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D.3.2 ITS Knowledge Database

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Project funded by the European Union’s Horizon 2020 Research and Innovation Programme (2014 – 2020)
Abstract

This deliverable (D3.2) reports the outcome of Task 3.2 and consists of the ITS knowledge database of studies. The ITS knowledge base of studies is composed of nine independent topic studies aiming to describe the current state of the art on ITS and C-ITS.
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## Abbreviations and Acronyms

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<th>Definition</th>
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<tr>
<td>BCR</td>
<td>Benefit-Cost Ration</td>
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<tr>
<td>CAM</td>
<td>Cooperative awareness message</td>
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<td>CBA</td>
<td>Cost-benefit analysis</td>
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<td>CEA</td>
<td>Cost-efficiency analysis</td>
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<td>CEN</td>
<td>European committee for standardisation</td>
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<td>C-ITS</td>
<td>Cooperative intelligent transport systems</td>
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<tr>
<td>C-V2X</td>
<td>Cellular vehicle-to-everything</td>
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<td>DENM</td>
<td>Decentralized environmental notification message</td>
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<td>EC</td>
<td>European Commission</td>
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<td>ETSI</td>
<td>European Telecommunications Standards Institute</td>
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<td>EU</td>
<td>European Union</td>
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<td>GDPR</td>
<td>General data protection regulation</td>
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<td>GLOSA</td>
<td>Green light optimal speed advisory</td>
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<td>GSM</td>
<td>Global system for mobile communications</td>
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<td>ICT</td>
<td>Information and communication technologies</td>
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<td>IRR</td>
<td>Internal return rate</td>
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<td>ISO</td>
<td>International Organization for Standardization</td>
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<td>ITS</td>
<td>Intelligent transport systems</td>
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<tr>
<td>I2V</td>
<td>Infrastructure-to-vehicle</td>
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<tr>
<td>MaaS</td>
<td>Mobility as a Service</td>
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<tr>
<td>MCA</td>
<td>Multi-criteria analysis</td>
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<tr>
<td>NPV</td>
<td>Net present value</td>
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<td>P2W</td>
<td>Powered two wheelers</td>
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<tr>
<td>PCP</td>
<td>Pre-Commercial Procurement</td>
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<tr>
<td>PPI</td>
<td>Public Procurement of Innovative solutions</td>
</tr>
<tr>
<td>PPP</td>
<td>Public-private partnerships</td>
</tr>
<tr>
<td>SDO</td>
<td>Standards development organizations</td>
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<tr>
<td>TMC</td>
<td>Traffic management control</td>
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<tr>
<td>TS</td>
<td>Topic study</td>
</tr>
<tr>
<td>VRU</td>
<td>Vulnerable road user</td>
</tr>
<tr>
<td>WP</td>
<td>Work package</td>
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<td>3GPP</td>
<td>3rd generation partnership project</td>
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Executive Summary

The Collaborative cApacity Programme on Its Training - educAtion and Liaison (CAPITAL) aims to design and deliver a collaborative capacity building programme comprising of training and education in the field of ITS and C-ITS. The project consists of five work packages. The aim of Work Package (WP) 3 is to provide a common framework for the ITS deployment programme based on the knowledge gaps identified in WP2. The deployment programme will then be implemented and tested in WP4.

This deliverable (D3.2) reports the outcome of Task 3.2 and consists of the ITS knowledge database of studies. This consists of nine independent topic studies aiming to describe the current state of the art on ITS and C-ITS. The educational and informational material of the capacity development programme (Task 3.3) will be developed based on the topic studies. The included topics are:

- Introduction to ITS and C-ITS
- ITS and C-ITS user services
- TMC and roadside technologies for ITS
- Communication technologies for ITS and C-ITS including relevant standards
- Impact assessment of ITS and impacts of selected ITS and C-ITS systems
- Financial incentives, business models and procurement models for C-ITS deployment
- Cost-benefit analyses of ITS services
- Guidance in deploying ITS and C-ITS
- Data protection and privacy.

The topic studies were mainly carried out as literature reviews. The topic studies address all three stakeholder types; 1st level ITS start-up communities, 2nd level intermediary communities and 3rd level ‘train the trainer’ for professional users. The educational and informational material will be customized to the three levels of ITS deployment. The responsibility for the topic studies were distributed among the partners. To harmonise the work, the partners were provided with instructions for carrying out the topic studies and a template for the topic studies. The topic studies are both internally and externally peer reviewed.

This deliverable presents a summary from each individual topic study. The complete version of the finalised topic studies are included as annexes. The topic studies can be updated in the end of the project based on any additional material published during the project.
1 Introduction

1.1 Background

Intelligent transport systems (ITS) can be understood as the application of information and communication technologies (ICT) to transport. During the recent years, the development of ITS technologies has been fast, and many systems have been widely deployed. Cooperative ITS (C-ITS) is the next step in ITS development. C-ITS provides services based on wireless communication between vehicles, other road users, roadside units and back-office systems. The European Union (EU) has been supporting the development and deployment of C-ITS by granting funding for developing and testing systems, products and services, hardware and software for ITS and C-ITS. Linking the vehicle with the transport infrastructure is also one priority area in the “ITS Action Plan” of the European Commission (EC). Deployment of ITS and C-ITS and exploitation of the above-mentioned projects’ results is dependent on the involved stakeholders’ knowledge and awareness on the systems and their benefits.

The Collaborative Capacity Programme on ITS Training - educAtion and Liaison (CAPITAL) - project is a support action in the Horizon 2020 Work Programme of the EU. CAPITAL aims to address the current gap between research and deployment of ITS and C-ITS, by increasing the skills and knowledge of the involved stakeholders. The aim of the project is to design and deliver a collaborative capacity building programme comprising training and education in the field of ITS and C-ITS deployment for the public and private sector.

The first phase of the project was to assess the current knowledge gaps and needs of the involved stakeholders (Figure 1). In the second phase, the strategies for the capacity development will be developed as well as the background and educational material for the capacity development programme. Then the capacity development programme will be tested and adjusted as necessary (Phase III). The fourth phase involves evaluating the developed capacity development programme.

![Figure 1. Structure of the CAPITAL project.](image-url)
The project consists of five work packages and the third one concerns the ITS deployment programme and knowledge base (Phase II in Figure 1). The aim of the work package is to:
- design the capacity development program (Task 3.1, reported in Woroniuk et al. 2017)
- develop an ITS knowledge base of studies (Task 3.2)
- develop the educational and information material for the capacity development programme (Task 3.3)
- develop strategies for capacity development (Task 3.4, reported in Iordanopoulos et al. 2017).

The ITS knowledge base of studies consists of independent topic studies describing the current state of the art on the topic in question. The educational and informational material of the capacity development programme (Task 3.3) is developed based on the topic studies. The studies covers the following topics:
- Introduction to ITS and C-ITS
- ITS and C-ITS user services
- TMC and roadside technologies for ITS
- Communication technologies for ITS and C-ITS including relevant standards
- Impact assessment of ITS and impacts of selected ITS and C-ITS systems
- Financial incentives, business models and procurement models for C-ITS deployment
- Cost-benefit analyses of ITS services
- Guidance in deploying ITS and C-ITS
- Data protection and privacy.

The responsibility for the topic studies is allocated among the project partners. To harmonise the writing process and avoid overlap, the topic studies addresses all the three stakeholder types:
- 1st Level - ITS start-up communities
- 2nd Level - advanced and intermediary communities
- 3rd Level - train the trainer/highly experienced communities.

The educational and informational material is accommodated to the three stakeholder types.

1.2 Purpose of D3.2

The purpose of the deliverable is to report the outcome of Task 3.2 and summarise the information available on ITS and C-ITS. This was done by performing nine topic studies on the current state of the art of ITS and C-ITS technologies and deployment. The deliverable will serve as input for the Task 3.3 where the educational and informational material will be developed for the capacity development programme.

1.3 Structure of D3.2

The deliverable has the following structure: Chapter 2 presents the methods used to carry out the topic studies and Chapter 3 presents a summary of each topic study. The main findings and are discussed in Chapter 4. Chapter 5 discusses the conclusions and next steps. Annex 1–9 includes the complete version of the nine independent topic studies.
2  Methods

The topic studies provide a timely, comprehensive and consistent overview on the topic and support the preparation of the CAPITAL study modules. In total nine topic studies were carried out. To distribute the work, the responsibility for the topic studies were distributed among the partners. The final list of topic studies and the partners responsible for the topic studies and for the internal peer review are presented in Table 1.

Table 1. Distribution of work and aim of the topic studies.

<table>
<thead>
<tr>
<th>Topic study</th>
<th>Lead partner</th>
<th>Peer reviewer</th>
<th>Aim of the topic study</th>
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<tbody>
<tr>
<td>ITS1 - Introduction to ITS and C-ITS</td>
<td>UNEW</td>
<td>TTS Italia</td>
<td>Introduce and describe ITS and C-ITS terminology and abbreviations as well as the relevant stakeholders in the field. Introduce the policy framework and benefits from ITS and C-ITS. Describe the difference between C-ITS and ITS.</td>
</tr>
<tr>
<td>ITS2 - ITS and C-ITS user services</td>
<td>IRU/ITS United Kingdom</td>
<td>Austria Tech</td>
<td>Describe available ITS and C-ITS services for both professional and normal drivers. User acceptance and dissemination of ITS and C-ITS systems to the public.</td>
</tr>
<tr>
<td>ITS3 - TMC and roadside technologies for ITS</td>
<td>ITS United Kingdom</td>
<td>Austria Tech</td>
<td>Describe traffic management control and roadside technologies utilised in ITS systems. Technologies included: event detection, transport data collection, aggregation and management of transport data, incident management and dynamic transport data.</td>
</tr>
<tr>
<td>ITS4 - Communication technologies for ITS and C-ITS including relevant standards</td>
<td>VTT</td>
<td>ICCS</td>
<td>Describe communication technologies utilised in ITS and C-ITS systems. Introduce the standardisation of ITS and C-ITS systems and the relevant standardisation organisations. As well as the interoperability, testing and certification process of ITS and C-ITS systems.</td>
</tr>
<tr>
<td>ITS6 - Financial incentives, business models and procurement models for C-ITS deployment</td>
<td>VTT</td>
<td>DfT</td>
<td>Give an overview of financial incentives, business models and procurement models for C-ITS. As well as describing the stakeholder perspectives on business and procurement models. C-ITS ecosystems and their governance is also introduced.</td>
</tr>
<tr>
<td>ITS7 - Cost-benefit analyses of ITS</td>
<td>IRU</td>
<td>CERTH</td>
<td>Describe methods for determining costs and benefits of C-ITS. Costs include both installation, operation and maintenance of the systems.</td>
</tr>
<tr>
<td>ITS8 - Guidance in Deploying ITS and C-ITS)</td>
<td>Ertico</td>
<td>City of Helmond</td>
<td>Present best practices and lessons learnt from previous projects and pilots. Service implementation characteristics of employed hardware and software (C-ITS). Information on</td>
</tr>
<tr>
<td>ITS9 - Data protection and privacy</td>
<td>FIA</td>
<td>ICCS</td>
<td>Describe information security, user privacy and protection in the context of C-ITS.</td>
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The topic studies will support the preparation of the CAPITAL study modules in several ways. To harmonise the contents and layout of the topic studies, the partners were provided with 1) instructions for carrying out the topic studies, 2) template for the topic studies and 3) template for collecting the sources for the topic studies. All topic studies are expected to provide the following contributions to the development of corresponding study modules:

- define the terminology of the topic(s) in a clear and unambiguous way
- build a timely, comprehensive and consistent overview of the topic(s) covered by the study
- provide a summary of the most important literature of the topic
- provide references to the material which can be used for creating study modules on the topic

Literature studies and internet searches were used to collect information for the topic studies. In addition, other methods could be used to collect information for the topic studies e.g. targeted interviews of core stakeholders or selected experts. The expected length of a topic study was 20–50 pages.
3 Topic studies

The ITS Knowledge database is based on the topic studies carried out in Task 3.2 in WP3. The topic studies will form the base for the educational and informational material developed in Task 3.3. In total nine topic studies were carried out. Next a short (1–2 page) summary will be presented for each topic study. The complete version of the topic studies can be found in Annexes 1–9.

3.1 Introduction to ITS and C-ITS (UNEW)

‘Introduction to ITS and C-ITS’ is a topic study designed for anyone who wants to understand the fundamentals of ITS and C-ITS, especially beginners in the field and public-sector decision makers. The aim is to provide an overview of broad aspects of ITS and C-ITS, and to prepare students for the more detailed future study modules produced by CAPITAL. The topic study draws on existing lecture material, in particular from Newcastle University’s Master of Science (MSc) courses, a range of other referenced sources, and significant examples of European deployment projects and platforms in C-ITS. The topic study is set out as follows.

Intelligent Transport Systems (ITS)
The first part of the topic study focus on ITS. Firstly, a selection of accepted definitions is provided before examples of the application of ITS in different transport environments are presented. Three different categories of ITS application are identified:

- **Infrastructure-based systems** that include e.g. road user charging, variable message signs (VMS) and managed motorways. Infrastructure-based systems use short range and long range ICT as well as conventional communication technologies to contribute to goals of sustainability and accessibility, through the provision of the right information, at the right time and in the right place.

- **Vehicle-based systems** include e.g. blind spot monitoring, navigation systems and eco driving. Vehicle-based systems use telematics and in-vehicle technologies to contribute to high level goals of safety and sustainability.

- **Public transport systems** include e.g. journey planning, smart ticketing and smart cards. Public transport systems use Global System for Mobile Communications (GSM) technologies to contribute towards the overall goal of increased awareness and connectivity, promoting a more reliable and usable service to customers and better fleet and system operations.

The importance of ITS as a component in other broader concepts (transport and multi-sector) is emphasised. Such concepts include Connected and Autonomous Vehicles; Smart Cities; Mobility as a Service (MaaS); and, Integrated Transport.

Finally, the European legal framework (Directive 2010/40/EU) that underpins ITS is explained (European Union, 2010).

Cooperative Intelligent Transport Systems (C-ITS)
The main part of the topic study focuses on C-ITS. Firstly, a selection of accepted definitions is provided. Then, a brief overview is provided of the communications infrastructure and standards, along with the evolution in terms of the key phases of C-ITS development since the early 2000s. The topic study moves on to look more closely at the benefits and beneficiaries of C-ITS, that is, who benefits and in what way. The tangible benefits of C-ITS are introduced:

- Road network efficiency, for example to enable better implementation of traffic
management policies such as public transport or emergency vehicle priority

- Operational efficiency, for example for freight or public transport, giving greater service reliability, enhanced customer satisfaction, and operational savings
- Road safety for all users, for example the provision of alerts to drivers notifying them of a nearby vulnerable road user (VRU) such as a pedestrian or cyclist
- Environmental conditions, for example the provision of in-vehicle speed advice to encourage eco-driving with fewer brake events and thus reduced emissions

The next key part of the topic study investigates the services that can be provided as part of a C-ITS deployment. Specifically, the work of the Amsterdam Group and C-ITS Platform to define ‘Day 1’ and ‘Day 1.5’ services is presented (Amsterdam Group n.d. and C-ITS Platform 2016).

Following on from this, the concept of service bundling is introduced, that is, the idea of bundling services with other similar services to gain extra benefits. Examples include:

- Services to improve Efficiency: Green priority (selected vehicles); parking (selected vehicles); flexible infrastructure (e.g. peak hour lanes); in vehicle signage; mode / trip time advice; probe vehicle data
- Services to improve Safety: Road hazard warning; red light violation warning; pedestrian warning; powered two wheeler (P2W) / cycle detection; blind spot detection; emergency vehicle warning; road work warning
- Services to improve the Environment: Green light optimal speed advisory (GLOSA); eco-driving; speed advice

The topic study continues by presenting a range of important considerations for stakeholders who may be planning a C-ITS deployment. Firstly, is C-ITS better than ITS? This builds on the distinction between ITS and C-ITS, which can often lack clarity. Attempt is made to distinguish between ITS and C-ITS in the topic study and materials, whilst the clear advantages of C-ITS are explained:

- Fully connected technology for travellers, vehicles and infrastructure
- A rich choice of cooperative services for safety, network efficiency, and the environment
- Universal availability for every vehicle, and every traveller
- Ubiquitous coverage for every city, and every highway
- An open interoperable platform encompassing on-board units, roadside infrastructure and personal devices.

In the final part of the topic study, practical examples of C-ITS are provided, based primarily on existing national and EU-funded projects. Check lists of important considerations for deploying entities are also provided. These are elaborated in subsequent CAPITAL topic studies.

3.2 ITS and C-ITS user services (IRU/ITS United Kingdom)

This topic study compiles up-to-date information regarding the benefits, use cases, references, examples, and user acceptance of user services in Intelligent Transport Systems (ITS) and Cooperative ITS (C-ITS) for both professional and non-professional drivers and how
to communicate this information to the public (Annex 2).

Many ITS services use the sensors of the vehicle to monitor the driver, the vehicle, and the environment to warn the driver against dangerous situations. For example, speed alert systems monitor the current speed of the vehicle and the speed limit to warn against speeding. Blind spot information systems use sensors to scan areas the driver is unable to see in order to warn and prevent collisions during, for example, lane changes. Similarly, on the traffic management and control side, dynamic traffic management and local danger warnings allow the authorities to relay information to the road users about disturbances, accidents, road conditions and so on.

Other ITS services use the information at their disposal to guide the driver towards more optimal driving strategies. Eco-driving assistance monitors energy consumption and driving style to offer guidance for more economic driving, whereas dynamic navigation systems and advanced traveller information systems offer more optimal routes during the journey as they relay and process information regarding situations that can affect travel time, such as traffic jams and road closures.

Lastly, certain IVS services can, in addition to warning the driver about dangerous situations, perform corrective actions on behalf of the driver. Lane departure warning systems can monitor the lane markings to alert and make corrective steering manoeuvres against unintentional lane departures. Obstacle and collision warning systems together with emergency braking monitor the objects around the vehicle to predict if the vehicle is on a collision course. Corrective braking manoeuvres can be applied automatically to prevent these collisions. eCall reduces the time to accident by automatically relaying information to the emergency call centres in case the accident has occurred. Automatic actions more common in everyday driving are performed by, for example, adaptable headlights, which change the angle of the headlights for better illumination in cornering and for reducing glare to upcoming vehicles.

C-ITS services can provide information about other road users or the environment ahead to the vehicle even before the vehicle is in the situation where it could use its own sensors. Thus, it allows for warnings, guidance, and corrective actions earlier and with more precision than with the above mentioned ITS services. The information can come from road-side infrastructure or from other vehicles on the road. They are in many cases more developed iterations of the ITS services, that require closer presence to the situation and good conditions (e.g. bad weather or motorcycle occluded by a truck). The C in C-ITS mitigates this requirement.

By enabling a communication channel between road infrastructure and the vehicle, C-ITS services can provide the user with information about the route they are taking, such as warning them about upcoming road works, hazards, slow or stationary vehicles, congestion or other road conditions, or weather conditions, and real-time actual information about the contents of the traffic signs along the road provided by a trusted source. Emergency vehicles could themselves send warning signals to other vehicles on the road, so that they have more time to plan how to give way to the emergency vehicle.

Other C-ITS services aim to optimize the trips further. Green Light Optimal Speed Advisory system relays information about the timing of the traffic lights to optimise the speed at which the driver should approach the lights for smoother passing. Urban and motorway parking availability informs the vehicle about free parking places, services at the parking lot (capacity, equipment, limitations, security, etc.), and could automatically pay parking fees. C-ITS parking services enhance existing processes, such as rest-time management of truckers, by offering the parking information automatically at a relevant frequency.
Cooperative Adaptive Cruise Control is the next step in cruise control technology and allows vehicles to synchronize their motion in a platoon by communicating trajectory related information between the vehicles.

Certain C-ITS services adapt features of the road network based on the vehicles on the road. For example, the green priority service changes the status of traffic signals when emergency or public transportation vehicles approach it. Similarly, cooperative traffic lights for vulnerable road users (VRUs) monitor the conditions at the junction and the VRUs using it and can warrant priority or change the crossing time based on the data. Dynamic lane management can change the status of auxiliary, reserved, or reversible lanes based on the real-time traffic conditions and propagate the information about the status change to the vehicles on the road. Similar process applies to dynamic road signs.

The European Commission’s work has produced a list prioritising C-ITS services to be delivered based on the amount of benefits to drivers and the ease of delivery starting from hazard warnings and advisory services. With time, more intelligent, advanced, and dynamic services will be implemented.

There is little information regarding user acceptance of C-ITS services. Thus, user views on the wide range of advanced driver assistance systems (ADAS) have to be used to gain some insight on how the general public will embrace cooperative ITS services. Besides, C-ITS services may not appear very different to the user than more traditional ADAS. If the new services do not radically alter individual driver experiences and the information provided is accurate and timely, it is likely that the public will welcome C-ITS, as they have welcomed ADAS, which are now popular and desirable.

In general, ITS is poorly understood by the public. Campaigns for raising awareness should be held to increase user acceptance and to keep members of a democratic society in the known on how the publicly funded services work and why they are deployed. However, nobody seems to take the responsibility for public communication. It is recommended that the transport authority would communicate developments to the public, but the private sector would also benefit from people being more knowledgeable about the new services, as it can increase demand, but also translates to a better supply of potential workers. The information campaigns produced should recognise the concerns and fears of the public, explain why they are unfounded, and highlight the benefits of ITS and C-ITS services.

3.3. TMC and roadside technologies for ITS (ITS United Kingdom)

This topic study introduces and gives an overview on the principle of traffic management and control (TMC) carried out by Intelligent Transport Systems (ITS) (Annex 3).

Traffic is typically managed and controlled by collecting information from the road network with cameras, loops, and other sensors and processing the data for the Traffic Control Centre, who uses a variety of tools to effectively achieve its objectives. The objectives of urban traffic management are in part straightforward (e.g. minimise congestion and increase safety for road users), but are likely to be partly political (e.g. prioritising some modes of transport over others).

A key role for ITS is in integrated traffic management, which seeks to combine multiple ways of managing and controlling traffic into new innovative operational systems. For example,
combining information systems, speed control, adaptive traffic signal control, and weather information can lead to an integrated system that can deliver greater improvements to air quality than the sub-systems could on their own.

The increasing number of data sources, advanced methods for aggregation and fusion of data, and improved means of telecommunication have opened up new possibilities in collaborative connecting of road and vehicle technologies. With Cooperative Intelligent Transport Systems (C-ITS) urban traffic management and control is entering a new era. Systems where the road user and their vehicle communicate with the road operator, the infrastructure and with other vehicles will continue to improve upon the integrated methods. In essence, existing ITS services can be developed into C-ITS services using available technology.

This is exemplified in the public transport sector, where ITS is well established with automatic vehicle location (AVL), smart ticketing systems, surveillance and security systems. The rudimentary beginnings of C-ITS principles are already present as integrating these systems with each other and with vehicle-sourced and passenger-sourced data has clear potential for a system and an agreement that benefits all parties involved.

Data sharing is one of the barriers for C-ITS service employment, as vehicle manufacturers might not immediately see sharing vehicle-sourced data with authorities as an attractive opportunity for them. Instead, they might prefer developing a private third-party system as a selling point for their customers. Furthermore, vehicle occupants might be hesitant to share data sourced from them when driving private vehicles. In the public transport scenario, these issues are less obstructive.

Other barriers include integrating C-ITS system with existing legacy systems, high investments and running costs, and a lack of knowledge and awareness of C-ITS systems and their benefits amongst local authorities, the public, and relevant stakeholders. This necessitates the creation of standards and interoperability specifications, public awareness campaigns, and addressing local policy goals and demonstrated traffic challenges. Thus, successful adoption of C-ITS requires both technical, non-technology-led, and policy-led approaches.

### 3.4 Communication technologies for ITS and C-ITS including relevant standards (VTT)

This topic study (Annex 4) provides background information for the CAPITAL study module “Communication technologies for ITS and C-ITS including relevant standards”. Due to the large number and variability of ITS systems available, this topic study provided a view to a limited number of ITS and C-ITS services as examples and focused on communication technologies and standards behind the ITS applications and especially C-ITS services.

ITS is already on the market and it has been utilized for many years to support safer, cleaner and more efficient transport. There are numerous ITS applications on the market and there are some variations in their implementations and use between different countries. However, there are certain types of ITS applications used by the consumers (or the drivers) and others focused more on the traffic management purposes. The ITS applications traditionally have utilised available general communication technologies like fixed networks, broadcast radio and cellular networks.

The standards for the first C-ITS services have been completed and they are currently being
piloted e.g. in European corridor projects. The commercial deployment of the Day-1 C-ITS services in Europe is starting soon. The architecture for the C-ITS is defined in European Telecommunications Standards Institute (ETSI) standards. These standards provide the global communication architecture for C-ITS and specify mandatory and optional elements and interfaces. C-ITS architecture allows use of several communication technologies, but the standardisation work has been focusing on the short-range ITS-G5 technology.

The communication technologies for C-ITS can generally be specified as “short-range” and “long-range” communication networks. For time-critical safety C-ITS applications equipped vehicles communicate with their close environment via the short-range ITS-G5 / IEEE 802.11p protocol. The low-latency signal is broadcasted from a vehicle or a roadside unit with ranges between 300 and 500 meters. Broadcast messages is received and processed by other vehicles and roadside units and in the future by personal devices. In addition to ITS-G5, 3GPP has recently specified the Cellular Vehicle-to-Everything (C-V2X) communication for both direct short-range communication (e.g. between vehicles) and for long-range cellular communications with networks.

The long-range communication in C-ITS is usually implemented by cellular networks with different generations of technology. The cellular technologies are used for connecting vehicles to infrastructures via cloud services and backend interfaces (vehicle-to-network). Currently, the most likely hybrid communication mix for C-ITS deployment of the first C-ITS services is a combination of ETSI ITS-G5 and existing cellular networks (3G, 4G, LTE).

There are several message services specified for C-ITS. The most important ones are the Cooperative Awareness Message (CAM) and the Decentralized Environmental Notification Message (DENM) services. CAMs is to inform others about status and presence of the sender (e.g. vehicle). DENM contains information related to a road hazard or an abnormal traffic condition.

The communication technologies for C-ITS are based on standards which are developed by the Standards Development Organizations (SDO). ETSI CEN (the European Committee for Standardization) and ISO (International Organization for Standardization) as well as the 3GPP (3rd Generation Partnership Project) since they produce the most C-ITS standards relevant for the European market. The interoperability of C-ITS components from various vendors cannot be guaranteed only with standards. The standards cannot be used without alignment and agreement among the stakeholders. These decisions are captured within a Profile. A profile includes the minimum set of requirements, referencing to the standards used. The C-Roads Platform is working towards a common C-ITS profile in order to achieve interoperability. The first release of the harmonised communication profile for C-ITS services has been published in 2017. This profile is based on the IEEE 802.11p/ETSI ITS-G5 short range communication and I2V (Infrastructure-to-Vehicle) communication for Day-1 C-ITS services.

### 3.5 Impact assessment of ITS and impacts of selected ITS and C-ITS systems (CERTH/ VTT)

The objective of the topic study (Annex 5) was to provide a timely, comprehensive and consistent overview of ITS impact assessment methods and frameworks as well as the safety, environmental and traffic efficiency impacts of selected ITS and C-ITS systems at the European level. A literature study was carried out around six subtopics: evaluation methods, ITS evaluation frameworks, considerations in ITS service evaluation, criteria for an effective ITS and C-ITS evaluation methodology, data collection for ITS impact assessment and the
FESTA handbook for ITS impact assessment.

Various methods exist for evaluation of ITS and C-ITS projects. The methods differ in terms of the level of complexity and the results they deliver. The main problem with evaluation of ITS projects is that all evaluation methods require a significant amount of data which is difficult to collect due to the evolving nature of ITS projects. It is important to choose the right method for evaluating an ITS project. The method to be applied has to maintain a balance between the complexity and cost of evaluation and the cost of the potential project. The complexity of the evaluation also depends on the purpose of the evaluation results. For example, calculating the net worth of the project for society is a more complex task than performance measurement.

Cost-benefit analysis (CBA) is the most commonly used method for evaluation of ITS and C-ITS projects. The cost-benefit ratio can be incorporated in a goal-based evaluation framework where it will serve as one of the indicators of the evaluation framework. In practice, this leads to the use of multi-criteria analysis (MCA) analysis. Cost-efficiency analysis (CEA) can be used to compare ITS and C-ITS projects when a defined service impact is expected, and information is available on the costs of the projects. (e.g. Newman-Askins et al. 2003).

The evaluation process consists of a number of steps from clarifying the evaluation background to implementing the evaluation data collection program and implementation of the chosen evaluation framework (e.g. Hills and Junge 2010, Tarry et al. 2012). Two different evaluation approaches are described: goal-oriented approach and the economic analysis approach (e.g. Turner and Stockton 1999, Peng et al. 2000, Mehta et al. 2001, Kulmala et al. 2002, EC 2010, Kaparias et al. 2011). Both the goal oriented approach and the economic analysis approach have their limitations. Sometimes, project objectives are not clear, or monetary valuation of impacts may be difficult. The approaches are complementary, and they should be used together or individually when their prerequisites are met. Regardless of the approach, the evaluation should consider the groups affected by the ITS project, evaluation time frame and use of appropriate measures and parameters for evaluation of impacts. The criteria for an effective ITS and C-ITS evaluation methodology is also reviewed briefly as well as the data collection methods for ITS impact assessment.

The study on the impacts of ITS and C-ITS was focused on systems that have previously been identified as priority systems in Europe, which have potential to contribute transport policy objectives and which are sufficiently mature from a technological point of view. For ITS systems, priority systems defined by the iMobility Forum were selected for analysis. For C-ITS systems, the Day-1 systems of the C-ITS Platform were covered by the study. Information on the impacts of ITS and C-ITS systems was collected with a literature study.

The impacts of the following ITS systems were reviewed in the study (iMobility Effects Database, no date (n.d.)):
- eCall
- Real-time travel and traffic information
- Extended environmental monitoring
- Dynamic traffic management
- Speed alert
- Dynamic navigation systems
- Eco-driving coaching
- Local danger warnings
- Adaptive headlights
- Eco-driving assistance
- Blind spot monitoring
- Lane departure warning
- Obstacle and collision warning
- Emergency braking.

The impacts of the following C-ITS systems were summarised in the study (e.g. Kulmala et al. 2008, Kulmala et al. 2012, Malone et al. 2014, C-ITS Platform 2016, Asselin-Miller et al. 2016):

- Hazardous location warning:
  - Emergency brake light
  - Emergency vehicle approaching
  - Slow or stationary vehicle(s) warning
  - Traffic ahead warning
  - Road works warning
  - Weather conditions
  - Other hazardous notifications

- Signage applications:
  - In-vehicle signage
  - In-vehicle speed limits
  - Probe vehicle data
  - Shockwave damping
  - Green Light Optimal Speed Advisory (GLOSA)
  - Signal violation/Intersection safety
  - Traffic signal priority request by designated vehicles.

### 3.6 Financial incentives, business models and procurement models for C-ITS deployment (VTT)

The topic study (Annex 6) aims to give an overview of the financial incentives, business models and procurement models for deploying C-ITS. The study includes the following subtopics: business model frameworks, stakeholder perspectives on business models, governance schemes and data exchange and engagement of stakeholders. The before mentioned aspects are important for C-ITS deployment, since the adoption process presents a multi-actor and multi-dimensional challenge due to interrelations between the supply and demand for C-ITS as well as risks related to investment, technology and acceptance.

A *business model* can be simply said to be the plan and realization of that plan that enables a firm to make money. However, both the academic research and practitioners have gone much beyond such simple view of business models. According to Osterwalder & Pigneur: “a business model describes the rationale of how an organisation creates, delivers, and captures value.” (2010). It can be said “that value proposition, value architecture, value finance, and value network articulate the primary constructs or dimensions of business models.” (Al-Debei and Avison, 2010). In a C-ITS context business models have to move beyond the single firm and work for multi-partner businesses which work together to create, deliver and capture value.

Business ecosystems work for incorporating innovations (Moore 1993) and strengthening their market position by bringing synergies of different companies and public actors together towards a common innovation and share benefit. The common grounding of an ecosystem is the shared fate of the involved actors (market players, customers, regulators) and the need to understand an organization’s own role in the ecosystem (Iansiti and Levien 2004).

