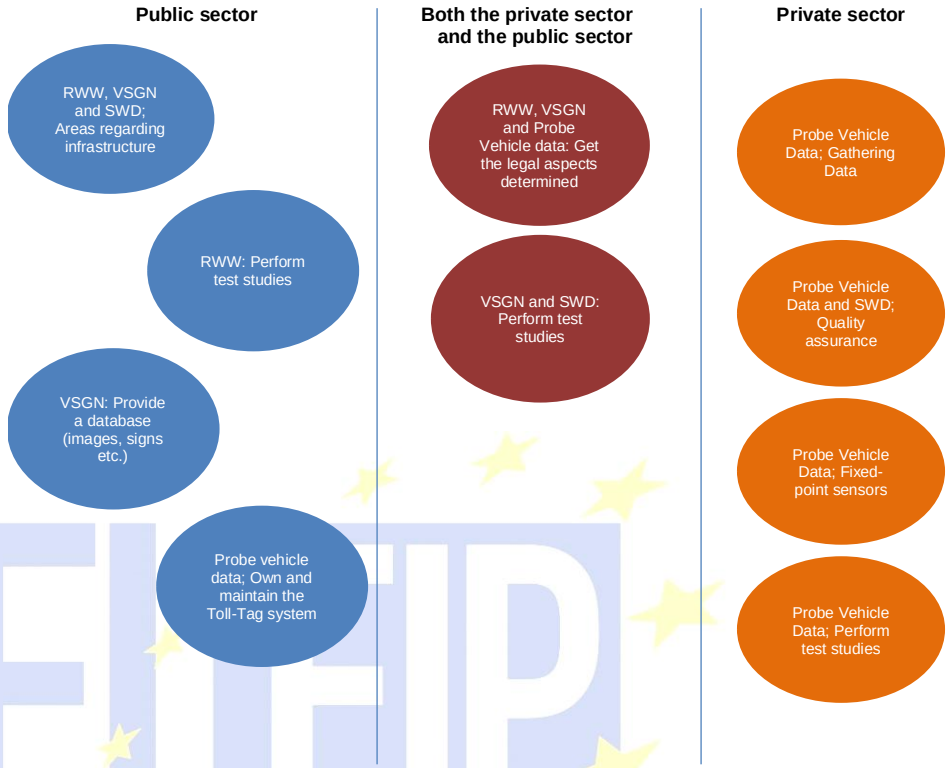


Figure 19 Possible areas of responsibility (Motorway C-ITS services) based on an analysis by the authors of this study

4. Day 1,5 services and applications

Table 2 List of Day 1,5 services

#	Day 1.5 Services		
1	Off street parking information	V2I	Parking
2	On street parking information and management	V2I	Parking
3	Park & Ride information	V2I	Parking
4	Information on AFV fuelling & charging stations	V2I	Smart Routing
5	Traffic information and smart routing	V2I	Smart Routing
6	Zone access control for urban areas	V2I	Smart Routing
7	Loading zone management	V2I	Freight
8	Vulnerable road user protection (pedestrians and cyclists)	V2X	VRU
9	Cooperative collision risk warning	V2V	Collision
10	Motorcycle approaching indication	V2V	Collision
11	Wrong way driving	V2I	Wrong Way

The following selection of Day 1,5 services and applications is based on services that are related to some type of communication with the infrastructure. Number 1 - 4 have been omitted, together with the omission of the service "Information on AFV fuelling & charging stations", since the role of road authorities is not entirely clear from the beginning.

4.1. Traffic Information and Smart Routing (SmartR)

The purpose of SmartR is to optimize routes based on the traffic lights, traffic flows and speed limits. Based on real-time traffic information re-routing suggestion can be provided. The service is intended to aid traffic flow management and improve traffic efficiency.[60]

4.1.1. FUNCTIONAL DESCRIPTION

[60] European Commission "Study on the Deployment of C-ITS in Europe. Final Report", 2016

Day 1 V2I service, based on hybrid communication concept, either on cellular network or ITS-G5.[61]

4.1.2. STATUS OF THE SERVICE

Numerous reports have studied the impacts of SmartR and significant improvement regarding the traffic efficiency have been measured. The traffic speed for both passenger and freight vehicles are improving when the service is used, and specifically in urban areas. Reports point out a reduction of the fuel consumption and CO2 emissions for passenger and freight vehicles across all road types. Other impacts have so far not been identified. [62]

4.1.3. ROAD AUTHORITIES' POSSIBLE AREAS OF RESPONSIBILITY

Road authorities will need to align the deployment and use of these kinds of services with overall ideas related to smart transportation developments. Smart city strategies are one such area of concern, particularly in terms of future transportation needs such as for autonomous and connected vehicles, smart and connected mobility services and similar data intense measures. Road authorities will most likely need to cooperate with regional and/or city planners to develop these services in line with both current and future transport demands.

When deploying this service, the responsibility for the installation and the maintenance need to be determined. The financial aspects also need to be established. The mentioned areas of responsibility should fall on the private sector. The route-based services' available today are mainly the private sectors responsibility. This opens for a discussion weather there is a need for opening up for a cooperation between the private sector and road administrators in order to provide for a more sensible routing which takes into account traffic management aspects.

4.2. Zone access control for urban areas (ZAC)

The service ZAC is intended to manage access to specified zones. The provided information will enable the driver to choose an appropriate route. The impact of this service depends on the individual schemes implemented on the current urban area.[63]

4.2.1. FUNCTIONAL DESCRIPTION

ZAC shall assist the management of low emissions zones and congestion charging schemes through communication between vehicles and road sensor infrastructure. In

[61] European Commission "Study on the Deployment of C-ITS in Europe. Final Report", 2016
[62] European Commission "Study on the Deployment of C-ITS in Europe. Final Report", 2016
[63] European Commission "Study on the Deployment of C-ITS in Europe. Final Report", 2016

practice this means, the driver will be informed when entering a managed zone and depending on the access zone or emission characteristics of the vehicle the driver will may be charged. The service is based on a hybrid communications concept, either cellular network or ITS-G5.[64]

4.2.2. STATUS OF THE SERVICE

There is very little data available regarding ZAC.

4.2.3. ROAD AUTHORITIES' POSSIBLE AREAS OF RESPONSIBILITY

The areas of responsibility regarding installation, maintenance and financial aspects need to be determined. The main possible responsibility for these areas should be the road authorities', since the infrastructure on the road network usually is the road authorities' responsibility. There is no reason why infrastructure associated with this service would be an exception. How active a role the road authorities should undertake when performing test studies is another issue.

4.3. Loading Zone Management (LZM)

The service, Loading Zone Management, is intended to support road operators, fleet managers and the driver when it comes to booking, monitoring and management of urban areas. This service is a system that applies to freight vehicles.[65]

4.3.1. FUNCTIONAL DESCRIPTION

The service is based on a hybrid communication concept with either cellular network or ITS-G5. The fleet operator or the driver will have the possibility to book an urban loading in advance. In the booking the delivery time, loading/unloading time and vehicle type is specified. Information such as desired flexibility and estimated time to reach parking zone will also be provided. Due to the increased knowledge, the road operator will be able to optimize delivery time, reduce driver stress and solve congestion problems.

4.3.2. STATUS OF THE SERVICE

There is very little data and studies available regarding this type of service.

4.3.3. ROAD AUTHORITIES' POSSIBLE AREAS OF RESPONSIBILITY

The responsibility for the installation and the maintenance of the service need to be determined. The financial aspects also need to be resolved in order to deploy this service. Financing this service should be a co-responsibility between the private and the public

[64] European Commission "Study on the Deployment of C-ITS in Europe. Final Report", 2016
[65] European Commission "Study on the Deployment of C-ITS in Europe. Final Report", 2016

sector including road administrations. The private sector and the public sector both have an interest to deploy this service since it is desirable to make the freight traffic more effective and optimized for both parties. The installation and maintenance should also be these actors' responsibility. Regarding test studies, the private sector and the public sector should have the main responsibility to perform these since they both are highly involved in the deployment process.

4.4. Wrong Way Driving (WWD)

The service, Wrong Way Driving, is intended to prevent accidents caused by wrong way driving. The service's main functions are; to alert the driver who is driving in the wrong direction and to warn the surrounding vehicles of the danger.[66]

4.4.1. FUNCTIONAL DESCRIPTION

The service is likely to be based on ITS-G5 communication technology. Roadside units will detect the wrong way driver and thereafter send out a warning notification to other vehicles as well as to the vehicle driving in the wrong direction.[67]

4.4.2. STATUS OF THE SERVICE

Likely to be based on ITS-G5 communication technology.[68]

4.4.3. ROAD AUTHORITIES' POSSIBLE AREAS OF RESPONSIBILITY

The responsibility for the installation, maintenance and financial aspects need to be determined when deploying this service. The road authorities should have the main responsibility for the installation and maintenance of the infrastructure associated with the service, such as R-ITS-S. Since the road authorities usually have the main responsibility for the road network and the infrastructure, the responsibility for these areas therefore seems given to be the road authorities. The financial aspects should also be the road authorities' responsibilities since the same conditions as above could be applied regarding the financial aspects. Another issue is the responsibility towards the end-user, that the information will reach the end-user. This responsibility should mainly be the OEM:s since the responsibility is associated with HMI, given that the road authorities have the proper infrastructure and a database that will enable In-Vehicle signage. Regarding test studies, the road authorities will have the main responsibility to perform these since they are the

[66] European Commission "Study on the Deployment of C-ITS in Europe. Final Report", 2016
[67] European Commission "Study on the Deployment of C-ITS in Europe. Final Report", 2016
[68] European Commission "Study on the Deployment of C-ITS in Europe. Final Report", 2016

most involved actor in the deployment process. If test studies do not involve infrastructure the responsibility should instead be the private sectors.

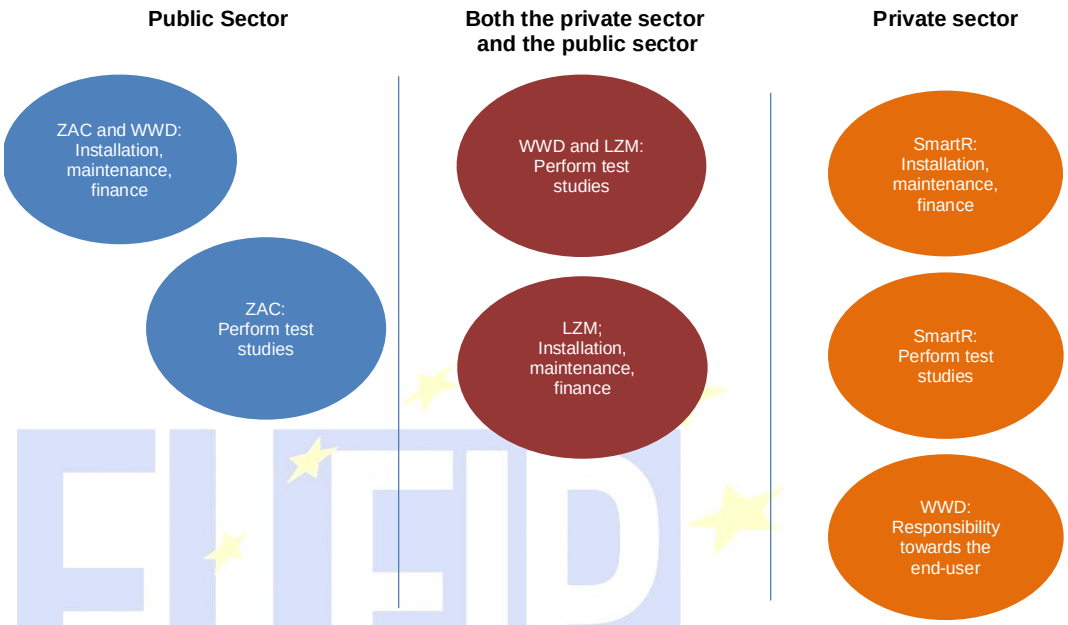


Figure 20 Possible Areas of responsibility (Day 1,5 services) based on an analysis by the authors of this study

5. International trends related to C-ITS

This chapter provides an overview of C-ITS related trends around the world in terms of C-ITS developments and initiatives in some parts of Europe, USA, Japan, and South Korea. They have been chosen to give an overview of what different areas in the world are envisioning in terms of C-ITS efforts and more specifically in terms strategies for deploying communication solutions for achieving Day 1 and Day 1,5 services.

Findings from the questionnaire and those gathered from interviews have also been included throughout these sections.

5.1. Europe

The European commission has issued a European C-ITS strategy which is based on the work carried out in the C-ITS platform where all where all member states were invited to

participate. The strategy states that continuity of services is prioritized, meaning that the availability of C-ITS services across the EU for end-users, is the most important factor for swift deployment of C-ITS in Europe. The services should from the start be deployed as widely as possible both on the infrastructure and on the vehicle side. The strategy therefore set priorities for coordinated C-ITS service deployment by member states and industry.

The European strategy strives towards full scale deployment of Day 1 C-ITS services in 2019. To achieve this the commission have identified several areas where work is needed, furthermore specific actions have been identified for each area.

The first area is *Priorities for deployment of C-ITS services* where the Day 1 services are to be prioritised in first phase deployment. The commission will support development in deploying Day 1 C-ITS services and research and innovation of Day 1,5 services through funding programs such as Connecting Europe Facility and Horizon 2020.

Two other areas identified are security of C-ITS communications and privacy and data protection safeguards. Two of the specific actions that will be taken is to publish guidance regarding data protection and guidance regarding the European C-ITS security and certificate policy.

Communication technologies and frequencies is another area, and the commission suggest a hybrid communication mix. A specific action identified is that road authorities, service providers, vehicle and radio equipment manufacturers and other industrial players should adopt a strategy for hybrid communication in procurement and serial production to support the full Day 1 C-ITS services list. The other areas identified are interoperability at all levels; compliance assessment; legal framework and international cooperation.

The C-Roads Platform brings together road authorities and operators currently covering 16 Member States (Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Hungary, Ireland, Italy, Portugal, Slovenia, Spain, Sweden, The Netherlands and UK) as well as Norway, Switzerland and Australia.

The aim of the C-Roads platform is to realize a road safety goal at a European level by aligning specifications for cooperative intelligent transport systems (C-ITS) to ensure European interoperability. A rapid and EU-wide deployment of harmonized C-ITS services is key to this objective in order to introduce C-ITS measures that support connected and automated driving by 2019. C-Roads Member States are focused at realizing flawless operation of C-ITS services cross border today and as such are contributing to the foundations for connected and automated driving.

The Netherlands, Germany and Austria have according to CODECS taken it upon themselves to strive for EU-wide deployment by implementing several projects such as the C-ITS corridor Austria-Germany-The Netherlands (Tool & Verweij, 2017).