Public procurement refers to the process by which public authorities, such as government departments or local authorities, purchase work, goods or services from companies. The European law sets out some minimum rules that are harmonized around the European Union.
and transposed into national legislation. The core principles of these directives are transparency, equal treatment, open competition, and sound procedural management. They are designed to achieve a procurement market that is competitive, open, and well regulated. To deal with challenges different approaches were developed, which should foster the further procurement of innovative solutions namely PPI, PCP, Innovation Partnerships, or the PPP model:

- **Public Procurement of Innovative solutions (PPI)** is used when challenges can be addressed by innovative solutions that are nearly or already in small quantity in the market and don't need new Research & Development (R&D).
- **Pre-Commercial Procurement (PCP)** can be used when there are no near-to-the-market solutions yet and new R&D is needed.
- **Innovation partnerships** were defined in Article 49 of the European procurement directive of 2014 (2014/24/EU) for the first time to enable public authorities to create structured partnerships with a supplier with the objective to develop an innovative product, service or works, with the subsequent purchase of the outcome.
- **Public-private partnerships (PPPs)** are long-term contracts between two units, whereby one unit acquires or builds an asset or set of assets, operates it for a period and then hands the asset over to a second unit.

C-ITS is about creating value and it should be created not only for the carmakers but also to stakeholders around C-ITS context. The value creation questions have been discussed in number of academic and professional works (e.g. Harrison & Wicks 2013, Argandona 2011, Crane et al. 2009, Kochan & Rubinstein 2000, Flak & Rose 2005). The common message is by and large (excluding the criticism towards stakeholder theory) that modern, systemic challenges such as climate change, social justice, equity, environmental concerns, etc. require businesses to adopt a stakeholder approach in their business planning and engineering. For C-ITS the simple fact is that stakeholder approach is no less than absolutely necessary, regardless of whether one views the business potential or the socio-economics of the system or service under consideration.

### 3.7 Cost-benefit analyses of ITS (IRU)

The topic study (Annex 7) aims to prepare a study module on cost-benefit analysis (CBA) for the cooperative intelligent transport system services (C-ITS). It provides a consistent and comprehensive overview of the recent developments of the CBA previously applied to transport projects, in particular, on the deployment of C-ITS services. It briefly discusses methodology (how to conduct a CBA) and what are the requisite elements for this analysis. It also explains key terminology and provides some relevant case studies to understand the advantages as well as limitations of the CBA. This topic study is supported by relevant literature and other materials that can be used in the study module.

The study tackles four key questions defined by the CAPITAL project, namely definition of the costs and benefits of C-ITS; financing of C-ITS services; identification of the costs for instalment, operation, maintenance of C-ITS services and building C-ITS on existing investments.

The CBA is one of a set of tools of assessing efficiency of investment decision, i.e. it helps to identify how to allocate resources to obtain the maximum possible benefits from invested resources. However, the CBA is rather an approach than a methodology that helps to compare benefits and costs that are states in monetary terms.
While applying CBA for the C-ITS services, it is important to keep in mind the social aspects as well as the environmental impact and how they can be calculated. These benefits are not always easy to identify and assess. It is agreed that the CBA still contains many limitations and a number of enhancements are possible to be included in the process that can increase the reliability of the results.

There are three main indicators that can be estimated to evaluate an investment and that need to be computed to carry out the CBA to evaluate the C-ITS services:

- **Internal Return Rate** (IRR), which refers to the measurement of the profitability of potential investments;
- **Net Present Value** (NPV), which computes the benefit and cost cash flow;
- **Benefit-Cost Ratio** (BCR) that aims to discover the relationship between qualitative and quantitative benefits and costs.

This study briefly discusses some possible limitations of CBA, which are combined into three main groups: limitations related to choice of CBA, uncertainties related to cost, and uncertainties related to benefits.

Providing an added value of the C-ITS in the transport sector, their deployment are considered to be slow and fragmented. The main reason of it is that the ITS services are public oriented in their nature. Therefore, in many cases the innovative business models that would support the deployment of the C-ITS services are often missing. It is also important to understand that various stakeholders pursue different goals and try to achieve different benefits, namely public authorities are interested more in the social benefits (e.g. reduction of accidents, emissions, increasing safety, etc.), whereas transport operators are looking at the benefits linked to costs saving (e.g. reduction of fuel consumption, better lead time, safety of freight, etc.) While preparing CBA, the interests and benefits of all stakeholders need to be identified and thoroughly calculated.

One of the sub-chapters of this topic study gives a short overview of all costs of the ITS and C-ITS services that are grouped into three sets related to three implementation phases:

- The **value of pre-existing equipment** that is needed to run the existing services used to deploy the new services;
- The **current operational costs** that should be taken into account in the CBA. It also includes the investment needed for the deployment of the services;
- The operational costs needed to run and maintain the ITS services.

This topic study also discusses some main risks that can jeopardise the investments into the C-ITS services (Leviäkangas, 2011). Two high risks related to ITS investment need to be initially addressed, namely technological risks and flexibility with regard to the whole system. It is also believed that adding new actors to service supply chain can create additional risks, which can lead to overpricing of services because of multiplication in risk accounting in the service supply chain.

### 3.8 Guidance in deploying ITS and C-ITS (Ertico)

This topic study aims to offer a practical guide for assisting local government officers, service providers, and traffic operators in ITS and C-ITS services in Europe (Annex 8). It explains the main challenges, opportunities, and guidelines for service implementation including the sharing of deployment experiences. It lays out the policy background of deployment services, strategies used for implementation, pilots and the procedures they followed, barriers to deployment and solutions proposed, and business opportunities proposed.
The ITS directive provides four Priority Areas: optimal use of road, traffic, and travel data; continuity of traffic and freight management ITS services; ITS road safety and security applications; and linking vehicles with the transport infrastructure. Within these, six Priority Actions were defined for provision of EU-wide multimodal travel, real-time traffic, and road safety related minimum universal traffic information services, interoperable eCall, and information and reservation services for safe and secure parking places for trucks and commercial vehicles. Apart from reservation services, all of the above have specifications already adopted.

European level policy initiatives heavily influence deployment in guiding, harmonising, and kick-starting deployments in the ITS sector. EasyWay and EasyWay2, EU EIP and EU EIP+, and EU ITS Platform have been major producers of important guidance for the accelerated, harmonised, and co-ordinated deployment of ITS services in Europe. Multiple platforms and associations of relevant parties help to guide, support, and harmonise ITS deployment, such as ERTICO, POLIS, CEDR, UITP, ASECAP, EU ITS Platform, and ACEA.

European Commission's C-ITS Strategy aims to facilitate the convergence of investments and regulatory frameworks across the EU, including adoption of appropriate legal framework, availability of EU funding for projects, continuation of the C-ITS Platform process, international cooperation, and continuous coordination in a learning-by-doing approach. It prioritises C-ITS services to be deployed to end-users into Day 1 and Day 1.5 categories based on the maturity of the underlying technology and on the benefits of the service. Day 1 services are to be deployed as soon as possible and research and writing of specifications and standards for Day 1.5 services should continue. The lists are kept up to date as research and deployments progress.

Pilot installations, recommendations, testing, and specifications of the Day 1 C-ITS services are being harmonised, including cross-border interoperability, based on cooperation within the C-Roads Platform. The national pilots included in the C-Roads Platform form the basic elements for transnational, interoperable C-ITS implementation.

It is recommended that public authorities prepare a C-ITS Strategic Plan in a city, region, or a member state when beginning to deploy C-ITS services. The Plan is a road-map for decision-making that

- involves the whole transportation and mobility value chain: find out the actual needs of the public and what stakeholders can offer and want in return, involve them in the process
- matches policy goals versus emerging trends: specify objectives and identify problems, then identify policy measures and projects to achieve and overcome them
- analyses existing city conditions: assess whether the potential of current infrastructure, resources, and any planned works is maximised, do not only focus on the solution but leave room for improvement, current equipment could support C-ITS, open up data, investigate cloud-based systems, share knowledge
- ensures commitment and resources: changes in department staff, functions, responsibilities; project management, communication

Examples of strategic plans are Sustainable Urban Mobility Plan (SUMP), Sustainable Urban Logistic Plan (SULP), and the ITS Strategic Plan, each of which can be used separately or together in an integrated way.

After the C-ITS Strategic Plan, in the deployment of C-ITS services, comes initiating the project planning process. The steps generally are:

- work with the industry: distinguish stakeholders involved in the installation of the C-ITS service and users of the system; identify their interests, motivations, and needs; identify the general expectancy of the pilot and how to evaluate it
- adapt the ITS Architecture to local needs: systems engineering approach in designing, describing, reasoning about, defining, developing, and managing the project. Use, for example, the FRAME Architecture
- describe services, technology, and installation traits: equipment at road-side or on-board units, communication channels, HMI
- involve vehicle fleets and users: engage stakeholders in testing and reviewing the system, identify areas of improvement
- procurement, operation, and maintenance: investigate different procurement models such as technology as a service, make sure there is incentive to invest during maintenance

Once the service has been deployed, evaluation should take place with proper methodology. Usually this means generating relevant performance indicators, separating the data into comparable populations, and analysing the changes in the performance indicators. The most common barriers to C-ITS deployment are categorised to technical, legal, economic, interoperability, and other, which contains lack of awareness, road safety, privacy issues, and security.

3.9 Data protection and privacy (FIA)

C-ITS is inseparable from considerations on data protection and privacy. The topic study (see Annex 9) explores the legal and political background as well as concrete tools. Throughout the topic study, data protection is understood as a legal regime to protect personal data in a socially acceptable way (Blume 2010). Privacy is understood as a legal, psychological, social, philosophical and cultural concept (Bloustein, 1964), which places autonomy and freedom of personal information at its centre (Glancy, 2012).

Approaching the topic from a legal perspective, the main question is, which legal basis needs to be applied. If car data qualifies as personal data, the General Data Protection Regulation (GDPR) and the upcoming e-Privacy regulation will apply. For non-personal car data, the upcoming Regulation on the Free Flow of Data will apply. Personal data allows the identification of a data subject (EU 2016). Non-personal data can be anonymised data, which places it outside the scope of the GDPR. Apart from anonymization, personal data can be processed, if users give consent. Users need to be asked for their consent in an accessible, legible and distinguishable form in writing. It must be possible to easily withdraw consent. It is not the responsibility of the data subject, but of the controller to ensure that valid consent has been given. (EU 2016). The GDPR sets out six principles of data protection (EU 2016): lawfulness, fairness and transparency, purpose limitation, data minimisation, accuracy, storage limitation, integrity and confidentiality. Two principles are especially relevant for C-ITS. The first one is transparency, as this principle expects users to be aware of the nature and purpose of data collection. It is not clear, to what extent this principle is met at the moment. The second relevant principle is data minimization, as C-ITS is connected to big data collection, where the usefulness is often established after the collection of data, which contravenes the obligations of the GDPR.

Approaching the topic from a political angle, the question remains the same: Which type of data is car data. For the European Commission “data broadcast by C-ITS from vehicles will, in principle, qualify as personal data as it will relate to an identified or identifiable natural person.” (EC, 2016). In the eyes of the German Association of Car Manufacturers: “The data of in-vehicle systems generated in the vehicle are primarily technical data” (VDA 2014). This distinction between technical data and personal data is not universally accepted. “Data might even primarily contain technical information but can at the same time qualify as personal data”
There are no case studies available on data protection for C-ITS applications or services managed by public authorities in European cities. Therefore, the topic study instead presents material for two case studies, which serve as proxy situations for some of the implementation issues related to C-ITS.

The first case study looks at eTicketing in public transportation, which relies on smart cards. These cards collect a lot of personal information, including photos and credit card information. Users are not always aware of these implications of eTickets. In addition to general data minimisation (i.e. not uploading a photo, not checking out at the end of a trip), “an important element of the discussions around e-ticketing is always the option to travel anonymously” (Eisses, van de Ven and Fievee 2012). However, a case study of the Italian city of Cesena reveals that anonymous e-tickets cannot guarantee anonymity (Avoine et al. 2014).

The second case study explores eCall, which triggers automatic data transmission in case of an accident. This data includes time, position, driving direction, identity of vehicle and optional qualifications on incident severity and fuel type (Eisses, van de Ven and Fievee, 2012). The European Data Protection Supervisor commented on the eCall system that “permanent tracking of the vehicle is not needed for the purpose and shall be avoided. The data are only to be exchanged in case of an emergency.” The same position is taken by the European Parliament, which deems the storage of the last three locations as sufficient (Konarski, Karwala & Schulte-Nolke 2014).

These two case studies summarise some key points on data protection and privacy implications of C-ITS. First, C-ITS necessarily involves the extensive broadcasting of location and mobility data. Users appear to not yet be prepared to share these data points, as they are aware of the possible privacy implications. Second, users need to be aware of the types of data collected, the recipients, how these are processed and for which purpose. This awareness is needed to establish user consent, which is a tricky question for C-ITS in general. Last, the amount of data collected in C-ITS is ripe for business exploitation. This opens questions on the free flow of non-personal data (either technical, or anonymised) and the question of data access and data ownership. This area is not yet sufficiently legislated to make a definitive judgement of what will happen. (WP29 2017).
4 Discussion

CAPITAL aims to design and deliver a collaborative capacity building programme comprising training and education in the field of ITS and C-ITS. This deliverable (D3.2) reports the outcome of Task 3.2 and consists of a summary from each individual topic study. The finalised versions of the topic studies are included as Annexes. The topics include:

- ITS1: Introduction to ITS and C-ITS
- ITS2: ITS and C-ITS user services
- ITS3: TMC and roadside technologies for ITS
- ITS4: Communication technologies for ITS and C-ITS including relevant standards
- ITS5: Impact assessment of ITS and impacts of selected ITS and C-ITS systems
- ITS6: Financial incentives, business models and procurement models for C-ITS deployment
- ITS7: Cost-benefit analyses of ITS services
- ITS8: Guidance in deploying ITS and C-ITS
- ITS9: Data protection and privacy.

ITS1 describes ITS and C-ITS terminology and abbreviations as well as the relevant stakeholders in the field. The topic study also introduce the policy framework and benefits from ITS and C-ITS. ITS2 describes available ITS and C-ITS services for both professional and normal drivers. The topic study also includes user aspects such as acceptance and dissemination of ITS and C-ITS systems to the public.

ITS3 describes traffic management control and roadside technologies utilised in ITS systems such as event detection, transport data collection, aggregation and management of transport data, incident management and dynamic transport data. ITS4 describes communication technologies and architectures utilised in ITS and C-ITS systems as well as the standardisation, interoperability, testing and certification process of ITS and C-ITS systems.

ITS5 describes methods for impact assessment of ITS including data collection and evaluation methodologies. The topic study also present impacts of ITS and C-ITS systems on safety, environment and emissions. ITS6 gives an overview of financial incentives, business models and procurement models for ITS and C-ITS. C-ITS ecosystems and their governance is also introduced in the topic study.

ITS7 describes methods for determining costs and benefits of C-ITS, including costs for installation, operation and maintenance of the systems. ITS8 presents best practices and lessons learnt from previous projects and pilots such as different stakeholders’ role during introduction and operation. ITS9 gives an overview on information security, user privacy and protection in the context of C-ITS.
5 Conclusions and next steps

Based on the ITS deployment framework as this has been shaped within deliverable 3.1 of the project, nine topic studies on the current state of the art of ITS and C-ITS technologies and deployment were identified and elaborated. All these topic studies will serve as input for the Task 3.3 where the educational and informational material will be developed for the capacity development programme. The topic studies can be updated in the end of the project based on the comments from any additional material published during the coming year.

All the collected material provides up-to-date information on ITS and C-ITS status of evolution, progress and implementation worldwide. The predefined nine topics are considered to include the most recent information regarding ITS and act to each other in a complementary way in order to provide a consolidated overview and in depth analysis of ITS and C-ITS current status to the reader. In this way the nine topic studies will constitute the main term of reference for the creation of the CAPITAL education material and training modules.

In line with the development of the topic studies the development for the educational and information material for trainees (and trainers) will target decision makers, technicians, authorities and transport institutions across the three generation levels (1st, 2nd and 3rd). The material mainly will be both in text, audio and visual form including courses, syllabus called “module outline form” (MOF), presentations in ppt, scripts, recorded presentations by preselected lecturers and questions and tests for module comprehension by the trainees. All this material will be formed in an on-line training course outline and will be available through the CAPITAL on-line training platform. For each course, additional evaluation forms will be available to the trainees in order to evaluate the course overall.

The material that will be developed will be designed in a way that allows them to be readily updated meaning that these materials can have a long-lasting and broad impact across numerous countries and regions. Additionally, the capabilities of the CAPITAL on-line training platform offer the possibility to create additional training modules and relevant courses giving the potential to become a one-stop-shop for ITS and C-ITS training and information provisioning. The final product of the on-line platform is designed to be the core element of the CAPITAL capacity development strategy for the education and training of all target groups defined in the strategy plan of the project.

The training platform is expected to be fully operational within the next few months and eventually will be utilized in full as the training means of the upcoming on-line and physical training programmes of the project.

CAPITAL is piloting the training experience of practitioners through online courses but also face to face trainings. At the physical trainings, there will be invited experts with considerable knowledge and expertise who may add further elements to the training courses developed in the online version in order to possibly modify them at a later stage, and only after receiving the feedback from the registrants to the platform, together with the participants to the event, to whom a feedback form is provided. The reiteration of the courses taking into account the feedback provided is necessary and follows the project methodology in the final phase.
References


Impact Assessment. CODIA Deliverable 5: Final Study.


List of Annexes

Annex 1: Introduction to ITS and C-ITS
Annex 2: ITS and C-ITS user services
Annex 3: TMC and roadside technologies for ITS
Annex 4: Communication technologies for ITS and C-ITS including relevant standards
Annex 5: Impact assessment of ITS and impacts of selected ITS and C-ITS systems
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Annex 8: Guidance in deploying ITS and C-ITS
Annex 9: Data protection and privacy
Annex 1: Introduction to ITS and C-ITS

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**Topic study 1: Introduction to ITS and C-ITS**

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Abstract

This document presents the topic study 'Introduction to ITS and C-ITS'.

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## Abbreviations and Acronyms

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<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAM</td>
<td>Cooperative Awareness Message</td>
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<td>C-ITS</td>
<td>Cooperative Intelligent Transport Systems</td>
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<tr>
<td>DSRC</td>
<td>Dedicated Short Range Communication</td>
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<tr>
<td>EC</td>
<td>European Commission</td>
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<td>EEIS</td>
<td>Energy Efficient Intersection Service</td>
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<td>European Telecommunications Standards Institute</td>
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<td>FOT</td>
<td>Field Operational Test</td>
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<td>GA</td>
<td>Grant Agreement</td>
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<td>GLOSA</td>
<td>Green Light Optimized Speed Advisory</td>
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<td>Global System for Mobile Communications</td>
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<td>Mobility as a Service</td>
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<td>Master of Science</td>
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<td>P2W</td>
<td>Powered Two Wheeler</td>
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<td>Project Officer</td>
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<td>VMS</td>
<td>Variable Message Sign</td>
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<tr>
<td>V2V</td>
<td>Vehicle-to-Vehicle</td>
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<td>V2I</td>
<td>Vehicle-to-Infrastructure</td>
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<td>V2X</td>
<td>Vehicle-to-Anything</td>
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<td>VRU</td>
<td>Vulnerable Road User</td>
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<tr>
<td>WAVE</td>
<td>Wireless Access for Vehicular Environment</td>
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<td>WP</td>
<td>Work Package</td>
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1. Introduction

‘Introduction to ITS and C-ITS’ is one of the six core topic studies identified in the CAPITAL description of work. Originally entitled ‘What is ITS (or C-ITS)?’ it was designed as an introduction to the subject area, and to the five remaining topic studies that focus on more detailed aspects of ITS and C-ITS. As the CAPITAL project evolved, so too did the number and scope of the topic studies. This is reflected in the revised title (‘Introduction to ITS and C-ITS’) and content of this topic study. All topic studies are presented in sections D3.2 ITS Knowledge Database.

‘Introduction to ITS and C-ITS’ is a topic study designed for anyone who wants to understand the fundamentals of ITS and C-ITS, especially beginners in the field and public-sector decision makers. The topic and its associated study module are both concise and intended to be completed in a short period of time. The study module is designed to require approximately two hours study time and should be completed within two weeks. The aim is to provide an overview of broad aspects of ITS and C-ITS, and to prepare students for the more detailed future study modules produced by CAPITAL.

In this opening module, students learn about the fundamentals of ITS and C-ITS, including appropriate definitions, how to differentiate between them, services and applications, and aspects of the impacts and benefits of C-ITS for anyone considering deployment. Specifically, the topic study covers the following:

- How to recognise core ITS technologies and functions
- Definition of C-ITS, and distinction between ITS / C-ITS
- Developments in C-ITS including Day 1 and Day 1.5 Services
- How to identify and learn about C-ITS in practice through case studies

The module draws on existing lecture material, in particular from Newcastle University’s masters of science (MSc) courses, along with significant examples of European deployment projects and platforms in C-ITS, specifically Compass4D, C-ITS Corridor, C-MOBILE, C-Roads and InterCor. A variety of reference materials is provided to accompany the study module, along with video links, a quiz and a final assessment.

2. Objectives

This topic study contributes directly to the ‘Introduction to ITS and C-ITS’ study module. Its scope is to introduce students to the concepts and characteristics of ITS and C-ITS as follows:

- To recognise core ITS technologies and functions
- To define C-ITS, as distinct from ITS
- To give examples of the latest research and development in ITS / C-ITS
- To demonstrate the implementation of C-ITS through selected best practice case studies
- To introduce the role of C-ITS within a wider policy context

In this way the topic study and associated study module prepare the novice for more detailed CAPITAL topic studies and modules. They also act as a refresher for students who already have some experience of ITS / C-ITS. Hence, ‘Introduction to ITS and C-ITS’ is a starting point – and prerequisite - for other topic studies and study modules developed by CAPITAL.
3. Methods

The topic study and associated study materials were developed to provide answers to the following questions:

- What is ITS?
- What is C-ITS?
- Where can I see C-ITS in operation?
- What can C-ITS do for me?

Information was obtained through the following methods:

<table>
<thead>
<tr>
<th>Methods</th>
<th>How the information is used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecture materials</td>
<td>Existing lecture materials from Newcastle University’s MSc course in ITS underpin the topic study and material development. The ITS course is wide-ranging, introducing many examples of transport technology at an international level, and includes detailed coverage of C-ITS. For the topic study and study module the materials have been tailored to the needs of a short introductory course targeting the professional development student</td>
</tr>
<tr>
<td>ITS/C-ITS deployments and projects</td>
<td>A selection of large-scale C-ITS deployment projects has been identified at the European level. General characteristics such as location, services delivered and stakeholders are covered, along with pre-deployment issues such as communications standards, engagement, business case, and evaluation activities. As the professional development of the student is the aim, the focus is on understanding the practicalities rather than detailed technical or academic study</td>
</tr>
<tr>
<td>Video links</td>
<td>Relevant video links are provided in the course materials where they add value to the course</td>
</tr>
<tr>
<td>References to other links</td>
<td>A reference library exists in the course materials to enable the student to engage in wider reading around the subject. This is included in the reference section of this topic study</td>
</tr>
</tbody>
</table>
4. Content of the Topic Study

This chapter presents the topic study that supports the associated study module. The study module is designed to be undertaken in two parts, each of which requires approximately one hour study time. The module should be completed within two weeks. This topic study is therefore structured to provide an overview and, where appropriate, additional detail of the different components of the study module, as delivered over the two week duration.

4.1 Intelligent Transport Systems

Definition of ITS

‘ITS’ is the commonly used abbreviation for Intelligent Transport Systems. Many definitions of ITS exist, including the following:

*ITS are systems in which information and communication technologies (ICT) are applied in the field of road transport, including infrastructure, vehicles and users, and in traffic management and mobility management, as well as for interfaces with other modes of transport*

(European Commission: 2010/40/EU)

*ITS combine information and communication technologies, sensors, maps, and other data, for applications and services to enable seamless journeys of people and goods*

(ERTICO)

Put simply, ITS is the application of computer, communications and other information technologies to transport, in order to improve efficiency, robustness and safety. ITS make use of available technologies like wireless, mobile, satellite, and ICT.

Underpinning European Legal Framework

A legal framework (Directive 2010/40/EU) was adopted on 7 July 2010 to accelerate the coordinated deployment of ITS across Europe. It aims to establish interoperable and seamless ITS services while leaving Member States the freedom to decide which systems to invest in. Under this Directive the EC has to adopt specifications (functional, technical, organisational or service provision) to address the compatibility, interoperability and continuity of ITS solutions across the EU. The first priorities were traffic and travel information, the eCall emergency system and intelligent truck parking.

The Commission had previously taken a major step towards the deployment and use of ITS in road transport (and interfaces to other transport modes) on 16 December 2008 by adopting an Action Plan. The Action Plan suggested a number of targeted measures and included the proposal for the subsequent Directive. The goal was to create the momentum necessary to speed up market penetration of mature ITS applications and services in Europe.

Application of ITS

ITS can significantly contribute to a cleaner, safer and more efficient transport system. ITS can be applied across many aspects of the transport sector, including (for example) network management, public transport information and ticketing, driver information (roadside and in-vehicle), road user charging, parking management, and freight and logistics.
Work has taken place to categorise ITS services, applications and benefits. The iMobility Forum (http://ertico.com/projects/imobility-forum/) defined vehicle-based and infrastructure-based services. Other significant work in this area has been performed by the US Department of Transport, the 2Decide project and EuroFOT:

- http://www.itsbenefits.its.dot.gov/
- http://www.its-toolkit.eu/ (2Decide)
- http://wiki.fot-net.eu (EuroFOT)

In CAPITAL, three categories of ITS are identified: infrastructure-based systems, vehicle-based systems, and public transport systems.

*Infrastructure-based* ITS systems include (for example) road user charging, variable message signs (VMS) and managed motorways. Infrastructure-based systems use short range and long range ICT as well as conventional communication technologies to contribute to goals of sustainability and accessibility, through the provision of the right information, at the right time and in the right place.

*Vehicle-based* ITS systems include (for example) blind spot monitoring, navigation systems and eco driving. Vehicle-based systems use telematics and in-vehicle technologies to contribute to high level goals of safety and sustainability.

*Public transport* ITS systems include (for example) journey planning, smart ticketing and smart cards. Public transport systems use Global System for Mobile Communications (GSM) technologies to contribute towards the overall goal of increased awareness and connectivity, promoting a more reliable and usable service to customers and better fleet and system operations.

ITS underpins many other systems and services in addition to those listed above. It is also a prerequisite of broader concepts such as:

- **Connected and Autonomous Vehicles**
  - Operation of a vehicle without direct driver input (sometimes referred to as ‘driverless’)

- **Smart Cities**
  - Cities using new technologies (usually ICT) and data capacity to solve economic, social and environmental challenges across different sectors

- **Mobility as a Service (MaaS)**
  - Multiple transport services / modes are integrated into a single mobility service accessible on demand, making use of ICT (e.g. Apps)

- **Integrated Transport**
  - Multiple components of a transport system interact in a seamless way (e.g. modes, ticketing, etc.)
4.2 Cooperative Intelligent Transport Systems

**Definition of C-ITS**

‘C-ITS’ is a commonly used abbreviation for **Cooperative Intelligent Transport Systems**. C-ITS are ITS that provide real time communication between vehicles, infrastructure and other road users. Precise definitions of C-ITS include:

> Cooperative ITS is a group of technologies and applications that allow effective data exchange through wireless technologies among elements and actors of the transport system, very often between vehicles (vehicle-to-vehicle or V2V) or between vehicles and infrastructure (vehicle-to-infrastructure or V2I) (but also with) vulnerable road users such as pedestrians, cyclists or motorcyclists

(EC COM (2016) 766)

**Cooperative ITS (is ITS) in which the vehicles communicate with each other and/or with the infrastructure**

(ETSI)

Interestingly, ETSI also defines ITS as:

> … Telematics and all types of communications in vehicles, between vehicles (e.g. car-to-car), and between vehicles and fixed locations (e.g. car-to-infrastructure)

(ETSI)

This indicates that the distinction between ITS and C-ITS, if one truly exists, is not clear cut. However, in general, C-ITS can be understood to **enhance** conventional ITS through the latest communications standards, enabling provision of tailored services that can provide direct benefits in terms of customer experience, operational savings, and delivery of traffic management objectives, whilst contributing to broader policy goals such as road safety and reduced energy and emissions.

C-ITS involves different types of digital connectivity – or cooperation – between vehicles and infrastructure:

- Vehicle-to-vehicle (V2V)
- Vehicle-to-infrastructure (V2I)
- Infrastructure-to-vehicle (I2V), and
- Vehicle-to-anything or (V2X)

Because vehicles are **connected** with the world around them, C-ITS is sometimes referred to as **connected vehicle technology**.

**Communications**

The communications technology for C-ITS is ITS-G5 (sometimes known as 802.11p or dedicated short range communication (DSRC)). DSRC are a special form of wireless networking technology (wifi) which operates on a different frequency. The standard has been developed by the automotive and telecoms industry and has been used extensively in field operational tests (FOT) and pilot schemes. The technology behind the short range communication standards is **Wireless Access for Vehicular Environment (WAVE)**. An
extensive review on communication technologies for ITS and C-ITS is found in Topic study 2: Communication technologies for ITS and C-ITS including relevant standards.

**Evolution of C-ITS**

C-ITS has developed quickly since the mid-2000s. Much of the development has come through EU-funded projects which refined the V2V and V2I communications and assessed the standards necessary for wider uptake. Early pilot studies consolidated the technology and applied the standards, evolving in the 2010s into large scale FOTs and ultimately real-world deployments. A key part of this evolution has been understanding C-ITS services and applications, impacts and benefits, with a particular focus on the needs of stakeholders, especially cities and road / transport operators.

Examples of early projects include CVIS, COOPERS, SAFESPOT, COMeSAFETY, DRIVE C2X and FOTSIS. These developed and demonstrated both the supporting technology and numerous applications for cooperative infrastructure involving two-way communication of data between vehicles and road-side infrastructure.

The evolution of C-ITS can be summarized in the following four phases:

1. V2V and V2I communications refinement
2. Standards identified and developed for wider uptake
3. Early pilots consolidate the technology and apply the standards
4. Large-scale field operational tests and real-world deployments

**Stakeholders**

Stakeholders include cities, government (local, regional and national), passenger transport operators and service providers (public and private), fleet operators (e.g. emergency vehicles or commercial vehicle operators), and other road users (including vulnerable road users such as pedestrians or cyclists). Broadly, C-ITS deployment is policy-driven or user-driven.

Because C-ITS enables communication and sharing of information between vehicles, infrastructure and other road users, it is an influential tool enabling cities, fleet operators and other stakeholders to ‘get smarter’. In this way C-ITS is also a key stepping stone towards longer term transport innovations like platooning (that is, linking two or more vehicles – usually trucks - in convoy, using connectivity technology and automated driving support systems) and fully autonomous systems.

**Benefits of C-ITS**

C-ITS can initiate specific actions that provide direct benefits in the form of enhancements to:

- *Road network efficiency*, for example to enable better implementation of traffic management policies such as public transport or emergency vehicle priority
- *Operational efficiency*, for example for freight or public transport, giving greater service reliability, enhanced customer satisfaction, and operational savings
- *Road safety for all users*, for example the provision of alerts to drivers notifying them of a nearby vulnerable road user (VRU) such as a pedestrian or cyclist
- *Environmental conditions*, for example the provision of in-vehicle speed advice to encourage eco-driving with fewer brake events and thus reduced emissions
**Services**

The Amsterdam Group\(^1\) has defined ‘Day 1’ and ‘Day 1.5’ services. Day 1 services are those services that are already being deployed or will be deployed very shortly. They use mature technology and are expected to provide a high level of benefits to society.

Day 1.5 services are those services to be deployed in the next phase. They are considered mature and highly sought after by the market, but their business cases, standards and specifications may not yet be complete.

In 2014 the EC inaugurated the C-ITS Deployment Platform as a cooperative framework including national authorities, stakeholders and the Commission, to develop a shared vision on the interoperable deployment of C-ITS in the EU. The second phase of the platform (2016-17) further developed a shared vision towards cooperative, connected and automated mobility in the EU.