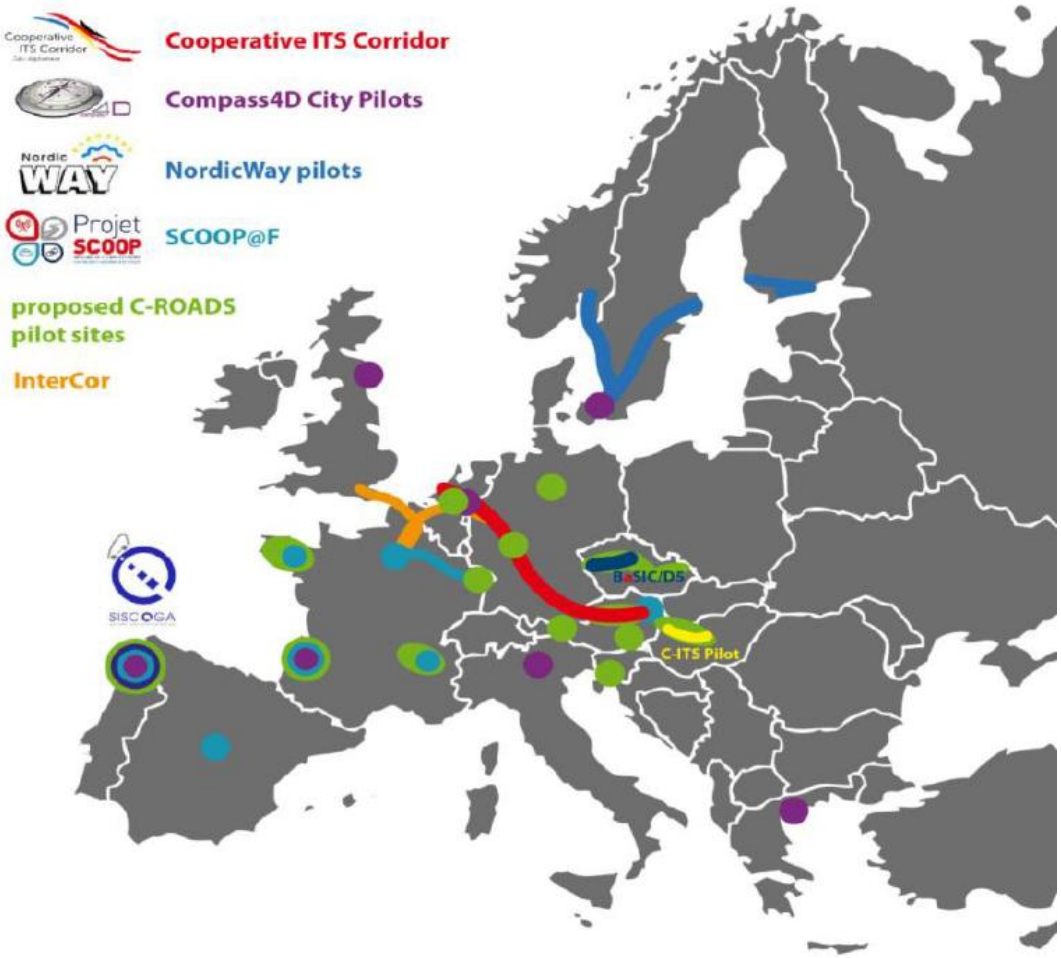
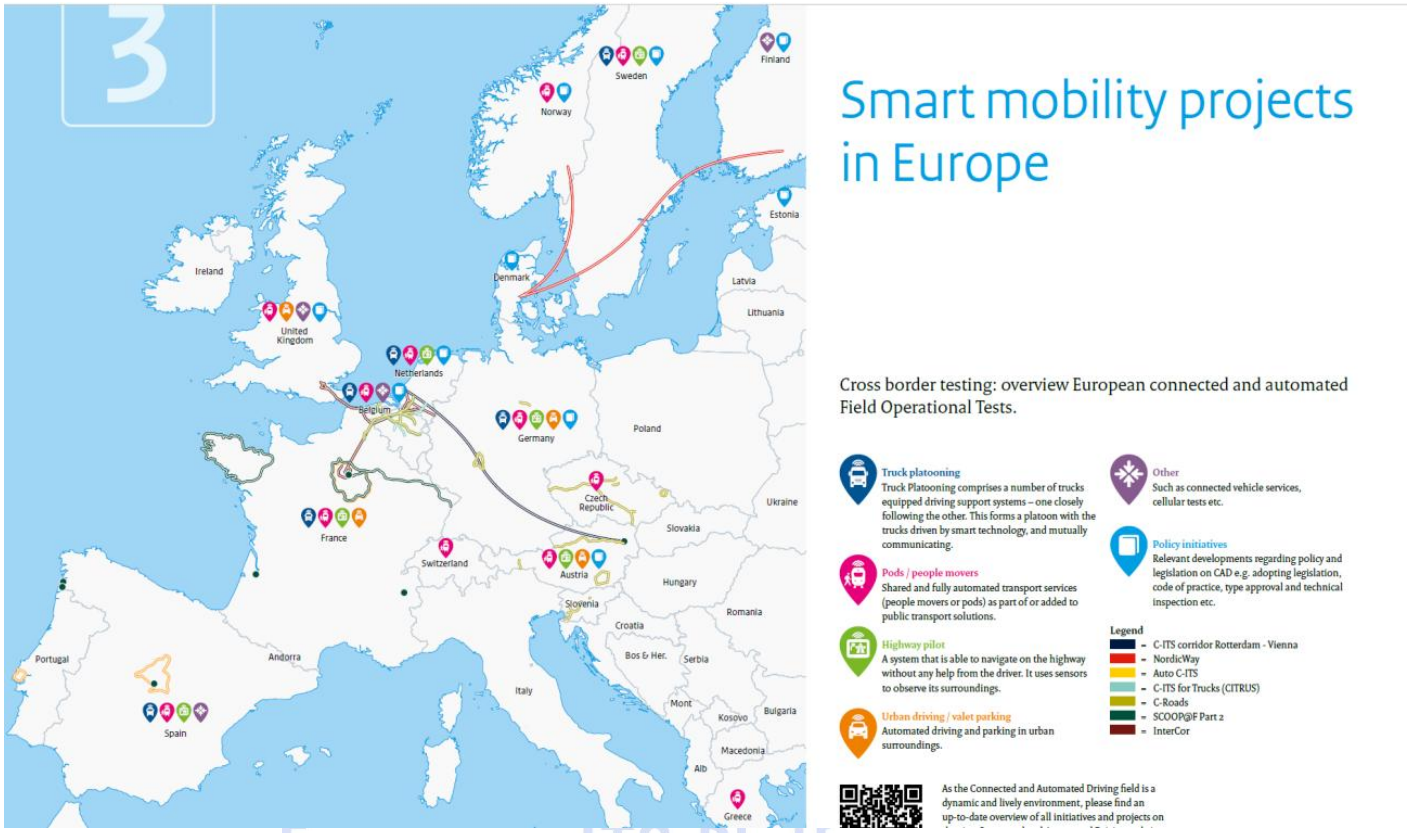


Figure 21 C-ITS status today – deployment initiatives. Source: CIMEX CODECS (Cooperative ITS Deployment Coordination Support) 2016.



European ITS Platform

Figure 22 Smart mobility projects in Europe. Source: Ministry of Infrastructure and the Environment, the Netherlands "On our way towards connected and automated driving in Europe", February 2017.

Table 3 Services and technologies covered by C-Roads. Source. 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

The following sections per country are partly based on interviews and responses from the questionnaire.

5.1.1. SWEDEN, FINLAND, NORWAY AND DENMARK

5.1.1.1. NORDICWAY

NordicWay was a pre-deployment pilot in 2015-2017 of Cooperative ITS (C-ITS) services in four countries (Sweden, Norway, Finland and Denmark) which will be followed by wide-scale deployment and in Europe (European Commission - INEA, 2014).

Part of the objective was to further develop interoperable Day 1 and Day 1,5 C-ITS services and support infrastructure readiness for connected and automated driving in Sweden, Norway, Finland and Denmark.

Sparsely populated Nordic countries, with extensive road network, seek cost-efficient solution for C-ITS. Therefore, the NordicWay project utilized mainly cellular C-ITS (i.e. the existing communication network). The project results include the development of an Interchange Node which acts as a neutral server supporting hybrid communication

architecture distributing Safety Related Traffic Information between private and public partners. The NordicWay project's results including safety, technical and socio-economic evaluations are available at www.nordicway.net.

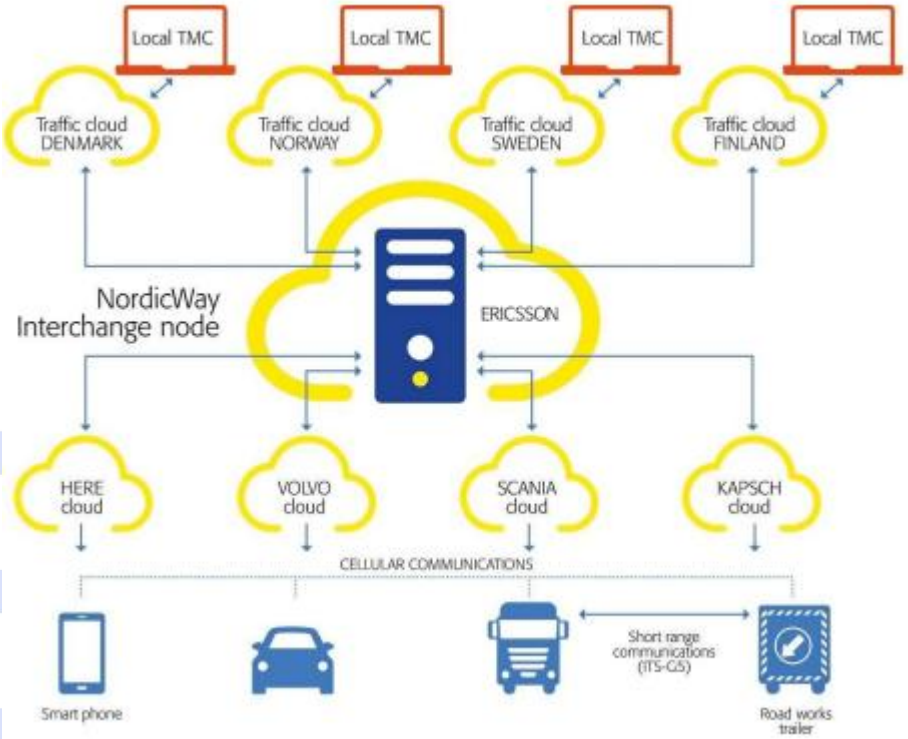


Figure 23 NordicWay Source: www.nordicway.net

European ITS Platform

5.1.1.2. NORDICWAY2

NordicWay2 is the continuation of the NordicWay project, a pilot project that seeks to enable vehicles to communicate safety hazards through cellular networks on a road corridor through Finland, Norway, Sweden and Denmark, through a collaboration between public and private partners in the four countries. The objective of NordicWay2 is to contribute to the harmonisation and interoperability of the C-ITS services in Europe by ensuring that the architecture, systems and services that are put in place under the project are interoperable and in line with European developments, including specifications and other interoperability and harmonisation requirements agreed by the C-Roads Platform. A second objective is to support the deployment of Day 1 and Day 1,5 C-ITS services in Nordic countries, extend its use in vital road freight transport routes subject to extreme weather conditions and in urban and interurban environments.

A third specific objective is to support the infrastructure readiness for connected and automated driving in Nordic countries. This objective will be met by testing the infrastructure readiness for connected and automated driving on major freight routes of the comprehensive network in Norway and by analysing the automated driving in snowy and icy arctic conditions in Finland.

5.1.1.3. SWEDEN

When it comes to land area, Sweden is one of the largest European countries but with fewer inhabitants and not as densely populated as for example France and Spain. It is therefore essential that the infrastructure communication solution chosen for the C-ITS deployment in Sweden is economically sustainable. Consequently, the evaluation of both ITS-G5 and cellular LTE V2X is an essential part of the Swedish strategy. Projects in Sweden and in other Nordic countries are testing hybrid technology and cellular solutions for vehicle-to-vehicle and vehicle-to-infrastructure communication.[69]

The Swedish part of NordicWay has the focus of building up an authentic C-ITS ecosystem based on available technologies and relevant organizations. Existing organizations will as such, and as far as possible, contribute with available solutions and technologies. The strength of NordicWay is its cross-border dimension and the Swedish part has a focus on how interoperability and market measures can contribute to the overall project goals. This is an important step for digitally connecting vehicles and infrastructure that deals both with technology and organization, but also with business models and driving forces (Wedlin, 2018).

By 2020 Sweden should have the best conditions for development, demonstration, validation and production of solutions concerning C-ITS. The Swedish aim to succeed lies in a combination of new technology in vehicles and road infrastructure which is adapted and expanded upon. The ambition is that Swedish and foreign vehicle industry has the possibility to develop, test and launch leading ITS-solutions in the Swedish road infrastructure avoiding having Swedish OEM:s having to go abroad to test their solutions.

5.1.1.4. FINLAND

All Day 1 and Day 1.5 service pilot deployments will focus on cellular communication utilizing several Interchange Nodes with private industry implementation. Pilots also include private industry roadside infrastructure and vehicles that will be equipped with ETSI ITS-G5 when needed to ensure hybrid communication interoperability. Applies on all NordicWay2 services. Finnish pilots include study of road transport automation and C-ITS in snowy and icy conditions, i.e. the Arctic Challenge project in Aurora E8 10 km test section.

[69] Directive 2010/40/EU Progress Report 2017 Sweden, 2017

The Finnish road authorities as well as EU CEF funded main deployment pilot within NordicWay2 starts in summer 2019. Pilot's C-ITS services cover the whole Finnish road network (main roads 80,000 km), also including the main corridors along the E18 corridor between Helsinki and Turku, and urban ring road parts plagued with accident prone stretches of road in Helsinki.

Finnish deployment pilots include 19 industry partners divided to three coalitions with each having an Interchange Node to share SRTI data. The 19 industry partners utilize existing vehicle fleets, C-ITS services and users. The pilot works in collaboration with the NordicWay2 and C-Roads Platform to harmonize following Day 1 and Day 1.5 services in Europe.

Day 1 C-ITS services:

- Hazardous location notifications:
- Slow or stationary vehicle(s) & traffic ahead warning
- Road works warning
- Weather conditions
- Emergency vehicle approaching
- Other hazards
- Signage applications:
- In-vehicle signage
- In-vehicle speed limits
- Signal violation / intersection safety
- Traffic signal priority request by designated vehicles
- Green light optimal speed advisory
- Probe vehicle data

Day 1,5 C-ITS:

- Traffic information and smart routing

5.1.1.5. NORWAY

The Norwegian road administration identifies three technological solutions for their C-ITS. One is G5 that is being developed together with the industry and researchers. The second one is the cellular network, and the third is 'extended vehicle' to acquire data from the cars. This is developed through a cooperation with Volvo. Norway is, according to experts interviewed, looking for a balance, in which the support of a hybrid solution is an option. Norway cannot install G5 all across the Norwegian road network according to one interviewee, who also argues that a mix is needed for C-ITS to work.

Norway has been following the development of C-ITS since 2005 and have established test pilots to test C-ITS solutions. Particularly so in terms of automated driving which has become an important topic for their road administration. This is reflected in the national road

map being established in which a bigger focus will be made on larger ITS pilots and C-ITS between 2018-2023. NordicWay is of particular interest according to the interviewee and particularly the larger project with Finland within 'Aurora Borealis' along the stretch E8. Along this stretch are now connected systems between Aurora in Finland and Borealis in Norway.

According to the people interviewed as well as in the questionnaire response it is apparent that the Norwegian strategy at the moment involves open data. Another aspect mentioned is to have it based on a triple helix perspective. They mention the Swedish Drive Me initiative as a good example of an ambition which Norway also has.

Day 1 services and applications

According to interviewees and respondents of the questionnaire the Norwegian road administration has the means to establish requirements of the vehicle manufacturers such as particular equipment. EU directives are to be used first most in this aspect according to the interviewee.

The Day services and applications within a C-ITS context are not in operation yet according to the information provided by interviewees and questionnaire. They are being looked upon in a C-ITS test environment at the moment they added. When they will be rolled out depends on government decisions. The responders believe that in 2019 there will be a common vision on C-ITS related to the day services and applications, and Norway will be ready for when the services become a more common part in the transportation system.