The C-ITS Deployment Platform recommends a number of Day 1 and Day 1.5 services. Day 1 services include:

- **Hazardous location notifications**: slow or stationary vehicle(s) and traffic ahead warning, road works warning, weather conditions, emergency brake light, emergency vehicle approaching, and other hazardous notifications
- **Signage applications**: in-vehicle signage, in-vehicle speed limits, signal violation / intersection safety, traffic signal priority request by designated vehicles, Green Light Optimized Speed Advisory (GLOSA), probe vehicle data, CAM Aggregation, and shockwave damping

Day-1.5 services include:

- Information on fuelling and charging stations for alternative fuel vehicles, Vulnerable Road User (VRU) protection, on street parking management and information, off street parking information, Park & Ride information, connected and cooperative navigation in urban areas (first and last mile, parking, route advice, coordinated traffic lights), traffic information, and smart routing

It is useful to understand these services, as identified by the C-ITS Platform, by type of communication. Some of the services are vehicle-to-vehicle (V2V). These include:

- Emergency brake light to inform drivers about vehicles ahead which are braking hard
- Emergency vehicle approaching to provide an early warning before the driver has heard the siren or seen flashing lights
- Systems that provide warnings for slow or stationary vehicles; congestion warning; hazardous location warning

Some of the services are vehicle-to-infrastructure (V2I) targeted at motorway use. These include:

- Services in the vehicle such as warnings about road works, and speed advice
- Probe vehicle data, where vehicles provide data to the network manager that can be

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\(^1\) The Amsterdam Group is a strategic alliance of key stakeholders with the objective to facilitate joint deployment of cooperative ITS in Europe (https://amsterdamgroup.mett.nl/default.aspx)
used to help manage the road delivering information to VMS or in-vehicle

- Shockwave damping which helps road managers implement strategies to smooth traffic flow

Some of the services identified are vehicle-to-infrastructure (V2I) targeted at urban use. These include:

- Green Light Optimized Speed Advisory (GLOSA)
- Time-to-green information and green priority

These services aim to increase traffic efficiency and reduce vehicle emissions.

Some of the Day 1.5 services identified by the C-ITS Platform are vehicle-to-infrastructure (V2I). These include:

- Parking (including Park & Ride) and refuelling information to drivers (including EV charging)
- Bespoke information for certain road users such as disabled licence holders
- Optimising routes based on traffic flows, re-routing where required, and intelligent speed adaptation (ISA)
- Loading Zone Management and Zone Access Control for freight vehicles
- Booking, monitoring and management of urban parking zones for freight vehicles

Some of the services identified by the C-ITS Platform are vehicle-to-anything (V2X). Safety is the main objective. These include:

- Protection of vulnerable road users in particular pedestrians or cyclists

**Service Bundling**

Service bundling is a way of delivering multiple C-ITS services in a modular way, so that it is easy to ‘plug in’ a new service to a C-ITS platform, as long as it is in a common bundle (i.e. requires the same infrastructure). Bundling can help make deployment more flexible and more cost effective, because of similar infrastructure requirements.

Examples of bundling services include (for example) those contributing to road network efficiency, to road safety, and to environmental improvements.

Services to improve Efficiency:

- Green priority (selected vehicles); parking (selected vehicles); flexible infrastructure (e.g. peak hour lanes); in vehicle signage; mode / trip time advice; probe vehicle data

Services to improve Safety:

- Road hazard warning; red light violation warning; pedestrian warning; powered two wheeler (P2W) / cycle detection; blind spot detection; emergency vehicle warning; road work warning

Services to improve the Environment:

- GLOSA; eco-driving; speed advice
**Is C-ITS better than ITS?**

While conventional ITS tends towards a number of standalone installations, C-ITS can provide an integrated, flexible and tailored package of measures, utilising the latest ITS and communications technologies, that will provide direct benefits to stakeholders, and contribute to broader longer-term policy goals. In the future, C-ITS will enable:

- Fully connected technology for travellers, vehicles and infrastructure
- A rich choice of cooperative services for safety, network efficiency, and the environment
- Universal availability for every vehicle, and every traveller
- Ubiquitous coverage for every city, and every highway
- An open interoperable platform encompassing on-board units, roadside infrastructure and personal devices.

The broad range of benefits to be gained from C-ITS deployment include:

- Improved safety and comfort for public transport passengers and VRUs, enhanced operational efficiency for service providers, and reduced environmental impact of transport
- Multiple stakeholder benefits, for cities, transport planners, traffic managers, fleet managers, public transport and taxi operators, road haulage operators, and VRUs
- A crucial ingredient in holistic large-scale concepts like Mobility as a Service (MaaS), Smart Cities, vehicle platooning and fully autonomous systems

**Preparing a C-ITS Deployment**

This section provides a check list of guidelines and recommendations for stakeholders actively considering a C-ITS deployment. The checklists are elaborated in greater detail in other topic studies and study modules in the CAPITAL study programme.

When scoping a possible C-ITS deployment, there are a number of fundamental questions to be considered:

- Is there a business case?
- What stakeholders should be involved?
- Is there a business case for multiple stakeholders?
- Should vehicle manufacturers who may be developing their own in-vehicle systems be involved?
- Who pays if there are no government or European funds?

Once these basic questions have been satisfactorily addressed planning for a deployment can begin, however there are some important ground rules which must be undertaken:

- Be clear on the goal of the project
Plan suitable delays for equipment provision / testing

Be clear on exact duties and responsibilities of stakeholders when the project is operational

Check that the data obtained is accurate and meets requirements (quantity and quality)

Design an evaluation or impact assessment that is achievable and useful

Engage early and often with the system end users (not just with a transport operator, but with management, drivers, trade unions, etc. within that organisation)

Evaluation, if not done correctly, can be meaningless, or at worst misleading. Some important recommendations when undertaking evaluation or impact assessment include:

- For a Field Operation Trial (FOT) designing a control group to assess whether any benefits are a result of C-ITS or some other factor(s)
- Ensuring quantity and quality of data collection
- Understanding the variation in a metric in order to obtain accurate impact assessments
- If possible, producing an ‘expected’ change. This can highlight whether a change will appear above the variation
- Creating a documented, systematic approach to analysis
- Using micro-simulations to inform and expand real world results, but not to replace them

There are many practical issues that must be clarified when deploying C-ITS. These include:

- Clarity of leadership
- Where possible, ensure the commitment of government
- Clarity of service organisation (who does what)
- Agree a business model and implement it
- Understand public policy and the legal framework
- Ensure data protection legislation is correctly applied
- Ensure an open and interoperable architecture
- Ensure technology be adapted for local customers’ needs
- Choose and implement an appropriate selection (‘bundle’) of user services
- Agree first (‘core’ / ‘Day 1’) user services
- Define a rollout plan for infrastructure, vehicles, etc.
- Work with (and understand constraints of) procurement systems
- Availability of assistance and guidance
4.3 Examples of C-ITS in the Real World

The study module contains a non-exhaustive list of C-ITS deployments and initiatives. The main focus is on pan-European schemes. In addition, there are many national schemes up-and-running, especially in locations such as Helmond, Bordeaux and Newcastle upon Tyne, as well as good examples internationally, information about which can be accessed through the resources. In the study module, the following projects are introduced:

Compass4D

An important example of an early C-ITS FOT was the EC-funded Compass4D project, which ran from 2013-16. The aim of COMPASS4D was to deploy C-ITS in selected real-world zones of seven European locations (Bordeaux, Copenhagen, Helmond, Newcastle upon Tyne, Verona, Vigo and Thessaloniki), in order to demonstrate the C-ITS-generated benefits of safer and cleaner road transport for citizens and drivers.

The services included:

- Road Hazard Warning, with an in-vehicle HMI displaying warnings about road hazards
- Red Light Violation Warning, where the HMI displayed warnings about other vehicles violating red lights, and
- Energy Efficient Intersection Service (EEIS), comprising 3 services:
  - GLOSA
  - Green priority
  - Idling support

A key focus for the evaluation was the energy and environmental benefits of C-ITS. Results showed that:

- Light and Heavy vehicles show energy saving (CO₂) of up to 10%
- Buses can show large savings (up to 10%) but this is route and site dependent
- Green Priority has a greater impact than GLOSA, with a wider range of working use cases and vehicle types
- Simulations show that increasing penetration rates (number of equipped vehicles) can increase benefits
- Whilst deployment in specific urban zones can bring benefits, simulation suggests that the effect on the overall network may be neutral

C-ITS Corridor

The C-ITS Corridor involves German, Dutch and Austrian road operators deploying cooperative systems on a trans-continental road network (Vienna-Frankfurt-Rotterdam) to:

- Improve safety by informing drivers about traffic situations and hazards
- Improve traffic flow through better communication of data from vehicles to traffic control centres
- Reduce emissions through improved traffic conditions and management

https://itscorridor.mett.nl/English/default.aspx
C-MOBILE

Accelerating C-ITS Mobility Innovation and Deployment in Europe, and building on the Compass4D project, the deployment cities include: Barcelona; Bilbao; Bordeaux; Copenhagen; Newcastle; North Brabant; Thessaloniki; Vigo. The main aims are:

- To promote large-scale deployment of real-world C-ITS in complex urban environments
- To define operational processes for large-scale deployment of sustainable C-ITS services
- To achieve interoperability of systems, services and stakeholders
- To develop service bundles and assess their benefits
- To help cities invest in C-ITS
- To engage the general public
- To create a Strategic Research Agenda
- To perform a cost benefit analysis (CBA) and impact assessment

http://c-mobile-project.eu/

INTERCOR

Interoperable Corridors deploying cooperative intelligent transport systems, InterCor links C-ITS corridor initiatives of the Netherlands, France, UK and Belgium. It aims to achieve a sustainable network of corridors providing continuity of C-ITS services and offering a testbed for beyond Day-1 C-ITS deployment. The deployment locations are:

- Belgium – the site includes motorway sections between France and the Netherlands via Ghent and Antwerp and connections between Antwerp and Eindhoven, Antwerp and Brussels and Brussels and just south of Leuven
- France – the site extends the SCOOP@F coverage north from Paris to Lille and beyond to the Belgian border. An extension has been added from Lille towards Dunkirk and Calais
- Netherlands – the site is in the south of the Netherlands and consists of the TEN-T Core Network road section from Europoort Rotterdam to the Belgian border and from Eindhoven to Venlo
- UK – the site is a linear 100 km connected/digital corridor on A102/A2/M2 comprising a major urban tunnel, motorway, rural dual carriageways and London urban and link roads in Kent

http://intercor-project.eu/

C-Roads

This is not a deployment project, but is a Platform open to all ongoing C-ITS deployment activities across Europe to promote interoperable C-ITS services. The aim of the C-Roads Platform is to develop harmonised specifications taking the EU’s C-ITS platform recommendations into account, linking all C-ITS deployments and planning intensive cross-testing. The overall goals include safer roads, more efficient traffic, and reduced emissions from transport. The core member states are Austria, Belgium, Czech Republic, France,
Germany, Netherlands, Slovenia, and the UK.

The main goal of C-Roads is to link C-ITS pilot deployment projects in EU Member States, and to:

- Develop, share and publish common technical specifications (including common communication profiles)
- Verify interoperability through cross-site testing
- Develop system tests based on the common communication profiles by focusing on hybrid combinations of ETSI ITS-G5 and existing cellular networks

https://www.c-roads.eu/platform.html

5. Discussion and conclusions

The topic study presented in this document relates to the ‘Introduction to ITS and C-ITS’ study module. It is a concise, introductory module designed to prepare students for more detailed, challenging modules later on. The content includes basic understanding of concepts of ITS and C-ITS, terms and definitions, and an overview of key elements, such as benefits, impacts, and the challenges of developing a business case, evaluation and deployment, which are covered in detail in dedicated modules.

The target audience is the ITS/ C-ITS novice, or public-sector employees who may have some experience but require a refresher course.

A study module has been developed covering all the key elements of an ‘Introduction to ITS and C-ITS’. Relevant information has been straightforward to obtain given access to comprehensive and up-to-date lecture materials and close partner involvement in innovative projects and real-world deployments in C-ITS throughout Europe.

Obtaining a pass in this module is essential to proceeding further with other modules developed by CAPITAL.

The study module associated with this topic study is already online and will go live on 1st February 2018: https://www.its-elearning.eu/courses/course-v1:Capital+ITS1+test/about
6. References


URL
- [https://amsterdamgroup.mett.nl/](https://amsterdamgroup.mett.nl/) (accessed 3 Jan 2018)
Annex 2: ITS and C-ITS user services

Grant Agreement Number: 724106

Project acronym: CAPITAL

Project full title: Collaborative cApacity Programme on Its Training-educAtion and Liaison

**Topic study 2: ITS and C-ITS user services**

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**Document Control Sheet**

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<td>Editor:</td>
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**Abstract**

This document presents a summary on ITS and C-ITS user services.

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# Abbreviations and Acronyms

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<th>Definition</th>
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<tr>
<td>ABS</td>
<td>Anti-lock Braking System</td>
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<td>ACC</td>
<td>Adaptable Cruise Control</td>
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<td>ADAS</td>
<td>Advanced Driver Assistance System</td>
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<td>AEB</td>
<td>Automatic Emergency Braking</td>
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<td>ATIS</td>
<td>Advanced Traveller Information System</td>
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<td>BLIS</td>
<td>Blind Spot Information System</td>
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<tr>
<td>CACC</td>
<td>Cooperative Adaptable Cruise Control</td>
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<td>CCC</td>
<td>Conventional Cruise Control</td>
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<tr>
<td>CEN</td>
<td>European Committee for Standardisation</td>
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<td>C-ITS</td>
<td>Cooperative Intelligent Transport System</td>
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<td>CPC</td>
<td>Certificate of Professional Competence</td>
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<tr>
<td>DENM</td>
<td>Decentralised Environmental Notification Message</td>
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<tr>
<td>DSRC</td>
<td>Dedicated Short Range Communication</td>
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<td>DTM</td>
<td>Dynamic Traffic Management</td>
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<td>EBA</td>
<td>Emergency Brake Assist</td>
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<td>EC</td>
<td>European Commission</td>
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<td>eCMR</td>
<td>Electronic Consignment Note</td>
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<td>ECU</td>
<td>Electronic Control Unit</td>
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<td>EP</td>
<td>European Parliament</td>
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<td>ESS</td>
<td>Emergency Stop Signal</td>
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<td>EVA</td>
<td>Emergency Vehicle Alert</td>
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<td>FCD</td>
<td>Float Car Data</td>
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<td>I2V</td>
<td>Infrastructure-to-Vehicle</td>
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<td>iTLC</td>
<td>Intelligent Traffic Light Controller</td>
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<td>ISA</td>
<td>Intelligent Speed Assistance</td>
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<td>IVI</td>
<td>In-Vehicle Information</td>
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<td>IVS</td>
<td>In-Vehicle Signage</td>
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<td>GA</td>
<td>Grant Agreement</td>
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<td>GLOSA</td>
<td>Green Light Optimal Speed Advisory</td>
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<td>GPS</td>
<td>Global Positioning System</td>
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<td>HGV</td>
<td>Heavy Goods Vehicle</td>
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<td>LCV</td>
<td>Light Commercial Vehicle</td>
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<td>LDW</td>
<td>Lane Departure Warning</td>
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<td>LIDAR</td>
<td>Light Detection and Ranging</td>
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<td>LGS</td>
<td>Lane Guard System</td>
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<td>MSD</td>
<td>Minimum Set of Data</td>
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<td>NST</td>
<td>Non-stop Truck</td>
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<td>OBU</td>
<td>On-board Unit</td>
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<td>OEM</td>
<td>Original Equipment Manufacturer</td>
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<td>PKI</td>
<td>Public Key Infrastructure</td>
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<td>PO</td>
<td>Project Officer</td>
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<td>PSAP</td>
<td>Public Answering Points</td>
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<tr>
<td>Acronym</td>
<td>Description</td>
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<tr>
<td>PVD</td>
<td>Probe Vehicle Data</td>
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<td>RDS</td>
<td>Radio Data System</td>
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<td>RHS</td>
<td>Road Hazard Signalling</td>
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<td>RLVW</td>
<td>Red Light Violation Warning</td>
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<td>RSU</td>
<td>Roadside Unit</td>
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<td>RTTI</td>
<td>Real-Time Travel and Traffic Information</td>
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<td>RWW</td>
<td>Road Work Warning</td>
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<td>SAS</td>
<td>Speed Alert System</td>
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<td>SPAT</td>
<td>Signal Phase and Timing</td>
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<td>SPATEM</td>
<td>Signal Phase and Timing Extended Message</td>
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<td>TMC</td>
<td>Traffic Message Channel</td>
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<tr>
<td>URI</td>
<td>Uniform Resource Identifier</td>
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<tr>
<td>V2V</td>
<td>Vehicle-to-vehicle</td>
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<tr>
<td>V2X</td>
<td>Vehicle-to-Everything</td>
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<tr>
<td>V-ITS-S</td>
<td>In-vehicle ITS Station</td>
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<tr>
<td>VMS</td>
<td>Variable Message Signs</td>
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<td>VRU</td>
<td>Vulnerable Road Users</td>
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<td>VSL</td>
<td>Variable Speed Limit</td>
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<tr>
<td>WAVE</td>
<td>Wireless Access in Vehicular Environments</td>
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<td>WLAN</td>
<td>Wireless Local Area Network</td>
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<td>WP</td>
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Table 1 - Adapted from The Talking Traffic Case Study, Ericsson 2017
1. Introduction

This study looks at user services in Cooperative Intelligent Transport Systems (C-ITS) both for professional and non-professional drivers. C-ITS have quickly developed from a futuristic concept compared to mainstream ITS to widely adopted services supporting drivers in many different functions, from finding a parking spot to receiving in-vehicle warnings of adverse weather conditions ahead.

In many ways C-ITS are a next step on from by now conventional ITS, and from Advanced Driver Assistance Systems (ADAS), rather than brand new concepts. For instance, assisted braking systems have been standard in vehicles for a number of years, and C-ITS which use information about upcoming hazards to pre-charge or even apply brakes should be considered as a development of ABS rather than a new application.

Properly implemented C-ITS works together with existing on-road ITS and builds on existing in-vehicle support and advisory systems. An extensive review on communication technologies for ITS and C-ITS is found in Topic study 2: Communication technologies for ITS and C-ITS including relevant standards.

For this reason, in order to properly consider C-ITS, the student needs to have a good understanding of ITS as currently in use in all aspects of traffic management, safety, routeing and parking applications. He or she also needs to be familiar with the common ADAS now in use. Imparting this shallow but broad knowledge is not in the scope of this topic study, which assumes that the reader will have a high level familiarity at least with these areas.

2. Scope and objectives

The objectives of the study are to leave the reader with up-to-date information about all the C-ITS services currently available to drivers, whether professional drivers or those who use cars purely for personal transport. Many of the systems are applicable to both types of driver, and the study makes it clear where the demarcations lie. It also spells out the benefits of the C-ITS to the different categories of driver, to fleet operators and to road operators. This sketching of use cases gives some good clues to potential business cases, which are without the scope of this particular module but are covered elsewhere in the course. As with many ITS, the financial benefit does not necessarily accrue to the person or organisation which funded the service. Subscribing to services which enable HGV drivers to find safe and secure parking facilities will ultimately save money for the haulage operator, but services which reduce crashes due to poor road surface conditions save money for health services, the emergency services, insurers and individual drivers to a far greater extent than for the road operator who invested in the service. Understanding the different services enables a more informed approach to thinking about business cases, and is one of the contributions of this study.

At the same time as listing the C-ITS services for professional and non-professional drivers, the study in current or imminent use, the study also contains references to real life examples of implementations with references, so that the reader can seek detailed information about any particular service from those who have actually implemented or used it.

The study also looks at user acceptance of C-ITS services for non-professional drivers. Closely connected to the much more widely discussed topic of user acceptance of autonomous vehicles, this field of enquiry is both interesting and important. Professional drivers can to a large extent be compelled by their employers to use C-ITS (trade union activity and privacy legislation being the only possible barriers to this) but private car owners will only engage with C-ITS if they see a benefit to themselves, believe that there are no risks to
themselves via privacy infringements or the detection of illegal activity such as speeding or red light running, and find the service affordable. The authors believe that the benefits in safety, comfort, reliable and predictable journeys outweigh the risks of surveillance inherent in C-ITS. A parallel might be the use of mobile phones, which constantly pin points the whereabouts of the user but appears to cause no fears about surveillance. The convenience and enjoyment the phones bring seem to stop users thinking about how their providers know their whereabouts in detail, all of the time.

However, other views on the non-professionals’ user acceptance of C-ITS can also be substantiated and it is hoped that this section of the module will engender thought and discussion in this area.

Finally, the study takes a look at how to communicate ITS to the public. This is of course connected to the issue of user acceptance, and it is fair to say that public understanding of ITS is generally low. While most people have some understanding of how clean water is made to come out of their taps, or how the engine of their car works, they have no idea of why traffic lights change colour when they do or how the correct fare is deducted from their smart card bus ticket. There is perhaps a general failure of all areas of IT to explain to lay people how their technology works – just as people do not understand traffic management technology, they generally do not understand how their emails or web browsing works, either. If we agree, as we hopefully do, that a better understanding of ITS would be a good thing, then the relevant section of this study looks at whose responsibility that might be and how it might be accomplished.

3. Methods

Information for this study was collected from a wide range of sources available to the FIA and ITS (UK), particularly published papers and project dissemination materials. With much C-ITS work having been undertaken in the form of publicly funded projects, research and implementations, the existing C-ITS are well documented in a fairly accessible way.

The information has been organised into a comprehensive list of C-ITS as currently available, plus some more analytical sections covering attitudes, different roles, and thoughts on what the future might hold and what we might wish to do now in order to shape this in the way we would like it to develop.
4. ITS and C-ITS services for professional drivers

Before starting a discussion on various ITS and C-ITS services for professional and non-professional drivers, first of all, it is necessary to explain the terminology used in this chapter, namely, who are the ‘professional’ and ‘non-professional’ or ‘normal drivers.’ A brief summary of the ITS and C-ITS terminology is going to be presented in this chapter. In the next step, some ITC and C-ITS services designed for professional drivers will be presented more in detail.

4.1 Definition of professional and non-professional drivers

There is not a clear definition that can define both professional and non-professional drivers. A very simple explanation of a ‘professional driver’ is someone who is paid for driving a vehicle. It includes chauffeurs, taxi, bus, truck, and test drivers, etc.

The Directive 2003/59/EC of the European Parliament and the Council (15 July 2003)\(^2\) says that “certain drivers engaged in the carriage of goods or passengers by road must, depending on their age, on the category of vehicle used and on the distance to be travelled, hold a certificate of professional competence in conformity with Community rules on the minimum level of training for some road transport drivers. That minimum level is determined by Directive 76/914/EEC.” Then in §7 it is said “In order to establish that the driver complies with his or her obligations, Member States should issue the driver with a certificate of professional competence, hereinafter referred to as ‘CPC’ (Certificate of Professional Competence),\(^3\) certifying his or her initial qualification or periodic training.” Therefore, a professional driver needs to have a CPC and a valid driving license for the category of driven vehicle.

4.2 Definition of ITS and C-ITS services

Before starting the discussion about ITS and C-ITS services, it is important to mention Advanced driver-assistance systems (ADAS). They are the systems that help the driver during the driving process. ADAS are the system designed to automate, adapt and enhance vehicle systems for safety and better driving. The developed systems proved to reduce road fatalities, by decreasing the human error. Safety features of ADAS designed to avoid accidents by providing technologies that alert driver about the potential problems, or avoid collisions by engaging safeguards and taking over control over vehicle. Adaptable features of ADAS may automate lighting, provide adaptable cruise control, connect to smartphones, alert the driver about the danger, lane departure or show what is in blind spot. ITS and the C-ITS make the part of ADAS.

There is no homogeneous definition that can explain ITS and C-ITS. The reason for it is that ITS have a very fast exponential development and highly cross-cutting and interdisciplinary nature.

The term ‘ITS’ stands for the ‘Intelligent Transport Systems’ or ‘Intelligent Transportation Systems.’ In a wider sense, ITS mean a system related to mobility that enhances the development through information technology (IT).

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\(^3\) Driver CPC is a Certificate of Professional Competence issued to drivers who are entitled to hold one. It was first introduced across the EU in 2008 for professional bus drivers and 2009 for professional truck drivers. Its objective was to set and maintain high standards of road safety, health and safety and driving among professional drivers of buses and trucks. Therefore, in order to drive a bus or truck, it is required that a driver holds a current valid driving license for the category of driven vehicle, and a current valid driver’s CPC card for the category of driven vehicle. Both documents need to be carried while driving a vehicle.
ITS apply advanced technologies of electronics, communications, computers, control and sensing and detecting in all kinds of transportation system in order to improve the management of the transport system, increase safety, efficiency and service, and traffic situation through transmitting real-time information. It can help to tackle congestion, pollution, poor accessibility and even social exclusion.

According to the EC “ITS are advanced applications which – without embodying intelligence as such – aim to provide innovative services relating to different modes of transport and transport management and enables various users to be better informed and make safer, more coordinated and ‘smarter’ use of transport networks” (European Commission, 2010b).”

The ‘C-ITS’ term stands for the ‘Cooperative Intelligent Transport Systems.’ C-ITS focus on the communication or exchange of data between intelligent transport systems, whether it is a vehicle communicating with another vehicle, with the infrastructure, or with other C-ITS systems.

The NEWBITS project defines ITS and C-ITS, as following: “C-ITS are considered a subset of the overall ITS that communicates and shares information between ITS stations to give advice or facilitate actions with the objective of improving safety, sustainability, efficiency and comfort beyond the scope of stand-alone system.” It also considers the main function of ITS as increased efficiency in the transport system, with special focus on the service and information provision for the full spectrum of users (drivers, passengers vehicle owners, network operators…) which involves a diversity of stakeholders (network operators, public authorities, OEMs, service providers, technology developers…).

With C-ITS communication is happening between vehicles (vehicle to vehicle, V2V), between vehicles and infrastructure (vehicle to infrastructure, V2I; infrastructure to vehicle I2V) and/or between vehicles and other transport participants (V2X), for instance pedestrians or cyclists.

Figure 1 shows how various C-ITS (safety systems, warning systems, travel assistance, traffic signals, navigations, fleet management etc.) communicate and interact between themselves by using different communication networks, such as MAN, Mobile, WLAN, ITS-G5, and

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4 https://cordis.europa.eu/project/rcn/205765_en.html
satellite to exchange the information and data.

Figure 1. Intelligent Transport Systems\textsuperscript{5}

It is essential to understand that ITS as well as C-ITS are not limited to only one mode of transport, i.e. road, but they also include other modes of transport such as rail, aviation and waterways and communication between them. Because of numerous benefits and relatively moderate costs related to deployment of C-ITS, there is a big interest and need in society towards a fast introduction of these services.

All ITS and C-ITS services will be divided into two groups, i.e. the services that are designed only for the professional drivers and services that are intended for non-professional drivers. The last categories of the services can be used also by both categories. Therefore, in the next chapters we will try to present the existing ITS and C-ITS services aimed for professional drivers as well as their cooperation with the public authorities. Then the focus will be on the ITS and C-ITS services for normal or non-professional drivers and their cooperation with the public authorities.

5. ITS and C-ITS services for professional drivers

There are a number of ITS and C-ITS services that were created for professional drivers. However, in this chapter only some ITS and C-ITS services are going to be briefly presented. Many of these services are designed to be used by only professional drivers, or by both professional and non-professional drivers.

The chapter consists of two part, i.e. the first part discusses some ITC services and the second one will focus on the C-ITS services. The main purpose of this chapter is to briefly present these services, explain how they function and what their benefits are for professional drivers. The covered services are supported by some examples.

5.1 ITS services for professional drivers

The selected ITS services are:

- Speed alert system
- Dynamic navigation system
- Eco-driving assistance
- Adaptable headlights
- Blind spot information system
- Lane departure warning
- Obstacle and collision warning
- Emergency braking

5.1.1 Speed alert system

Speed alert system (SAS) or intelligent speed assistance (ISA) helps drivers to keep their speeds within the recommended limits and warns a driver when the local valid speed limit is exceeded. The system uses audio, visual or haptic feedback.

The information regarding speed limit is received from transponders in speed limit signs or from a digital road map that reads positioning information, or is determined by software which analyses images from a camera and recognises traffic signs. Other systems also can use GPS information from satellites to monitor the actual speed of a vehicle and give alarms to a driver. The modern systems combines information from both sources, namely a camera and digital speed map/GPS.

This service can be used by both professional and non-professional drivers.

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7 https://apkpure.com/speed-alarm/com.sqzsoft.speedalarm
5.1.2 Dynamic navigation systems

Navigation systems guide a driver to the destination according to the objective function, which optimises travel time or travel distance, whereas a dynamic navigation system also takes into account dynamic traffic information, by using a real time traffic event and transport network status data to carry out a correct routing process in electronic navigation systems.

The system uses a positioning system to estimate a vehicle’s location and certain algorithms to calculate the best route to the destination. The estimation is based on information stored in a digital map. The dynamic navigation system helps drivers to avoid parts of roads with accidents, or roadworks, or congestions, etc.\(^8\)

The Traffic Message Channel (TMC)\(^9\) is used to send the basis traffic information by means of Road Data System (RDS) radio communications. In dynamic navigation system more improved sourced content is utilised to improve the standard TMC services. The system informs a driver about the obstacle on a route and provides information regarding alternative routes. These services are provided via cellular networks.

![An example of dynamic navigation system (GPS Navigation & Maps Sygic app)](image)

5.1.3 Eco-driving assistance

Eco-driving assistance provides information to a driver regarding the actual fuel and energy consumption in a vehicle. It also suggests gear selection, taking into account engine and transmission efficiency, vehicle speed, rate of acceleration etc. The information on instantaneous fuel consumption is displayed on the instrument panel. There also can be an Eco Drive Indicator, which informs the driver when a vehicle operates in a fuel-efficient

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\(^9\) [http://www.esafety-effects-database.org/applications_17.html](http://www.esafety-effects-database.org/applications_17.html)
manner. Eco-driving\textsuperscript{10} also indicates when a gearshift\textsuperscript{11} needs to be done.

One example of eco-driving assistance is Mitsubishi-Motors ECO indicator\textsuperscript{12} or, as it also called, instrument cluster to support eco-driving. ECO drive support has several indicators:

ECO indicator (ECO lamp), which is displayed when fuel efficiency is achieved:

![ECO indicator](image1)

Fuel consumption gauge, which shows fuel consumption and average fuel consumption:

![Fuel consumption gauge](image2)


AUTO STOP & GO (AS&G) monitor, which shows the accumulated time the engine has been stopped by AS&G system.

![AUTO STOP & GO (AS&G) monitor](image)

ECO drive assist, which displays how fuel-efficiently a vehicle is driven:

![ECO drive assist](image)

ECO score indicates the points a driver scored by driving fuel-efficiently:

![ECO score](image)

### 5.1.4 Adaptable headlights

Adaptable headlights are an active safety feature designed to make driving at night safer by increasing visibility over hills and around curves. The system consists of electro-mechanic controlled headlights. The system aims to have optimal illumination of the lane in curves of a road.

The system is activated when a vehicle starts cornering. At that moment, headlight is directed into the bend according to steering input so that the vehicle’s actual path is lit up. Similarly, when a vehicle approaches a hill, the headlights beams are pointed down or up, according to the position of the vehicle. The system also ensures reduction of glare to the upcoming vehicle. The system uses yaw-rate and steering wheel angle as well as vehicle speed as input data to adapt headlights.
Adaptable headlight system consists of several sub-components that are monitored and controlled by an electronic control unit (ECU). There are four main sensors:

- Wheel speed sensor that monitors speed or rotation of each wheel;
- A yaw sensor that tracks a vehicle’s side-to-side movement;
- A steering input sensor that monitors the angle of the steering wheel;
- Small motors attached to each headlight.

The data is collected from all sensors and interpreted by ECU, which determines the vehicle’s speed and the angle and length of the curve. The ECU also controls each motors attached to headlights to move the beam to the degree specified by the ECU. In most cases, the headlight degree is up to 15 per side. The system also includes self-leveling. A leaving sensor sends information to the ECU about the vehicle’s position, whether it is tilted forward or backward. The headlights are then moved up or down to correct the vehicle’s position.

5.1.5 Blind spot information system

Blind spots are the areas outside a vehicle that a driver is unable to see. They can be caused by the window pillars, headrests, passengers and other objects. These areas are quite small close to the vehicle, but cover larger areas further away. Another type of blind spot is a driver’s peripheral vision and the area reflected by the rear-view mirrors.