In terms of Day 1,5 services and applications the interviewees and responses to the questionnaire state that in general there is a big interest data related to vehicle to infrastructure services such as for slippery road warnings and safety related services such as inside tunnels.

5.1.1.6. DENMARK

The status on Day 1 services and applications in Denmark as of the middle of 2017 is as follows: in vehicle signage is not running. The Danish Single Point of Access (SPA) is to be a national access point in order to be able to get messages from the car companies. Signal Violation and Traffic Signal Priority designated vehicles exist for some signal priority (only for buses, not fire department) according to the information gathered via interviews and questionnaires. There is no Green Light service, but the City of Copenhagen has green light trucks and buses and a pilot running at the moment. ITS-G5 has been installed on two roads. Probe vehicle data can be received if it is provided by the vehicles but for the moment are being collected via data from loops in the road's status. In terms of shockwave damping

there are attempts to get the data from third part companies in order to get some warning, for example if there are congestions outside rush hour or if there is slow traffic out on the roads.

The view is that in Denmark the solution for C-ITS will probably be different for the dense urban areas and the country side. The urban areas could use a hybrid solution with both ITS-G5 and Cellular, while the country side could use Cellular communications.

5.1.2. THE NETHERLANDS

The current state of C-ITS in the Netherlands, as one responder put it, can be seen as "learning by doing". There is a fast development going on which has prompted a focus on learning and building experiences, according to the same respondent. Many trials and demoes have been and are being conducted in order to learn about different technologies. Considering the specific situation of the Netherlands having a very dense network and a lot of infrastructure which needs to be managed, with tunnels and rush hour situations, will according to responders require a hybrid strategy. One responder stated that "Whatever we can do with mobile networks we will use, also with G5". The same respondent states that they are now at a stage in which they need to deploy C-ITS solutions.

There are not many OEM:s in the Netherlands according to the responses. NXP is an important partner according to the responses, who are pushing towards C-ITS, but more in terms of mobile networks and cloud services. C-ITS communication standards are still important, one respondent adds. The Netherlands have, via a large C-ITS related project, actually deployed C-ITS services over mobile networks and are quick to add that they are embracing the hybrid approach, but it is not clear what communication standards will finally be used. The view is according to some of the responders that the Netherlands has a great challenge ahead in terms of policy making related to C-ITS. There is an agreement that C-ITS can contribute greatly to traffic safety but there is still a debate, according to one respondent.

In terms of the status of Day 1 services and applications, the responses have been that some of them have been partially deployed. Some of them have been deployed or will be deployed through cellular services.

The status of Day 1,5 services and applications are considered to be partly achieved according to the responses. The issue according to one respondent is that it is not done via ITS-G5. Instead, most of the services are provided through cellular based solutions, into the vehicle through mobile services or via apps. Related to this they add that they have

made a framework for the safety element of traffic information services to be used as a guidance for app-based services, to influence how those local apps are designed.

A policy has been adopted for a transition programme (running between 2013-2023) where the collective traffic information and management will be extended with individual traffic information offering possibilities for individual traffic management. The goal is that it will be achieved by applying innovative in-car and handheld services resulting in a reduced investment in conventional roadside systems when the approach is proven to be feasible as a joint public-private cooperation. The objective is to achieve more effective and efficient traffic management and information services.

According to the Amsterdam Group (2013):

> "The Dutch Integrated Testsite for Cooperative Mobility (DITCM), The 'PraktijkProef Amsterdam' (PPA: pilot Amsterdam on network management and in-car services) and the Corridor project Netherland-Germany-Austria serve as important deployment tests to demonstrate and prove/test the added value of in-car services on a large scale. Important criteria are scalability, continuity, cross-border, cost efficiency, portability and acceptance/appreciation by road-users."
>
> – Amsterdam group "Road Map" (Amsterdam Group, 2013).[70]

The Day 1 services will be related to the communication in InterCor which will be either G5 only, or hybrid - separate G5 and cellular. For freight services, important for InterCor, a cellular only solution will be established.

[70] The Amsterdam Group is a strategic alliance of committed key stakeholders with the objective to facilitate joint deployment of cooperative ITS in Europe. It includes the umbrella organizations CEDR (Conference of European Directors of Roads) – ASECAP (the European Association of Operators of Toll Road Infrastructures) – POLIS (network of European cities and regions working together to develop innovative technologies and policies for local transport) and C2C-CC (CAR 2 CAR Communication Consortium).

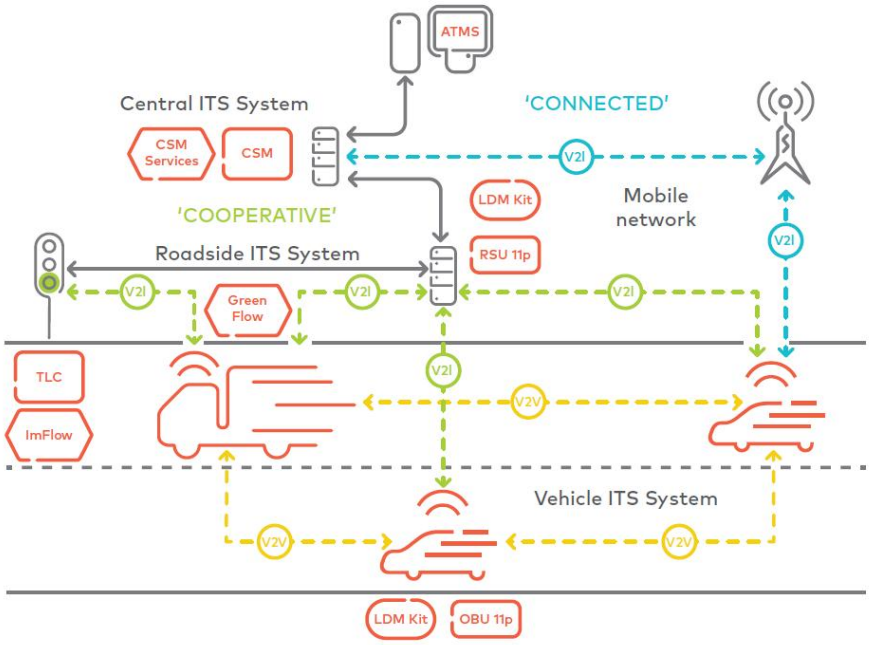


Figure 24 C-ITS traffic management system Dynic. Source: Dynnic.uk.com[71]

5.1.3. GERMANY

Responses from the interviews and the questionnaire coming from Germany state that Germany is very busy with C-ITS to deploy it on the road, while also developing it for installation in vehicles. They point out that when the ITS directive came into place it informed a national plan on ITS, then C-ITS became one area of interest and some concrete measures were proposed. With the increasing interest surrounding automated driving emerging they state that they have started a strategy for automated driving measures connected to C-ITS. The German ministry sees a strong relationship between automated driving and C-ITS according to one respondent while adding that C-ITS is evolving from the classic road telematics.

C-ITS is part of Digitalisation and Internet of Things (IoT) according to respondents. The view is that open data is one aspect that in the domain of traffic is not only about creating data but also how combine data between different stakeholders such as the OEM (car manufacturers) or the police. They will all have different types of data and the best step according to one respondent would be to combine the data that is available in order to

[71] http://www.dynniq.co.uk/storage/app/media/UK%20Brochures/New%20May%202017/dyn10663-coop-connected-4pp-bro-04.pdf, 2017

identify what gaps exist. The German Federal ministry has talked about the need for opening up the data, also with a view of the relation between the Federal level and the Federal States. This falls in line with one respondent's statement: "We work with something called "mobility market data place" to lower transaction costs but not to intervene in the market relation." There will according to some of the respondents be a fundamental change of road operation in Germany, brought forth with changes made in June 2017 to some articles of the constitution, in order to bring the operation of roads back to a federal level. According to one respondent the change will bring opportunities but also threats. The main contribution will be to make it easier to implement things when needed.

In terms of Day 1 services and applications, the status is according to respondents that purely V2V is active at the moment. Road works warning is priority at the moment and has been in an open trial until the end of September 20017. If it was successful they plan to roll it out 2018.

5.1.4. FRANCE

The approach of governance related to ITS in general is according to a representative of the public sector in France that the road operator is key in the system. That means according to the person: "That what you are trying to build through C-ITS, is not only a link between vehicles but also to V2I (The traffic center of road operators) in order to send information to the driver as detailed and validated as possible."

In terms of Day 1 services and applications they are quite in line with the development as defined by the European commission, according to the responses from France. One person adds that the Day 1 services and applications is also part of the European strategy released last November and that they are fully in line with the strategy and that the services are seen as related to the Part C of the ITS directive. From a technological maturity point it is believed that it is mature for users and should be deployed on the roads. Their pilot project on the French side of Scoop@F started 2014 with a focus on most of the Day 1 services and applications in which Renault and PSA car manufactures have helped. They have also worked with the whole eco system including for the road manufactures. In the project Cero Trans they have involved Bordeaux and Strasbourg according to one reply. Another major project is InterCor, a project that links the C-ITS corridor initiatives of the Netherlands (C-ITS Corridor NL-DE-AT) and the French SCOOP@F and extending to United Kingdom and Belgium C-ITS initiatives. [72] The coordinator is the Dutch Rijkswaterstaat.

[72] InterCor (Interoperable Corridors) links the C-ITS corridor initiatives of the Netherlands C-ITS Corridor NL-DE-AT and the French SCOOP@F and extending to United Kingdom and Belgium C-ITS initiatives to achieve a

Vehicles are being prepared for C-ITS in the factories of car manufacturers in France according to one responder. The person adds that 3000 vehicles will be deployed throughout five test sites in France, deploying what they consider mature technology and in line with the goal of the European commission. The focus is on G5 as a basis, and then Cellular network (3G and 4G) as a complementary solution, a hybrid solution. They have been specifying the cellular part of the system to be hybrid, according to the responses.

5.1.5. AUSTRIA

Austria has an early history of C-ITS activities. Starting already in 2006 the first cooperative services were developed and tested in the project COOPERS (CO-OPerative SystEms for Intelligent Road Safety) under the direction of AustriaTech. The main partners in C-ITS are the bmvit, road infrastructure operators for the high level road (ASFINAG), for state roads (the provinces) and the cities and municipalities, as well as industry and research institutions.[73] A consortium of research, industry and public companies have tested how cooperative services should be designed and implemented in order to optimally contribute to increased safety, efficiency and sustainable mobility in the transport network, and how to best meet the requirements and needs of the users.

Austria is working together with the Netherlands and Germany to implement C-ITS services along a corridor from Rotterdam via Frankfurt/Main to Vienna. The Austrian part of this corridor will be defined in the project ECo-AT ("European Corridor – Austrian Testbed for Cooperative Systems"). In the first phase a complete system specification will be developed, tested and approved. This specification will be the basis for subsequent tenders for C-ITS units on Austrian motorways. The goal has been to have defined "Day 1 applications" available along the corridor. These applications will be "Roadworks Warning", "In-Vehicle Information", "Probe Vehicle Data", "SPAT / MAP applications" and certain "DENM applications".

sustainable network of corridors providing continuity of C-ITS services and offering a TestBed for beyond Day-One C-ITS service development. Http://intercor-project.eu/.

[73] https://www.bmvit.gv.at/en/service/publications/transport/citsstrategy.html, 2017

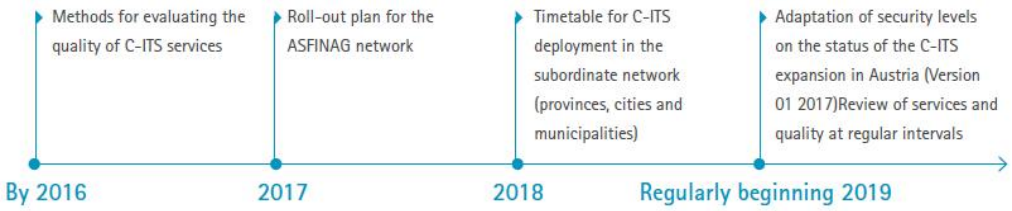


Figure 25 Roadmap for C-ITS Deployment. Source: C-ITS Strategy Austria,2016[74]

5.1.6. CZECH REPUBLIC

In the Czech Republic the C-ITS deployment is supported by national strategic documents approved by their Ministry of Transport and the government. It specifies the need to deploy C-ITS services nationwide by 2020. They have carried out some R&D projects concerning C-ITS. A short-term testing of the following applications was carried out in the BaSIC project between 2012-13, which involved:

- Slow moving vehicle warning
- Stationary vehicle / trailer information
- Decentralized FCD
- Approaching Emergency Vehicle Warning
- Traffic Jam Ahead Warning
- IVS (In-Vehicle Signage)
- Weather Conditions
- RWW

ITS-G5 was used exclusively as communication solution during the whole test. The project resulted in technical, operational and legal recommendations for future deployment being created and was seen as a very successful test run. Another more long-term pilot is currently being done with focus on long-term real operation of the C-ITS and related deployment issues from the road operator perspective, regarding warranties, responsibilities, operations. In this project two RSUs are installed on the highway together with a number of fitted warning trailers and maintenance vehicles. They will deploy RWW and SMVW with some further applications such as maintenance monitoring and performance evaluation.

[74] https://www.bmvit.gv.at/en/service/publications/transport/citsstategy.html, 2018

The Road and Motorway Directorate implemented a Roadmap for C-ITS deployment in 2015. It divides the deployment in 5 stages in terms of deployed services, geographical coverage and stakeholders' involvement.[75] [76]

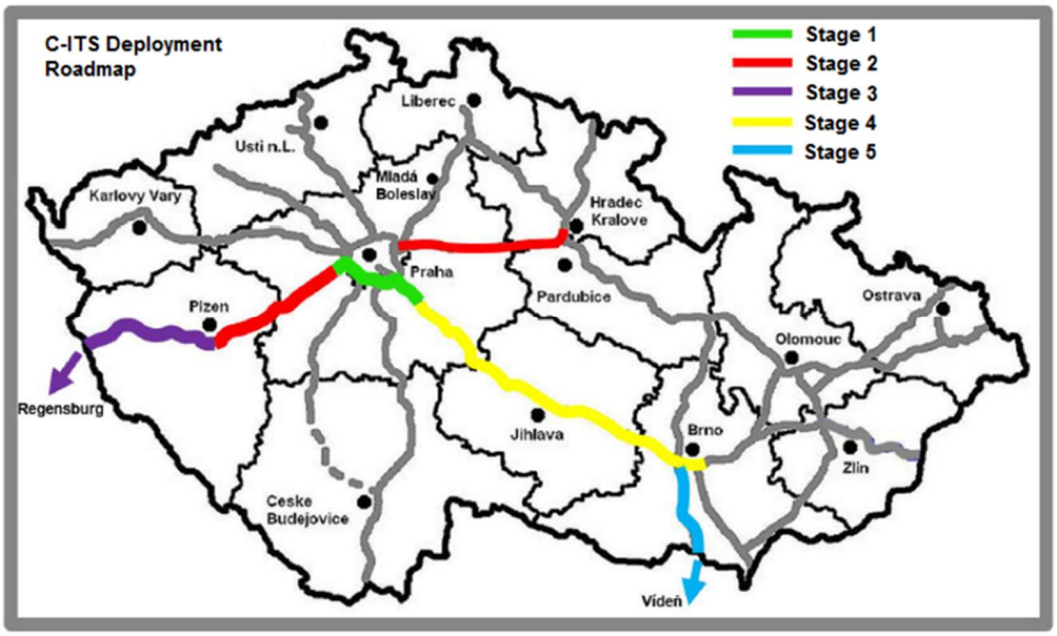


Figure 26 Czech Republic C-ITS deployment roadmap

5.2. United States of America

The US Department of Transportation (USDOT) is focusing on activities that permit adoption and eventual deployment of C-ITS related systems (USDOT, 2018).