Blind spot information system (BLIS)\(^\text{14}\) aims to either provide better vision into blind spot area or provide information to a driver about an obstacle that is located in this area by informing the driver using warning signals. Using cameras with image processing or radar sensors can provide additional information to a driver about the situation on both sides of the vehicle blind spots.

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\(^{13}\) [http://brainonboard.ca/safety_features/driver_assistance_technology_adaptive_headlights.php](http://brainonboard.ca/safety_features/driver_assistance_technology_adaptive_headlights.php)

The main benefit of the blind spot warning system is to prevent lateral accident between a vehicle leaving its own lane and an obstacle (other vehicle) moving on a road in the same direction.

5.1.6 Lane departure warning

Lane departure warning (LDW) system was designed to warn a driver of a vehicle about the unintentional leaving of the lane and take corrective action if required. The most used technology is video image processing that detects lane marking on a road surface. The warning provided by the system can be either acoustic, or visual, or haptic, or combination of several types of warning.

Figure 6. Lane departure system (Kia, Sorento safety lane departure warning system)\textsuperscript{16}

\textsuperscript{15} http://overdrive.in/news-cars-auto/radar-based-safety-features-offered-in-cars/
The forward viewing camera located on a vehicle sends the image of marking on the road to a central computer.\textsuperscript{17} By identifying reflective lane markings, an indication of vehicle lane position is established. The information from the steering wheel angle is combined with information received from a camera. The system determines whether the driver is unintentionally leaving the intended driving path. Then a warning is issued. The system can also attempt to correct the situation by nudging the steering wheel in a direction to maintain lane position.

5.1.7 Obstacle and collision warning

The obstacle and collision warning system provides an alert to a driver of a vehicle when collision is imminent. This service is a part of Adaptable Cruise Control (ACC) systems that use information received from radar sensors/radar or camera that are attached to the front of the vehicle monitor both distance and relative speed to the object in the forward travel path. The system sends visual and acoustic warnings to a driver.\textsuperscript{18} Some devices use a graduate warning system, employing a range of audible, visual or tactile responses, which can vary according to proximity and likelihood of a collision. It is possible that future systems will likely use long range / near range radar sensors or LIDAR\textsuperscript{19} and video image processing.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure7.png}
\caption{Obstacle and collision warning system (brake assist in 3 levels)\textsuperscript{20}}
\end{figure}

Sometimes collision warning systems with pre-charged brakes are bundled with automatic braking or emergency braking assist systems (refer as well to chapter 5.1.8). It can provide a driver with a substantial amount of braking power\textsuperscript{21} the moment he depresses the pedal. It can

\textsuperscript{18} Ibid.
\textsuperscript{19} LIDAR is a surveying method that measure distance to a target by illuminating the target with pulsed laser light and measuring the reflected pulses with a sensor. Differences in laser light return and wavelength is used to produce a 3D representation of the target. The system is used to produce high-resolution maps and to control and navigate for some autonomous cars.
\textsuperscript{20} http://www.coherentchronicle.com/automotive-collision-avoidance-system-market-is-expected-to-show-significant-growth-over-the-forecast-period/
\textsuperscript{21} https://blog.roboauto.cz/how-it-works-collision-avoidance-system-d05bd9807f1a (Accessed:
effectively reduce the severity of an accident. In some systems when a collision is forthcoming, it can engage the brakes rather than merely pre-charge them.

5.1.8 Emergency braking

Emergency braking system is based on long range / near range radar sensors or LIDAR and/or camera. The system is designed to provide support in situations with a high risk of collision on a road by deploying the braking systems of a vehicle to reduce the collision speed and the total crash energy. There are various level of support available, namely enhancement of driver’s braking if necessary, automatic activation of partial braking, and automatic activation of full braking. In some systems reversible measures of occupant protection is triggered.

Many modern cars have automatic emergency braking (AEB) systems. Different car companies use various methods which bundle AEB with other systems, such as ACC, radar, camera, ABS, etc. These systems controlled by on-board computer can react faster to avoid situations with a high risk of collision.

![Figure 8. EBS by MAN](image-url)

MAN, for instance, has introduced a new generation of advanced emergency braking system with sensors fusion, the emergency brake assist (EBA) and the emergency stop signal (ESS). The EBA and the new lane guard system (LGS) will become standard accessories in majority of MAN trucks, both MAN and NEOPLAN coaches and intercity buses.22

5.2 C-ITS services for professional drivers

There is a number of C-ITS services that have been designed for professional drivers. However, in this chapter we will focus only on some of them.

The selected C-ITS services are:

- Urban parking availability
- Signal violation warning
- Warning system for pedestrian
- Green priority
- Green Light Optimal Speed Advisory (GLOSA)
- In-vehicle signage (IVS)
- Emergency Brake Light
- Cooperative Adaptive Cruise Control
- Motorcycle approach indication
- Blind spot detection / warning (VRUs)
- Non-stop truck

### 5.2.1 Urban parking availability

C-ITS service that focuses on urban parking availability provides information about parking availability and guidance for drivers to make informed choices about available parking places. This service aims at a reduction of congestion, time loss, pollution, and stress caused by cruising for parking. It can be used by truck and coach drivers as well as any vehicle driver. It provides information on the availability of parking places and it indicates dimension and weight restrictions, which is valuable information for truck and coach drivers. This service gives information about pick-up and drop-off places where coaches and trucks can stop for a limited time.

The service works as follows: when a truck or coach leaves a parking lot, it sends a message via the C-ITS app (V2V). This information is transmitted to and received by other search for a parking place vehicle (V2V). Then the searching vehicle confirms that it is approaching and when it arrives at the destination, the leaving vehicle leaves its parking space. The information is communicated through the C-ITS app that is installed on the driver’s smartphone or on-board unit.

There are multiple benefits of this service, namely a truck or coach driver does not need to spend a lot of time on searching for a parking place, congestion is reduced, pollution in urban areas is cut, and there is higher occupancy of parking lots.

However, this C-ITS service has some limitations. The service will not work in the covered parking lots due to positioning problems.

One of the intelligent parking systems was created in partnership by Deutsche Telekom and Kiunsys and a pilot project was deployed in Piazza Carrara in Pisa, Italy.\(^\text{23}\) The system combines sensors on the floor of spaces, information signs across the city and smart street lighting. It helps drivers to find parking spots. The information is send from the infrastructure to vehicles (I2V).

The sensors on the floor of each parking spot detect whether they are free or occupied. The data is collected by several units and sent to the city’s server infrastructure, using the mobile network. The information is then sent to the drivers and guides them to a free parking lot. They can also choose whether they want to pay for a parking lot by using Pisa’s existing Tap&Park app, which is integrated with the new system.

5.2.2 Signal violation warning

Signal violation warning service aims to reduce the number and severity of accidents at signalised intersections by warning drivers who are likely to violate a red light, or when another vehicle is likely to make a red light violation. Also known as the “Signal violation / Intersection Safety” or “Red Light Violation Warning” (RLVW). This service provides timely assistance information on a red light violation downstream of the current position.

The drivers are informed about the current and future state of relevant traffic light. They are also warned in case of probable own red light violation and other drivers are warned for a red light violation. In cases where an emergency vehicle is approaching, the drivers are warned to make way and that the emergency vehicle will run the red light. The service warns the drivers who make turn to give way to the vehicles from the opposite direction who have green light in the same time. The drivers are also notified when they make a turn to give way to vulnerable road users who have a green light at the same time and are crossing the side road.

A vehicle driver receives a red light violation information on a smart phone or the on-board unit. A road operator / RSU detects and signals the presence of a red light violation. This information is sent by the service provider to vehicle drivers. The information includes the remaining distance or time to reach the signalised intersection, traffic light state, which includes its presence, colour and time to change. This C-ITS service provides a driving recommendation.

There are three systems designs, depending on different level of complexity, namely

informative, rule-based or predictive.

- Informative system provides the information about a traffic light state, i.e. its presence, colour and time to change.

- The rule-based system is based on monitoring spatial-temporal variables, for instance vehicle speed and time to stop line, subject to the traffic light state and informs a driver if pre-set thresholds are reached.

- The predictive system predicts the trajectory of the vehicle to estimate the likelihood of red light violation.

The turning warning in the signal violation warning can be static or dynamic. Static turning warnings are based on signal phase and timing information which indicates signal phases with a green light for two conflicting directions. Dynamic turning warnings also take into account the actual presence of traffic on these directions before a warning is given. Static turning warning messages are sent constantly, but dynamic turning warnings are provided when conflicting traffic is present.

### 5.2.3 Warning system for pedestrian

A warning system for pedestrian (not limited to crossing) is a C-ITS service that intends to detect risky situations (e.g. road crossing) involving pedestrians or cyclists, enabling the possibility of warning vehicle drivers or automatically controlling the vehicle (e.g. braking). This warning is based on pedestrian detection. The service is particularly valuable when the driver is distracted or visibility is poor. (Also known as "Vulnerable road user Warning" (ETSI TR 102 638, 2009)).

The service aims to inform a driver about a dangerous situation that is bound to occur, either due to driver behaviour, or VRU behaviour in the vicinity of the vehicle.
There are several ways to implement this service. The traffic lights can be connected to roadside units (RSU) which can collect and transmit the information about traffic, namely traffic lights, road hazards as well as position and behaviour of traffic users. The data may also be gathered from on-board unit (OBU) applications. Both sets of data are used to track whether a dangerous situation may arise and inform the user to improve decision making and safety.

![Pedestrian warning example](image)

**Figure 11. A pedestrian warning example from an in-car safety application developed by BMW**

The C-ITS application is installed on the driver’s smart phone or on-board unit and it detects a situation that may result in a traffic accident involving a VRU. The app receives the information from RSUs and other traffic users, VRUs and other on-board sensor and scans for dangerous situation. It provides warning to the driver. This message includes information about the presence of the VRU, accident avoidance advice and information about the detected situation. The driver takes the accident avoidance advice. The RSU can be installed in the crossing and VRU can be equipped with signalling beacons. An alternative approach, which is supported by the Telcos is based on recognising pedestrians via their smartphones and/or with WiFi (V2X).

### 5.2.4 Green Light Optimal Speed Advisory (GLOSA)

The GLOSA service provides advice to drivers allowing them to optimise their approach to a traffic light (maintain actual speed, slow down or adapt a specific speed, time to green light). If a green traffic light cannot be reached in time, GLOSA may also provide time-to-green information when the vehicle is stopped in the stop bar. Application of GLOSA takes advantage of real-time traffic sensing and infrastructure information, which can then be communicated to a vehicle aiming to reduce fuel consumption and emissions.

There are several benefits from GLOSA service, namely expected smoother vehicle trajectory while passing a signalised intersection, reduction of stops, lower CO₂ emissions as well as fuel consumption. Other benefits are enhanced traffic flow and driver comfort.

The service can be available in two versions, namely for professional drivers (public transport, that make use of the maximum performance) and for commuters, who will use the light version (no sensor interfacing).

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The GLOSA service can be implemented in various ways. For example, the traffic light that is connected to a roadside unit (RSU) can transmit information about the topology of the intersection and the traffic light phases to nearby vehicles. An approaching vehicle receives the information about the traffic light and calculates the optimal speed to the intersection. A driver of a vehicle will adjust the speed following the speed advice given by GLOSA.

When a driver approaches an intersection the intelligent traffic light controller (iTLC) sends the signal phase and timing information to the vehicle. The ITS G5 RSU transforms the data into a Signal Phase and Timing Extended Message (SPATEM) message which is received by the C-ITS app installed on the driver’s smart phone or on-board unit. The app provides a driver with GLOSA. The driver adjusts the speed of the vehicle and reaches the intersection at the beginning of the green phase.
Figure 12. Traffic light optimal speed advisory illustration (Source: Dutch Profile Part A - Use case catalogue)

Figure 13. Symbols from the EU's green light optimal speed advisory (Source: ITS International)

Figure 14. GLOSA Application

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27 www.itsinternational.com/
28 http://c-thedifference.eu/
5.2.5 Emergency Brake Light

Emergency Brake Light service intends to avoid rear end collisions, which can occur if a vehicle ahead suddenly brakes, especially in dense driving situations or in situations with decreased visibility. The driver is warned before being able to perceive that the vehicle ahead is braking hard, especially if the driver does not see the vehicle directly (vehicles in between).

The main benefits of this C-ITS service is enhancement of safety in dense driving environment by providing timely in-car driving assistance information. It is expected that this service will decrease the number of accidents.

![Figure 15. Emergency brake lights](image)

The service is activated when a vehicle driver receives emergency brake light warning on the C-ITS app installed on a smartphone or in-vehicle display. A vehicle automatically detects the emergency braking, activates emergency brake lights and sends the detected emergency braking information to RSUs and other vehicles within the range. RSUs send this information to a road operator or traffic manager who flags up the sudden slowdown. Then the service provider sends the emergency brake light warning to vehicle drivers and it is shown on the C-ITS app.

5.2.6 Cooperative Adaptive Cruise Control

Cooperative Adaptive Cruise Control (CACC) is an evolutionary development of conventional cruise control (CCC) and adaptive cruise control (ACC). It uses V2V communications to automatically synchronize the motion of many vehicles within a platoon. While ACC uses Radar or LiDAR measurements to derive the range to the vehicle in front, CACC also takes the preceding vehicle’s data included in CAM (e.g. position, speed, acceleration, etc.) and tries to maintain a fixed following time with the preceding vehicle, minimising the lack of stability and responding more quickly to speed change. (This is closely related to "Co-operative vehicle-highway automation system (Platoon)" (ETSI TR 102 638, 2009)).
This service intends to ensure smooth driving of vehicles with CACC function or platooning technologies for driving through C-ITS equipped intersections. Vehicles with this technology benefit from V2V information exchange to improve the efficiency of driving and traffic flow. When these technology are combined with V2I functionalities, the driving pattern and the traffic lights on intersections can be optimised for traffic flow around intersections.

Two pilot sites were selected, namely Bordeaux and North Brabant. The vehicles equipped with CACC service can improve their flow through a series of intersections by adjusting their speed and spacing in accordance with the advice received from the iTLC in order to reach the subsequent intersection during the green-light phase.

In case of truck platooning, a set of three trucks will drive along the highway to a distribution centre in an urban area. The benefit is to maintain the platoon-mode when a set of trucks exits the highway and approaches traffic lights before reaching the distribution centre of a city. The iTLC will interact with the platoon leader, advising the speed for the platoon to approach the intersection at the proper time and guaranteeing a longer duration of the green light phase in

order for the whole platoon to pass the intersection safely.

5.2.7 Motorcycle approach indication

Motorcycle approaching indication service that also include other VRUs intends to warn the driver of a vehicle that a motorcycle is approaching / passing. The motorcycle could be approaching from behind or crossing at an intersection. This service assists the driver with blind spots. This service aims to improve safety of two-wheelers and other VRUs.

There are two cases of deployment of this service, namely the warning message is transmitted from other vehicles (V2V) or from a vehicle to infrastructure (V2I) and to other vehicles (V2V).

In the first case the C-ITS app on the motorcycle continuously sends movement and position information to vehicles nearby. A vehicle driver receives an awareness warning about the motorcycle in proximity and can automatically compare his own movement data with the motorcycle data. A warning is issued to the driver when a possible conflict with the motorcycle is detected or the relative distance between both decreases below a given safety margin. The motorcycle also receives the information about other vehicles in proximity on the C-ITS app. The message is transmitted by the service provider.

![Figure 18. Approaching motorcycle warning (CAR2CAR Consortium)](https://www.car-2-car.org/index.php?id=171)

In the second case the information is not only sent from the motorcycle to nearby vehicles but also to the traffic infrastructure (RSU).

5.2.8 Blind spot detection

The blind spot detection service intends to detect and warn the drivers about other vehicles of any type located out of sight. This can be considered as an extension to or an application of the motorcycle approaching indication service.

This C-ITS service provides information to a vehicle driver regarding a vehicle in a designated blind spot location. The information appears on the screen of the on-board unit or a smartphone. The information comes from the RSU located at the proximity of the designated blind spot location. When a vehicle enters the blind spot area the RSU and other vehicle drivers receive a timely awareness message on the C-ITS app. This message includes

information about the presence of another vehicle in the blind spot location and, if necessary, a driving recommendation is displayed (e.g. to brake or adapt speed).

Figure 19. Dynamic cooperative networks with Blind spot detection (Source: SAFESPOT Integrated Project)\textsuperscript{32}

SAFESPOT Integrated Project\textsuperscript{33} has created a dynamic cooperation network where the vehicles communicate with infrastructure (Roads Side Unit) and other vehicles to share information that is gathered on-board and at the RSU. The network includes various systems to detect potentially dangerous situations in advance and increase the drivers’ awareness of the surroundings in space and time. It also includes blind spot detection.

\textsuperscript{32} \url{http://www.safespot-eu.org/}
\textsuperscript{33} \url{https://cordis.europa.eu/project/rcn/80569_en.html}
6. ITS and C-ITS cooperation among professional drivers and public authorities

This chapter aims to briefly present the existing ITS and C-ITS services that are designed for cooperation between professional drivers and public authorities. Due to a vast number of existing services only some of them will be discussed in this section of this topic study. This chapter consists of two parts, namely the ITS cooperation among professional drivers and public authorities and the second one presents selected C-ITS cooperation among professional drivers and public authorities.

6.1. ITS services

Selected ITS services that are going to be discussed in this chapter:
- eCall
- Advanced traveller information system (ATIS)
- Dynamic Traffic Management
- Local danger warnings

6.1.1 eCall

e-Call is an ITS service that provides a European in-vehicle emergency call system. The purpose of eCall is to send an automated emergency call by an In-Vehicle System (IVS) in case of a serious road accident. The service dials the European emergency number 112 and establishes a telephone link to the appropriate emergency call centre (Public Safety Answering Point – PSAP).34 The system is automatically triggered when a collision sensor installed in the vehicle detects an accident, or manually by pushing a button in the vehicle. It sends details of the accident (Minimum Set of Data - MSD) to the emergency centre.35 The message contains information on vehicle type, exact location (GPS), time of accident and direction of travel. In addition, the PSAP can make use of EUCARIS (EUropean CAR and driving license Information System) to retrieve more vehicle-related information. This service is included as one of the priority actions in the EC’ ITS Directive 2010/40/EU. On 28 April 2015 the European Parliament EP voted in favour of eCall regulation which requires all new cars need to be equipped with eCall technology from April 2018 (Directive 2007/46/EC in accordance to COM(2013) 316).36

![Figure 20. eCall system](http://www.righttoride.eu/eu-e-call/)

The EU funded project I_HeERO deals specifically with the needs and issues related to how

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eCall would operate in a commercial vehicle environment, including vehicles carrying dangerous goods, buses and coaches. It intends to provide a recommendation for CEN to develop a standard for eCall that includes HGV buses and coaches.

In a case of eCall for HGV, in order for the emergency service to respond in a proper manner and get to the scene equipped with appropriate tools and protection gear in case of dangerous goods, it is important that the emergency services possess information on the content of the cargo. This information can be provided by the IVS or can be retrieved from external source of information, for instance e-CMR. It is the carrier who needs to decide which of two solutions to use but any PSAP needs to support both.

The project came up with two solutions that are based on CEN Technical Specification TS16405 and consider other eCall related standards.

The first solution is based on cargo information from a vehicle. In this approach the information regarding the transported cargo needs to be entered in the IVS before a vehicle starts the journey. Sensor data (e.g. cargo temperature, pressure) can be included in MSD which is sent to the PSAP. Since the capacity of MSD is quite limited, only some information on cargo can be transmitted to the PSAP. Furthermore, in such solution IVS requires an interface which increase the price of such units. This solution uses Schema A that is described in TS 16405.

Another solution is based on the principle that cargo information comes from an external source. In this case the information that is sent by MSD is not limited by size, since the IVS only provides the URI of the endpoint, the HGV information service, where the PSAP can retrieve full data on the cargo. This solution uses Schema B that is described in TS 16405.
In the Schema B, the communication between PSAP and HGV information service is secured using standard mechanisms (e.g. HTTPS). It was proposed by the project to use REST or SOA web-services, using e-CMR data format based on UN/CAFACT Electronic Consignment Note (e-CMR) Business Standards data model. By using a single data format, it decreases the implementation burden for PSAPs, but it requires cargo management solutions of transport operators to implement e-CMR.

The project proposes a decentralised solution in which PSAP and HGV information services use Public Key Infrastructure (PKI) to ensure authenticity and data security. In a (semi) centralised option, where the cargo information service is provided by the widely-used EUCARIS service, this does not act as data storage, but instead only as a proxy/routing service.

Regarding eCall service for buses and coaches, it differs from eCall designed for passenger cars for a number of reasons, such as the type and size of the vehicle, its weight, number of passengers, etc. The project I_HeERO identifies that the number of passenger on board is key information that needs to be transferred to the PSAP in case of an incident. Similarly to passenger cars and HGV, buses and coaches need to be equipped with IVS, which requires information on the number of passengers.

The project provides two solutions. One is based on information regarding the number of passengers which is obtained from the vehicle and the second one is based on information on the number of passengers which is received from an external source. In the first solution the on-board systems that can estimate the number of passengers include as ticketing systems, CCTV on board cameras, seatbelt sensors and air-suspension sensors as possible sources of data. This information is passed to the IVS and is later sent to PSAP in case of an accident. The second solution uses the URI parameter from the MSD to connect to an external data source and retrieve information on the number of passengers.

eCall ITS is obligatory for private cars from 1 April 2018 but has not yet been mandated for HGVs, buses and coaches. However, the benefits of its deployment on other types of vehicles will be immense, and will impact road safety and the efficiency of emergency services in quicker responses to accidents.

### 6.1.2 Advanced traveller information systems

Advanced traveller information system (ATIS) provides drivers with information in real time on traffic jams, road closures, weather conditions and other situations that may impact travel time.
ATIS can be categorized into two groups: pre-trip and en-route.\textsuperscript{38}

Pre-trip ATIS may provide drivers with real-time traffic information (RTTI) to help them to plan their route, namely to decide on departure time, and route. RTTI aims to help drivers to make informed decisions when on the road.

En-route ATIS, such as variable speed limit (VSL) may impact the entire road network and may be intended as a link control strategy. VSL system can be installed on certain segments of the road to provide dynamic speed limit, warning information, travel time, route guidance, etc.

The information on traffic situation is collected from the floating car data (FCD) and floating phone data (FPD) by service providers. The data is processed, integrated and transmitted to the vehicles, smart phones, etc. of the customers through traffic message channel (TMC) technology. This information is digitally coded into radio data system (RDS) and transmitted via FM radio broadcasting. Information on traffic can also be transmitted on digital audio broadcasting (DAB) or satellite radio. A new technology of transmitting traffic data is known as TPEG (Transport Protocol Expert Group). It sends information via digital broadcast formats such as DAB or internet. The real-time information can be read by a synthetic voice aloud or displayed as a text message, an icon or a colour-coded map.\textsuperscript{39}

6.1.3 Dynamic Traffic Management

Dynamic traffic management (DTM) systems as well as local danger warning are services that aim to increase the safety and flow of traffic in case of disturbances or accidents on a road. DTM also include ramp metering, dynamic lane management, overtaking bans (HGV), dynamic speed limitation, warning messages about critical road conditions (e.g. snow/ice on road), etc. These systems are managed either automatically, or semi-automatically, or


\textsuperscript{39} Ibid.
manually by traffic control centres who receive information on traffic flow from fixed monitoring systems or mobile sensors (FCD etc.) in certain locations on a road. The systems use variable message signs (VMS) to provide information to drivers. There are three categories of VMS, depending on the type of message, i.e. ‘regulatory messages,’ ‘danger warning messages’ and ‘informative messages.’

The dynamic traffic management is an ITS service that is used by all users of a road traffic, including professional and non-professional drivers.

6.1.4 Local danger warnings

Local danger warning systems for drivers aim to increase safety and flow of traffic in case of any disturbance caused by an accident, congestion or weather conditions. The system works automatically, semi-automatically, or manually from traffic control centre. The system collects information from fixed monitoring systems or mobile sensors on location. It uses VMS to provide information on the drivers.

There are three types of VMS, based on types of messages given: ‘regulatory messages,’ ‘danger warning messages’ and ‘informative messages.’ As for local warning systems, they use danger warning messages.

6.2 C-ITS services

There is a number of C-ITS services that have been designed for professional drivers. However, in this chapter we will focus only on some of them.

The selected C-ITS services are:
- Rest-time management
- Motorway parking availability
- Road works warning
- Road hazard warning
- Emergency vehicle warning
- Cooperative traffic light for VRUs
- Mode & trip time advice for drivers
- Probe Vehicle Data (PVD)
- Slow or Stationary Vehicle Warning
- Non-stop truck

6.2.1 Rest-time management

Rest time management service will support managing the working hours of drivers engaged in the carriage of goods and passengers by road. The process is regulated by policies, laws or regulations (e.g., EU regulation (EC) No 561/2006) that lay down the rules on driving times, breaks and rest periods for the drivers. Driving time is measured by tachograph installed on coaches and trucks.

This C-ITS service provides truck drivers with real-time information on parking availability at a relevant frequency. There are two main benefits from this service, namely a better compliance with driving and resting time and also a reduction in time taken by drivers to find a parking space. It shows available parking spots along the route at a certain frequency, which can be adjustable, depending on type of vehicle, e.g. every two hours for LCV and for HGV drivers the frequency can be based on the driving time already completed to the rest time from the

There are two types of stakeholders involved in rest-time management service: the driver of the vehicle and parking operators. The driver receives advice when to rest according to available truck parking spaces and regulated driving times and resting times. A parking operator provides information about parking space availability and services provided at a parking lot.

All information is displayed on the C-ITS application that is installed either on the driver's smartphone or on an on-board unit. The programme needs to run in the background. The system works by the parking or road operator collecting information, then sending this information to all vehicle within a perimeter. While the truck driver is driving, the information about the parking becomes available on the app or on-board unit at a certain frequency. The driver receives the information and adapts his route and can choose the parking area.

### 6.2.2 Motorway parking availability

Another C-ITS service that is designed for professional drivers is motorway parking availability. This service provides information on parking availability along the motorways. It proposes a number of options for truck drivers about available parking places and guides the drivers to a parking place. This existing service provides information about the location of HGV parks, capacity, and available equipment, facilities on site, security equipment and information about dangerous goods parking. Other options such as booking of a parking lot and payment of parking charges can be included in the service in future, as soon as the regulatory framework would allow that. Currently it is not possible to reserve parking lots in the public domain.

This service includes numerous benefits, namely it allows a driver to quickly identify the parking lots located along a motorway, it simplifies access to the parking lots, it reduces the time it takes a driver to find a parking lot; it optimises the flow of trucks in the parking lot which also reduces congestion and traffic jams in the lot; it improves safety in the parking lot; and it simplifies complying with driving times and rest periods and using driving time more efficiently.

The motorway parking availability service uses an Internet connection. The information on a specific parking lot (e.g. location of the lot, the number of available spaces, the vehicle types permitted to use the parking, services available and information on whether the parking area is secured) is collected by the parking lot operator and transmitted to trucks (I2V). A driver makes a reservation for a specific parking lot and the service guides the driver to the destination.
One of the examples of such service is the Truck Parking Europe platform.\textsuperscript{41} It is a free app that provides information on availability of parking spaces for truck drivers. It not only includes information on official parking lots along a route, but also parking places accessible to heavy traffic, for example in industrial areas.

Other parking management tools are: Talking Traffic Innovation Partnership,\textsuperscript{43} Parckr Smart Truck Parking,\textsuperscript{44} Praktijkproef Amsterdam,\textsuperscript{45} Transpark IRU,\textsuperscript{46} Truck-Parking,\textsuperscript{47} the European Truck Parking Area LABEL Project\textsuperscript{48} and Aegean Motorway MSS locations.\textsuperscript{49}

\subsection*{6.2.3 Road works warning}

The road works warning (RWW) is a C-ITS service which is designed for all drivers that are on a road. It informs them in a timely manner about road works, restrictions, and constructions. It allows them to be better prepared for potential obstacles downstream on the road, therefore reducing the probability of collisions.

All road works areas are marked by road signs that are located prior to the working areas. However, often such changed conditions on roads / motorways frequently come as a surprise to drivers. It can lead to increased risk and sometimes even accidents, both for road users and workers. The road works warning service aims to make drivers not only aware far in advance about the coming road works on a route, but also make driving more attentive while approaching and passing a work zone. It improves traffic safety, for it decreases the likelihood

\begin{itemize}
\item \textsuperscript{41} https://truckparkingeurope.com/
\item \textsuperscript{42} https://appshop.transportlab.org/en/
\item \textsuperscript{43} https://www.beterbenuiten.nl/talking-traffic
\item \textsuperscript{44} http://www.parckr.com/en/
\item \textsuperscript{45} https://www.praktijkproefamsterdam.nl/
\item \textsuperscript{46} https://www.iru.org/apps/transpark-app
\item \textsuperscript{47} http://www.truck-parking.com/locations-map/?lang=en
\item \textsuperscript{48} http://truckparkinglabel.eu/assets/default.htm
\item \textsuperscript{49} http://www.aegeanmotorway.gr/en/ypiresies/sea
\end{itemize}
of accidents or collisions with safety equipment such as barriers located close to the road work area. It also helps safeguard the site workers.

The service provides drivers with information about approaching work zones. The guidance is displayed on the screen of a smartphone or on-board vehicle display. The instruction may include a recommendation to reduce the driving speed, change lanes, make certain manoeuvres, detouring, etc. It communicates the remaining distance to the hazardous location in real time.

The information is transmitted using ETSI ITS-G5 DENM messages over DSRC (Dedicated Short Range Communications 802.11p) or cellular network (2G, 3G, 4G).

There are three possible data downstreams:

Downstream 1: A traffic centre knows the location of the road works and sends the location to the vehicles through cellular networks.

```
Traffic Centre

Cellular 2G/3G/4G


```

Downstream 2: A traffic centre knows the location of the road works and sends the location to the vehicles using RSU with DSRC.

```
Traffic Centre

RSU with 802.11p


```

Downstream 3: The work site management sets up a mobile RSU at the start of the works to send the necessary DSRC (DENM) messages.

```


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One example of RWW is C-The Difference.\(^50\) It is a traffic app that allows drivers to adapt driving depending on the infrastructure and various road events that may occur, including road works. The app was deployed and functional in the Bordeaux urban area.\(^51\)

\(^50\) [http://c-thedifference.eu/](http://c-thedifference.eu/)

\(^51\) [https://apkpure.com/c-the-difference-bordeaux/com.geolocsystems.cthedifference](https://apkpure.com/c-the-difference-bordeaux/com.geolocsystems.cthedifference)
This app allows the drivers to receive information regarding the road events and traffic in real time. It has been designed to improve urban mobility while respecting traffic movement, the security of users as well as the environmental footprint.

6.2.4 Road hazard warning

The road hazard warning service intends to inform the drivers in a timely manner of upcoming, and possibly dangerous events and locations on a road. This allows drivers to be better prepared for the upcoming hazards and make necessary adjustments and manoeuvres in advance. (This is also known as "Hazardous location notification" (ETSI, 2009) or 'Road hazard signalling'). The information on hazard situation is detected by a vehicle. This information is sent to traffic control centre (TCC). TCC provides services to other vehicle that are located in the vicinity to the hazardous area by warning them. The key benefit of this C-ITS service is to improve traffic safety.

Road hazard warning includes three services:
- hazard location notification,
- traffic condition warning,
- weather condition warning.

6.2.4.1 Hazard location notification

Hazard location notification service provides drivers with an advance warning of upcoming hazardous locations in the road that may lead to a driving situation with increased risk or in the worst case accident. Examples of these hazards include a sharp bend in the road, steep hill, pothole, obstacle, or slippery road surface. Using this information, drivers are better prepared for upcoming hazards and will be able to adjust their speed accordingly. This service aims at improving traffic safety and decrease the risk of accidents.

A driver of a vehicle receives the information about a hazardous location on a smart phone or on-board unit. This information is prepared by a road operator and transmitted by a service provider (I2V). Other organisations responsible for repair, maintenance or cleaning may act on the hazardous location information. When a vehicle approaches a hazardous area, a driver receives information via the C-ITS service. This information includes the remaining distance.
or time to reach the location and, when it is appropriate, the driver receives a driving recommendation regarding, for instance, speed or lane.

![Figure 26. Hazard location notification](image)

### 6.2.4.2 Traffic condition warning

The traffic condition warning\(^{54}\) service provides an alert to a driver who approaches the queue end of a traffic jam at a certain speed. An example is when a traffic jam is hidden behind a hilltop or curve. This allows the driver to react safely to traffic jams ahead. The main objective is to avoid collisions that are caused by traffic jams on highways. Therefore, the service provides a driver with information regarding traffic conditions on a road.

![Figure 27. Traffic condition warning](image)

A driver of a vehicle receives information about the traffic conditions on a smart phone or on-board unit. This information is prepared by a road operator and transmitted by a service provider (I2V). The information on traffic jams can be also used by an end user in route planning. When a vehicle approaches an area on a road with a traffic condition, the driver receives an awareness message on the C-ITS app. This message contains information about the remaining distance or time to the traffic condition. The recommendation can be issued to a driver to adapt speed or change a lane. It may include an adjustment of the scheduled route to the final destination on the basis of the designated diversion route.

\(^{54}\) [https://www.beterbenutten.nl/talking-traffic](https://www.beterbenutten.nl/talking-traffic)
6.2.4.3 Weather condition warning

The weather condition warning service provides an alert to a driver of a vehicle on weather conditions on a route derived from the current position and the driving direction of the vehicle. The vehicle detects a slippery road stretch and sends this information to the road operator (V2I). Then this information is sent to other drivers' smartphone or on-board unit (I2V) as a warning message. This information on traffic conditions intends to improve traffic safety by reducing the risk of accident. The driver receives the information on traffic condition which is prepared by a road operator and transmitted by a service provider.

When a vehicle approaches a weather condition such as fog, rain, snow, or ice, the driver receives a timely awareness message on the C-ITS app. The message contains information on the remaining distance or time to reach the weather condition and, if necessary, a driving recommendation, which includes for instance speed adaptation, mandatory equipment or deviation.

6.2.5 Emergency vehicle warning

Emergency vehicle warning uses information that is provided by the emergency vehicle itself. The purpose of it is to identify and inform other vehicles about the position, direction and speed of the emergency vehicle even when its siren and light bar may not yet be audible or visible. This is also known as “Emergency Vehicle Alert (EVA),” and alerts the driver about the location and the movement of public safety vehicles responding to an incident so the driver does not interfere with the emergency response. The service is enabled by receiving information about the location and status of nearby emergency vehicles responding to an incident (CVRIA, 2017).

The main objective of this service is to provide an early warning indication of an approaching emergency vehicle and to facilitate the driver to give way to it. It also aims to create more attentive driving, better awareness of emergency vehicles and better response by giving way in a less hasty manner thus preventing risky behaviour and causing accidents. It also intends to create an uninterrupted route for the emergency vehicle to its destination.

Figure 28. Emergency vehicle warning

In a real world scenario, when an emergency vehicle approaches a vehicle from behind, the

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55 https://www.beterbenutten.nl/talking-traffic
56 https://www.linkedin.com/pulse/your-connected-vehicle-largest-wearable-setrag-khoshafian/
driver of this vehicle is informed about the emergency vehicle. The driver is expected to give priority to the emergency vehicle by pulling over or speeding up in order not to block it. In such a scenario, the driver of the vehicle receives the information on the display when an emergency vehicle is approaching. The emergency vehicle transmits the information on its location. The road operator may signal about the existence of an emergency vehicle. All information about the emergency vehicle location is transmitted by a service provider.

The information is transmitted using ETSI ITS-G5 DENM messages over DSRC (Dedicated Short Range Communications 802.11p) or cellular network (2G, 3G, 4G).

There are three possible data downstreams:

Downstream 1: a traffic centre sends information about an emergency vehicle location to the vehicle via cellular networks.

![Downstream 1](image1)

Downstream 2: the emergency vehicle transmits the DENM message using DSRC to be received by the equipped vehicles (V2V).

![Downstream 2](image2)

Downstream 3: the RSUs disseminate information about the emergency vehicle to the equipped vehicles (I2V), using DSRC.

![Downstream 3](image3)

Project MOBiNET discussed a similar service called “Ad-Hoc Priority.”\(^{57}\) The service aimed to grant priority to VIP vehicles, HGV and emergency service vehicles at intersections. The driver needs to specify his route and in the back-office the RSUs will be informed of the direction the driver plans to take. Authentication is a crucial part of the service. The navigation system is incorporated in the C-ITS app, and enables the system to extract the route and request the correct priority along the route.

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6.2.6 Green priority

Green priority C-ITS service intends to change the traffic signals status in the path of an emergency or high priority vehicle (e.g., public transportation vehicles), halting conflicting traffic and allowing the vehicle right-of-way, to help reduce response times and enhance traffic safety, as well as emissions. This service is also known as “Traffic signal priority request by designated vehicles” (EC: C-ITS Deployment Platform, 2016) or “Priority Request” (Sambeek et al., 2015). This service aims to enhance traffic safety and increase punctuality and response times for the services provided by emergency vehicles.

Green priority service aims to change the traffic signal status along the route of an emergency vehicle, suspending conflicting traffic and allowing the vehicle to pass. It will help to reduce response times and increase traffic safety.

In the implementation of the service, the green priority requests including the identification information of the high priority vehicle can be sent via an on-board software app in the vehicle. The signal is picked up by traffic light controllers (see Figure 4) which determine in what way they can and will respond to the request. This information can also be received by RSUs and communicated to other traffic light controllers on the route of the vehicle. Here, different levels of priority can be applied, e.g. extension or termination of the current phase to switch to the required phase. The appropriate level of green priority depends on vehicle characteristics, such as type (e.g. HGV or emergency vehicle) or status (e.g., public transport vehicle on-time or behind schedule). The vehicles request priority for an intersection, and the traffic light controller determines in what way it can and will respond the request.

The C-ITS app calculates the distance to the intersection and sends the priority request to the intelligent traffic light controller (iTLC) in the vicinity and fixes its intersection ID. The iTCL sends this information to the traffic manager. The traffic manager authenticates and authorises the C-ITS app and processes the priority request and sends the reply to the iTLC. The iTLC decides whether to give green priority or not. The decision is made on a basis of vehicle data and conditions set by the road traffic manager. The iTLC sends the signal phase and timing (SPAT message) to the C-ITS app. The message is received by the app and the driver is informed about the priority status. Meanwhile iTLC realises green priority. After passing the intersection, the C-ITS app stops the priority request and iTLC stops the green priority.

### 6.2.7 Cooperative traffic light for VRUs

The cooperative traffic light for vulnerable road users (VRU) service aims to increase the safety of VRUs through warranting priority or additional crossing time (i.e., extending the green light phase or lessening the red phase) based on pedestrian characteristics (or on special conditions, such as weather). The service can also be extended to cover other VRUs, such as cyclists. The service is also known as “Pedestrian Mobility” (CVRIA, 2017) or “Traffic light prioritisation for designated VRUs.”

This C-ITS service has several benefits, namely it intends to increase VRUs safety, enhance traffic flow and comfort of VRUs, as well as reduction of emissions rates as a result of decreased car usage.
The service provider offers a priority crossing for VRUs at intersections. The provider equips VRUs with a code to activate the app, which runs in the background and interacts with traffic lights at intersections. When a VRU approaches the iTLC, the app sends the priority request to the iTLC. Then the iTLC sends the priority request with its current state information to the traffic manager. The traffic manager authenticates and authorises the C-ITS app. He also creates a reply and sends it to the iTLC and iTLC acts on the request.

![Cooperative traffic light for VRU Illustration (Source: VRUITS)](http://www.vruits.eu/)

**6.2.8 Dynamic lane management**

The dynamic lane management service aims to exchange information about lanes with traffic users. It provides dynamic lane management in certain circumstances, such as traffic congestion. The dynamic lane management includes solutions such as auxiliary lanes, reserved lanes, and reversible lanes. It intends to provide better awareness and safer traffic and traffic optimisation (the road operator can improve the management of the dynamic lane in real time).

The dynamic lane management service informs drivers of the presence of a reserved lane and notifies them whether they can use it (I2V). The road manager informs the drivers about a dynamic lane in a specific area. The C-ITS services installed on the driver’s smartphone or on-board unit of the vehicle, receives this information in this specific area. The information on its characteristics (PVD) relevant to the dynamic lane is sent via an app (V2I). Then the road manager receives the PVD and decides to open or close the dynamic lane, to adapt the features of the lane, etc. The service provider transmits in-vehicle signage (IVS) information, warning or guidance from the road operator to vehicle drivers.

**6.2.9 In-vehicle signage**

The in-vehicle signage (IVS) service intends to inform drivers through in-vehicle information systems about static and dynamic road signs along the road. The service includes both mandatory and advisory signs. The information is transmitted by means of infrastructure to vehicle communication (I2V). The driver receives actual and continuous IVS related information.
information on the in-vehicle display. The transmitted information may include reducing the driving speed, changing lanes, and preparing for a manoeuvre.

The expected benefit is more attentive driving by providing actual and continuous information about road signage and speed limits, which improves traffic safety.

6.2.9.1 In-vehicle signage (static traffic signs)

In-vehicle signage aims to provide static IVS information (speed limits) to the driver about the road signs. Having received this information, the driver adapts the driving velocity of the vehicle to the applicable driving regulation according to the static road signs. The benefit of this service is more attentive driving by providing actual information and warnings which improve the awareness of driving.

The driver receives information and warnings from the vehicle display. The information about road signage is provided by a road operator and a service provider transmits IVS related information. IVS messages are transmitted into different data streams:

Data stream 1: the RSU transmits the road signs information to relevant equipped vehicles using DSRC (802.11p).

![Data stream 1: RSU transmits road signs information using DSRC](image)

Data stream 2: a traffic centre sends the speed limit information to the relevant vehicles using cellular communication.

![Data stream 2: Traffic centre sends speed limit information using cellular](image)

6.2.9.2 In-vehicle signage (dynamic traffic signs)

In-vehicle speed limits service aims to provide information to drivers about speed limits on the
Annex 2: 47 / 61

roads. This is typically performed through broadcasting roadside units (RSU) at key points along the roads.

A vehicle driver receives information from the in-vehicle display or smartphone. The actual information on dynamic road signage is provided by the road operator. The IVS information is disseminated by the service provider. The information includes warnings and guidance to drivers. The IVS message can be transmitted by two different data streams:

Data stream 1: a traffic centre is aware of the dynamic information and sends it to the RSU which disseminates the road signs information to equipped vehicles using DSRC (802.11p).

Data stream 2: a traffic centre is aware of the dynamic information and sends it to the relevant vehicle using cellular communications.

6.2.10 Mode & trip time advice for drivers

Mode & trip time advice aims to provide drivers with information on the most efficient route while driving as well as the expected travel time based on floating vehicle data. The floating vehicle data is collected either through roadside units (RSUs) or through an on-board software app in the vehicle to assess the density, throughput and congestion of traffic within a specific area. The service offers drivers reliable arrival times at delivery locations. They can plan their trip according to the advice received by the mode & trip advice service.
When a truck driver wants to obtain the best time advice for his journey, C-ITS app asks for the departure time and the arrival locations. Having indicated both locations, the app connects to the service provider and requests traffic information (FTD, dynamic traffic data, urban and highway parking availability data, static road network data, etc.). Then the service provider collects the traffic information from the Data / Content provider and sends this information to the C-ITS app. The app generates mode & trip time advice, which is based on the traffic information and shows it on the screen to the driver.

### 6.2.11 Probe Vehicle Data

Probe Vehicle Data (PVD) is data generated by vehicles. The collected traffic data (traffic conditions, road surface conditions and the surroundings) can be used as input for operational traffic management (e.g., to determine the traffic speed, manage traffic flows by informing drivers, where the danger of accidents accumulates), long-term tactical/strategic purposes (e.g. road maintenance planning) and for traveller information services.

The impact of this service includes safer road conditions (e.g. traffic jams/collisions alert and adverse weather conditions warnings), less CO₂ emissions (from a more stable traffic flow) as well as faster travel times.

Driver assistance technologies that are installed on modern vehicles know their own position, speed and direction and sometimes other vehicle properties (e.g. collision sensors, ABS, windscreen wiper status, etc.) This data can be communicated when a vehicle is in range of a RSU. This data will provide the road authority with information about traffic, road surface and environment conditions which can be used further in traffic management.

When driving along RSUs, the C-ITS app sends information or a message that contains information about the vehicle and surroundings. The road operator collects this data via a central system and it is then sent to the third parties (OEMs, service provider) for the app. The users of the service receive warnings to avoid dangerous situations and advice to change the driving behaviour (accelerate, brake, change route, etc.) OEMs may act as a service provider and also as an intermediate between the service provider and end users.

![Figure 32. Probe vehicle data](https://itscorridor.mett.nl/default.aspx)

The probe vehicle data service was implemented in the Netherlands in the Dutch C-ITS Corridor⁶⁰ and Praktijkproef Amsterdam.⁶¹

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⁶⁰ [https://itscorridor.mett.nl/default.aspx](https://itscorridor.mett.nl/default.aspx)

⁶¹ [https://www.praktijkproefamsterdam.nl/](https://www.praktijkproefamsterdam.nl/)
6.2.12 Slow or Stationary Vehicle Warning

The slow or stationary vehicle warning service intends to inform or alert approaching vehicles about (dangerously) immobilised, stationary or slow vehicles that impose significant risk. This service aims to improve traffic safety due to the reduction in number of accidents.

The service will notify drivers about accidents or incidents on the road, stationary vehicles with problems, or roadside inspection, roadside assistance and emergency vehicles located on a road. The slow and stationary vehicles that are on the road may cause hazardous situations especially when they are not noticed in a timely way by other vehicle drivers passing by.

The purpose of slow or stationary vehicle warning is to alert the drivers so that they can adapt their driving behaviour compliant to any advice or guidance received.

When a vehicle approaches a stationary vehicle on a road, the driver will receive stationary vehicle information on the C-ITS app in-vehicle display or smartphone. The information is sent by road operator who detect and signal the presence about a stationary vehicle. A service provider sends the information to all vehicle drivers in the vicinity. The message includes information on the remaining distance or time to reach the stationary vehicle and, if appropriate, driving recommendation. The information about traffic jams on a road can be also used by the end user for route planning.

![Stationary vehicle illustration](image_url)

Figure 33. Stationary vehicle illustration (Dutch Profile Part A Use Case Catalogue)

6.2.13 Non-stop truck

The non-stop truck (NST) service intends to transfer the weight information from a truck to the road administrator, when a truck is on move. Since vehicle weight control requires vehicles to stop in order check their weights at a physical scale, it has a negative effects on traffic throughput, fuel consumption as well as emissions. The non-stop truck service aims to reduce these negative effects by sharing the truck weight information with public authorities to obtain a free pass for law-abiding vehicles in vehicle control.

The non-stop truck is a service by means of which trucks share information with public authorities.

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62 [https://www.beterbenutten.nl/talking-traffic](https://www.beterbenutten.nl/talking-traffic)
authorities to receive a free pass for law-abiding vehicles in vehicle controls. When a vehicle passes a road-side ITS Station (R-ITS-S), the in-vehicle ITS Station (V-ITS-S) sends the information on vehicle weight together with its identifier to the R-ITS-S. The road administrator will use the history of the vehicle. It will be decided whether to grant a clearance to the vehicle or a manual control of the vehicle is required.

The owners of trucks can register their trucks for voluntary sharing of identity and truck status to public authorities and road operators to allow the interaction. The MOBiNET service matches vehicle data from on-board devices to data required by public authorities. The service allows trucks to decide to share data with public authorities and it allows public authorities to offer self-declaration to any truck that has an appropriate on-board device.
7. ITS and C-ITS services for non-professional drivers and user acceptance

7.1 ITS and C-ITS services for non-professional drivers

The European Commission's work on C-ITS has among other things produced a list prioritising C-ITS services to be delivered, known as Day 1, Day 2 etc services. The list is the result of extensive consultations with stakeholders and can be taken to represent a broad consensus of experts in the field.

Day 1 C-ITS services list

**Hazardous location notifications:**
- Slow or stationary vehicle(s) & traffic ahead warning;
- Road works warning;
- Weather conditions;
- Emergency brake light;
- 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;
- Shockwave damping (falls under European Telecommunication Standards Institute (ETSI) category ‘local hazard warning’).

Day 1.5 C-ITS services list

- Information on fuelling & charging stations for alternative fuel vehicles;
- Vulnerable road user protection;
- On street parking management & information;
- Off street parking information;
- Park & ride information;
- Connected & cooperative navigation into and out of the city (first and last mile, parking, route advice, coordinated traffic lights);
- Traffic information & smart routing.

Adapted from *A European strategy on Cooperative Intelligent Transport Systems, a milestone towards cooperative, connected and automated mobility, 2016*

The services to be deployed first for the benefit of drivers cover hazard warnings and other in-vehicle advisory services relating to speed limits and traffic signals. These have been judged to be those of most benefit to drivers, including non-professional drivers, and also relatively easy to deliver at the beginning of C-ITS implementations.
7.1.1 Talking Traffic project

The Talking Traffic project in the Netherlands is a good example of early C-ITS adoption for the benefit of everyday drivers. The Dutch Ministry of Infrastructure and Environment set out to maximise traffic flow on existing roads, rails and waterways while avoiding costly investments in new infrastructure. They decided to utilise the cloud and IoT (Internet of Things) to build a national Intelligent Vehicles and Road Infrastructure (IVRI) system.

![Figure 34. Talking Traffic project (Source: Ericsson)](image)

<table>
<thead>
<tr>
<th>Project highlights:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• First government-led project to create a national ITS solution</td>
</tr>
<tr>
<td>• A cloud-based solution delivered within 6 months</td>
</tr>
<tr>
<td>• 25% of all traffic lights nationwide connected so far</td>
</tr>
<tr>
<td>• 10% less road congestion during peak hours</td>
</tr>
</tbody>
</table>

Table 1 - Adapted from The Talking Traffic Case Study, Ericsson 2017

In the Talking Traffic project, the following six services in 12 Dutch regions are in the first tranche made available to drivers:

1. In vehicle signage and speed advice
2. Individual real-time data on potentially dangerous situations and road work warnings
3. Prioritising (conditioned and general) of groups of road users at traffic lights
4. Provide road users with real-time data from traffic lights (first 20% of all Dutch TLIS)
5. Optimising traffic flow through traffic lights
6. In-car parking data.

So, Dutch drivers will be able to make use of information, including speed limits, which was previously only available via road signs, now being delivered straight into their vehicles and displayed via a dedicated interface. They will also get real time warnings about unplanned hazards, such as crashes or weather events, faster than by relying on variable message signs or radio broadcasts. Parking information will also be made available.
In addition, the Talking Traffic service will use C-ITS data to dynamically manage traffic lights to optimise traffic flow and prioritise vehicles or groups of vehicles. Drivers will not have the option of “opting out” of using these C-ITS services, like they do for instance with the speed limit or hazard warning information which they can choose to ignore. But these “involuntary” C-ITS services will deliver benefits in terms of journey times and smoother journeys. Most likely drivers will often simply not realise that their journeys are supported by a C-ITS services. If they do, they will also notice the benefits and find the C-ITS “interference” with their driving to be beneficial.

7.1.2 Next steps for C-ITS for non-professional drivers

As C-ITS mature, a wider range of services (“Day 1½, Day 2”) are envisaged for drivers. More intelligent, dynamic routeing; more advanced parking information; and information about vulnerable road users (VRUs) such as pedestrian and cyclist proximity warnings are some of these services. Private cars will gradually become part of a nation- or even Europe-wide ecosystem of vehicles and infrastructure. Commercial fleet operators will of course keep their business-related data confidential, but in many areas of C-ITS, both private and commercial vehicles will play their part in providing data and using the services partly created with their data input.

7.2 User acceptance of ITS and C-ITS services for non-professional drivers

The general public is at a very early stage of finding out about, let alone using, cooperative ITS services. At the same time, these will never become widely adopted if non-professional drivers do not embrace them.

<table>
<thead>
<tr>
<th>Response</th>
<th>US</th>
<th>UK</th>
<th>Australia</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very positive</td>
<td>22.0</td>
<td>23.3</td>
<td>25.2</td>
<td>23.4</td>
</tr>
<tr>
<td>Somewhat positive</td>
<td>34.9</td>
<td>43.3</td>
<td>39.2</td>
<td>39.0</td>
</tr>
<tr>
<td>Neutral</td>
<td>36.5</td>
<td>29.4</td>
<td>31.6</td>
<td>23.6</td>
</tr>
<tr>
<td>Somewhat negative</td>
<td>5.0</td>
<td>3.8</td>
<td>2.8</td>
<td>3.9</td>
</tr>
<tr>
<td>Very negative</td>
<td>1.6</td>
<td>0.2</td>
<td>1.2</td>
<td>1.0</td>
</tr>
</tbody>
</table>

There are two sources of knowledge for us when exploring the topic of user acceptance of C-ITS: user views on the wide range of advanced driver assistance systems (ADAS) already in well-established use, and a small amount of research into non-professional drivers' attitudes to C-ITS services.

Until around 20 years ago most drivers manually controlled and executed all tasks associated with travelling by car. There were a small number of ADAS already in existence, but only in vehicles with the highest specifications. Most drivers would not experience these.

Gradually ADAS spread through the fleet as vehicle manufacturers found that there was demand from car buyers, and in a virtuous circle the technology became both better and cheaper as it went into mass production. No doubt there was a small number of drivers who either believed that their own driving skills were better than anything technology could achieve, or were suspicious of technical assistance believing that it might be prone to malfunction or...
failure and therefore not to be relied on. However, enough of a majority welcomed ADAS for them to develop into a normalised part of the driving experience. Speed warnings, lane following assistance, assisted parking and so on are now ubiquitous and accepted.

To a non-professional driver with no special knowledge of transport technology C-ITS will not appear so very different from ADAS. Therefore the ADAS implementation and acceptance processes are a valuable source of information about how C-ITS may work in the everyday driving context.

Experts know that C-ITS are something quite different from ADAS. In C-ITS, the data powering the services comes from other vehicles or from the infrastructure and the services may well be provided from a traffic control centre or from a private sector service provider. C-ITS integrate the vehicles into a much larger eco-system of infrastructure, vehicles, information, advice and control. This may even entail an individual driver having a worse experience, with a longer trip, slower speeds or more congested conditions, in order for a much larger number of drivers having a better trip. It may also mean a large number of drivers having a slower or longer journey in order to deliver air quality benefits to people not even on the road, but living or working adjacent to it.

But at the point where the driver is affected by the C-ITS service, it will not appear very different to him or her than a more traditional ADAS. The driver will perceive that they are assisted in the driving task via for instance speed or parking advice, or weather warnings, and will not question how this advice has been created or transmitted as long as it is accurate and useful. In the case of C-ITS such as dynamic traffic light settings to optimise traffic flow or reduce air pollution, the driver is unlikely to be aware that he has even received (or been subjected to) a C-ITS service.

It is therefore likely that C-ITS will be acceptable to drivers and even popular and desirable. The only alternative scenario is one where the network operator implements policies which radically alter individual driver experiences for what the drivers perceive as worse. An example would be obvious and lengthy re-routing for air quality benefits. Most drivers are familiar with the networks they are using and would realise that they are taking what appears to them as lengthy detours, and would find this unacceptable. Conversely, if they were informed that the longer journey was to improve safety at a primary school or kindergarten, they may well find this more acceptable. So, a blend of not overreaching in the application of C-ITS to the detriment of individual drivers, and of taking care to explain the reasons for how C-ITS is use especially when these reasons are likely to be attractive to drivers, will ensure the highest levels of acceptability.

Just like traditional ITS, C-ITS services must also be of the highest accuracy and timeliness. Information delivered by VMS on the UK motorway network still suffers from drivers not taking it seriously and therefore ignoring it. They base their decision on previous experiences of the information being out of date or the problem overstated. Often, these experiences are by now years in the past, but the pattern of behaviour is hard to shift. This creates a vicious circle of drivers ignoring requests to slow down, drive in certain lanes, or take detours, and then adding to the problem which caused the warning to be given in the first place. C-ITS based information and actions must be close to real time and always accurate, or the same problems with driver behaviour will be created. The technical processes must be thoroughly and inventively tested, and it is also essential not to build in too many layers of checks and controls, including by human interventions.
8. Communicating ITS to the public

ITS are as a rule poorly understood by its users, which include more or less everybody who travels. Whether you travel by car, bus, rail or air, for some or all of your journey the operator of your services and you yourself will have used and/or been supported by ITS. But still, the general public has a very weak grasp of how traffic signals change or an out of date public transport ticket does not open the gate. It may be tempting to argue that this does not matter; that as long as the operators and their contractors and suppliers have the knowledge, it does not matter how deep is the ignorance of the users.

However, in a democratic society, the transport user is also a voter and the ITS are almost completely public sector funded, so in the longer term it would be better for ITS implementation if users both understood the basics of the services and appreciated the outcomes enough to support expenditure on transport technology. Instead, while it is not unusual to hear members of the public support the building of railway lines and roads, there will be a long wait if you are expecting to hear anybody outside the sector talking enthusiastically about dynamic traffic management or automatic vehicle location in the bus industry.

Perhaps part of the problem is that nobody takes responsibility for the task of communicating ITS to the public. Private sector provided services are explained as part of the task of selling them: advertising and more subtle information campaigns highlight all the benefits of the service and try to paint a picture of value for money.

In ITS, this task would need to be undertaken by a highways authority or a city public transport authority, both as a rule public sector organisations in Europe. This sits badly with the prevailing ethos of public service which can be summarised aspiring to deliver an adequate service as discreetly as possible.

When a transport authority decides to undertake this activity, the results are often just as good as anything the private sector can achieve. One example is the introduction of integrated public transport ticketing via smartcards in the 2000s, where cities such as Hong Kong and London were able to not only convince the public that getting these cards would be beneficial, but even create brand loyalty and recognition by naming the cards (“Octopus”, “Oyster”) and building relationships between passengers and their cards.

Another example is the “smart motorways” concept in the UK where the hard shoulder, initially mandatory as an emergencies-only lane on motorways, has been converted to a full- or part-time running lane. Communicating this to the public was a challenge: it could be predicted that there would be strong safety concerns when such a well established and recognised safety feature was simply removed. The information campaigns recognised these fears and explained all the reasons, including the use of mature and reliable technology, why they were unfounded. They also of course made much use of the fact that congestion would ease, and journey times improve.

So it can be seen that there are effective ways of communicating ITS to the general public. Transport operators could definitely do better at communicating ITS, and should take the lead in doing so. The benefit to them would be a better understanding of why ITS needs to be funded, implemented, maintained and developed. This better understanding would lead to better political support and fewer interventions along the line of “Why is this money not spent on care for the elderly?” It is also odd that a general education includes the basics of most of our utilities such as electricity and water supply, but not the basics of our transport systems, which these days would include ITS.

But private sector actors also have an important role to play in communicating ITS. Some do
it already and do it well: Siemens Intelligent Traffic Systems in the UK has both a community and a schools outreach programme, and welcomes organised visits to its factory in Poole, Dorset.

Figure 35. A visit by school girls and female engineers to Siemens in Poole, UK (Source: Smart Highways Magazine)

The benefits to a private sector company doing this type of communication is not just that increasing understanding increases support and demand and therefore is good for business. A higher profile for the ITS sector and a better general understanding of what it does, will also translate into a better supply of potential workers. It is not possible to choose to do a job you do not know exists.
9. Discussion and conclusions

This topic study focuses on cooperative intelligent transport systems (C-ITS) user services. It provides a concise and clear overview of the existing and new C-ITS services designed for professional and normal drivers and their functionality and limitations. In addition, the topic study offers some insight on the required cooperation and exchange of data between professional drivers and public authorities for C-ITS systems. Finally, the topic study introduces some best practices for increasing user acceptance of ITS and C-ITS and disseminating information on the systems in question to the public.

The topic study has listed a comprehensive set of C-ITS services, some of use to both professional and non-professional drivers, and some only applicable to the former. C-ITS for haulage operators has huge potential in terms of optimising routing, ensuring safe and secure parking with good facilities for the driver, reducing environmental impacts, and assisting drivers and managers in keeping to drivers’ hours legislation. It would be interesting to investigate how all these potential C-ITS for HGVs measure up in terms of costs and benefits against the AV approach of platooning HGVs.

C-ITS for non-professional drivers also offer many benefits: in the fields of safety, convenience, comfort, reduced and / or more predictable journey times, and less environmental impact. If we assume user acceptance will continue to be forthcoming, the next topic to consider will be how quickly C-ITS services will spread through the fleet. While older and cheaper vehicles do not use them, their impact will be less, and the imperative for the road operator to support and deliver them will be less. On the other hand, when they have fully penetrated the fleet, costs associated with traditional forms of informing, advising and enforcing road users will fall away. Here is another interesting research topic: when and how will C-ITS become the normal way of operating our road network?

User acceptance is key, and user understanding is key to user acceptance. Whose job is it to make drivers, professional or not, understand the technology on our roads, and how do we create and satisfy an interest in understanding?

Information on C-ITS for both professional and non-professional drivers is widely available in the form of published papers, project reports, trade magazine articles, conference presentations and conference reports, etc. It was a dominant topic in ITS activity for a number of years until autonomous vehicles became the number one priority around the world, and as a result is very well documented. If there was an issue with material for this study, it was rather that there was too much available than too little. The authors have taken the view that the best use of space in the study is to mention all C-ITS briefly, rather than a few C-ITS in depth. Readers wanting to research any particular C-ITS in detail should follow up the references provided.

The one area of C-ITS where information is harder to come by is business cases and this topic is examined further in Topic study 6 (Financial incentives, business models and procurement models for C-ITS deployment). The ITS sector has seemed unable to develop the rigour necessary to conduct solid cost – benefit analysis, which would involve detailed before-and-after studies and a wide ranging look at costs and benefits which often accrue well outside the transport sector, for instance in public health or in employee productivity. The reasons for this weakness in the ITS sector are complex and well outside the scope of this study, but it should be noted that credible C-ITS cost-benefit analysis is not widely documented. The available information on these topics have been summarised in Topic study 5 (Impact assessment of ITS and impacts of selected ITS and C-ITS systems) and Topic study 7 (Cost-benefit analyses of ITS services).
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http://www.truck-parking.com/locations-map/?lang=en
Annex 3: TMC and roadside technologies for ITS

Grant Agreement Number: 724106

Project acronym: CAPITAL

Project full title: Collaborative cApacity Programme on Its Training-educAtion and Liaison

**Topic study 3: TMC and roadside technologies for ITS**

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Abstract

This document presents the topic study “TMC and roadside technologies for ITS”

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<td>ABS</td>
<td>Anti-lock Braking System</td>
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<td>ACC</td>
<td>Adaptable Cruise Control</td>
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<td>ADAS</td>
<td>Advanced Driver Assistance System</td>