The activities fall into two principal areas:

- Vehicle-to-Vehicle (V2V): communications based on dedicated short-range communications (DSRC) technology.
- Other C-ITS related technologies and communications such as cellular, Wi-Fi, or satellite. Although the USDOT is not researching regulatory decisions related to these other communications technologies, they are very much a part of the overall research and development foci. Their research considers how various

[75] http://smartmobilitycommunity.eu/, 2018

[76] https://www.c-roads.eu/pilots/core-members/czech-republic/Partner/project/show/c-roads-czech-republic.html, 2018

technologies and communications media will interact and operate within the anticipated technological environment, including safety and other types of applications and messages (USDOT, 2018).

Figure 27 Planned Connected Vehicles deployment locations in the U.S. Source: Volpe - The National Transportation Systems Center (USDOT), 2017.

European ITS Platform

Different pilots are being developed in the U.S. Most of the applications that are being tested are in Europe classified as Day 1 services, but they are labeled a bit differently here. They are being tested by different actors in different states, and different pilots are testing the same services but with some varying applications and unique focus. In Wyoming the Department of Transportation wants to reduce the number and severity of adverse weather-related incidents in one of the interstate highway systems running through the state. They want to reduce incident-related delays and improve the road safety. The focus lies on the needs of commercial vehicle operators in Wyoming. One of the lessons learned so far is that developing a robust and scalable data design for connected vehicles is a challenge. A lot of different requirements add needs for storage and throughput which might not even be possible technically in the real world. Another lesson is that by utilizing existing standards as a part of the system architecture and design process it helped create a solid deployment effort for their Phase 2. It also simplified

technical documentation and assisted with interoperability according to a fact sheet published by the department.[77]

The Department of Transport in New York City wants to improve the safety and mobility of travelers through the use of connected vehicle technologies. V2V technology is installed in up to 8000 city-owned vehicles and around 350 V2I RSUs are installed along high-accident rate arterials in Manhattan and Central Brooklyn. Traffic lights along some of these streets will also be equipped with V2I technology. This pilot focus on the "proven" safety applications from prior R&D and will evaluate these on a much larger scale in a dense urban situation. One of the challenges that surfaced was cybersecurity, and that it is fundamental to connected vehicle deployment. Protection is needed for all connections and data exchanges. Login and security practices are needed in within the organizational framework as well as physical security of the TMC systems.

THEA, Tampa Hillsborough Expressway Authority, aims at alleviating congestion and improve safety during morning commuting hours. By deploying a variety of connected vehicle technologies on and in the vicinity of reversible express lanes and three major arterials in downtown Tampa they hope to solve some transportation challenges. The connected technology used for the vehicles will also be implemented in pedestrian's smartphones. The environmental benefits of using these solutions will be measured as well. Tampa identifies that cross functional coordination is critical in this type of project.

The OBUs and RSUs in these projects communicate in a 5.9GHz frequency DSRC. One important thing from the USDOT (U.S. Department of Transportation) perspective, that involves every pilot, is the need for device interoperability. It is essential according to the department that deployments like these regularly outline the device's specifications and that the devices conform to relevant industry standards. [78]

5.3. Japan

Japan has connected its C-ITS services to the same receivers they are using for toll collection. They use the same frequency, which is 5.8 GHz.[79]

A nationwide implementation of C-ITS related development commenced already in 2011 with the establishment of three Day 1 services: Dynamic Route Guidance, Safety Driving Support and Electronic Toll Collection (ETC). The country has a national strategy with

[77] https://www.its.dot.gov/factsheets/pdf/JPOCVPilot.pdf, 2018
[78] https://www.its.dot.gov/presentations/trb2018/CVP_TRB2018_Final.pdf, 2018
[79] https://www.adandp.media/blog/post/toyota-commits-big-to-dsrc, April 2018

clearly defines its approach for developing existing platforms and already deployed services (e.g., digital map database for car navigation systems; traffic information system for Vehicle Information & Communication Systems (VICS) or security management system for ETC transaction.[80] In 2015 it began offering Toyota and Lexus models DSRC. As of March 2018, it has more than 100,000 equipped vehicles on the Japanese roads.

Development of C-ITS technologies have also been developed (at least since 2016) to support automated driving to deal with fallen objects, disabled vehicles and other sudden incidents.

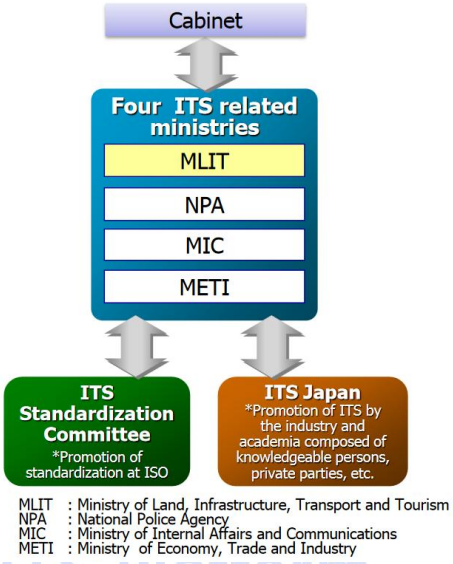


Figure 28 Organizational structure to promote ITS in Japan

Japan is not currently considering the 5.9 GHz band to deliver C-ITS services. Japan does utilise DSRC technology in the 5.8 GHz band for some ITS systems, including electronic toll collection (ETC), vehicle information communication system (VICS), and driver safety support services (DSSS). A next generation C-ITS service in Japan, the 'ITS Spot' was installed at 1,600 locations across Japan during 2011, mainly on expressways (Society of Automotive Engineers of Japan, Inc, 2016).
The initial wave of ITS Spot services includes the following:

- Mobility service, including dynamic route guidance, wider area route selection support, destination travel time and still images of traffic conditions.

[80] http://www.go-etc.jp/english/index.html, 2018

- Safety service, including congestion queue information, high-risk crash zones warnings, roadwork and obstructions warnings, weather information, still images of road surface condition and emergency information.
- Electronic Toll Collection (ETC), lately developed into ETC 2.0.
- Collection of vehicle probe data.

The ITS Spot service uses DSRC across the 5.8 GHz spectrum. In addition, Japan has allocated the 760 MHz channel for V2V (Weeratunga & Somers, 2015).

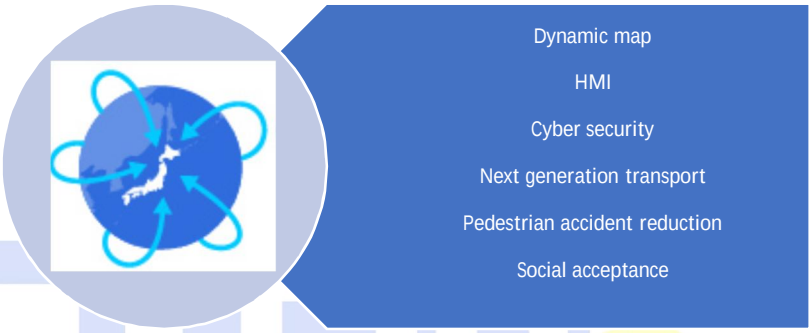


Figure 29 Field Operational Test (FOT) in Japan.

The Japanese National Institute for Land & Infrastructure Management has been running since April 2015 a C-ITS related program called “Joint public-private research on next generation V2I CITS”. Seventeen private companies are taking part in the joint research project, including companies such as Toyota, Honda, Nissan, and Hitachi. The project covers three main topics. The first is roadside services which will enhance road management and provide smoother road traffic by delivering information from vehicles to roadside infrastructure. The second is onboard-vehicle services which will support safe driving and also smoother road traffic by providing information from roadside infrastructure to vehicles. The third is the use of common platforms, to use cross-platform for communication media and data processing systems for both roadside and vehicles services.

Some examples of these services under development are wrong way driving prevention through visual and audio alerts, driving assistance for merging as well as diverging sections and Look Ahead Information which incorporates broken-down vehicles, slippery road surface conditions, obstructing objects and weather conditions. From this a more practical experiment will be deployed. Japans C-ITS is very closely interlinked with automated driving. The services and solutions provided by the connected and cooperative ITS are seen as facilitators for autonomous vehicles. For example the merging support is more for automated driving than assisting current traffic modes (Makano, 2017).

One key difference in Japan is that their DSRC uses 5.8 GHz band radio wave. Their highways also make use of tolls which means another aspect for intelligent transport systems. Through connected technology a solution has been developed called Electronic Toll Collection, ETC. This has been evolved into ETC 2.0 which now provides road traffic information to the car navigation system. This new version can also send and receive a larger quantity of data, which provides many advantages to both road users and road administrators. The probe data collected can be combined with various other types of data and then analyzed that pinpoints issues for the road administration, bottlenecks for example.[81]

5.4. South Korea

The Korean Ministry of Land, Infrastructure and Transport (MOLIT) perceive C-ITS as part of future traffic safety services being promoted globally as a means to prevent traffic accidents and will, as they see it, ultimately serve as an essential resource for self-driving vehicles. The ministry has established an agenda towards the development of C-ITS related safety technologies in the transport sector, with the goal to drastically decrease the number of accidents on Korean roads. Private Korean companies are promoting its relevance for automated driving. A C-ITS pilot project was launched already in July 2014 to be continued until July 2017, using 87.8 kilometres of roads between Daejeon and Sejong. The government plans to implement the system at all expressways in the country by 2020.

[81] https://www.go-etc.jp/english/etc2/index.html, 2018

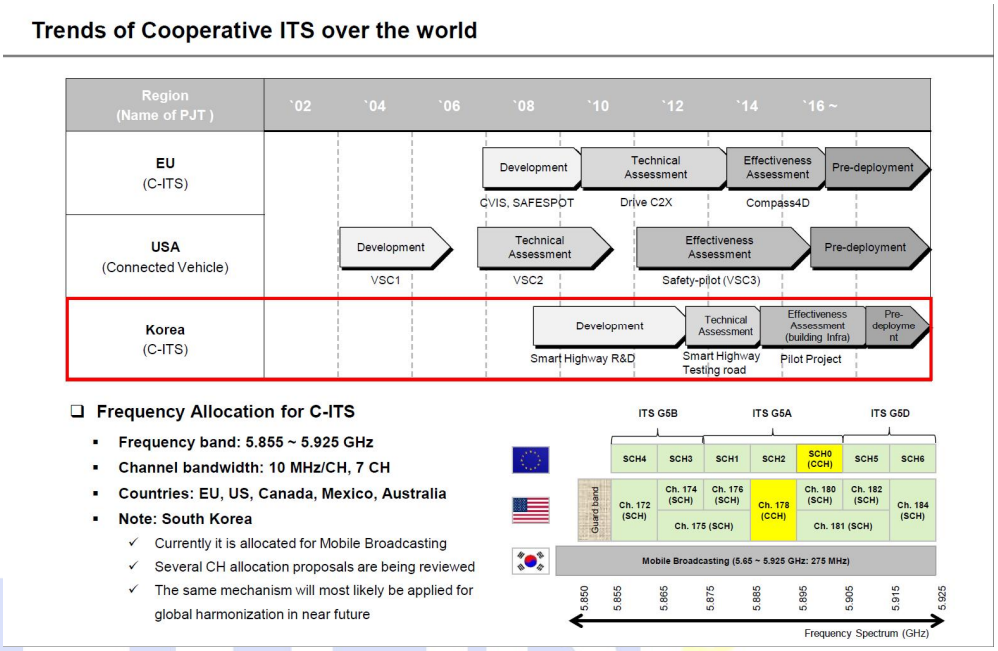


Figure 30 Illustration of C-ITS in South Korea comparison rest of world. Source: LG electronics, power point presentation 2015-03-26.

The Korea Transport Institute (KOTI) estimates that 76 percent of all road accidents could be avoided with the full deployment of its C-ITS plans.[82] According to Korean ministries' the commercialization of C-ITS technology will help cut losses from pedestrian car accidents by over 1 trillion won ($877 million) per year.[83] One of its pilots is a bus installed with C-ITS technology based on a system which issues various warnings and alerts related to road conditions, nearby pedestrians, any approaching ambulance, including vehicles doing U-turns. Once the official system launches, drivers will only need to install a C-ITS chip in their vehicle to receive the same information through their own navigation device, smartphones, or windshield.

[82] https://smartcitiesworld.net/transport/transport/intelligent-transport-technology-pilot-for-south-korea, 2018

[83] https://smartcitiesworld.net/news/news/intelligent-transport-technology-pilot-for-south-korea-751, 2016

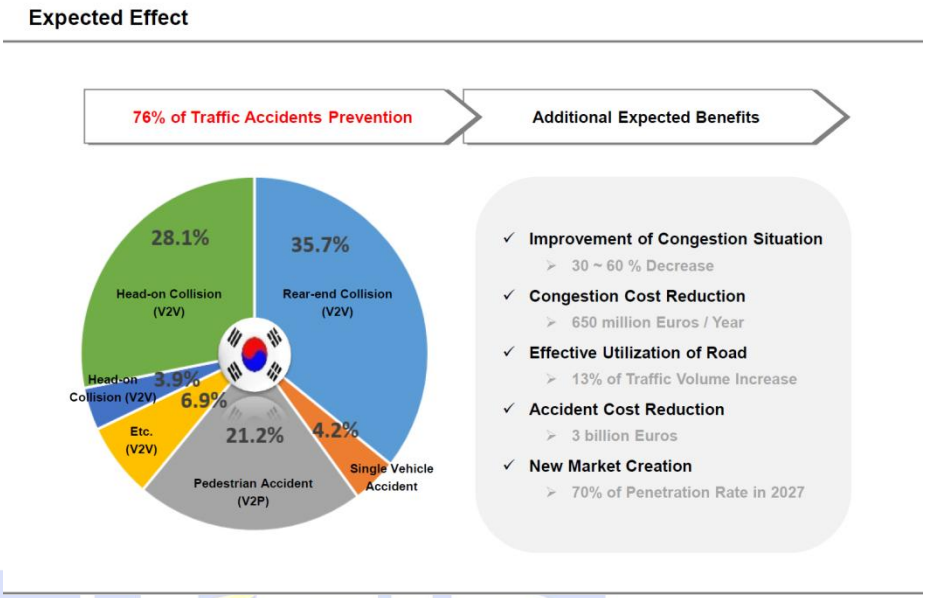


Figure 31 Expected effects of C-ITS in South Korea. Source: ITS Korea.

A range of smart transport technologies have been installed on national highways, including the primary highway for access to the 2018 Winter Olympic Games in Pyeongchang. The fundamental differentiator in these C-ITS measures is secure information exchange in real time between vehicles (V2V) and between cars and the surrounding intelligent infrastructure (V2I) including roadworks, traffic signs or traffic lights.