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<td>AEB</td>
<td>Automatic Emergency Braking</td>
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<td>ATIS</td>
<td>Advanced Traveller Information System</td>
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<td>BLIS</td>
<td>Blind Spot Information System</td>
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<td>CACC</td>
<td>Cooperative Adaptable Cruise Control</td>
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<td>CCC</td>
<td>Conventional Cruise Control</td>
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<td>CEN</td>
<td>European Committee for Standardisation</td>
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<td>C-ITS</td>
<td>Cooperative Intelligent Transport System</td>
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<td>CPC</td>
<td>Certificate of Professional Competence</td>
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<td>DENM</td>
<td>Decentralised Environmental Notification Message</td>
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<td>DSRC</td>
<td>Dedicated Short Range Communication</td>
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<td>EBA</td>
<td>Emergency Brake Assist</td>
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<td>EC</td>
<td>European Commission</td>
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<td>eCMR</td>
<td>Electronic Consignment Note</td>
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<td>ECU</td>
<td>Electronic Control Unit</td>
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<td>EP</td>
<td>European Parliament</td>
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<td>ESS</td>
<td>Emergency Stop Signal</td>
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<td>EVA</td>
<td>Emergency Vehicle Alert</td>
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<td>FCD</td>
<td>Float Car Data</td>
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<td>I2V</td>
<td>Infrastructure-to-Vehicle</td>
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<tr>
<td>iTLC</td>
<td>Intelligent Traffic Light Controller</td>
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<td>ISA</td>
<td>Intelligent Sped Assistance</td>
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<td>IVI</td>
<td>In-Vehicle Information</td>
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<td>IVS</td>
<td>In-Vehicle Signage</td>
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<td>GA</td>
<td>Grant Agreement</td>
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<td>GLOSA</td>
<td>Green Light Optimal Speed Advisory</td>
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<td>GPS</td>
<td>Global Positioning System</td>
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<tr>
<td>HGV</td>
<td>Heavy Goods Vehicle</td>
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<td>LCV</td>
<td>Light Commercial Vehicle</td>
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<td>LDW</td>
<td>Lane Departure Warning</td>
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<td>LIDAR</td>
<td>Light Detection and Ranging</td>
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<td>LGS</td>
<td>Lane Guard System</td>
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<td>MSD</td>
<td>Minimum Set of Data</td>
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<td>NST</td>
<td>Non-stop Truck</td>
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<td>OEM</td>
<td>Original Equipment Manufacturer</td>
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<td>PKI</td>
<td>Public Key Infrastructure</td>
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<td>PO</td>
<td>Project Officer</td>
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<td>Acronym</td>
<td>Description</td>
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<tr>
<td>PSAP</td>
<td>Public Answering Points</td>
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<td>Probe Vehicle Data</td>
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<td>RDS</td>
<td>Radio Data System</td>
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<td>RHS</td>
<td>Road Hazard Signalling</td>
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<td>R-ITS-S</td>
<td>Road-side ITS Station</td>
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<td>RLVW</td>
<td>Red Light Violation Warning</td>
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<td>RSU</td>
<td>Roadside Unit</td>
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<td>RTTI</td>
<td>Real-Time Travel and Traffic Information</td>
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<td>RWW</td>
<td>Road Work Warning</td>
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<td>SAS</td>
<td>Speed Alert System</td>
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<td>SPAT</td>
<td>Signal Phase and Timing</td>
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<td>SPATEM</td>
<td>Signal Phase and Timing Extended Message</td>
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<tr>
<td>TMC</td>
<td>Traffic Message Channel</td>
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<tr>
<td>URI</td>
<td>Uniform Resource Identifier</td>
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<tr>
<td>V2V</td>
<td>Vehicle-to-vehicle</td>
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<td>V2X</td>
<td>Vehicle-to-Everything Communication</td>
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<td>Variable Message Signs</td>
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<td>VRU</td>
<td>Vulnerable Road Users</td>
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<td>VSL</td>
<td>Variable Speed Limit</td>
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<td>WAVE</td>
<td>Wireless Access in Vehicular Environments</td>
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<td>WLAN</td>
<td>Wireless Local Area Network</td>
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<td>WP</td>
<td>Work Package</td>
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1. Introduction

“TMC and roadside technologies for ITS” is a topic study providing an introduction and overview of the principles of traffic management and control, functions now almost exclusively carried out by Intelligent Transport Systems (ITS) throughout Europe.

The study comprises three levels:

Level one covers urban traffic management implementation including traffic control in urban areas, the access to dynamic transport data, integrated traffic management, and C-ITS in urban areas.

Level two covers public transport ITS: event detection and transport data collection, multimodal journey planning, and using technology to deliver safety and security on public transport.

Level three focuses on the major road network: event detection and transport data collection, C-ITS on the network, aggregation and management of transport data, and access to dynamic transport data.

Most of these use cases go back to the beginnings of ITS in the early 1980s, and in many cases the technology is also a couple of decades old at this point. Legacy systems were already a barrier to the deployment of new solutions before the advent of C-ITS. The challenge now is to maximise the benefits of C-ITS in a landscape of existing, sometimes very old, ITS and involving vehicles from brand new to 30 years or more of age.

2. Objectives

The objective of this module is to outline the areas of existing ITS applications in traffic management and public transport. This topic is clearly extremely wide and therefore only an overview is attempted.

It is assumed that this study module will be used to provide a background for those who have no or little previous experience of ITS, but a good general knowledge of road based transport, before they go on to learn about C-ITS in depth. It is envisaged that there will also be a sub set of students with no intention of studying C-ITS, who will find this module useful simply as an introduction to ITS.

There is an excellent selection of study materials for ITS, but by far the most useful is the PIARC RNO-ITS website and students who want to learn more about ITS (as opposed to C-ITS) should be directed there.
3. Methods

This document was prepared using desk research drawing mainly on ITS (UK)’s collection of documents, particularly those from the European Commission’s C-ITS Platform, and on the RNO-ITS website.

4. Urban Traffic Management and Control (TMC)

The concept of urban traffic management and control goes back to the earliest days of ITS implementations in the 1970s. The principles of applying IT and communications technology to urban road traffic management were added to the long established methods of using signalised junctions and infrastructure and transport planning measures (designated lanes, one-way streets etc) for improving traffic flow. The possibilities opened up by computerised systems and telecommunications were remarkable: the capability of varying signal settings at first according to pre-known circumstances (rush hour, sporting fixtures) and then later on to do this dynamically according to real-time traffic flows and priority vehicles such as ambulances. We are now entering a new era of TMC – cooperative systems where instead of the operator and the infrastructure communicating with each other exclusively and the operator imposing TMC on the network user, the user and his vehicle also communicate with the operator and the infrastructure, and contribute dynamically to the TMC approach.

4.1 Traffic Control in Urban Areas

Urban traffic management and control systems are implemented by cities in order to achieve some of the following objectives:

- Minimise congestion
- Improve safety of all road users (with a specific focus on pedestrians/vulnerable road users)
- Reduce the air quality impacts of urban motorised transport
- Support the movements of particular modes of transport: public transport is the most common example but some cities also choose to prioritise freight vehicles or cyclists

Typically, information is collected from the network and processed for the use of a centralised Traffic Control Centre (also known as Traffic Operations Centre, Transport Operations Centre, etc.) The TCC then uses a variety of tools in order to manage traffic to achieve its pre-agreed objectives. These objectives may be agreed by TMC professionals but they are likely to be at least partly influenced by political imperatives such as more reliable journey times for cars or safer conditions for cycles.

The installation and operation of ITS are subject to financial pressures, just like any public authority function. Most urban transport authorities do not have the financial resources to jettison existing ITS and install completely new ones, which will affect the way C-ITS is introduced by urban (and other) transport authorities. In some cases, private sector actors may be interested, but most authorities will not wish to hand over all control over transport to the private sector and if the service cannot be adequately monetized by a private sector provider, the transport authority will be left with having to fund it itself.
4.2 Access to dynamic transport data

We have quickly moved from a simple shortage of data to a sometimes overwhelming supply of transport data, including real-time. Not all of this is useful, sometimes because there is no beneficial use for it but more often because the quality or format makes it difficult to process it in an affordable and timely way. But processing and analytical methods are improving continually and the overall picture is one of large and ever increasing amounts of transport data being available.

Urban dynamic transport data can come from a variety of sources, some within the urban authority’s control and some from elsewhere. Typical data sources in the urban realm are:

- Sensors in or adjacent to the road
- Probe vehicle data (formerly referred to as Floating Vehicle Data)
- CCTV
- Mobile devices such as smartphones
- Social media
- Commercial sources such as navigation service providers

Accessing the data sourced by the city’s own infrastructure or its own vehicle fleets is obviously simple. Data created by private smartphone users or social media can be accessed but would usually need to be anonymised in order to be permissible or acceptable. It should not be forgotten that many citizens take an active interest in the transport network and willingly and actively share information about their journeys and location. This may often be in the form of complaining about a transport service, but the data is still valuable. The principles of a sharing economy are coming through in transport, with for example the quickest information about a transport problem being available from another transport user on twitter rather than direct from the transport operator. Behaviour is changing and the transport data scene is changing as a result, with or without the approval of operators.

Data produced by commercial organisations can often be purchased by city authorities or it may be possible to come to a sharing agreement – the city often also has data which the commercial organisation wants. Open data principles have been adopted to varying degrees by European cities for their transport data. The London transport authority, Transport for London, publishes all its transport data via a dedicated website and actively encourages re-use by private sector information service developers and by researchers. EC Delegated Regulation 2017/1926 requires all public authorities to provide access to data by 2023 at the latest in defined formats such as DATEXII, NeTEx, SIRI etc.

The sticking point is likely to turn out to be internal vehicle data. The contribution of this to Cooperative Intelligent Transport Systems (C-ITS) is very important – while the vehicle’s presence on the network and its speed can be located by the network operator using traditional methods such as ANPR or radar, one of the benefits of C-ITS is to reduce road side infrastructure. Other vehicle data such as road condition information and braking patterns are crucial to a mature, effective C-ITS services, and can only be sourced from the vehicle’s own internal data sources. Sharing this with the network operator or a third party service provider is not immediately attractive to either the vehicle manufacturer, or the vehicle occupants. The former has invested heavily in creating the in-vehicle systems as part of creating a commercial advantage over competitors, and is also often interested in providing his own, bespoke,
ongoing services to the vehicle purchaser as a way of creating added value and cementing brand loyalty. The latter is likely to have concerns about the network operator compromising his privacy which somewhat bizarrely he does not extend to the OEM, his mobile phone service provider, his satellite navigation provider, his bank etc. Whatever the paradoxes, the reality is that while real-time vehicle data is essential for a first class C-ITS service, it may prove difficult and time-consuming to source. However, there are encouraging signs that OEMs are prepared to share road safety related data, such as road surface status notifications, for free, as requested in EU Delegated Regulation 886/2013.

4.3 Integrated traffic management

Integrated traffic management combines the measures which serve to preserve traffic capacity and improve the security, safety and reliability of the overall road transport systems. This is a key role for ITS, translating ITS systems, services and projects into day-to-day operations that impact on road network performance.

Central to this approach is the development and integration of a set of traffic management measures appropriate to the local and regional requirements – and to achieve this through a planning process that makes use of systems engineering, standardisation and documentation, and performance management.

ITS in the field of traffic control has enabled a number of new concepts to be applied in the framework of innovative operational systems. Examples include bus and tram priority, and pollution monitoring. These features are starting to be deployed within established traffic management systems.

Some examples of traffic management measures that can form part of an integrated traffic management system are (PIARC 2015):

- Traffic incident management
- Traveler information services
- Traffic signal and urban arterial management with adaptive signal control
- Ramp metering
- Bus and tram priority systems
- Part-time measures such as seasonal park & ride
- Route guidance
- Speed control
- Tidal flow (directional lane control)
- Preferential treatment for specific vehicle types, for example passenger transport and car sharing
- Parking management
- Freight management
- Road weather management
- Pollution minimization
- Work zone management
- Border control for people and freight

These measures can be used singly, but are most effective when deployed in an integrated
way. For example, by combining information systems, speed control, adaptive traffic signal control and weather information, it is possible to deliver air quality improvements over and above those possible through, say, speed control alone.

4.4 C-ITS in urban areas
The European Commission’s C-ITS platform identified a set of common, cross-cutting barriers to urban area C-ITS implementation (EC 2017):

- Lack of knowledge about C-ITS, difference between ‘traditional’ ITS and how to use it amongst local authorities
- Lack of awareness of full potential/benefits across entire urban stakeholder chain
- Lack of clear business models for urban applications
- Lack of knowledge about the evolving roles and responsibilities of different stakeholders
- C-ITS integration with existing legacy systems
- High investment and running costs

The same platform also published a table attempting to compare new C-ITS services with those already delivered by existing ITS:

<table>
<thead>
<tr>
<th>Function</th>
<th>Existing ITS example</th>
</tr>
</thead>
</table>
| Traffic signal priority request by designated vehicles | Vienna – a request for individual (on demand) priority can be triggered in several ways:  
- Infrared cameras detect the dedicated (emergency) vehicle;  
- electrical contacts installed on the catenary forward the impulse;  
Priority requests by radio communication  
- Electrical impulse triggered by a moving switch (after direction request by tram; also in combination with e.g. electrical contacts installed on the catenary). The data is processed de-centrally, directly at the intersection. |
<p>| Green Light Optimised Speed Advisory GLOSA/Time to Green (TTG) | Hungary – time to green/red signals in large signaled crossings using countdown timer |
| Traffic Information and smart routing           | Helmond – camera and loop detection of congestion (due to closing times of railway crossing) at main southern access road. |
| Park and Ride information                       | Vienna – real time information on the number of available parking spaces at specific P&amp;R facilities can be displayed (analog or via an application). |
| Road works warning                              | Budapest – Information on ongoing road work.                                                               |</p>
<table>
<thead>
<tr>
<th>Topic</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vulnerable road user protection (pedestrians, cyclists, motorcyclists)</td>
<td>Helmond – radar / camera systems to detect pedestrians and cyclists in order to increase green time at crossings. Sound support of traffic controller for visually impaired persons.</td>
</tr>
<tr>
<td>Signal violation / intersection safety</td>
<td>Madrid – has installed red light traffic safety systems that detect the steps of vehicles that pass the crossing in the red phase of the traffic light. The location information for these systems is published in the open data portal. The photographs of the infringing vehicle are received in the Traffic Management Centre of the City of Madrid and after their validation by the agents of the authority, they are processed automatically. Budapest – Cameras in busy intersections monitoring signal violation (red running) and prohibited turns. - Cameras monitoring busy bus lanes - Extra red light for speeding cars detected before dangerous intersections with pedestrian crossings.</td>
</tr>
<tr>
<td>On street parking information and management</td>
<td>Helmond – smart camera pilot at one location in Helmond to detect on street free parking spaces. Both for city management information as well as route guidance/information for individual car users.</td>
</tr>
</tbody>
</table>

The working group inferred from this exercise that there were currently many significant differences in how the data used to implement these services is collected, and how the different stakeholders in the services and the travelers benefiting from them received the information and advice. This has significant implications for how C-ITS can be implemented in cities which already implement ITS systems – which in Europe, more or less all cities do to at least a basic standard. In most cases, C-ITS systems will be implemented as a migration from current systems, rather than as a “big bang” complete reinstallation.

C-ITS, whether on the urban or on the national / international level, will require infrastructure installation and maintenance. Depending on the locality, this may involve more or less development of, and integration with, existing ITS. Again depending on the locality, this work may be entirely undertaken by public authorities, or partly outsourced to private sector actors. Most locations will require a fairly complex arrangements involving old ITS, new C-ITS, public authorities and private sector companies, including vehicle manufacturers and Tier 1 suppliers. It is too early at the time of writing (early 2018) to quote any examples of best practice, but these should become available during the next two years and will be very useful.
to the second wave of adopting cities.

The fact that C-ITS needs to be integrated into the ITS infrastructure of cities also necessitates the creation of standards and interoperability specifications which are not yet in existence. Work by the relevant standardisation bodies in this area has been mandated and funded by the European Commission and this work needs to be supported widely by stakeholders, who will after all be reaping the benefits.

In order to succeed in an urban context, C-ITS must match local policy goals and address challenges demonstrably faced by the city. The urban C-ITS context is unique in several ways (EC 2017):

- The general objective of reducing traffic, pollution and congestion to create more livable cities
- Priorities certain transport modes and intersections i.e. public transport, emergency vehicles, active modes etc.
- Cultural and behavioural aspects
- Geographical situation and configuration of existing road network
- Robustness of networks
- Technical and operational characteristics of the public transport network
- Multitude of road operators, particularly in inter-urban areas
- Parking availability and policy
- Multimodality / mixed traffic and safety implications of vulnerable road users (VRU)

The C-ITS services most likely to be of use in delivering urban policy goals are summarised in the table 2. The exact choice of services will vary from city to city, depending on local circumstances and policies. The levels; Day 1, Day 1.5 and so on refer to the generally agreed order in which C-ITS services should be implemented in order to secure the maximum benefit relative to resource expended.

Table 4. Summary of C-ITS services for urban areas (EC 2017).

<table>
<thead>
<tr>
<th>Level</th>
<th>C-ITS Service relevant for urban areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 1</td>
<td>Traffic signal priority request by designated vehicles</td>
</tr>
<tr>
<td>Day 1</td>
<td>Green light optimized speed advisory GLOSA / time to green (TTG)</td>
</tr>
<tr>
<td>Day 1.5</td>
<td>Traffic information and smart routing</td>
</tr>
<tr>
<td>Day 1.5</td>
<td>Park and ride information</td>
</tr>
<tr>
<td>Day 1</td>
<td>Road works warning</td>
</tr>
<tr>
<td>Day 1</td>
<td>In-vehicle speed limits</td>
</tr>
<tr>
<td>Day 1</td>
<td>Probe vehicle data</td>
</tr>
<tr>
<td>Day 1.5</td>
<td>Vulnerable Road User (VRU) protection</td>
</tr>
</tbody>
</table>

5. Public Transport ITS

ITS is by now well established in the public transport sector, with automatic vehicle location (AVL), smart ticketing systems, surveillance and security systems, and dynamic management
in terms of reacting to service disruptions, all in widespread use, with AVL and smart ticketing almost ubiquitous.

Light and heavy rail networks also use ITS, but not usually the term itself. However, their signaling systems particularly the recent ERTMS, ticketing systems, information and booking services are all recognisable forms of what we call ITS on roads and streets.

5.1 Event detection and transport data collection

Event detection for road based public transport works in two ways: the public transport vehicle and/or its driver detects an event – e.g. congestion or an accident – and reports it to the control centre, whether automatically via an ITS or manually. The control centre will in some locations be integrated into the city control centre (more advanced), or may be a stand-alone function for the service in question, in which case it is probably located at a depot (more basic).

Event detection may be via on-vehicle systems and sensors or by the driver, but increasingly public transport event detection is done by service users and transmitted via social media. The operator / service integrator may choose to use this free but at source unvalidated data and the trend is that more advanced cities are indeed doing so, finding ways of validating the information before adding it to their total data resource.

The rudimentary beginnings of C-ITS principles are already visible in public transport – the integration of some or all of vehicle, road, passenger / ticketing, security and social media information in order to provide a better service more efficiently. The barriers to obtaining vehicle-sourced data which may turn out to hamper C-ITS services linking private vehicles and infrastructure do not appear in fleet scenarios. Even a private sector bus operator has much more to gain from cooperating with the roads authority and therefore with the infrastructure, than he has to lose in terms of commercially valuable data and potentially harmful information about service delays, cancellations or over-crowding.

C-ITS for public transport will mean integrating the existing ITS in use with infrastructure systems, to create a cooperative system where the vehicle, road infrastructure, and passenger related information all meshes together to enable improved management systems and a better service. For instance, data relating to the number of passengers on a bus as well as whether it is running late, can be processed to decide whether to give the bus priority at a junction.

5.2 Safety and security of passenger transport

ITS is widely used to improve the safety and security of public transport. In-vehicle camera-based surveillance is in common use, either transmitting images to a control room where they are physically monitored as well as stored, or less advanced, recorded within the vehicle itself and downloaded at the depot.

AVL is used for security purposes: any deviation off route, unexpected lengthy stops or increases in speed can all be detected and interpreted as possible signs of a security problem.

The increase in safety and security has to an extent taken away from any privacy concerns drivers or passengers may have in connection to camera-based monitoring. It is interesting
to note that smart ticketing, whether via registered smartcards or latterly via devices such as
smart phones or watches, provides a wealth of highly personal data related to places visited
and therefore activities undertaken, but does not seem to create any privacy concerns.

Safety and security systems, alongside AVL and ticketing systems, will take their place in an
architecture of C-ITS for public transport, alongside the crucial links to the street network and
control centres, in order to make public transport part of the city's C-ITS structure.

5.3 Multimodal journey planning
Providing public transport users with online journey planners which provide information about
all available modes have been around since the early 2000s. The UK’s Transport Direct portal
was the first to provide this at the national level and included the use of a car as one of the
options. Similar national, regional and city-based planners proliferate around Europe, though
they often limit information to public transport modes, reflecting the priorities of the
organisation funding them.

The use of app based journey planners is growing rapidly in popularity and again, includes
most available options whether they are public transport, vehicle-for-hire or private car based.
This is powered by a combination of open data from public sector authorities and private
sector transport operators’ data.

Mobility as a Service (MaaS) is the next step in this area: the multimodal journey planner
fused with an equally multimodal and multi-operator payment system, so that even complex
combined journeys can be organised and paid for in one step. A MaaS offer is available in
Finland, and there is strong interest in many cities and areas around Europe. The West
Midlands area of the UK is running a MaaS trial with the MaaS provider MaaS Global.64

6. TMC and roadside technologies on the major road network
Roadside technologies such as cameras, loops and other sensors on the major road network
collect prevailing road network condition information and provide this to control centres in order
to support network operations and enable effective traffic management and control. Roadside
technologies such as VMS and other signage are used to feed the information, advice and
instructions back to drivers. RDS-TMC, the use of a dedicated radio channel for traffic updates
and road safety information, is in widespread use for over a decade. The traffic messages
automatically cut across the radio broadcast the driver is listening to, so that the information
is relayed in a timely manner for maximum impact.

6.1 Event detection and transport data collection
The collection of timely, accurate and reliable information about traffic flow and road conditions
is essential for effective use of ITS on the network.

64 For both MaaS examples, see https://maas.global
One of the most common means of event detection and data collection is CCTV, but fixed roadside detectors are also in widespread use and “probe data” generated by vehicles has become more important in recent years. Where free flow road tolling is in operation, the data generated by detecting vehicles in order to charge them correctly is also very valuable for road operations and driver information. A typical TMC function will aggregate data of different types from different sources in order to inform its operations. Especially in complex or congested traffic situations, this needs to be carried out in near-real time in order to be effective.

Common forms of data collected and processed for TMC functions are congestion, journey speed, weather and light conditions, road surface condition, and of course exceptional incidents such as accidents, wrong way drivers, shed loads etc.

6.2 C-ITS on high level road network
Cooperative traffic management describes a connected and de-centralised traffic management system where operators and drivers, infrastructure and vehicles, are enabled by connectivity to act collaboratively. This may be for the common good in terms of increased safety, less air pollution, more predictable journey times etc., or it may be for personal / business benefit of faster, cheaper journeys. The technology can deliver either outcome, and there needs to be a dialogue to establish democratically where the balancing point is to be fixed.

C-ITS has a lot to offer on the major road network. Some believe that these networks will be transformed by the arrival of fully automated vehicles, but there is little agreement on the time scales for this and a well designed C-ITS system can deliver safety, congestion and air quality benefits now, while having the inbuilt capability of being further developed to support AVs on the network in the future. The principles of vehicle and infrastructure in constant communication can apply to equally to a C-ITS based network operating model as to an AV based one.

Examples of C-ITS on major road networks:

Invehicle signage has been demonstrated to deliver significant road safety benefits. Providing dynamic speed limit information and intelligent speed assistance (ISA) directly into the vehicle showed a potential halving of accidents.

Using C-ITS for cooperative lane changing, combining slight reductions in speed with slightly increased distances between vehicles, have been shown to deliver significant traffic flow improvements. The study (by Trinity College, Dublin) suggested that with a 20% penetration of connected and cooperative vehicles on the network, motorway congestion could almost be eliminated (not taking into account any induced traffic increases).

6.3 Aggregation and management of transport data
As in 6.1, the aggregation and fusion of data is crucial to current major road network operations, and C-ITS will put even more emphasis on this aspect. The fixed data relating to
the physical aspects of the network, combined with the data relating to traffic conditions, weather conditions, and any incidents, must be processed in a timely and accurate way in order to deliver C-ITS services. This relies on the collecting equipment functioning correctly, the data transfer protocols being uniform and interoperable, the processes at the control centre (we use this term but the reality is that even complex TMC functions can now be carried out by an operative anywhere with reliable access into the system) being well designed, and the output mechanisms – back to the infrastructure, vehicles and drivers – appropriate.

This is a major undertaking and above all requires proper attention both to the technical requirements and to the human factor demands when communicating with drivers. In order to successfully deliver a C-ITS service, a team of diverse specialists needs to be assembled and managed in an outcome-, not process-based way.

6.4 Access to dynamic transport data
Dynamic data is essential to the creation and maintenance of C-ITS services. Most road operators already use their own equipment to collect significant amounts of dynamic data although not always in a format or of a quality which can be immediately fed into a C-ITS process.

It is also common to enter into agreements with large fleets, for instance hauliers or inter-city coaches, in order to use their vehicles as probes and collect their journey data. This can be on a straightforward payment basis but can also be in return for improved travel information or other benefits.

C-ITS implies that this concept will be extended to all vehicles, or at least all vehicles capable of sending and receiving data in this way. Older vehicles will be excluded unless retro-fitted. The extent to which non-participation in C-ITS will be allowed on the major road network in the future is a difficult question, just as in the AV scenario. But the default scenario is that more or less all vehicles are equipped, share their dynamic data with the operator and/or the C-ITS service provider (they may or may not be the same organisation), and benefit from their services.

7. Discussion and conclusions
The fields of traffic management and control, ITS infrastructure, and public transport ITS are well documented in a large variety of project reports, magazine articles, EC publications and notably PIARC's RNO-ITS website, which provides a comprehensive online guide to ITS. Since it was published in 2014-15, it is out of date in that it does not cover C-ITS in any detail, but it is an excellent resource for ITS up until the advent of C-ITS as a practical concept. It will also be updated towards the end of 2018, when it will start including information about C-ITS.

The concept of C-ITS being a development of "traditional" ITS is the correct way of thinking about this and the preparation of the course should start from the point of respecting and developing existing systems into C-ITS wherever they are found. An emphasis on the new and groundbreaking has its place, in research and in demonstrations, but actual installations can not usually be approached in this way, for reasons of affordability and practicality.
The course should therefore take a number of transport scenarios and show how the existing ITS applied to them, can be developed using available technology into C-ITS services.

The course must also give due weight to the policy and democratic aspects of any transport intervention. Any C-ITS service must be put into existence in order to deliver agreed policy objectives. It should never be technology-led, always policy-led.
8. References


Annex 4: Communication technologies for ITS and C-ITS including relevant standards

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Project acronym: CAPITAL

Project full title: Collaborative cApacity Programme on Its Training-educAtion and Liaison

Topic study 4: Communication technologies for ITS and C-ITS including relevant standards

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<td>RE       Restricted to a group specified by the consortium (including the GSA)</td>
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<tr>
<td>CO       Confidential, only for members of the consortium (including the GSA)</td>
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**Abstract**

This document presents a literature review on communication technologies for ITS and C-ITS including relevant standards, which serves as study guide for the preparation of a study module on the CAPITAL E-Learning platform.

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## Abbreviations and Acronyms

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<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
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<tbody>
<tr>
<td>CAM</td>
<td>Cooperative Awareness Message</td>
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<td>C-ITS</td>
<td>Cooperative intelligent transport system</td>
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<tr>
<td>CP</td>
<td>Certificate Policy</td>
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<tr>
<td>C2C-CC</td>
<td>CAR 2 CAR Communication Consortium</td>
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<tr>
<td>DCC</td>
<td>Decentralized Congestion Control</td>
</tr>
<tr>
<td>DENM</td>
<td>Decentralized Environmental Notification Message</td>
</tr>
<tr>
<td>DSRC</td>
<td>Dedicated Short-Range Communication</td>
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<tr>
<td>EC</td>
<td>European Commission</td>
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<td>ECTL</td>
<td>European Certificate Trust List</td>
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<tr>
<td>ESoP</td>
<td>European Statement of Principles on HMI</td>
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<td>FCD</td>
<td>Floating car data</td>
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<tr>
<td>GA</td>
<td>Grant Agreement</td>
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<td>GLOSA</td>
<td>Green light optimal speed advisory</td>
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<td>GN</td>
<td>GeoNetworking</td>
</tr>
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<td>HMI</td>
<td>Human-Machine Interaction</td>
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<td>IP</td>
<td>Internet Protocol</td>
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<td>ITS</td>
<td>Intelligent transport system</td>
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<tr>
<td>ITS-G5</td>
<td>ITS-G5 is a European standard for ad-hoc short-range communication on 5.9 GHz frequency band</td>
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<tr>
<td>IVI</td>
<td>In-Vehicle Information</td>
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<tr>
<td>LDM</td>
<td>Local Dynamic Map</td>
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<tr>
<td>LIDAR</td>
<td>Light Detection and Ranging</td>
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<td>LTE</td>
<td>4G mobile communications standard</td>
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<tr>
<td>MAPEM</td>
<td>MAP (topology) Extended Message</td>
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<tr>
<td>MSD</td>
<td>Minimum Set of Data</td>
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<tr>
<td>OFDM</td>
<td>Orthogonal Frequency-Division Multiplexing</td>
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<td>PKI</td>
<td>Public Key Infrastructure</td>
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<td>PO</td>
<td>Project officer</td>
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<td>PSAP</td>
<td>Public Safety Answering Point</td>
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<td>RDS</td>
<td>Radio Data System</td>
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<td>Road Hazard Signaling</td>
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<td>RTTI</td>
<td>Real-time traffic information</td>
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<td>SDO</td>
<td>Standards Development Organization</td>
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<td>SPATEM</td>
<td>Signal Phase And Timing Extended Message</td>
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<td>TLM</td>
<td>Trust List Manager</td>
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<td>TMC</td>
<td>Traffic Message Channel</td>
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<td>VDS</td>
<td>Variable Direction Sign</td>
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<td>VMS</td>
<td>Variable message sign</td>
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<td>VTP</td>
<td>Variable Text Panels</td>
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<td>V2X</td>
<td>Vehicle-to-Everything communication</td>
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<td>WAVE</td>
<td>Wireless Access in Vehicular Environments</td>
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<td>WLAN</td>
<td>Wireless Local Area Network</td>
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<td>WP</td>
<td>Work Package</td>
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1. Introduction

Intelligent Transport Systems (ITS) has many definitions. According to the European Commission: “Intelligent Transport Systems or ‘ITS’ means systems in which information and communication technologies are applied in the field of road transport, including infrastructure, vehicles and users, and in traffic management and mobility management, as well as for interfaces with other modes of transport”. (European Commission 2010)

Communication has always been a key feature of ITS and the role of communication between various road users and systems increase when we move to the Cooperative systems. Cooperative Intelligent Transport Systems (C-ITS) use technologies that allow road vehicles to communicate with other vehicles, with roadside infrastructure including traffic signals as well as with other road users. The systems are also known as vehicle-to-vehicle communications, or vehicle-to-infrastructure communications, or vehicle-to-everything (V2X), which covers all previously mentioned. (European Commission 2016, p. 8)