Korean NXP Semiconductors is partnering with the automotive electronics specialist 'eSSys' on a South Korean year-long Cooperative Intelligent Transportation System (C-ITS) project. NXP will supply eSSys with its RoadLINK V2X chipset, a vehicle-to-vehicle and vehicle-to-infrastructure (V2X) communication and security solution. It will be test-operated on an 87.8km route between Sejong City (city of government offices) and Daejon. The project is being promoted by the Korean Ministry of Land, Infrastructure and Transport. “eSSys’ WAVE communications systems based on NXP’s proven RoadLINK V2X chipset are expected to play a key role in the national C-ITS project. Based on software-defined radio technology, NXP’s hardware platform is able to support the Korean V2X standard, as well as the vast majority of regional variants around the globe. The technology, which has been proven in more than one million test kilometres in various projects worldwide, was also featured in the City of Columbus USA’s winning entry for the US Smart City Challenge in 2016.[84]

[84] https://smartcitiesworld.net/transport/transport/intelligent-transport-technology-pilot-for-south-korea, 2016

NXP's RoadLINK V2X communication and security technology enables vehicles to wirelessly exchange information such as speed, position and direction with other automobiles in their vicinity, and allows vehicles and infrastructure to communicate traffic management data or notices such as localised speed limits, traffic signalling and road works warnings, hazardous conditions and more. RoadLINK's secure element is an integral part of the chipset that protects the privacy of the driver and prevents hacking or manipulation. eSSys' WAVE communications systems based on NXP's RoadLINK V2X chipset are expected to play a key role in the project.

LG has introduced what it calls its "Second Generation" V2X Module for connected cars and autonomous vehicles. The core element that provides all of the communication functions combines three V2X core components into one product: the human-computer-interaction (HCI) module, a hardware security module (HSM) for controlling the communication protocol, and the application processor (AP). This integration saves automobile manufacturers from having to separately install different parts and undergo separate tests.

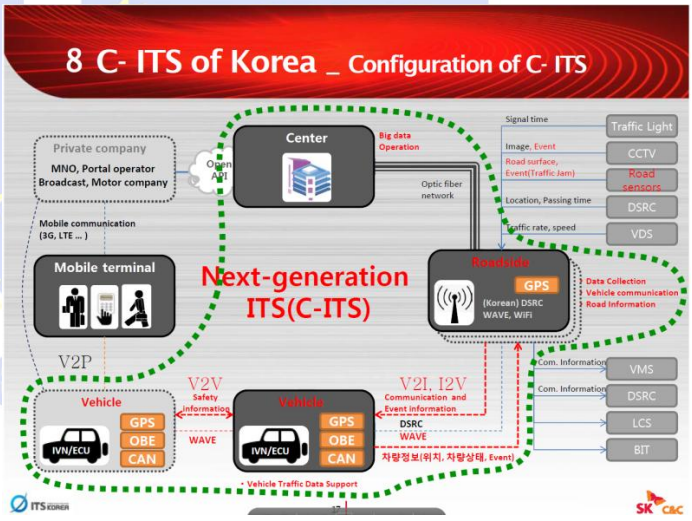


Figure 32 Illustration of Configuration of C-ITS. Source: ITS Korea.

Focus areas:

- Safety
- V2X Service
- Information exchange
- Open platform
- Cooperative ITS
- Connected Vehicles
- ITS Spots

- Talking Cars
- Car talk Systems

Key services and features in C-ITS in South Korea:

Improved information Collection

- Collecting Probe Vehicle Data(PVD)
- Providing Traffic Information

Smart tolling

- Smart Tolling (using WAVE communication)

Safe driving support

- Hazardous Location Notification
- Road obstacle warning
- Roadwork warning

Intersection safety

- Red Light Violation Warning (RLW)
- Right Turn Assistance (RTA)

Public transportation Safety

- Bus Information and management

Safety for children and Pedestrians

- School zone warning
- Yellow bus notification
- Pedestrian collision warning

V2V prevention of accidents

- Forward Collision Warning(FCW)
- Emergency Vehicle Warning
- Emergency Situation Notification

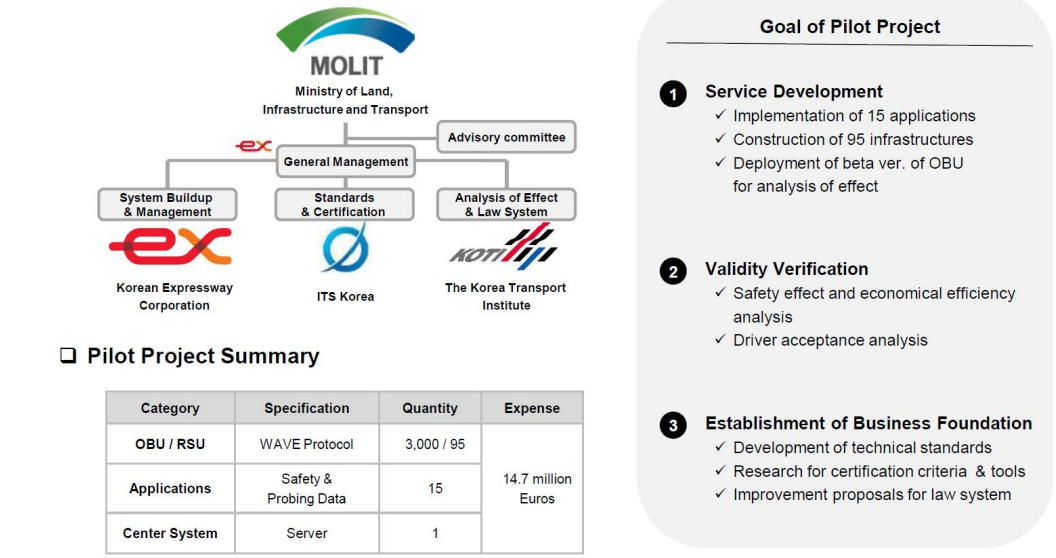


Figure 33 Illustration of C-ITS in South Korea Pilot project organizations Source: ITS Korea.

Table 4 Main Services C-ITS in South Korea. Source: ITS Korea.

Main Services (15 Applications)

No	Services	Target Year			Comm. Type			Target Area		
		`14	`15	`16	V2I	V2V	V2P	Express -way	National Highway	Urban Road
Probing Basic Data	1) Probing location based vehicle information	O	O	O	O	O	N/A	O	O	O
	2) Providing location based traffic information	O	O	O	O	O	N/A	O	O	O
	3) Tolling system using WAVE protocol	-	O	O	O	N/A	N/A	O	N/A	N/A
Safety Driving Support	4) Dangerous location warning	N/A	O	O	O	O	N/A	O	O	O
	5) Providing road condition and weather information	N/A	O	O	O	N/A	N/A	O	O	O
	6) Construction site warning	N/A	O	O	O	O	N/A	O	O	O
Intersection Safety Support	7) Intersection traffic sign violation warning	N/A	N/A	O	O	O	N/A	N/A	O	O
	8) Right turn warning	N/A	N/A	O	O	O	N/A	N/A	O	O
Public Safety Support	9) Bus operation management	N/A	O	O	O	-	-	O	O	O
	10) Providing yellow bus operation information	N/A	N/A	O	O	O	N/A	N/A	O	O
VRU[1] Safety Support	11) School zone, silver zone warning	N/A	N/A	O	O	N/A	N/A	N/A	O	O
	12) Pedestrian collision warning	N/A	N/A	O	O	N/A	O	N/A	O	O
Inter-Vehicle Safety Support	13) Forward collision warning	N/A	N/A	O	O	N/A	N/A	N/A	O	O
	14) Emergency vehicle approaching warning	N/A	N/A	O	O	O	N/A	O	O	O
	15) Vehicle emergency situation warning	N/A	N/A	O	O	O	N/A	O	O	O

5.5. Australia

Australia has started to develop their own strategies and test sites for C-ITS. In Queensland the Department of Transport and Mains Roads is setting up a pilot to prepare the department for the great advancements being made within the vehicle technologies. The project is shortened to CAVI, from Cooperative and Automated Vehicle Initiative. The largest part of the project consists of testing C-ITS V2V and V2I applications regarding traffic safety.

500 public and fleet vehicles will be retro-fitted with internationally compliant C-ITS devices, they will comply with European standards and support interoperability. The arterial and motorway infrastructure in around the City of Ipswich will be equipped with RSUs which will provide safety related messages and advisory messages to the participating vehicles. The project will mainly involve the European categorization of Day 1 services with slightly different naming but will include:

- Stopped or slow vehicle warnings (V2)
- Back-of-queue warning (V2I)
- Hazard warning (V2I)

- Emergency braking warning (V2V)
- In-vehicle speed warning (V2I)
- Turning warning for bicycle riders and pedestrians (V2V)
- Red light warning (V2I)
- Red light violator warning (V2I/V2V)
- RWW (V2I)

Another pilot in Australia is the Cooperative Intelligent Transport Initiative (CITI). This is Australia's first C-ITS testing facility. It is based in the Illawara region of New South Wales and is developed by Transport for NSW. The applications will be safety focused and include alert messages on an audio-visual display. The following alert messages will be displayed:

- Intersection collision threat
- Harsh braking ahead, EBL (electronic brake light)
- Red light alert
- Speed limit information

The C-ITS infrastructure will consist of three signalised intersections, one portable RSU broadcasting the speed limit information and three portable RSU for receiving and collecting data from C-ITS equipped vehicles according to Transport for NSW.[85]

It is proposed that the European standard ETSI EN 302 571 be adopted in Australia for C-ITS devices in the 5.9 GHz band.

6. Communication solutions and strategies for C-ITS

This chapter describes road authorities' views and strategies regarding the use of certain technologies related to a digital infrastructure in terms of:

- Connectivity for V2V, V2I (ITS-G5, 5G, cellular network), V2X.
- Pros and cons of respective communication solution (such as ITS-G5, Cellular, Hybrid solutions).
- Any delays or similar issues (such as latency, range issues).

Road authority's strategy related communication solutions for C-ITS, if any, for setting up C-ITS services in terms of:

- To purchase data from company clouds.
- To provide data from Company Clouds to the public.

[85] http://roadsafety.transport.nsw.gov.au/, 2018

- For using data? Such as for slippery road, need to send out vehicles to put sand on road, publish slippery road alerts to the public, and provide information signs along the roads.
- For providing data such as for influencing or complying with legal requirements.
- Regarding open interfaces such as for communication between different “clouds”, communication interchange servers.

The following tables provide an analysis of the solutions based on potentials, costs, scalability and any advantages or disadvantages associated with their use; such as latency, management, or range issues. The tables consist of a short description of each communication solution together with an analysis of pros and cons.

Table 5 Comparison of communication solutions for C-ITS

Communication solutions for C-ITS			
Description	**ITS-G5**	**Cellular technology**	**Cellular technology, device-to-device**
Physical connection	Communication with via one variant of WiFi According to the standard 80.11p.	Communication over the mobile network to one backend server, (often in the form of the cloud).	New standard for direct mobile communication (LTE - V) between units, mobile or vehicle, without communication via base stations. The technique is not mature for production in vehicles and can be described as one possible alternative to a dedicated 802.11p - network. LTE - V will most possibly be used for C-ITS in China and extensive field tests are planned for 2018. The upper part of the protocol stack will be shared with ITS-G5 / Wave.
Protocoll	ITS-G5 is based on standardizing messages directly between vehicles. The corre-sponding standard in the USA is called called WAVE. The technique supports both communication between vehicles (V2V) as well as between vehicle and infrastructure (V2I).	Both vehicle and infrastructure can be connected to the cloud. By connecting clouds to each other communication is made possible, both between vehicles, as well as between vehicle and infrastructure.	The technique would be able to support both communication between the vehicle (V2V) as well as between vehicle and infrastructure (V2I) in similar way as ITS-G5 and WAVE but with the radio layer 802.11p substituted with cellular communications based on device - to - device.
Hybrid solution	Hybrid solution, generally refers to a combination of ITS-G5 with WiFi - communications according to 802.11p together with cloudbased solutions with communication over the mobile network.		Device - to - device as part of new mobile standards, can also be used in combination with cloud solutions

Status	ITS-G5	Cellular technology	Cellular technology, device-to-device
Maturity (readiness)	Near to production. Hardware as well as standards considered mature for production.	Connection for vehicles over the mobile network, has been in production for many years. The mobile network is relatively well developed along major roads. A majority of new vehicles have system solutions for connecting over the mobile network.	New communications technology, possibly a few years left to an eventual production in vehicles. No available circuits with 'automotive grade'.

Cost	ITS-G5	Cellular technology	Cellular technology, device-to-device
Cost for data traffic	Free data traffic without cost on an assigned frequency band.	Data over the existing mobile network is made with a cost.	Free data traffic without a cost for the user if traffic is made in a unlicensed or licensed spectrum. If communication is made in a licensed spectrum it is fair to assume that costs will be added.
System cost in vehicle	Next generation and/or additional hardware must be added to vehicles for communi-cation according to 802.11p. IEEE 802.11p is a stripped variant of IEEE 802.11 and is approved for the automotive industry.	Modern vehicles are usually equipped for connection over the existing mobile phone network.	The existing hardware for mobile communications would need to be upgraded in order to also include device - to - device.
System cost in infrastructure	Expensive, especially for having a good availability in infrastructure with so-called RSU (Road Side Unit). The most likely scenario is to use a hybrid solution for information which requires that memory is managed via communication over a mobile network to a cloud.	None or very low since the existing mobile network is used. Connectivity of existing equipment in infrastructure, such as traffic lights, can sometimes be achieved via centralized solutions via the cloud so that no or just a few upgrades are required within the infrastructure.	Expensive, especially for providing good availability in the infrastructure with so-called RSU (Road Side Unit). Alternatively, one might use a hybrid solution where information which requires memory is managed via communication over a mobile network to a cloud.

Technical performance	ITS-G5	Cellular technology	Cellular technology, device-to-device
Latency	Direct communication between units is in principle optimally faster compared with communication via several links, for example the cloud.	Communication over the mobile network via back - end server (the cloud) is not equally fast as direct communication between vehicles, but is considered in many cases as still fast enough, even for demanding functions. With QoS or network slicing then capacity and performance can be guaranteed. Latency can vary depending on the load experienced within the mobile network being used.	Direct communication between units is optimally faster by principle compared to communication via several links, for example the cloud.
Availability at the communicative level	At situations with very close vehicular traffic and many transmitting vehicles within one area the communication is adapted in order to ensure stability. How this is achieved is defined in the standard.	Limitations/restrictions arise where mobile networks are not expanded. Solution relies in continued development of mobile networks and new generations of technology with a higher performance. Mobile operators, NMO (Mobile Network operator) usually have an interest of having good accessibility along the main road network and in urban agglomerations.	Limitations might arise at very congested vehicular traffic with many transmitting vehicles in the same area.

Bandwidth	Limitations may arise at very close or congested traffic with many transmitting vehicles in the same area. Vehicles are alone in communicating on the reserved frequency band. There is no competition with other types of units or applications.	Limitations/restrictions arise when data traffic exceeds mobile network capacity but QoS and network slicing can manage the issue. Mobile operators, NMO (Mobile Network operator) usually have an interest of having good accessibility along the main road network and in urban agglomerations.	The potential for device - to - device relies on having frequency band that allow sharing the band with other applications besides the vehicle related applications. This entails that more units are competing for bandwidth. Communication can be achieved over a wider frequency when assigned frequency to permit communication directly between vehicles via 802.11p.
Range	Limited to a combination of the transmitter and the receiver's performance, typically between 200 meters up to 1000 meters. The range can be affected by physical objects, such as buildings, often called 'urban canyons'.	Same as for todays connected vehicle. Depends on the vehicles antenna system and availability in the mobile network	The approach is based on device - to - device communicating directly between units when the distance is low enough, and via the mobile network when the distance is too big (if there is a mobile network available). Is a form of hybrid solution.