ITS is already on the market and it has been utilized for many years to support European transport policy - safer, cleaner and more efficient transport. During the recent years the standards of the first C-ITS services have been completed. C-ITS functionality has been already tested in various research projects and it is currently being piloted e.g. in European corridor projects. The commercial deployment of C-ITS in Europe is starting soon and the final open issues have been discussed in the framework of C-ITS Platform supported by the European Commission. Due to large number and variability of ITS systems available, this topic study provides a limited number of ITS and C-ITS services as an example while focusing more on architectures, communication technologies and standards behind the applications and services.

Standard is described by (CEN no date (n.d.)) in following way: “A standard is a document that sets out requirements for a specific item, material, component, system or service, or describes in detail a particular method or procedure. Standards are established by consensus and approved by recognized standardization bodies… Standards provide individuals, businesses and all kinds of organizations with a common basis for mutual understanding. They are especially useful for communication, measurement, commerce and manufacturing… Standards are voluntary, which means that businesses and other organizations are not legally obliged to apply them. However, in certain cases standards may facilitate compliance with legal requirements, such as those contained in European directives and regulations.”

2. Objectives

The objective of this topic study is to provide a timely, comprehensive and consistent overview of 1) Communication technologies for ITS and especially for C-ITS and it also includes 2) general information about standardisation and for C-ITS standards on the European level. The topic study aims to provide background information for development of CAPITAL study module “Communication technologies for ITS and C-ITS including relevant standards”.

Chapter 3 describes a few examples of ITS services and applications and short overview of the FRAME architecture. This topic study focuses more on the C-ITS architecture, communication and standards that is described in Chapter 4. The Chapter 5 provides information about the standardisation for ITS and C-ITS and finally the Chapter 6 includes a short overview on testing and interoperability.
3. Intelligent Transport Systems

3.1 ITS Applications (Technologies)

There are numerous ITS applications on the market and there are variations in their implementations and use between different countries. The iMobility effects database has been compiled by iCarSupport in order to maintain the state-of-the-art knowledge of the effects of different ITS, intelligent vehicle and infrastructure systems. This list provides a good overview of several ITS applications. A list of the ITS application examples, which includes communication element, is presented below. The stand-alone (in-vehicle) applications are not included. Another list of ITS applications from the road operator/authority point-of-view can be found from the EU EIP project Deployment Guidelines. EU EIP project supports European road operators and authorities in the deployment of harmonised ITS services. The list of these ITS applications is also included in this chapter.

3.1.1 Dynamic Traffic Management

The iMobility Effects Database (n.d.) provides the following description: “Dynamic traffic management systems and local danger warnings are used to increase the safety and flow of traffic in cases of disturbance caused by incidents, congestion and adverse weather. Dynamic traffic management systems may also be used to implement hard shoulder running to increase road capacity locally during peak hours. The systems are operated automatically, semi-automatically or manually from traffic control centres based on fixed monitoring systems or mobile sensors (FCD etc.) on location. The systems employ Variable Message Signs or VMS to give the information to the drivers. Three categories of VMS exist based on the types of messages given: ‘regulatory messages’, ‘danger warning messages’ and ‘informative messages’. The dynamic traffic management systems usually use regulatory messages, sometimes accompanied by danger warning and informative messages.”

As retrieved from http://www.imobility-effects-database.org/applications_11.html

3.1.2 Local Danger Warnings

The iMobility Effects Database (n.d.) provides the following description: “Dynamic traffic management systems and local danger warnings are used to increase the safety and flow of traffic in cases of disturbance caused by incidents, congestion and adverse weather. The systems are operated automatically, semi-automatically or manually from traffic control centres based on fixed monitoring systems or mobile sensors (FCD etc.) on location. The systems employ Variable Message Signs or VMS to give the information to the drivers. Three categories of VMS exist based on the types of messages given: ‘regulatory messages’, ‘danger warning messages’ and ‘informative messages’. Local warning systems use danger warning messages’ and ‘informative messages’. Local warning systems use danger warning messages.”

As retrieved from http://www.imobility-effects-database.org/applications_12.html

3.1.3 Dynamic Navigation Systems

The iMobility Effects Database (n.d.) provides the following description: “Dynamic navigation utilizes current traffic event and transport network status data for adjusting the routing process in electronic navigation systems. This enables users to avoid routes with accidents, roadworks, road closure, and congestion in “real time”. The Traffic Message Channel (TMC) is mostly used to provide the basic traffic event information countries in Europe using RDS radio communications. More enhanced and individually sourced content is used to improve the standard TMC services in terms of accuracy and quality. These kinds of services are being provided via cellular networks.”

As retrieved from http://www.imobility-effects-database.org/applications_17.html

3.1.4 Real-time Traffic Information

The iMobility Effects Database (n.d.) provides the following description: “Real-time Traffic and
Travel Information” includes all information which is relevant to organize and to optimize traffic flow and which can give advice to the mobile user, usually the driver, and to contribute to road safety and efficiency. The eSafety goal is to provide the majority of drivers with actual intra-urban traffic information and to get adequate urban traffic information in 50% of all major metropolitan areas in the EU. RTTI contains

- the collection of relevant traffic data,
- the interpretation of that information and prepare it for further use and distribution,
- the application of that information to operate infrastructural installations such as traffic lights or moving traffic signals,
- the wireless transmission of the RTTI to the mobile user by public or private broadcast and/or two-way systems such as cellular networks, WLAN, Satellite transmission.”

As retrieved from http://www.imobility-effects-database.org/applications_10.html

3.1.5 Extended Environmental Information (Extended FCD)
The iMobility Effects Database (n.d.) provides the following description: “The idea of Floating Car Data (FCD) is to monitor individual vehicles to gather data concerning the traffic situation on the whole road network. The in-vehicle equipment records the location of the car, speed and possibly other information such as acceleration or deceleration, and sends the recorded information to the central system or to other cars. The central collected data can be used as content for different applications and services.”

As retrieved from http://www.imobility-effects-database.org/applications_09.html

3.1.6 eCall
The iMobility Effects Database (n.d.) provides the following description: “The 112 eCall automatically dials Europe’s single emergency number 112 in the event of a serious road accident and communicates the vehicle’s location to the emergency services. eCall is activated automatically as soon as in-vehicle sensors and/or processors (e.g. airbag) detect a serious crash. Once set off, the system dials the European emergency number 112, establishes a telephone link to the appropriate emergency call centre (aka Public Safety Answering Points – PSAPs) and sends details of the accident (aka Minimum Set of Data – MSD) to the rescue services, including the time of incident, the accurate position of the crashed vehicle and the direction of travel. An eCall can also be triggered manually by pushing a button in the car, for example by a witness to a serious accident.”

As retrieved from https://ec.europa.eu/transport/themes/its/road/action_plan/ecall_en

The European Parliament adopted the legislation on eCall type approval requirements and made it mandatory for all new models of M1 and N1 vehicles to be equipped with eCall technology from 31 March 2018 onward. The Public Safety Answering Points (PSAP) need to be equipped with eCall from 1 October 2017.”

3.1.7 Forecast and Real time event information
The ITS Deployment Guideline fact sheet (EU EIP 2015) provides the following description: “Forecast and Real Time Event Information Services” are defined as the provision of information about both expected and unexpected events to road users on identified road segments of the TEN-T network and interfaces. This predictive or real-time information could be provided on-trip and pre-trip using different information channels, accessible by the road user via different end-user devices. The service may comprise common information as well as individual (personalised, on-demand) information. “Events” are defined as – expected or unexpected – abnormal situations which may lead to adverse effects on the road regarding traffic safety, efficiency and environmental effects.”

“Forecast and real-time event information services are currently well developed and widespread across Europe. Many European road operators/service providers use websites as a means of information provision, which can assist with journey and route planning. Road network information combined with both historic and real time passenger information enables
road users to make informed choices between private and public transport options and help impact on the mode choice of travel. On-trip information using Variable Messages Signs (VMS) exists extensively across much of Europe. Traffic information (spoken word), used pre-trip as well as on-trip, is available on several radio stations throughout Europe. RDS-TMC (Radio Data System Traffic Message Channel) has been deployed in most European countries and deployment is underway in several Central and Eastern European countries."

“The use of in-vehicle navigation systems with traffic information is also widespread. These systems tend to have a data connection which offers them the possibility to connect with a service provider. There is also exponential growth in the market for smartphones and software applications which can act as in-vehicle navigation system.”

3.1.8 Traffic Condition and Travel Time Information Service
The ITS Deployment Guideline fact sheet (EU EIP 2015) provides the following description: "Traffic condition and travel time information service" means, both pre-trip and on-trip, the provision of traffic condition (Level of Service) and travel time information on identified road segments of the TEN-T network and interfaces, thus enabling road users to optimize and better anticipate their journey ahead. This predictive or real-time information will use different information channels, accessible by the road user via different end-user devices. The service may comprise common as well as individual (personalised, on-demand) information."

“There are various European services in operation which can be distinguished according to the information providers, i.e. public road authorities, private road operators, broadcaster and other private service providers. Different information channels could be used for the provision of the service to the road user as there are roadside information infrastructure, Internet, broadcasting facilities used by media, data communication, mobile radio or infrastructure to vehicle facilities."

3.1.9 Speed Limit Information
The ITS Deployment Guideline fact sheet (EU EIP 2015) provides the following description: “The function of a speed limit information service is to provide road users with credible travel information about the prevailing speed limits that applies on the roads that they are travelling on.”

“Delivery platforms for the speed limit information service will range from traditional media such as roadside signs to innovative media such as VMS, in vehicle navigation systems, digital maps and smart phone applications.”

3.1.10 Weather Information Service
The ITS Deployment Guideline fact sheet (EU EIP 2015) provides the following description: “The main objective of providing weather information to the driver is improving the traffic safety and the efficiency of the European road transportation system. If the driver is informed on the upcoming weather situation he is able to adapt his driving behaviour. Weather information can be included into both pre- and on-trip journey planning. This may reduce congestion and the number of fatalities and accidents. The vision is that a user provided with high quality information will react and adapt his travelling and driving behaviour including a change of routes, modes or trip schedule (time of departure) as well as changes in the way of driving.”

3.1.11 Co-Modal Traveller Information Services
The ITS Deployment Guideline fact sheet (EU EIP 2015) provides the following description: “Co-modal traveller information services offer in parallel comparative information of different modes / means of transport (multi-modal) and / or the combination of different modes / means of transport within the same route (inter-modal). The services offer information for at least public transport, car transport and usually pedestrian and bicycle transport. Co-modal traveller
information services can foster a modal shift towards reputed more environmental-friendly modes / means of transport and lead to a more efficient network operation as well as a better utilization of the transport infrastructure."

3.1.12 Dynamic Lane Management
The ITS Deployment Guideline fact sheet (EU EIP 2015) provides the following description: “The fundamental concept behind Dynamic lane management (DLM) is to provide a service that enables a temporarily modifiable allocation of lanes by means of traffic guidance panels, permanent light signals, multiple-faced signs, LED road markers and closing and directing installations. Applications of this service are related to tidal flow systems, lane allocation at intersections, lane allocation at tunnels and hard shoulder running. The overall objective of the dynamic lane management (DLM) service is to allocate traffic flows and therefore obtaining a higher capacity through better usage of the available cross-section and also to achieve a temporary closing of lanes in case of accidents, incidents, maintenance work and construction measures (safeguarding of lanes)."

3.1.13 Variable Speed Limits
The ITS Deployment Guideline fact sheet (EU EIP 2015) provides the following description: “The main purpose of VSL is to help drivers to travel at an appropriate speed considering the prevailing traffic or weather conditions. Sensitive road segments, like tunnels, are often subject to VSL deployment for safety reasons. VSL can also be used to mitigate negative effects for society in general, like pollution or noise and to increase throughput. The use of VSL for environmental purposes is small today, but an increase is expected."

3.1.14 Ramp Metering
The ITS Deployment Guideline fact sheet (EU EIP 2015) provides the following description: “Ramp metering (RM) is implemented via the installation of traffic signals on the on-ramps which regulate the flow of traffic joining the motorway during peak or congested periods. It does this by controlling the discharge of vehicles from the on-ramp, holding vehicles back and breaking up on-ramp platoons, thus reducing the interference of merging vehicles and helping maintain the flow of traffic on the main carriageway. The traffic signals are generally operated in dependence of the currently prevailing traffic conditions on both the main carriageway and the on-ramps."

3.1.15 Hard Shoulder Running
The ITS Deployment Guideline fact sheet (EU EIP 2015) provides the following description: “Hard Shoulder Running enables the dynamic temporary use of hard shoulders at road sections, including junctions with the aim to increase road capacity when necessary. Hard Shoulder Running could be considered similar to the creation of an extra lane, but with specific safety issues due to the fact that it is still a hard shoulder where users can stop if they break down. Hard Shoulder Running is triggered by traffic demand, at fixed times or due to manual requests and applied to bottlenecks, locations with poor safety records (black spots) with a recurrent - but not constant - lack of capacity."

3.1.16 HGV Overtaking Ban
The ITS Deployment Guideline fact sheet (EU EIP 2015) provides the following description: “Service Description –An HGV Overtaking ban service means to channel the heavy goods vehicles onto a single lane (slow lane). The heavy goods vehicles overtaking ban implementation is one of the traffic management measure allowing traffic managers and road operators to propose solution for a better fluidity of their network during peak periods. This traffic control measure constitutes one of the priority services to improve the cohabitation of heavy goods vehicles and private cars on networks with high levels of traffic."
3.1.17 Intelligent and secure truck parking
The ITS Deployment Guideline fact sheet (EU EIP 2015) provides the following description:
“The objective of parking area operators is to make the optimum use of the existing truck parking capacities along the highways and to improve safety and security on their (truck) parking area. “Intelligent Truck Parking” will contribute towards optimising the use of available parking areas, which are a limited resource in many corridors today.”

“Pre-trip travel planning has developed towards dynamic smartphone applications and easy-to-access websites with TPA as Point of interest, or to information platforms. A few European road operators employ websites as a means of information provision, which can assist with route planning.”

“There is also an exponentially growing market for smartphones which can act as in-vehicle navigation systems and/or provide parking information through parking apps on smartphones.”

3.2 Communication technologies for ITS
The previous chapter listed a number of ITS applications that have been implemented with various communication technologies. Here is a short list of communication technologies (except C-ITS communication technologies, which are covered later in the document).

The EIP+ project C-ITS White paper (EIP+ 2016) includes a comprehensive list of various communication technologies, which are used in ITS sector, and their characteristics:

3.2.1 Fixed networks
The EIP+ project C-ITS White paper (EIP+ 2016) provides the following overview:
“Fixed communication networks carry the majority of communications traffic worldwide and were used for the earliest telephone circuits, they cover a wide range of bandwidths from single telephone lines to 100s of Tbit/s.”

In ITS fixed networks are utilized between the backend systems, between control centres and fixed outstation equipment (like fixed monitoring systems or message signs, etc.) and mobile communication infrastructure nodes.

3.2.2 Broadcast radio
The EIP+ project C-ITS White paper (EIP+ 2016) provides the following overview:
“FM broadcast has been in use for many years and is readily available in most vehicles via a built radio receiver, it is one of the main mediums for distributed traffic information. The area coverage is close to 100%. Many local and regional radio stations broadcast traffic reports at peak times throughout the day with car radio programs or music interrupted for the traffic alerts.”

3.2.3 RDS-TMC and DAB-TPEG
The EIP+ project C-ITS White paper (EIP+ 2016) provides the following overview:
“Traffic Message Channel is sent via the Radio Data System (RDS) embedded in some FM broadcasts. The system is based on geographical reference points (TMC locations) in combination with text and timestamps. Information about traffic accidents, road works and road weather is transmitted. To receive the messages the car radio, a GPS-navigator or Smartphone must support RDS-TMC.”

“In Europe (and throughout the world), the FM radio system is in the process of being replaced by DAB-radio (Digital Audio Broadcast). As with FM, Traffic Messages can be transmitted using DAB radio with the encoding being in accordance with Transport Protocol Expert Group (TPEG).”
3.2.4 Public Land Mobile Networks (cellular networks)

The EIP+ project C-ITS White paper (EIP+ 2016) provides the following overview: “2G GSM has coverage over most of the population and has been used in certain telematics applications. eCall was designed to use 2G communications, but will inevitably use later generations of cellular network with higher bandwidth.”

“3G WCDMA is the first generation of mobile broadband and has good coverage in populated areas. It has low latency and can be used to exchange messages between vehicles for many C-ITS use cases. However transmission from remote transmitters may be unreliable.”

“4G LTE is a much improved mobile broadband being deployed at the time of writing. The coverage of mobile broadband will expand rapidly as new spectrum (700 and 800 MHz) with good propagation characteristics is deployed and existing spectrum licenses become “technology neutral”.”

“5G is the next generation of mobile network technology. It is under definition now with expected deployment around 2020. The performance target is to make it “ten times better” than 4G in many categories including latency and reliability and it is designed to support all aspects of the ‘internet of things’.”

3.2.5 Satellite communications

The EIP+ project C-ITS White paper (EIP+ 2016) provides the following overview: “Satellite communications systems can offer a huge benefit of wide coverage. Several operators have hence developed services that offer both voice and data services on regional or global basis, the following represent the type of satellite constellation with 100+ operators offering broadcast, broadband & mobile services and application. Enhancement in capacity and coverage at regional scale can be achieved by the launch of a single GEO satellite payload. Unlike terrestrial networks, satellite services are designed to cover and provide reliable connectivity to large areas of land (rural and urban), sea and air.”

3.3 FRAME architecture for ITS and C-ITS

The FRAME Architecture (FRAME Forum, 2017) is a top-down approach to plan the implementation and deployment of ITS and C-ITS architectures in an integrated and interoperable manner. It is a methodology in the early stage of system engineering process to collect the requirements for the new system systematically and follow up the collected requirements in various standard views as output, which together form the ITS architecture. These views, or single aspect representations of the architecture, can be functional, data, communication, security or organizational views of the system, depending on the extent to which stakeholders are involved in implementing a new system. The common methodology allows for different stakeholders, such as users, operators, and providers, to share a “common language” in expressing their requirements for the applications and services provided by the ITS architecture. It aims to formalise the desires and produces a structure for the architecture that does not impose technical or organisational assumptions on the final deployment in the first functional and data views. This way the final system structure and the original design concept do not need to change when the technology evolves.

ITS architectures can represent systems from local services to national level systems and they can cover anything from the technical aspects to legal issues. An ITS architecture should integrate to existing systems with appropriate interfaces and, at the same time, allow for future extensions and upgrades. It also has a set of expectations on its performance, maintainability, ease of use, and so on, all of which it has to satisfy.

Designing and implementing such a system in a networked transport environment is a complex task. The FRAME architecture was created to solve this task by offering a shared, common approach to capture the objectives and requirements of each actor and map them into specific,
pre-defined, formalised components of the system.

The creation of an ITS Architecture with the FRAME Architecture starts with a conversation with the stakeholders to extract their Aspirations for the overall concept of the system. The Stakeholder Aspirations are high-level objectives and requirements of the whole ITS system and are received from everyone involved in the deployment of the ITS architecture. These Aspirations are then mapped onto the pre-determined User Needs provided by the FRAME Architecture, or, the Aspirations determine the sub-set from all available User Needs that will then lay the groundwork for the system structure for the ITS architecture. The User Needs describe what behaviour the system will provide in a clear and unambiguous way and connect to Functions, which describe exactly what is done to the data at that point in the system. The sub-set of User Needs extracts the ITS Architecture from the whole FRAME Architecture.

Each Low-level Function has a list of User Needs that are served by that Function and an Overview of its functionality. It also has a list of input and output Data Flows and a detailed Functional Requirements, which describe exactly what the Function does with the data. They are intended to be simple and easily describable. High-level functions are just groups of Low-level Functions to mask a more complicated series of functions as one Function.

The FRAME Architecture also list different Data Stores that hold the data used by components of the system. They have detailed description of the data and connect to Functions that use that data.

Data Flows are the links between Functions, Terminators, and Data Stores. They specify how data is moved around in the ITS Architecture. Terminators are points of the system that connect to the real world (e.g. input data from a sensor or a driver of a vehicle).

These abstract concepts, and others not listed here, create the structure of the system, the ITS Architecture, in a technology independent way. This structure can then be viewed from different perspectives with views provided by the FRAME Architecture.

The Functional View will provide the functionality and processes needed, as a set of diagrams and specifications, to implement the ITS Architecture in a way that satisfies the User Needs. The Physical View will show, in a similar manner, where each component (for example, the Data Stores) are physically located in the deployment. The Communications View will describe the different types of communication channels between components of the system. The Organisational View described the ownership and business issues of the ITS Architecture, e.g. who owns or manages different parts of the structure and what are the contractual relationships between the parties involved.

Thus, the system structure produced by the FRAME Architecture will describe the components of the system and their connections, as well as their relationship with the outside world and, if needed by the specific system implemented, the organisational and business connections. If each component of the system, and their connections, are developed to match the descriptions and specifications provided in the system structure, the final deployment will satisfy the User Needs and, thus, satisfy the original Stakeholder Aspirations for the deployed ITS architecture.

Within the FRAME NEXT project a series of implementation architectures for the priority areas of the ITS Directive (2010/40/EU) will be implemented together with their organisational and physical views. These architectures will include ITS services such as eCall, C-ITS and truck parking. With these implementation examples from various countries, future users can start with predefined elements in their development of ITS Architectures. The elements adapt to the users’ needs and, at the same time, contribute to the interoperability of systems. In the best-case scenario, they could extend the interoperability to generated ITS services.
4  C-ITS

The European Commission has published the European strategy on C-ITS systems in 2016 (European Commission 2016a). The Commission has supported the development of C-ITS for more than a decade via substantial funding. C-ITS research activities have been complemented by large-scale field-operational and during the recent years by deployment projects on the European Trans-European Transport network.

In 2016 the C-Roads Platform was established as the platform of Member State authorities and road operators for harmonising the roadside C-ITS deployment across Europe. In addition, the C-Roads Platform is linking all ongoing C-ITS deployment activities, supported by the European Commission. Also the automotive industry has been active in C-ITS development especially via CAR 2 CAR Communication Consortium (C2C-CC), which is an industry driven organisation initiated by European vehicle manufacturers and supported by equipment suppliers, research organisations and other partners. As the number of infrastructure C-ITS deployment initiatives in Europe are growing, the CAR 2 CAR Communication Consortium in collaboration with the C-Roads Platform are together promoting the C-ITS deployment which should be starting in 2019. (C2C-CC 2017)

Starting from 2014 the European Commission introduced the C-ITS platform to identify barriers and find solutions for C-ITS deployment in Europe. The first phase of the C-ITS platform published the final report in January 2016 (European Commission 2016b). After the first phase of the C-ITS Platform, the Commission has identified issues, which need to be tackled at EU level to ensure coordinated deployment of C-ITS services in 2019. The second phase of the C-ITS Platform has published the final report in September 2017 including results from the Working Groups on Security, Data Protection, Compliance Assessment and Hybrid Communication and others (European Commission 2017c).

In Europe C-ITS deployment is based on voluntary market introduction. In USA, the Notice of Proposed Rulemaking (NPRM): 49 CFR Part 571 “Federal Motor Vehicle Safety Standards; V2V Communications” has published for comments in early 2017 (Federal Register 2017). Currently it is still open if V2V communication based on dedicated short-range radio communication (DSRC) will become mandatory in the USA. DSRC standards in the U.S. are similar to the Cooperative Intelligent Transport (C-ITS) standards in Europe.

4.1 C-ITS Architectures

4.1.1 ETSI architecture

The architecture for the C-ITS is defined in ETSI standards. Intelligent Transport Systems (ITS); Communications Architecture (ETSI EN 302 665) provides the global communication architecture of communications for ITS. It specifies mandatory and optional elements and interfaces of ITS architecture (HIGHTS 2016). In addition some elements of ITS applications, especially those directly related to the ITS architecture, are also considered in the overall high number of relevant standards in the C-ITS area. These documents are enabling different implementation architectures, based on two steps of work in the direction of common implementation of C-ITS on roadside infrastructure networks and in vehicles, these steps are (C-Roads 2017c):

- A selection of the group of standards necessary and the common definition of those elements which are mandatory in the standards, and
- The publication of the choices and decisions taken in the definitions for the Common implementations in a fully documented communication profile for the respective group of C-ITS Stations (e.g Vehicle, or Roadside or personal ITS Station).
The communication architecture for ITS in EN 302 665 is derived from the OSI model (Open Systems Interconnection Reference Model). This is an open standard supporting GeoNetworking (GN) IP stack and multiple access technologies. Cooperative ITS systems today are based on an IEEE802.11p access layer including higher layer extension developed by IEEE WAVE and ETSI TC-ITS (ETSI-G5). (HIGHTS 2016)

The C-ITS messages of ITS-G5 use the GeoNetworking (GN) protocol. The GeoNetworking protocol supports:
- point to point
- point to multi point
- message dissemination with a defined hop count
- message dissemination within a defined geographic area

The following ITS sub-systems (including ITS station) are defined in the ETSI EN 302 665:
- central ITS sub-system (central ITS-S); part of an ITS central system,
- vehicle ITS sub-system (vehicle ITS-S); in cars, trucks, etc., in motion or parked,
- roadside ITS sub-system (roadside ITS-S); on gantries, poles, road trailers,
- personal ITS sub-system (personal ITS-S); in hand-held devices,
These stations together including the stakeholders operating them form the C-ITS network and need to cooperate to be able to exchange traffic information seamlessly between them.

### 4.1.2 C-ITS messages

The Cooperative Awareness Message (CAM) has been described by ETSI (ETSI 2014a): “The several message services specified for C-ITS. The most important ones are the Cooperative Awareness Message (CAM) and the Decentralized Environmental Notification Message (DENM) services. The Cooperative Awareness Service enables the exchange of information between road users and roadside infrastructure, providing each other's position, dynamics and attributes. Awareness of other road users is the basis for several road safety and traffic efficiency applications. This is achieved by regular exchange of information from vehicle to vehicle (V2V), and between vehicles and road side infrastructure (V2I) based on wireless networks. Typically, vehicle ITS station broadcasts the Cooperative Awareness Messages (CAM) at maximum rate of 10 Hz, providing real time high dynamic information of the vehicle, such as position, time, basic sensor data, vehicle type, size, etc. EN 302 637 specifies the syntax and semantics of the Cooperative Awareness Message and provides detailed specifications on the message handling."

A document prepared by the Data Protection WG of the C-ITS Platform (C-ITS Platform 2017) provides a good overview of the CAM messages and how they are used: “C-ITS equipped vehicles communicate with their close environment via the short-range IEEE 802.11p protocol. The signal broadcast from the vehicle ranges between 300 and 500 meters depending on the circumstances. This technique has been chosen because of the low latency of short-range communication directly between the vehicles involved and to be less dependent from other means of information and communication. This low latency is necessary because safety related messages require very short reaction times. The short reaction time becomes even more relevant in higher levels of automation. Broadcast messages will be received and understood in other vehicles or by roadside units.

CAM are standardised to be ‘single-hop’ messages. They can only be processed by vehicles in range and are not meant to be forwarded to other vehicles, since their relevance outside of their range would be limited and forwarding of CAM would create excessive volumes of data traffic. The CAM contains by default a heading, a timestamp, then basic data like vehicle pseudo ID and position. There is also a sub-set refreshed in high frequency mode (HF) that includes data like: speed, acceleration and curvature. Other vehicle status information are given in low frequency refreshing mode, like vehicle role or category and some basic sensors. There is also an optional container relating to vehicle category details (public transport, rescue). The aim of the CAMs is to inform other ITS Stations about current vehicle/C-ITS status and presence.”
### Annex 4:

#### Figure 2. Structure of a CAM (ITS Platform 2017)

The Decentralized Environmental Notification Message (DENM) has been described by ETSI (ETSI 2014a): “EN 302 637 defines the Decentralized Environmental Notification (DEN) Basic Service. The Decentralized Environmental Notification Message (DENM) contains information related to a road hazard or an abnormal traffic condition, including its type and position. Typically for an ITS application, a message is disseminated to ITS stations that are located within a geographic area through direct vehicle-to-vehicle or vehicle-to-infrastructure communications, in order to alert road users of a detected and potentially dangerous event. The transmission of DENM may persist at a typical transmission rate of 10 Hz, as long as the detected event persists. At the receiving side, the message is processed and the application may present the information to the driver if it is assessed to be relevant.”

A document prepared by the Data Protection WG of the C-ITS Platform (C-ITS Platform 2017) provides a good overview of the DENM messages and how they are used: “The DENM is event-based, it is sent, if a vehicle senses special conditions or incidents. It is meant for urgent emergency situations. The DENM is sent in addition to the CAM. It contains location information about the event (not the transmitting vehicle) and complements that data with a range of events or conditions (e.g.: different weather conditions, visibility, road adhesion or collision warnings). DENM are ‘multi-hop’ messages. They could be sent from an ITS Station to a certain area and get there ‘hopping’ from ITS station to ITS station. Similar to the CAM it also consists of data containers that are mainly filled with data defined in the Common Data Dictionary (specified in ETSI TR 102 894).”

<table>
<thead>
<tr>
<th>Header</th>
<th>Signer Info</th>
<th>Generation Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basis Container</td>
<td>ITS-Station Type</td>
<td>Last Geographic Position</td>
</tr>
<tr>
<td></td>
<td>Speed</td>
<td>Driving Direction</td>
</tr>
<tr>
<td></td>
<td>Longitudinal Acceleration</td>
<td>Curvature</td>
</tr>
<tr>
<td></td>
<td>Vehicle Lenght</td>
<td>Vehicle Width</td>
</tr>
<tr>
<td></td>
<td>Steering Angle</td>
<td>Lane Number</td>
</tr>
<tr>
<td>CAM Information</td>
<td>Low Frequency Container</td>
<td>Vehicle Role</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lights</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Trajectory</td>
</tr>
<tr>
<td></td>
<td>Emergency</td>
<td>Police</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fire Service</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Road Works</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dangerous Goods</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Safety Car</td>
</tr>
<tr>
<td></td>
<td></td>
<td>...</td>
</tr>
<tr>
<td>Signature</td>
<td>ECDMA Signature of this Message</td>
<td></td>
</tr>
<tr>
<td>Certificate</td>
<td>According Certificate for Signature Verification</td>
<td></td>
</tr>
</tbody>
</table>
Other important messages are In-Vehicle Information (IVI) message and messages for signalised intersections. ISO/TS 19321:2015 specifies the In-Vehicle Information (IVI) data structures that are required for exchanging information between ITS Stations for In-vehicle presentation of external road and traffic related data (ISO/TS 17425) and Contextual speed (ISO/TS 17426). IVI messages transmit information, which has been verified by road operator, and are coherent with the information that is displayed on a road sign or VMS. Messages related to signalised intersections (defined in ETSI TS 103 301) are Signal Phase And Timing Extended Message (SPATEM) and Intersection topology extended message (MAPEM). These messages provide information on signalised intersections, enabling applications such as Green Light Optimized Speed Advisory (GLOSA). (Scholliers 2016)

A Roadside ITS-S provides roadside information to road users using ITS networks, such as road sign information, traffic light phase and timing information and road topology data. At the reception of the roadside information, vehicle ITS-S may process the information for application usage, for example informing driver of the road signage information (e.g. speed limit) or adjust the speed to pass the intersection (GLOSA).

### 4.1.3 C-ITS services

C-ITS service deployment has been boosted by the European Commission e.g. via C-ITS Platform activities. One of the conclusions of the C-ITS Platform final report in 2016 (European Commission 2016a) was a list of early deployment Day 1 and Day 1.5 C-ITS services. This list of Day 1 services includes technologically-mature C-ITS services should be deployed as soon as possible.

- Hazardous location notifications:
o Road works warning
o Slow or stationary vehicle(s) & traffic ahead warning
o Weather conditions
o Emergency brake light
o Emergency vehicle approaching
o Other hazards

- Signage applications:
  o In-vehicle signage
  o In-vehicle speed limits
  o Signal violation / intersection safety
  o Green light optimal speed advisory
  o Probe vehicle data
  o "Shockwave damping (falls under European Telecommunication Standards Institute (ETSI) category 'local hazard warning')"

("Shockwave Damping is a service that aims to smoothen traffic flow in dense traffic conditions by giving optimal speed recommendations which can be for example displayed in a vehicle to the driver")

In a second phase, the Day 1.5 C-ITS services list would be deployed:
- Information on fueling & charging stations for alternative fuel vehicles
- Vulnerable road user protection
- On street parking management & information
- Off street parking information
- Park & ride information
- Connected & cooperative navigation into and out of the city (first and last mile, parking, route advice, coordinated traffic lights)
- Traffic information & smart routing

The list of Day 1.5 C-ITS services includes services for which full specifications or standards might not be ready for large-scale deployment from 2019. Although, these service have been considered to be generally mature.

C-Roads Platform (C-Roads 2017c) provided detailed descriptions of the day-1 C-ITS services in the first release of the harmonised communication profile for Cooperative Intelligent Transport (C-ITS) services document in September 2017. Overview for every category of C-ITS Services from the document is presented below with example use cases.

Road Works Warning (RWW) Service