European ITS Platform

Scalability, flexibility and innovation	ITS-G5	Cellular technology	Cellular technology, device-to-device
Scalability	Scalability depends on to what extent new vehicles are equipped with 802.11p sender/ receiver capability and to what extent road administrators upgrade the infrastructure with 802.11p sender/ receiver capability.	In certain vehicle platforms, in which there is existing support for mobile based communication, new functions can be included via new vehicle software without a need for new hardware. Existing vehicles may in certain cases be covered via updates of the vehicle software.	—
Standards	Direct messaging between vehicles requires unified standardization of messages. Standards exist for this in the form of ITS-G5 and WAVE. The premise is that all vehicles must be able to understand each other.	Messaging between the vehicle and the cloud is regarded as proprietary per vehicle manufacturer.	Standardization work is underway within the 5GPP project (https://5g-ppp.eu/).
Protocoll	Permits new protocols to support new types of applications. Protocols that are built on top of ITS-G5 (IEEE 802.11p) are structured in a way that permits protocols to be added or removed in order to support various different applications.	Each vehicle manufacturer is responsible for connecting up their vehicles to a "vehicle unique cloud". The premise is that manufacturers will be competing with each other in trying to create an effective and rational system solution. By connecting various clouds communication between major groups of vehicles and infrastructure is allowed.	As mentioned, standardization work is underway within the 5GPP project (https://5g-ppp.eu/).

Note: Cellular V2X standards, with direct PC5, have been defined already in 2016 by the 3rd Generation Partnership Project (3GPP). [86]

Organization	ITS-G5	Cellular technology	Cellular technology, device-to-device
Certificate	Direct communication between vehicles requires a global certificate solution so that messages can be authenticated.	Each vehicle manufacturer is responsible for having each vehicle connected to its vehicle manufacturers cloud to be signed and authenticated. That's why there is no need for a one globally and common certificate solution.	Direct communication between vehicles requires a one-global certificate solution so that messages can be authenticated. Alternatively, via authentication in the mobile network (SIM card).

[86] http://www.3gpp.org/news-events/3gpp-news/1798-v2x_r14, September 2016

Table 6 Table with a list of commonly discussed Day 1 C-ITS services from the Amsterdam Group, and comments on the applicability of cellular or local communications. Source: Transport Technology Forum, UK, March, 2017.

Day 1 service	Cellular	Local
Slow or stationary vehicle(s) & Traffic Ahead warning	Timing may be an issue for local warning services but dependent on use case, as road ahead warnings are already done by sat nav using cellular (but immediate road ahead are not)	High level of performance needed for immediate hazard warning
Road works warning	Timing may be an issue for local services but dependent on use case as warnings are already done by Sat Nav using cellular (but immediate road ahead are not). Potential use of data to monitor signal performance	High level of performance for immediate hazard
Weather conditions	Apps available already using cellular but not necessarily immediate road ahead (e.g. icy patch)	Local Comms will provide immediate road ahead warnings (e.g. 'icy patch 100m ahead') but broadcast will be needed for wider messaging ('Snow on Snake Pass – don't leave home')
Emergency electronic brake light	Must be local	Local communications essential for timing
Emergency vehicle approaching	Suitable for vehicles which are further away in the network	Better suited to critical elements such as road crossings
Other hazardous notifications	Suitable for longer-distance warnings, e.g. road works or flooding a mile ahead	Suitable for immediately adjacent hazards (e.g. pothole, debris, animals in road)
In-vehicle signage (fixed signs)	Already done with cellular sat nav for non-time dependent.	Unlikely to be necessary or beneficial for most signs
In-vehicle speed limits	Done by sat nav and OEM device – HE and TfL have shown cellular app – but may be latency issues for smart motorways	May be useful for immediate warnings or enforcement action
Signal violation / Intersection safety	Latency likely to be too high	Needs local comms
Traffic signal priority request by designated vehicles	Most UK bus priority works satisfactorily over cellular using fixed time plans through bus scheduling information	Possible beneficial for emergency services or public transport where the need for dynamic requests are necessary
Green Light Optimal Speed Advisory (GLOSA)	May or may not work well enough for customers and OEM performance needs and depends on if adaptive or fixed time signals. More research is needed on users' needs and performance in peak times	Local comms assure timing of messages

Probe vehicle data	Proven for most applications; signal strategies, journey time, asset management, emissions	Useful as probe data input to signal control algorithms – local data needed for some approaches. But not for wider point-to-point across network information
Shockwave Damping	Driver advice can be provided over cellular (smart motorways)	Local comms needed for automated vehicles, driver support, platooning
Smart parking	Suitable for navigation and payment	Suitable for automated parking (i.e. not under driver control) but not wider zones
Tolling	Suitable for spots, cordons and zones, including payment	Suitable for cordons and zones (non-integrated payment) but not wider distance charging
Infotainment	Well suited, using mainstream entertainment applications	Unlikely to be suitable because of coverage

Green: Should be suitable for many applications.
Yellow: Supports but dependent on location (i.e., immediate road or general road ahead)
Red: Will not support characteristics that this application needs based on current state of the art. Note that this table reflects technical capability, not cost-effectiveness or effectiveness on outcomes. Also, soft factors such as public acceptability, ability to evolve, or maintainability are not included (Transport Technology Forum, UK, March, 2017.

7. Roles and responsibilities related to C-ITS

The findings below are based on interviews and a questionnaire gathering responses from experts and practitioners within the field of ITS and from both public and private stakeholders such as the vehicle industry involved with the development of C-ITS related solutions. Focus has been on the Road Operator/Administrations role but also includes perspectives from Original Equipment Manufacturers (OEM) and the telecom industry.

The interviews set out to gather views on roles and responsibilities associated to the implementation of C-ITS and potential scenarios for road administrators. The aim is to identify overlaps or gaps in the roles and responsibilities concerning C-ITS from a road administrator's perspective. The aim has been to provide recommendations based on the overall study together with findings provided through the interviews and the questionnaire.

Most of the interviews were carried out via Skype or telephone. They were done by one person acting as the main interviewer.

7.1. Roles and responsibilities

All the interviewees were asked about their respective countries current work with C-ITS related to any work being made or not by its road administrators. Additional questions concerned the status of Day 1 and Day 1,5 services and applications and whether they thought the services would be operational or not in a near future. For roles and responsibilities associated to C-ITS three groups could be identified mentioned by the interviewees. Road operators, the vehicle and equipment manufacturers and the telecom industry where the first most groups mentioned.

Road operators were interviewed in some cases in a slightly different manner (connected to particular pilot studies such as NordicWay, as an example) and the following answers should be interpreted with caution. The Swedish Road Association could be seen as putting a rather high emphasis on the market forces and the importance of not interfering with them. The Danish Road Directorate was found assuming more a role of an observant in following the development and participating in different workgroup and standardisation groups in the EU. One person mentioned more in detail that "We have one pilot on how the cars can read the sign on the road involving two tests: one with sunlight and the other during the night time. We also want one during heavy rain. Yes, it is a C-ITS test. It is about what should we have on the road side to be a good operator. We have defined it but also our government has defined it, that we should be good at this. We are defining the role and our capacity. In terms of the technological solutions we are part of the NordicWay project, were these ITS-G5 and cellular communications is used. We are looking at different costs and what our differences between the different technologies, business case end of the year. We need a case to show the benefit to decisionmakers. If all is perfect it should be ready by 2020. Maybe an optimistic view."

Some of the responses indicate an opinion that the vehicle manufacturers should share and contribute to the development of C-ITS, in a joint responsibility, but should in principle take responsibility for vehicles. The corridor projects Holland, Germany and Austria each have test sites and pilots and it is an open test environment set out to be a testing ground for how it could look in the future, with open trial test operations in which an OEM can contact the test site and ask to test their solution.

The view is that it needs to be seamless, or at least clear, how the services are offered in the same way for a user anywhere. The Amsterdam Group is a neutral ground for testing this according to one respondent.

Some of the interviewees also state that in the case of C-ITS in Europe that the European Commission has a central role in having overview and a coordinating capability to ensure user oriented and compatible solutions to ensure that connected vehicles (and related car industry products) will work across brands. A representative of the Norwegian Public Roads Administration (NPRA) stressed the importance for an increased cooperation between road operators and vehicle manufacturers adding that "we want to explore how we can get access to, and be able to use, information from the car as a sensor. One goal, according to the representative, is to better enable a business model on interoperability for C-ITS services by having more cooperation between the national authorities in Norway, who are responsible for infrastructure and the TMC: s, with the automobile industry, who are responsible for equipping vehicles with the necessary equipment.

An interest in Day 1 and Day 1,5 services and applications can clearly be seen amongst responders from the vehicle manufacturing industry. One respondent states that:" The interest in these services is high among the vehicle manufacturers and with that there will be projects that implement and test this from now to completion. On the other hand, there are some questions about how some services will work."

The following sections provide some of the perspectives gathered from the responses concerning a particular role and responsibility for road authorities related to communications solutions for C-ITS.

7.2. Related to ITS-G5, 5G

Starting with solutions related to ITS-G5 and 5G many of the interviewees thought that those solutions could be good for deploying C-ITS. One person said "A big topic which drives the market now is connected and automated vehicles and we think that especially ITS-G5 could be a good solution for this. We believe that the communication infrastructure will be part of the safety infrastructure to be available by the road operators." Another person mentioned that "They have started a commission/working group, 5GGP to define standards that everyone needs to follow, both broadcasters and recipients need to comply with these standards, even in other parts of the world, especially in Europe. So it is important to look at what's in the standardization of the texts coming out from this workgroup." Many of the interviewees believed the standardization work for 5G is fast. One person mentioned that "Within 3-4 years from now it should be possible to be rolled out. The question becomes: Whether the market is ready or not and how the rollout will look. It might become dangerous."

7.3. Related to an interchange server, services and safety

A traffic systems expert stated that “Users out in traffic, how do you make sure they do not get frustrated? The answer: Ericsson interchange server allows you to subscribe to what you are interested in, asking for what you want. Right now we do not know how well tailored the data will be. In the future maybe we will know.”

Another respondent answered: “We know that it is difficult to get people to pay for safety. But the benefits on a societal level is huge so it is one of those things that make sense for public authorities go in and finance.”

7.4. Related to technology

The view on certain communication solutions to facilitate C-ITS is in large shared by most of the responses. There are exceptions, such as one respondent who states that “The vehicle communication technology today is like the 1990s; much talk but not knowing how to use it. We think that Day 1 and Day 1,5 is important but it is not the pinnacle of this development, it might move into platooning and remote control. It is hard to predict what services will come in the future. This is where the business model is important, for example the one in NordicWay.

Another response states “I think they [road authorities] are very capable of this [using the potential of new technologies] but they can be slow moving. It would make sense from our perspective that they would move a bit faster.”

7.5. Related to technological solutions, users and the future

Representatives from Germany answered that their perspective is that the technological debate is not the core priority and that they will go with the best technological solution, supporting all different sorts of solutions, ITS- G5, Cellular, DAB (Digital audio broadcast). The view was that no technology should be excluded.

One representative from France stated that the major issue is interoperability. Any car manufacturer can provide a solution, but to ensure interoperability between different cars (different car manufacture brands) there is a need to have a common specification, according to the same person. Scoop@F have developed them, but the main issue is the way messages are written according to the person: “The standards are not self-standing, systems developed by different stakeholders might not be interoperable. That is a key problem”.

On the other side, the Norwegian Public Roads Administration (NPRA) identifies three technological solutions for their C-ITS. One is ITS-G5, that is being developed together

with the industry and researchers. The second one is the cellular network, and the third is extended vehicle to acquire data from the cars. They are looking for a balance of solutions for C-ITS and are supporting a hybrid solution between these. According to one representative of the NRPA it is not feasible that they can install ITS-G5 all over the Norwegian road network, which means that a mix is needed for C-ITS to work.

A great action for Europe would be, according to one person, to gather all stakeholders in Europe around the table, to find a solution. The same person believes that the NordicWay solution is viable. Distribution of C-ITS via a vehicles OBD port is also a way, according to the same person.

7.6. Related to deployment of roadside infrastructure

One response stated that "The urban areas could use a solution with both ITS-G5 and cellular, while the country side can use Cellular communications".

In Australia, to take another example, the view is that roadside infrastructure requirements will be defined by what technology may be used for communications, which will largely be driven by commercial market forces and interests.[87] From a road administrative view Australia sees their main role as being to support applications that deliver significant safety, efficiency and environmental benefits for their customers, based on cost/benefit analysis for investment needed in roadside infrastructure and back-office systems.[88]

They state that they will need more guidance nationally as to when, where and how to make such investments.[89]

8. Conclusions and recommendations

Findings from this overview indicate that C-ITS is a worldwide development in which organizational issues related to both technical and organizational standardization is called for by many countries, and interoperability is seen as a major concern. Other issues include security and privacy aspects related to C-ITS with regard to business cases and national roadmaps towards Connected, Cooperative and Automated Mobility.

While many C-ITS related pilot projects have shown that cooperative systems work at a technical level, there is still a need to provide evidence of how real benefits for road

[87] Connected vehicles: are we ready? Internal report on potential implications for Main Roads WA, 2015
[88] Connected vehicles: are we ready? Internal report on potential implications for Main Roads WA, 2015
[89] Connected vehicles: are we ready? Internal report on potential implications for Main Roads WA, 2015

authorities and local authorities can be proven, such as how they can contribute to either policy objectives and/or cost-effectiveness (Amsterdam Group, 2013).

Cybersecurity, interoperability and collaboration forms is perceived as central and important in C-ITS deployment. The common view is that the C-ITS communicative solutions will not work unless there is a means of ensuring that each connection is a secure connection. Standards are part of this aspect of the interoperability challenge, such as in the work being pursued by C-Roads in Europe. It relates to achieving interoperability between different working groups and actors in which communication and cooperation are "crucial".

According to the CODECS group interoperability will be key for a successful introduction of C-ITS systems and services. In this context, standards are one essential tool to achieve interoperability, but standards alone are not sufficient to ensure interoperability. A shared understanding and consistent interpretation of applications and useful standards is necessary to provide benefits to all C-ITS stakeholder.

8.1. Europe

Road authorities and operators, particularly in Europe, are preparing in one form or another, for a deployment of C-ITS enabled services in their respective countries. Findings from the CODECS group indicate the following reasons for this engagement: [90]

- C-ITS deployment is rooted in public goals such as improving road safety and efficiency of transport. The road authorities see their role related to the traffic management, provision of supporting infrastructure and improved safety.
- The most common view amongst those involved in C-ITS deployment is that it will be based on a smart mix of communication technologies involving ETSI ITS-G5 and cellular communication, potentially also others.
- Connectivity will play an important role towards automated driving. This relates to many issues connected to chosen communication solutions, such as security, latency and coverage.
- Many of the road authorities are engaged in multi-stakeholder coordination groups like the C-ITS Platform and the Amsterdam Group which provides knowledge that provide opportunities for cost-reducing learning effects.

Some general observations of C-ITS deployment in Europe indicate that:

- Europe is actively supporting international cooperation with regard to C-ITS.
- C-ITS implementation is driven by EU Member States (16 Members States engaged in national and cross-border pilots in close cooperation with industry)

[90] http://www.codecs-project.eu/, 2018

- Addresses not only European road corridors but also urban nodes with increasing number of cities involved as pilot sites
- Hybrid communication (ITS-G5 and cellular 4G) is perceived as a reality and a priority. The view among many of the countries is that hybrid communications offer more flexibility in implementation, especially for V2I / I2V services.

8.2. The rest of the world

Developments in C-ITS internationally are seeing significant progress in several regions around the world, most notably in Europe, the US and Japan. This is reflected in how international organisations that consider radiofrequency spectrum harmonisation efforts, such as the International Telecommunication Union (ITU), the Asia Pacific Telecommunity (APT), and the APT Wireless Group (AWG) have been considering ITS systems as a whole, specifically for C-ITS systems in the 5.9 GHz band, since early 2016.

Since it is not completely clear what is expected of road administrators, countries such as Australia have stated that they are looking into two possible alternative positions that may be taken regarding the roadside infrastructure and RSUs required for C-ITS (Weeratunga & Somers, 2015).

- Do not deploy RSUs and instead wait for communication options such as 4G and 5G mobile communications and satellite communications to emerge.
- Deploy limited RSUs in critical corridors and hot spots such as rail crossings with a poor safety record.

They also state that the case for deploying RSUs should be subject to staged installation with additional benefits being relative to additional costs. The ongoing subscription nature of 4G or 5G communications means that the entire cost of installing roadside infrastructure should not be considered an additional cost.

Access to multiple communication technologies to support service provision is essential in order to be able to achieve the best outcomes in relation to costs, reliability and safety.

They also contend that from a road agency point of view there is a need for more guidance nationally as to when, where and how to make such investments.

8.3. Recommendations for road administrators

Most countries are still focused on bringing together public and private parties before they can start thinking about deployment activities (Tool & Verweij, 2017). The view has increasingly been that the deployment of C-ITS needs a multi-stakeholder cooperation.

Road authorities in particular, and road operators such as those contributing to the European C-Roads platform, would benefit from the following recommendations which are supported by other studies (e.g., Böhm, 2017):

- Interoperability is a must: Vehicles need to "speak" to each other or implemented RSUs via interoperable communication systems (e.g. interoperability of ITS-G5 and LTE-V2X).
- Road authorities should not be forced to equip the roadside with two or more competing technologies (ITS-G5, LTE-V2X, or potential future technologies) serving the same use cases or providing the same content to road users.
- "Backwards compatibility" is needed in which new C-ITS equipment beyond Day-1 services and applications, such as those developed for Day 1,5 or even Day 2 services, need to support and safeguard already deployed C-ITS services.
- A consideration that the evolution of cellular communication standards towards 5G is expected to bring further improvements to long range cellular communication (such as coverage improvements and signalling efficiency), which will provide benefits to the hybrid communication approach while complementing short range connectivity.
- The C-Roads Platform as an example supports the use of hybrid communication technologies. The starting point for pilot deployments will be the combination of ETSI ITS-G5 and existing cellular network according to Martin Böhm at C-Roads (2017).
- Cloud solutions and their technologies need to support secure connections and be based on strategies for achieving interoperability between all stakeholders.

8.4. Concluding remarks and future work

The deployment of C-ITS faces many important issues still unresolved, such as legal, organisational, administrative, governing aspects, technical and standardisation issues as well as implementation and procurement issues addressing in particular two types of end-user's services, as those found in the Day 1 and the Day 1,5 services.

Interoperability will be key for a successful introduction of C-ITS systems and services. In this context, standards are one essential tool to achieve interoperability, but standards alone are not sufficient to ensure interoperability. A shared understanding and consistent interpretation of applications and useful standards is necessary to provide benefits to all C-ITS stakeholder.

Communication technologies and strategies for C-ITS still bring forth uncertainty for whether there is a need for special roadside equipment for C-ITS, such as if communication can be handled via ITS-G5, or the 5G network, or V2V communication. Related questions become who is responsible for the installation and maintenance of the

roadside equipment and the importance of V2I and V2V communication, the availability and provision of digital maps or what associated costs for implementation, particularly by the road administration, if indeed the cost should be connected to them and what dialogue or not exists with OEM:s regarding what C-ITS technology they will equip in their vehicles and when.

Successful C-ITS deployment will most likely require a targeted list of Day 1 and Day 1,5 services and applications that deliver value to customers. These services and applications will need their own set of roll-out plans linked to specific roles and responsibilities for their implementation and management and business plans.

While the Day 1 and 1,5 services and applications are not directly linked to a specific communication technology or solution they may require specific technologies and communications solutions to function optimally. The scenarios looked at through the many test pilots being conducted around the world are some of the determinants of what technologies will ultimately be used. It is expected that new technologies will emerge on a regular basis but the main requirements will still persist for good service provision, such as costs, reliability and safety, latency and speed, to mention some of them. It is also important that the C-ITS applications being used be based on standardised sets for communication and have been tested but also validated in relevant field operation tests.

The international overview of C-ITS development around the world indicates a continued need for collaboration on a national and international level particularly towards a strategy for facilitating the cooperation and sharing of knowledge and experiences concerning a digital infrastructure for C-ITS. Such a strategy would benefit from an increased collaboration with countries outside of Europe such as Japan, Korea, the United States and Australia.

What the road administrator may need to do to support these Day 1 and Day 1,5 services and applications will most likely be defined through the standardisation works and through both national and cross-national test pilots being made.

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10. Appendix 1: Day 1 and Day 1,5 services status worldwide

The following tables depict the status of Day 1 and Day 1,5 services as of today.

Table 7

Day 1 service	Type	Function	Sweden	Finland	Norway	Denmark	Netherlands	Germany	France	Austria	Czech Republic	USA	Japan	South Korea	Australia
Emergency vehicle approaching	V2V	Safety	Will be implemented (NordicWay 2), Cellular	Will be implemented (NordicWay2). All services will focus on Cellular but select roadside infrastructure and vehicles will be equipped with ETSI ITS-G5 where needed to ensure interoperability. Applies on all NordicWay services. Both 1 & 2.	Will be implemented (NordicWay2)	Don't know	Don't know	Don't know	Don't know	Will be implemented	Almost in operation. Dedicated Short Range Communication (DSRC)	Don't know	Almost in operation. Hybrid		Don't know
Slow or stationary vehicle(s)	V2V	Safety	Don't know	Will be implemented	Will be implemented (NordicWay2)	Will be implemented	Don't know	Almost in operation (C-roads). Hybrid	Almost in operation (C-roads). Hybrid	Almost in operation (C-roads). Hybrid	Almost in operation. Dedicated Short Range Communication (DSRC)	Will be implemented. Dedicated Short Range Communication (DSRC)	Almost in operation. Hybrid	Will be implemented (CAV). Dedicated Short Range Communication (DSRC)	Will be implemented (CAV). Dedicated Short Range Communication (DSRC)
Traffic jam ahead warning	V2V	Safety	Don't know	Will be implemented (NordicWay2)	Will be implemented (NordicWay2)	Will be implemented	Don't know	Almost in operation (C-roads). Hybrid	Almost in operation (C-roads). Hybrid	Almost in operation (C-roads). Hybrid	Almost in operation. Dedicated Short Range Communication (DSRC)	Will be implemented. Dedicated Short Range Communication (DSRC)	Almost in operation. Hybrid	Will be implemented. Dedicated Short Range Communication (DSRC)	Will be implemented/CAV). Dedicated Short Range Communication (DSRC)
Hazardous location notification	V2V	Safety	Almost in operation (NordicWay). Cellular	Almost in operation (NordicWay)	Almost in operation (NordicWay)	Almost in operation (NordicWay)	Don't know	Will be implemented. Hybrid	Almost in operation (C-roads). Hybrid	Will be implemented. Dedicated Short Range Communication (DSRC)	Will be implemented. Dedicated Short Range Communication (DSRC)	Will be implemented. Hybrid	Almost in operation. Dedicated Short Range Communication (DSRC)	Will be implemented (CAV). Dedicated Short Range Communication (DSRC)	Will be implemented (CAV). Dedicated Short Range Communication (DSRC)
Road works warning	V2I	Motorway	Will be implemented (NordicWay 2), Hybrid	Will be implemented (NordicWay2)	Will be implemented (NordicWay2)	Almost in operation (Nordic Way)	Almost in operation (Interco). The communication in InterCor will be either G5 only, or hybrid - separate G5 and cellular. For freight services,	Almost in operation (C-roads). Hybrid	Almost in operation (C-roads). Hybrid	Almost in operation (C-roads). Hybrid	Almost in operation. Dedicated Short Range Communication (DSRC)	Will be implemented. Hybrid	Almost in operation. Hybrid	Will be implemented (CAV). Dedicated Short Range Communication (DSRC)	Will be implemented (CAV). Dedicated Short Range Communication (DSRC)
In-vehicle signage	V2I	Motorway	Don't know	Will be implemented (NordicWay2)	Will be implemented (NordicWay2)	Almost in operation	Almost in operation (Interco)	Almost in operation (C-roads). Hybrid	Almost in operation (C-roads). Hybrid	Almost in operation (C-roads). Hybrid	Almost in operation. Dedicated Short Range Communication (DSRC)	Will be implemented	Almost in operation. Hybrid	Will be implemented (CAV). Dedicated Short Range Communication (DSRC)	Will be implemented (CAV). Dedicated Short Range Communication (DSRC)
Weather conditions	V2I	Motorway	Almost in operation (NordicWay)	Almost in operation (NordicWay)	Almost in operation (NordicWay)	Almost in operation (Nordic Way)	Don't know	Will be implemented	Almost in operation (C-roads). Hybrid	Almost in operation (C-roads). Hybrid	Almost in operation. Dedicated Short Range Communication (DSRC)	Will be implemented	Almost in operation. Hybrid	Will be implemented (CAV). Dedicated Short Range Communication (DSRC)	Will be implemented/CAV). Dedicated Short Range Communication (DSRC)
In-vehicle speed limits	V2I	Motorway	Don't know	Will be implemented (NordicWay2)	Will be implemented (NordicWay2)	Almost in operation	Don't know	Will be implemented	Almost in operation (C-roads). Hybrid	Almost in operation (C-roads). Hybrid	Almost in operation. Dedicated Short Range Communication (DSRC)	Will be implemented. Dedicated Short Range Communication (DSRC)	Almost in operation. Hybrid	Will be implemented (CAV). Dedicated Short Range Communication (DSRC)	Will be implemented (CAV). Dedicated Short Range Communication (DSRC)
Probe vehicle data	V2I	Motorway	Almost in operation (NordicWay)	Almost in operation (NordicWay)	Almost in operation (NordicWay)	Almost in operation (Interco)	Almost in operation (Interco)	Almost in operation (C-roads). Hybrid	Almost in operation (C-roads). Hybrid	Almost in operation (C-roads). Hybrid	Almost in operation. Dedicated Short Range Communication (DSRC)	Will be implemented. Dedicated Short Range Communication (DSRC)	Almost in operation. Dedicated Short Range Communication (DSRC)	Almost in operation. Hybrid	Will be implemented (CAV). Dedicated Short Range Communication (DSRC)
Shockwave damping	V2I	Motorway	Don't know	Don't know	Almost in operation (C-Roads). Hybrid	Almost in operation (C-Roads). Hybrid	Almost in operation (C-Roads). Hybrid	Almost in operation (C-roads). Hybrid	Almost in operation	Almost in operation	Don't know	Don't know	Don't know	Don't know	Don't know
GLOSA / Time to Green (TTG)	V2I	Urban	Will be implemented (NordicWay 2)	Will be implemented (NordicWay2)	Will be implemented (NordicWay2)	Almost in operation (Interco)	Almost in operation (Interco)	Almost in operation (C-roads). Hybrid	Almost in operation (C-roads). Hybrid	Almost in operation (C-roads). Hybrid	Don't know	Will be implemented. Dedicated Short Range Communication (DSRC)	Don't know	Don't know	Don't know
Signal violation/Intersection safety	V2I	Urban	Don't know	Will be implemented	Will be implemented (NordicWay2)	Will be implemented	Don't know	Will be implemented. Hybrid	Will be implemented. Hybrid	Will be implemented. Hybrid	Will be implemented	Will be implemented. Dedicated Short Range Communication (DSRC)	Don't know	Almost in operation. Hybrid	Will be implemented/CAV/CITI.Dedicated Short Range Communication (DSRC)
Traffic signal priority request by designated vehicles	V2I	Urban	Don't know	In operation	Don't know	Will be implemented	Don't know	Don't know	Don't know	Don't know	Don't know	Will be implemented	Don't know	Don't know	Don't know

Table 8

Day 1,5 service	Type	Function	Sweden	Finland	Norway	Denmark	Netherlands	Germany	France	Austria	Czech Republic	USA	Japan	South Korea	Australia
Off street parking information	V2I	Parking	Don't know	Almost in operation	Don't know	Don't know	Almost in operation (For trucks along	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know
Off street parking information and management	V2I	Parking	Don't know	Will be implmented	Don't know	Will be implemented	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know
Park & Ride information	V2I	Parking	Don't know	Almost in operation	Don't know	Will be implemented	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know
Information on AFV (alternative fuel vehicles) fueling & charging stations	V2I	Smart routing	Don't know	Will be implemented	Will be implemented (NordicWay2)	Will be implemented	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know
Traffic information and smart routing	V2I	Smart routing	Will be implemented (NoridcWay 2)	Will be implemented (NordicWay2)	Will be implemented (NordicWay2)	Will be implemented	Almost in operation (For logistic companies in	Will be implemented	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know
Zone access control for urban areas	V2I	Smart routing	Don't know	Will be implemented	Don't know	Don't know	Will be implemented (for cargo transp.)	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know
Loading zone management	V2I	Freight	Don't know	Almost in operation	Don't know	Don't know	Will be implemented (for	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know
Vulnerable road user protection (pedestrians and cyclists)	V2X	Vulnerable road user	Don't know	Will be implemented	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Will be implemented.Dedicated Short Range Communication (DSRC)	Don't know	Almost in operation. Hybrid	Will be implemented (CAVI). Dedicated Short Range Communication (DSRC)
Cooperative collision risk warning	V2V	Collision	Don't know	Almost in operation	Will be implemented (NordicWay2)	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Almost in operation. Hybrid	Will be implemented (CAVI)
Motorcycle approaching indication	V2V	Collision	Don't know	Will be implemented	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know	Don't know
Wrong way driving	V2I	Wrong way	Don't know	Will be implemented	Don't know	Will be implemented	Don't know	Will be implemented	Don't know	Don't know	Don't know	Will be implemented	Don't know	Don't know	Don't know

11. Appendix 2: Results from the questionnaire

The questionnaire is based on a theoretical assignment of roles and is titled ”Roles and Responsibilities for Deploying C-ITS”

- Sent to approximately to 90 individuals around the world.
- At least 40 autoreplies” I am on vacation”
- At least 10 replies” I am no expert” so no filled in questionnaire.
- Answers from 17 %, approximately 20 respondents
- Good diversity sector wise (Road authority, academia, consultancy…).

The questionnaire was answered by individuals from the following countries:

- Spain
- Switzerland
- Austria
- Sweden
- Germany
- Norway
- UK
- Finland
- Denmark

Representing the following types of organisation:

- Transport/Road authority
- Transport operator/company
- Public administration
- Drivers’ association/consumer association
- Consultancy
- Academic institution/Research

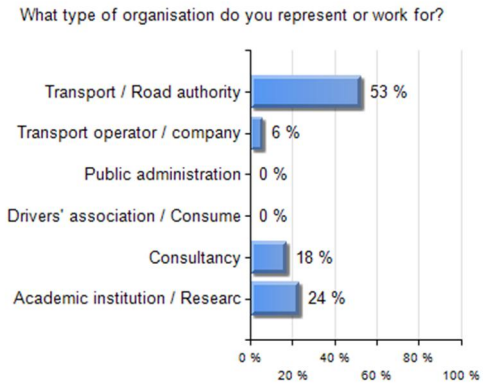

Figure 34 What type of organisation do you represent or work for?

11.1. Road administrators' responsibilities for communication solutions for C-ITS

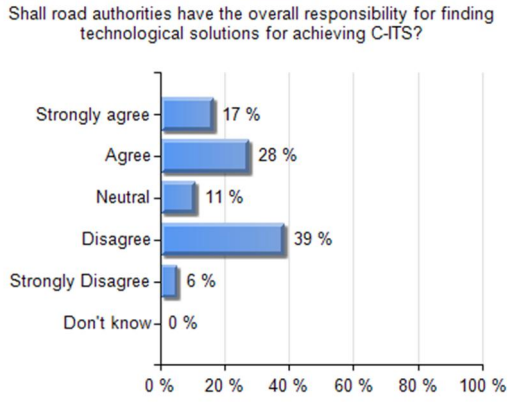

Figure 35 Shall road authorities have the overall responsibility for finding technological solutions for achieving C-ITS?

One comment was "Will support private companies in finding the most appropriate solutions".

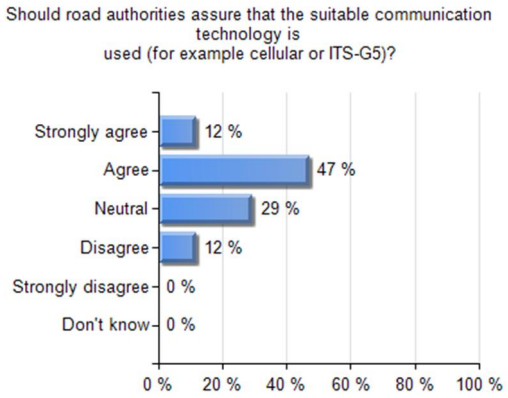

Figure 36 Should road authorities assure that the suitable communication technology is used (for example cellular or ITS-G5)?

Figure 37 Should road authorities together with other stakeholders have a common responsibility for deploying hybrid communication solution?

One comment stated, “Road authorities don't have the responsibility for the deployment of communication solutions, but services.”

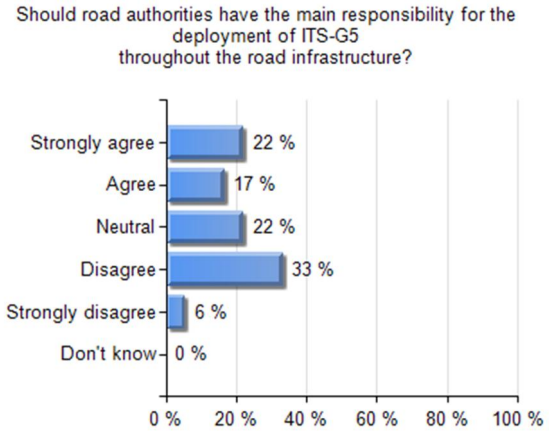

Figure 38 Should road authorities have the main responsibility for the deployment of ITS-G5 throughout the road infrastructure?

One comment stated “Certainly "Agree" regarding "publicly owned" road infrastructure, e.g. VMS and traffic lights - but this does not exclude additional "private" roadside infrastructure, e.g. for specialized services or offering backend connectivity”.

Another comment stated, “If needed for service deployment, a clear yes”.

And one more commented read “My problem is the word "throughout"”.

11.2. ITS-G5

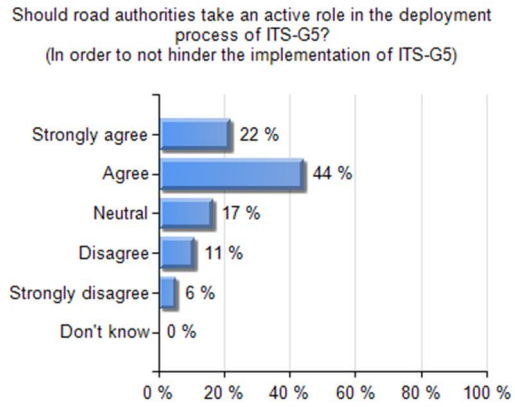

Figure 39 Should road authorities take an active role in the deployment process of ITS-G5?

11.3. Roles and responsibilities

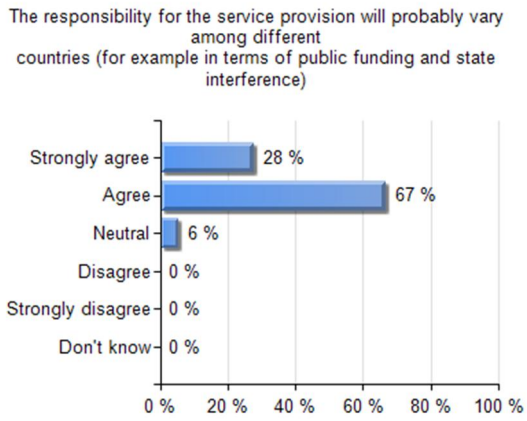

Figure 40 The responsibility for the service provision will probably vary among different countries (for example in terms of public funding and state interference)

One individual responded, “But not desired”.

Another comment stated that “The responsibility for providing safety critical services will be with road authorities. Comfort services will be with different stakeholders. So a high variety can be expected.”

11.4. Strategy

The questionnaire asked the following question, “What type of strategy do you believe would be needed?”

The options to select from were:

- More state funding and/or involvement to accelerate the deployment of selected C-ITS services
- Facilitating collaboration between government, industry and academia
- Facilitating collaboration with civil society
- Adopting an international strategy on C-ITS (for example on EU-level)
- Setting standards and specifications for the deployment of selected C-ITS services
- Mandating in-vehicle (communication) equipment

- No comment

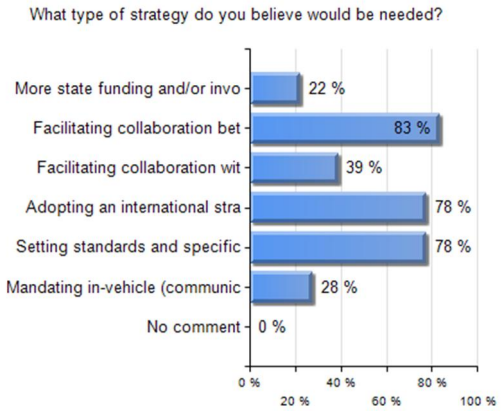

Figure 41 What type of strategy do you believe would be needed?

There were many varying comments to the question. One person stated that, “I see above options as results or best practises. Since thorough testing is required, it cannot be a "top-down" strategy only, but needs to account for "bottom-up" experiences. “Another comment stated that “All kinds of cooperation are needed”. While another comment read “Together with other stakeholders facilitate incentive driven deployment.” Yet another comment read “The road authorities should focus on reducing barriers to use of C-ITS technology that helps the achieve their goals, traffic safety, mobility and environmental goals.”

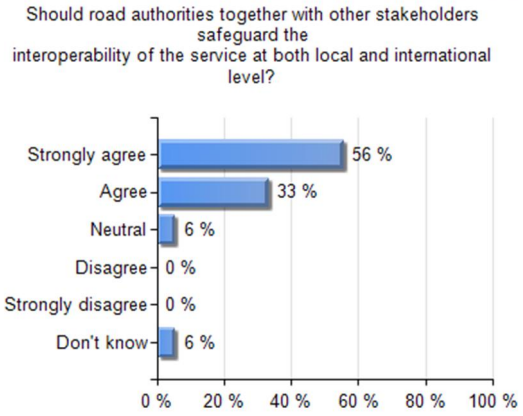

Figure 42 Should road authorities together with other stakeholders safeguard the interoperability of the service at both local and international level?

One comment read, “Should is too weak. A shall or must would be the right word.”

11.5. Day 1 services

This section focuses on the roles and responsibilities of road administrators for Day 1 services. The following answers were gathered.

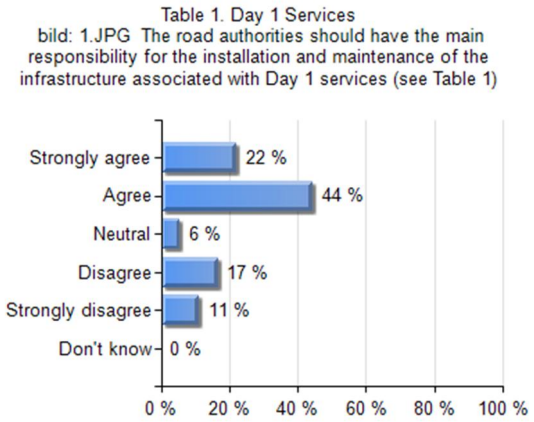

Figure 43 The road authorities should have the main responsibility for the installation and maintenance of the infrastructure associated with Day 1 services

One comment stated “Deploying road infrastructure and updating backend systems like TCC/TMC - Yes! Does not preclude installation of additional private infrastructure, e.g. at petrol stations or parking lots.”

Another comment read, “Responsibility should be shared between all stakeholders.”

One more comment read, “When it concerns the I2V services of this list.”

And yet another comment read, “If the infrastructure in question is cellular, the road authorities have no role at all in its installation.”

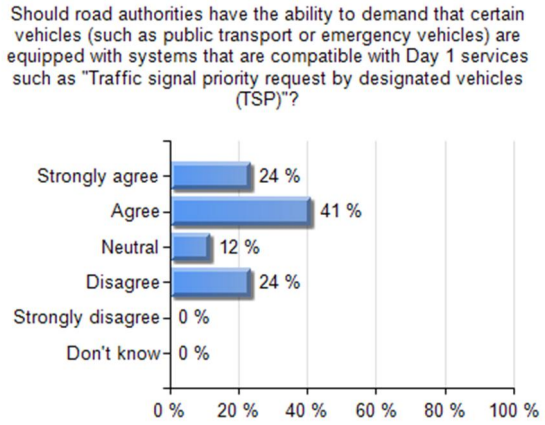

Figure 44 Should road authorities have the ability to demand that certain vehicles (such as public transport or emergency vehicles) are equipped with systems that are compatible with Day 1 services such as "Traffic signal priority request by designated vehicles (TSP)"?

One comment read, "Should" is a good phrase - realistically there is hardly any measure to enforce this quickly."

Another comment read, "But not only ITS-G5 systems"

And yet another comment stated, "This will depend which capacity a road authority normally has."

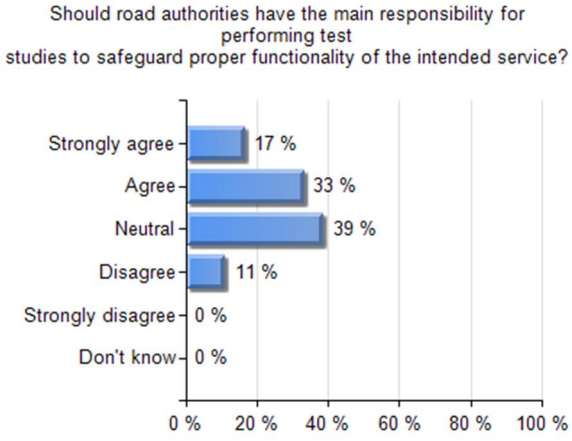

Figure 45 Should road authorities have the main responsibility for performing test studies to safeguard proper functionality of the intended service?

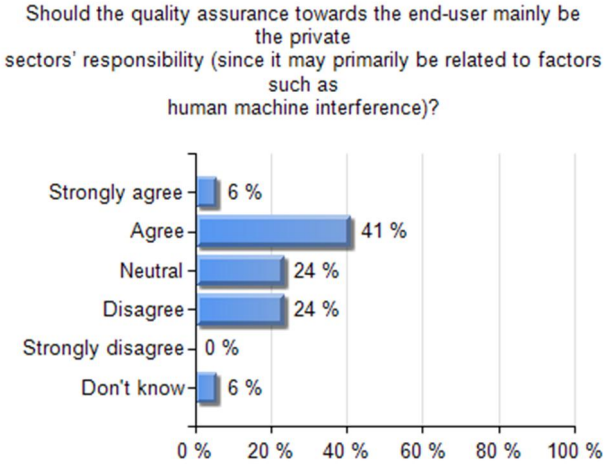

Figure 46 Should the quality assurance towards the end-user mainly be the private sectors' responsibility (since it may primarily be related to factors such as human machine interference)?

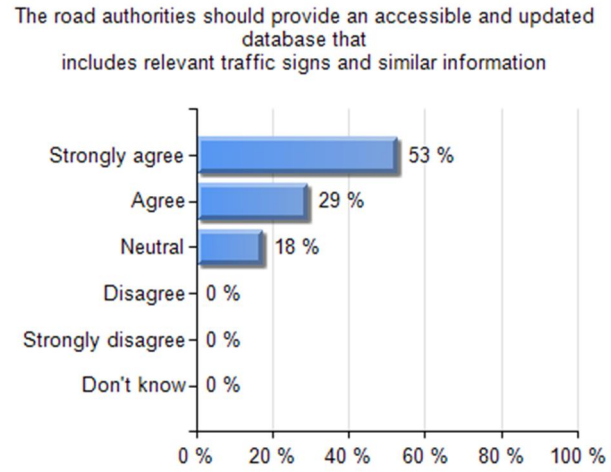

Figure 47 The road authorities should provide an accessible and updated database that includes relevant traffic signs and similar information

One comment read, ""Should" - but this won't happen in the near future".

Another comment stated, "Including updates/signal detection from private stakeholders".

One more comment read “It is not about databases. It is about data and service feeds. C-ITS is about dynamic information. Static information as stored in databases has in principle nothing to do with C-ITS (C-ITS services need also to work with non-accurate maps...”.

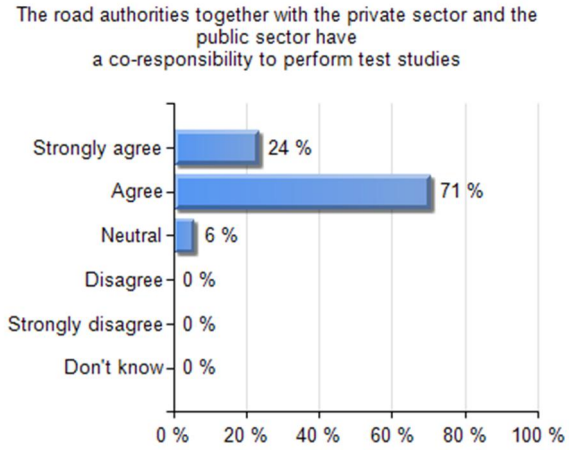

Figure 48 The road authorities together with the private sector and the public sector have a co-responsibility to perform test studies?

One comment read,” what is meant by studies? I expect field tests and pilots that are performed together.”

11.6. Day 1,5 services

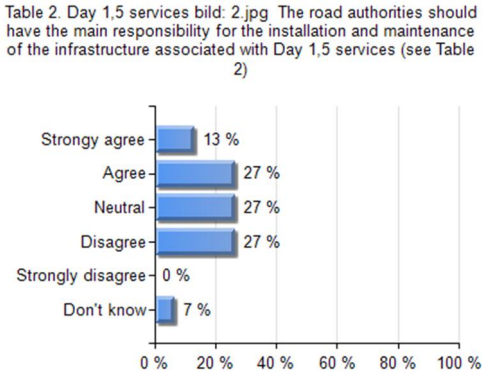

Figure 49 The road authorities should have the main responsibility for the installation and maintenance of the infrastructure associated with Day 1,5 services.

One comment stated “This depends on what is considered as infrastructure. For cellular services, there is a limited need for roadside equipment.”

Another comment stated “As Day 1,5 is not defined in detail, it is currently difficult to decide, if a deployment will take place or not. For all C-ITS related issues, it is always good to refer to the C-Roads Platform.”