C-Roads Platform (C-Roads 2017c) service introduction and use cases: "The service is to provide warnings to road users about road works, which can be mobile or static. Possibly, when a dangerous vehicle approaches a road works, a warning can be sent to the driver of the dangerous vehicle and to workers.

Use Cases:
- Closure of part of a lane, whole lane or several lanes
- Alert planned closure of a road or a carriageway
- Alert planned road works – mobile (e.g. cutting the grass or renewing the lane markings)
- Alert operator vehicle approaching / in intervention / in patrol
- Winter maintenance (Salting, snow removal)
- Dangerous vehicle approaching a road works: warning to the dangerous vehicle
- Dangerous vehicle approaching a road works: warning to workers"
In Vehicle Signage (IVS) Service
C-Roads Platform (C-Roads 2017c) service introduction and use cases: “In Vehicle Signage is an information service to inform road users on actual, static or dynamic (virtual) road signs via in-car systems. The road signs can be mandatory or advisory.
Use Cases, several use cases where Variable Message Signs (VMS), Variable Text Panels (VTP) or Variable Direction Signs (VDS) is used:
- In-vehicle signage dynamic speed limit information
- In-vehicle signage embedded VMS
- In-vehicle signage other signage information
- Smart routing / route advice
- Travel time (of specific vehicles)”

Other Hazardous Location Notification Service
C-Roads Platform (C-Roads 2017c) service introduction and use cases: “This C-ITS service describes an I2V warning message related to a series of “possibly hazardous” events on the road, were the road users approaching it are informed and hereby warned about a hazardous location on their way.
Use Cases, The events (and therefore the scenarios of the C-ITS service) can be e.g. the following warnings:
- Accident zone
- Temporarily slippery road
- Animal or person on the road
- Obstacle on the road
- Vehicle stopped or broken down”

TLM – Traffic Light Manoeuvre and RLT – Road and Lane Topology Services
C-Roads Platform (C-Roads 2017c) service introduction and use cases: “The service is to provide information to road users for a safe and efficient crossing of an intersection. Objective is more attentive driving while approaching and passing an intersection by providing in-car information and speed advice for better energy efficiency and improved road safety.
Use Cases:
- GLOSA – Green light optimal speed advisory
- Signal Phase and Timing and Map Data Message
- Signal violation
- Intersection Safety”

4.1.4 Other Relevant C-ITS Architectures
ECo-AT (European Corridor – Austrian Testbed for Cooperative Systems) is part of the EU Cooperative Corridor, Netherlands-Germany- Austria is the Austrian project to create harmonised and standardised cooperative ITS applications jointly with partners in Germany and the Netherlands. 3rd parties have access to the published system specifications. The main objective of the project ECo-AT (www.eco-at.info/) is to close the gap between research and development and the deployment of cooperative ITS services by definition of all necessary elements deployment of day-1 services.
The common specifications and results of the EU cooperative Corridor are also included in the C-ROADS service specifications and communication profiles.

US Department of Transportation (USDOT) has recently published the Architecture Reference for Cooperative and Intelligent Transportation. The architecture is a support to the initiated pilot projects in the US and is available from the Connected Vehicle Reference Implementation Architecture (CVRIA) website (http://local.iteris.com/cvria/) and it will remain online through the life of the USDOT’s Connected Vehicle pilots.
4.2 C-ITS Communication technologies

The communication technologies for C-ITS are based on standards which are developed by the Standards Development Organizations (SDO). ETSI (the European Telecommunications Standards Institute), CEN (the European Committee for Standardization) and ISO (International Organization for Standardization) are the most important standardisation organisations as they produce the most C-ITS standards relevant for the European market. Please refer to chapter Error! Reference source not found. for more details.

The communication technologies for C-ITS can very generally be specified as “short-range” and “long-range” communication networks, which both imply a series of communication characteristics and which complement each other in the C-ITS domain with the necessary link between road infrastructure in various operating environments and the vehicles and the personal C-ITS Stations. Hereby the short-range network supports safety relevant direct communication between stations and needs roadside units in dense transport networks, whereas long-range communication will be implemented by cellular networks with different generations of technology. In addition, in the light of the future connecting vehicles this combination of complementing communication networks adds reliability in the case one network is in a specific situation not fully operational. Examples of the communication networks are the following:

4.2.1 Short range communication, ITS-G5 / IEEE 802.11p

The CAR 2 CAR Communication Consortium (C2C-CC) provides a short overview of the ITS-G5 technology: “The communication technology for cooperative ITS and Car-2-Car Communication is derived from the standard IEEE 802.11, also known as Wireless LAN and a frequency spectrum in the 5.9 GHz range has been allocated on a harmonised basis in Europe in line with similar allocations in USA. As soon as two or more vehicles or ITS stations are in radio communication range, they connect automatically and establish an ad hoc network. As the range of a single Wireless LAN link is limited to a few hundred meters, every vehicle is also router and allows sending messages over multi-hop to farther vehicles and ITS stations. The routing algorithm is based on the position of the vehicles and is able to handle fast changes of the ad hoc network topology.” (C2C-CC 2017)

ETSI technical report provides additional details of the IEEE 802.11p technology: “The radio interface of ITS-G5 is specified in ETSI EN 302 571 and ETSI EN 302 663. It is based on IEEE 802.11 and uses a 10 MHz channel bandwidth Orthogonal Frequency-Division Multiplexing (OFDM) signal. The default configuration uses a Quadrature Phase Shift Keying (QPSK) modulation of the OFDM carriers with a coding rate of 1/2. The resulting data rate is 6 MBit/s. The transmit power level is limited by regulation to 33 dBm, and the default value is 23 dBm. ITS-G5 uses the CSMA/CA MAC protocol as specified in IEEE 802.11. Packet prioritization is done by the EDCA mechanism with four different access categories as specified in IEEE 802.11. Decentralized Congestion Control (DCC) is a mandatory component of ITS-G5 stations operating in ITS-G5A and ITS-G5B frequency bands to maintain network stability, throughput efficiency and fair resource allocation to ITS-G5 stations. A set of access layer DCC mechanisms has been specified in ETSI TS 102 687.” (ETSI 2016)

ITS-G5 short-range communication has been developed especially for low-latency time-critical safety C-ITS services. From 2019 on the first set of C-ITS applications, the so-called “day one services” will be implemented in the road network of more than 10 countries in Europe and by the members (vehicle manufacturers) of the C2C CC.

4.2.2. Short-range communication, Cellular V2X

During recent years, 3GPP has had an activity to define and specify a LTE based V2X system.
With this activity, 3GPP was defining cellular based alternatives for already existing IEEE802.11p based C-ITS systems. 3GPP developed functionality to provide vehicular communications - both in terms of direct communication (between vehicles, vehicle to pedestrian and vehicle to infrastructure) and for cellular communications with networks. The Cellular Vehicle-to-Everything (C-V2X) standard, for inclusion in the Release 14, was completed in 2016. As part of Release 14, the 3GPP has included a technology for direct short-range V2V communication operating in ITS bands (e.g. ITS 5.9 GHz) which can work also independent of cellular network. (3GPP 2016)

As stated in the white paper from the 5GAA (5GAA 2017), C-V2X - as part of the 3GPP standards family - offers an evolution path from LTE based C-V2X (Rel. 14) to 5G. However, the readiness and timetable of the C-V2X technology for real world deployment is still unclear and decisions to deploy the C-V2X have not been taken yet. Several pilots with C-V2X technology has been started during 2017 in Germany (Qualcomm 2017a), France (Ericsson 2017), USA (Qualcomm 2017b), Japan (Qualcomm 2018) and China (Continental 2017).

4.2.3. Long-range communication, Cellular

C-ITS utilise the existing cellular networks (3G, 4G LTE) for long-range communication. The cellular technologies are used for connecting vehicles to infrastructures via cloud services and backend interfaces (vehicle-to-network). According to the European Commission communication (European Commission 2016a), the way forward with the C-ITS deployment is through a hybrid communication approach, i.e. by combining complementary communication technologies. Currently, the most likely hybrid communication mix is a combination of ETSI ITS-G5 and existing cellular networks. This enables full support for deployment of all Day 1 C-ITS services. It combines low latency of ETSI ITS-G5 for time-critical safety-related C-ITS messages with wide geographical coverage and scalability of access to large number of devices of existing cellular networks.

4.3. C-ITS Security

In the first phase of the EU C-ITS Deployment platform security was one of the main topics with the agreement of a single trust model in Europe based on a PKI – Public Key Infrastructure was achieved at expert level, which has in the mean time also been incorporated in the EU Strategy for cooperative systems (KOM2017/766). Based on this Trust model a common security Certificate Policy (CP) has been defined and is available as the basis for stakeholders to participate in the future C-ITS Network. First security functionalities for ITS-G5 is based on the ETSI TS 103 097, were also references to other standards of the security domain are mentioned. (ETSI 2016)

The Commission has published the first version of the European C-ITS Certificate Policy on its website in June 2017. This is a result from the C-ITS platform. This report (European Commission 2017b) defines the certificate policy for C-ITS data communication scenarios in following way: "For many data communication scenarios, it is very important to verify the authenticity and integrity of the messages containing information such as position, velocity and heading. This authenticity and integrity allows to assess the trustworthiness of this sent information. At the same time, the impact on privacy of road users should be minimized. To ensure those main objectives, security architecture with support of a Public Key Infrastructure (PKI) using commonly changing pseudonym certificates, has been developed. The certificate policy defines the European C-ITS Trust model based on Public Key Infrastructure. It defines legal and technical requirements for the management of public key certificates for C-ITS applications by issuing entities and their usage by end-entities in Europe. The PKI is composed at its highest level by a set of root CAs "enabled" by the Trust List Manager (TLM), i.e. whose certificates are inserted in an European Certificate Trust List (ECTL), which is defined and published by the central entity TLM. "

Annex 4: 23/37
For further information: In CAPITAL Topic Study 9 (Information security, data protection and privacy) there are (two) case studies, discussing implementation issues related to C-ITS data protection and privacy.

![C-ITS Trust model architecture](image)

**Figure 4. C-ITS Trust model architecture (European Commission 2017b)**

5. ITS and C-ITS Standards

5.1. About Standardization

Standards are published technical documents on specifications, definitions, and procedures that are understood, implemented, and adopted by, in the ideal scenario, all in a given market. They guarantee interoperability, compatibility, safety, functionality of the product or service, method, material themselves and in connection to others. (IEEE-SA n.d., ISO n.d.).

By using standards, the development of the product, service, method or material can be simplified and made faster, the final products can be more easily compared and they can be deployed or sold internationally given that the standard has spread and been adopted globally. This reduces the cost of production and increases product quality, safety, interchangeability, and interoperability. (IEEE-SA n.d., ISO n.d.).

Standards are also important in verification and validation, as the verification or validation process can itself be standardized (e.g. IEEE 2017). Thus any product that has passed the verification process can be trusted to meet its requirements and regulations.

Standards are developed together by all interested parties under a Standards Development Organization (SDO) by following their standardization process. The development process of standards varies between different SDOs, but in general, they roughly follow a consensus-driven process of:

1) An idea is formally proposed by an entity to the SDO
2) The proposal is evaluated by the SDO and if it passes the SDO will help and oversee the development process, but the proposing entity will be responsible for the development itself
3) The proposing entity will organize a team to develop the standard in accordance to the rules and processes of the SDO
4) The team will iteratively work on drafts of the standard, communicate, and solve the issues raised, in accordance to the rules and processes of the SDO.
5) Once the team has finalized the standard, it is submitted for approval and will go through the hierarchy determined by the SDO.
6) When every stage in the hierarchy has reviewed and accepted the final iteration of the standard, it is published and distributed.
7) The standard will go through further revision after publication based on feedback, changing market conditions, and other factors. (IEE-SA n.d., ISO n.d.).

Details on the exact development processes of different SDOs can be read from their websites. For example:
- ISO: https://www.iso.org/developing-standards.html
- CEN: https://www.cen.eu/work/ENdev/how/Pages/default.aspx

Below is a list of some relevant Standards Development Organizations, their scope and conventions. After that, some relevant standard in ITS and C-ITS are presented.

### 5.2. Standardization Organizations

ETSI, CEN and ISO are the key standardisation organisation for C-ITS in Europe. Already in 2014 CEN and ETSI confirmed that the basic set of standards for Cooperative Intelligence Transport Systems (C-ITS) have been adopted and issued. However, the development of C-ITS standards in ETSI and CEN has continued.

#### 5.2.1. ETSI

ITS committee (TC ITS) is developing global standards for C-ITS. ETSI TC ITS role is described in their web site (ETSI 2017): “ETSI TC ITS develops standards related to the overall communication architecture, management (including e.g. Decentralized Congestion Control), security as well as the related access layer agnostic protocols: the physical layer (e.g. with ITS-G5), Network Layer, Transport Layer (e.g. with the GeoNetworking protocol), Facility Layer, (e.g. with the definition of facility services such as Cooperative Awareness - CA, Decentralized Environmental Notification - DEN and Cooperative Perception – CP, used by the ITS applications). Other addressed topics include, among other things, platooning, specifications to protect vulnerable road users such as cyclists and motor cycle riders, specifications for Cooperative Adaptive Cruise Control as well as multichannel operation.”

ETSI produces standards, specifications and reports for different purposes. These different types of standards are produced according to their corresponding purposes and the time needed to draft and approve them:
- European Standard (EN)
- ETSI Standard (ES)
- ETSI Guide (EG)
- ETSI Technical Specification (TS)
- ETSI Technical Report (TR)
- ETSI Special Report (SR)
- ETSI Group Report (GR)
- ETSI Group Specification (GS)

The Technical Committee for Intelligent Transport Systems (ITS) addresses all ITS-related aspects from Application down to the lower communication layers. ETSI standards are available from the ETSI web site: [http://www.etsi.org/standards-search](http://www.etsi.org/standards-search)
5.2.2. CEN

CEN, the European Committee for Standardization is one of three European Standardization Organizations (together with CENELEC and ETSI) that have been officially recognized by the European Union and by the European Free Trade Association (EFTA) as being responsible for developing and defining voluntary standards at European level.

CEN TC278-WG16 / ISO TC204-WG18 are the working groups responsible for development of C-ITS related standards, which are non-safety related Infrastructural use cases. CEN is developing related standards in direct cooperation with ISO. All standards will be categorized as World standards and are distributed by ISO. On a global level the corresponding standardization is handled by ISO/TC 204 'Intelligent Transport Systems'. Several standards are developed in conjunction with ISO/TC 204. This shows the alignment of the CEN and ISO working groups related to ITS. [http://www.itsstandards.eu/](http://www.itsstandards.eu/)


CEN standards can be found from the CEN web site: [https://www.cen.eu/Pages/default.aspx](https://www.cen.eu/Pages/default.aspx)
5.2.3. IEEE

The Institute of Electrical and Electronics Engineers (IEEE) Working Group 1609 provides standards for Wireless Access in Vehicular Environments (WAVE) which defines architecture and standardized set of services and interfaces for vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) wireless communications. IEEE 802.11 is the WiFi communication standard. This standard provides the lower layer standard (MAC-PHY) used within C-ITS communication in Europe (and USA). For Europe the ITS-G5 protocols run on top of the IEEE 802.11 including the 11p amendment (required for ITS-G5). These standards are fundamental to the operation of ITS-G5. (Spaanderman et al. 2014)

IEEE standards are available from the IEEE web site: http://standards.ieee.org/findstds/index.html

5.2.4. 3GPP

The 3rd Generation Partnership Project (3GPP) unites seven telecommunications standard development organizations (SDOs) across the globe and develops standards for cellular telecommunications network technologies ranging from 2G, 3G, to 4G (LTE and LTE-Advanced), and upcoming 5G. (HIGHTS 2016)

3GPP has developed functionality to provide enhancements to LTE specifically for vehicular communications - both in terms of direct communication (between vehicles, vehicle to pedestrian and vehicle to infrastructure) and for long-range cellular communications with networks. The Cellular Vehicle-to-Everything (V2X) standard, for Release 14, was completed in 2016. (3GPP 2016)

Also 3GPP standards are available from the ETSI web site: http://www.etsi.org/standards-search

5.3. Relevant Standards

To illustrate the role of standards in ITS and C-ITS, a few relevant standards are reviewed. This chapter is structured such that it starts with a standard that specifies a common architecture of different ITS sub-systems, from hand-held devices to roadside units. This offers an overview of the different functions and components of the systems. The architecture follows a common layered protocol stack design. Thus, next, a standard defining one layer from this stack is reviewed as an example. The same standard also, in general terms, defines basic C-ITS applications. The functional requirements of these applications are reviewed in the next standard. Finally, a standard covering the application requirements specification for one of these applications is reviewed. A list of other relevant standards not explained in such detail follows these chapters.

5.3.1. ETSI EN 302 665

The ETSI EN 302 665 standard (ETSI 2010b) specifies the basic architecture of communications in ITS systems. It is a common architecture that all ITS stations follow. ITS sub-systems are defined as "sub-system of ITS with ITSC components for a specific context" and they are divided into personal (e.g. hand-held devices), central (part of an ITS centre), vehicle (e.g. in cars), and roadside ITS sub-systems. Each ITS sub-system has an ITS station, which fulfills the functionality described in the ITS station reference architecture.

The architecture follows and extends the ISO OSI model (ISO/IEC 7498-1) which characterizes the communication in a computing or communication system. It uses abstraction layers to separate different parts of the communication in a hierarchical manner. Each layer depends on the layer beneath it and provides functionality to the layer above it to the extent that the layer above needs it.
From bottom up, the layers are

- **Access layer.** Communication interfaces, both internal and external, between physical communication channels (e.g. Bluetooth, GPS, Ethernet) and digital data links for layers above.

- **Networking & Transport.** Common networking protocols (e.g. IPv6) and transport protocols (e.g. TCP, UDP), also C-ITS specific protocols could be supported.

- **Facilities.** Supporting functionality shared by many applications of the application layer.

- **Applications.** ITS applications that are usually distributed in client and server applications. For example, "Emergency vehicle warning" would be a "Road Safety" application, where the server indicates to the client that an emergency vehicle is approaching it.

These are supported, on the sides of the stack in the architecture, by the "Management" and "Security" blocks with provide management of the communications and security services for all other blocks.

The standard also lists and specifies different ITS sub-systems, their stations, and certain types of ITS stations (host, gateway, router, border router) and how they communicate with other ITS stations and other entities within using networks. For example, the ITS-S gateway is usually connected to an ITS station-internal network and connects its facilities layer to another OSI protocol stack, which resides typically in a proprietary network.

### 5.3.2. ETSI TR 102 638

The ETSI TR 102 638 standard (ETSI 2009) defines the V2X facilities layer model and Basic Set of Applications (BSA). Facilities are defined as "functions or data which are common to several applications and are supporting them". The facilities layer model describes the functionalities that a V2X application, defined in the Basic Set of Applications (BSA), can require.

The BSA are defined as "group of mature applications (regrouped use cases), supported by a mature, relevant vehicular communication system" and are further developed in the ETSI TS 102 637-1 standard (see below). In essence, they are active road safety applications, traffic efficiency applications, and other applications that can be deployed in a cost-effective manner. They answer to the needs of several different users (e.g. vehicle owner, driver, passenger, road traffic managers, etc.) in a setting where the vehicles move at various speeds and driving conditions through different driving environments and contexts. All the applications use a vehicular communication system to send and receive information that enables the functionality of the application. Thus the applications operate in an environment, where there are stationary ITS stations (the infrastructure) and mobile ITS stations (e.g. the vehicles).

ITS applications are specified in an architecture that is an extension to the ISO OSI model (ISO/IEC 7498-1), in which layers are abstraction that have a set functionality that it provides for the layer above it and uses the functionality of the layer below it. The facilities layer is positioned between the applications layer (provides and defines the BSA and its services) and the networking and transport layer. The facilities in the layer are intended to provide generic support functions to the applications.

The functionalities of the facilities layer are divided into functional blocks, which form the architecture for the facilities layer. These are "Applications Support", "Information Support", and "Communication Support". The Applications Support block has facilities that provide the applications information on the position of ITS stations, the current state of the ITS stations, managing of the services the application provides, managing of Local Dynamic Map (LDM) of the application (e.g. mapped information about its surroundings), managing of the messages
the application sends and receives, security features, and time management. The Information Support block provides various processing facilities for the static and dynamic data the application use (e.g. conversion between data types). The Communication Support block provides the application support for different communication modes.

5.3.3. ETSI TS 102 637-1
The ETSI TS 102 637-1 standard (ETSI 2010a) defines the functional requirements for the Basic Set of Applications (BSA). They are lists of functions an application has to be engineered to perform in order to perform its intended behavior.

The standard lists 32 use cases divided into 7 applications and provides the functional requirements for these. For example, the application "Driving assistance - Road hazard warning" is intended to convey information about road hazard events to or from vehicles or roadside equipment. The information can be about the position, duration, severity, or other descriptions of the hazard event. It has 17 use cases listed for it. As an example:

• UC005: emergency electronic brake lights;
• UC006: wrong way driving warning;
• UC007: stationary vehicle warning - accident;

The messages are transmitted either as Cooperative Awareness Messages (CAM) or as Decentralized Environmental Notification Messages (DENM). They are defined in standards ETSI EN 302 637-2 (ETSI 2014b) and ETSI EN 302 637-3 (ETSI 2014c), respectively.

The functional requirements list for the use case "UC006: Wrong way driving warning" has 21 functional requirements. As an example, these include:

• [FR_UC006_004] If an ITS station detects a "wrong way driving" event, the corresponding RHW application shall be triggered.
• [FR_UC006_005] The RHW application shall request to construct and transmit a "wrong way driving warning " DENM construction.
• [FR_UC006_010] The originating ITS station shall transmit the "wrong way driving warning" DENM at a defined transmission rate as long as the "wrong way driving" event persist.
• [FR_UC006_018_VS] Information sent included in the "wrong way driving warning" DENM shall allow a receiving vehicle ITS station to check the relevance of the "wrong way driving " event and estimate the collision risk with vehicle driving in the wrong way level.
• [FR_UC006_019_VS] The RHW application shall decide whether warning "wrong way driving warning" information should be provided via HMI.

Thus, the standard does not provide a specification for the development or the implementation of the application use cases, but is intended to serve as a reference document on the functionality that the deployed implementation should contain.

5.3.4. ETSI TS 101 539-1
The ETSI TS 101 539-1 standard (ETSI 2013) covers the application requirements specification for the Road Hazard Signaling (RHS) application mentioned in the previous chapter. It divides the application into two different functional modes: (i) detection and signaling or road hazard events, and (ii) receiving messages about road hazards. Or, originating mode and receiving mode, respectively. The standard also defines a performance classification system for the incident data based on the age of the data. Performance class A is given if the time between data acquisition and positioning data acquisition (with 1 meter accuracy) is less than 150 milliseconds. Class B is given, if the time difference is less than 1,4 seconds.

The standard states that the main function provided by the originating RHS application are (i)
Annex 4:

The generation and signaling of a Decentralized Environmental Notification Messages (DENM) when a road hazard is detected, and (ii) setting a priority level for the situation if the data conforms to the performance class A. The priority level describes if the originating vehicle is in a pre-crash situation, warning situation, or is not in a critical safety situation.

The receiving RHS application receives all the different kinds of messages, processes them, and makes a decision, based on the accuracy, age, confidence level, and other such quality measures, on how best make use of the received messages. It could, for example, flash a warning sign to the user of the ITS station in question.

The standard describes the functional requirements for the use cases of the RHS application and details the data elements and their values that are included in the transmitted DENM. It also details the application operational requirements for the RHS. These, again, use the classification into performance class A and B. The requirements are lists of functions and behaviors the application shall and shall not do in a given situation as well as different failure and attack situation it needs to take into account.

5.4. Other standards

Here is a short list of other relevant C-ITS standards:

- ETSI TS 102 724: "Intelligent Transport Systems (ITS); Harmonized Channel Specifications for Intelligent Transport Systems operating in the 5 GHz frequency band".

- ETSI EN 302 571: "Intelligent Transport Systems (ITS); radio communications equipment operating in the 5 855 MHz to 5 925 MHz frequency band; harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive".

- ETSI TS 102 636 (all parts): "Intelligent Transport Systems (ITS); Vehicular Communications; GeoNetworking".

- ETSI TS 102 723 (all parts): "Intelligent Transport Systems; OSI cross-layer topics".

- ETSI EN 302 637-3 (V1.2.0): "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 3: Specifications of Decentralized Environmental Notification Basic Service".

- ISO/IEC 212177: "Intelligent Transport Systems - Communications access for land mobiles (CALM) - Architecture".

Security related standards:

- ETSI TR 102 893 V1.2.1 (Published 2017-03). “Security; Threat, Vulnerability and Risk Analysis (TVRA)"

- ETSI TS 103 097 V1.2.1 (Published 2015-06). “Security header and certificate formats”. This standard defines the security applied to the V2X messages exchanged between the On-board Unit (OBU) and the Road-side unit (RSU) via V2X communication in the use cases.

Relevant eCall standards:

- CEN EN 16072 (2015): "Intelligent Transport Systems - eSafety - Pan European eCall operating requirements".

6. Using standards and interoperability

6.1. Profiles

Profiling is described briefly in a report from the Rijkswaterstaat in Netherlands (Spaanderman et al. 2014): “In standards elements are defined which shall always be implemented and elements which “may” (options) be implemented. This means that standards cannot be used without alignment among the stakeholders, on how and what to use it in case of options. To ensure interoperability and conformity, alignment is required within the community of stakeholders using them. Therefore their agreement is needed on these options. These decisions are captured within a Profile. A profile includes the minimum set of requirements, referencing to those standards used. For the domain of C-ITS this is extremely important to ensure interoperability and conformity for all stakeholders.”

C-Roads Platform Workgroup Technical aspects is currently working towards a common C-ITS profile. The target is to achieve interoperability based on the commonly specified communication profile. In September 2017 C-Roads published the first release of the harmonised communication profile for Cooperative Intelligent Transport (C-ITS) services based on the respective ETSI and CEN standards. The first release focuses on the communication profile for IEEE 802.11p/ETSI ITS-G5 short range communication and I2V (Infrastructure-to-Vehicle) communication for high level Day-1 Services. (C-Roads 2017a)

6.2. Guidelines

In addition to standards, there are various guidelines to help developers to implement interoperable and safe to use ITS applications and service. Here are two examples described:

6.2.1. ITS Deployment Guidelines

The ITS Deployment Guideline fact sheet (EU EIP 2015) describes the guidelines as follows: “European road authorities and road operators have teamed up to unlock the benefits of cooperation and harmonisation in the deployment of Intelligent Transport Systems (ITS) on Europe’s major road network. Fragmented deployment on a national level will fail to deliver seamless European services and will not contribute to a coherent European Transport network at the end. The Member States – co-financed by the European Commission – have consequently developed a set of Deployment Guidelines (DG) created jointly by ITS experts and practitioners. The guidelines have undergone a thorough review by international domain experts in an intense peer review and they have been validated by the Member States in an extensive formal Member State consultation and mediation process, which finally led to their adoption as basis for all future European harmonised ITS deployment activities.

The harmonisation concept

Based on a Pan-European accepted understanding of the nature and the benefit of each ITS-service, European Added Value is generated through three main elements:

1. Interoperability in terms of functional, organisational and technical features to harmonise cooperation and collaboration between different road operators and other third parties involved in the deployment and operation of an ITS-service;
2. Common Look & Feel to present ITS-services to the road user in a harmonized European way;
3. European-wide accepted assessment criteria to offer assessment against the
background of harmonized level of service and operational environment criteria.”

Examples of the harmonized ITS services was introduced in chapter Error! Reference source not found..

6.2.2. HMI guidelines

Human-Machine Interaction (HMI) guidelines and standards have been developed in order to promote safe and usable in-vehicle systems and applications. The European Statement of Principles on HMI (ESoP) incorporates principles formulated as generic goals to be achieved by the design of a safe and user-friendly HMI of in-vehicle information and communication systems which have been intended to be used by the driver while driving. These principles of the ESoP are organised into 6 groups (Deserve 2013):

1. Design goals
2. Installation principles
3. Information presentation principles
4. Principles on interaction with displays and controls
5. System behaviour principles
6. Principles on information about the system

HMI related standard ISO ISO 9241-210:2010 Ergonomics of human-system interaction -- Part 210: Human-centred design for interactive systems provides requirements and recommendations for human-centred design principles. The standard is intended to be used in the design processes. (ISO 2010).

6.3. Testing and Interoperability

Testing and interoperability is defined in ETSI web site (ETSI 2018) in following way: “In a world of converging yet diverse technologies, complex ICT systems must communicate and interwork on all levels – this is interoperability. One of the key motives for the development of ICT standards is to facilitate interoperability between products in a multi-vendor, multi-network and multi-service environment. In addition, standards themselves need to be designed and tested to ensure that products and services complying with them do indeed achieve interoperability. Testing of products and systems to verify their interoperability is critical to their success – ideally this should take place throughout their development. Eliminating basic interoperability problems at an early stage helps reduce costs and avoid dissatisfied customers. A standardized approach to testing is essential if the results are to be trusted. Testing is an important part of providing a guarantee of interoperability. As an example ETSI focuses on two different, complimentary types of test activity: conformance testing and interoperability testing. The feedback from interoperability events is also extremely valuable in helping to validate the standards themselves.”

6.4. Certification

Certification can be seen as a specific form of compliance assessment. Standard ISO/IEC/IEEE/24765 defines certification as follows (IEEE 2010):

“1. a written guarantee that a system or component complies with its specified requirements and is acceptable for operational use, 2. a formal demonstration that a system or component complies with its specified requirements and is acceptable for operational use, 3. the process of confirming that a system or component complies with its specified requirements and is acceptable for operational use.
EXAMPLE a written authorization that a computer system is secure and is permitted to operate in a defined environment”
6.5. Compliance assessment

The C-ITS Platform final report from Phase II (European Commission 2017c) provides description for compliance assessment for C-ITS: “The aim of the work on Compliance Assessment was to define a top-level approach and methodology for testing and validation. This included evaluating and issuing recommendations on how this compliance assessment can be achieved, with a specific focus on C-ITS stations, and on the necessary legal and organisational frameworks for the setup and the operational phase of the C-ITS network.” The report provides an overview of the compliance assessment process for C-ITS which is depicted in Figure 6.

![Figure 6. Overview of the compliance assessment process for C-ITS (European Commission 2017c).](image)

7. Discussion and conclusions

This topic study addressed ITS and C-ITS communication technologies and standards. ITS is already established and widely used by road users, private companies and public road operators and authorities. C-ITS is coming to the market. The Day 1 (and later 1.5 C-ITS) services have been identified as priority. The C-Roads Platform lead by the European road operators and authorities is working actively to harmonise the deployment of these first C-ITS services across the Europe. The target is to have the final open issues solved and launch the commercial C-ITS services in 2019. The first deployments of C-ITS will be based on hybrid communication utilising ITS-G5 and existing cellular networks. It will be interesting to see how extensively the Day 1 services will be deployed and how widely they are supported by the vehicle manufacturers. In addition, it will be exciting to follow how the development of cellular V2X will go forward in coming years, how it will work together or parallel with short-range ITS-G5 technology and when they will be deployed on the market. In any case, the C-ITS services will be utilised more and more in the future.
8. References


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Annex 5: Impact assessment of ITS and impacts of selected ITS and C-ITS systems

Grant Agreement Number: 724106

Project acronym: CAPITAL

Project full title: Collaborative cApacity Programme on Its Training-educAtion and Liaison

**Topic study 5: Impact assessment of ITS and impacts of selected ITS and C-ITS systems**

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Abstract
This document presents a summary of impact assessment methods as well as safety, environmental and traffic efficiency impacts of selected ITS and C-ITS systems. The scope of the deliverable covers iMobility priority systems and Day-1 services of the C-ITS Platform.
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### Abbreviations and Acronyms

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<thead>
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<tr>
<td>EC</td>
<td>European Commission</td>
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<tr>
<td>CBA</td>
<td>Cost-benefit analysis</td>
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<td>CEA</td>
<td>Cost-efficiency analysis</td>
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<tr>
<td>C-ITS</td>
<td>Cooperative intelligent transport system</td>
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<tr>
<td>FCD</td>
<td>Floating car data</td>
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<tr>
<td>GA</td>
<td>Grant Agreement</td>
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<tr>
<td>GLOSA</td>
<td>Green light optimal speed advisory</td>
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<tr>
<td>GPS</td>
<td>Global positioning system</td>
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<td>GOA</td>
<td>Goal oriented approach</td>
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<tr>
<td>ITS</td>
<td>Intelligent transport system</td>
</tr>
<tr>
<td>MCA</td>
<td>Multi-criteria analysis</td>
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<tr>
<td>PO</td>
<td>Project officer</td>
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<tr>
<td>RTTI</td>
<td>Real-time traffic information</td>
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<td>TTG</td>
<td>Time to green</td>
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<td>VMS</td>
<td>Variable message sign</td>
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<tr>
<td>V2I</td>
<td>Vehicle to infrastructure</td>
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<td>WP</td>
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1. Introduction

The digitalization of transport and the deployment of intelligent transport systems (ITS) is proceeding rapidly. ITS apply information and communication technologies to transport. ITS have the possibility to improve the sustainability of transport by increasing safety and reducing emissions. Cooperative-ITS (C-ITS), the next step of ITS development, apply wireless technologies enabling communication between vehicles, infrastructure and other road users.

Uncertainty and lack of information on the impacts on new ITS and C-ITS systems is one of the barriers of deployment of new ITS technologies. This barrier will be addressed by one of CAPITAL study modules which will provide information on the safety, environmental and traffic efficiency impacts of ITS and C-ITS systems. The study module will be supported by a related topic study which aims to provide a timely, comprehensive and consistent overview of the impacts of selected ITS and C-ITS systems.

Due to large number of ITS systems available, this topic study had to be focused on a limited number of ITS and C-ITS services. When selecting the ITS systems and ITS services to be covered, it was considered preferable to focus the topic study on systems which are technologically mature and contribute to the objectives of transport policy - safer, cleaner and more efficient transport.

Efforts to identify priority ITS systems for deployment in Europe have been made by earlier projects such as iMobility Support, iCar Support and eSafety Support in cooperation with the European iMobility Forum (earlier: eSafety Forum). The list of priority systems developed by the iMobility Forum and related definitions of the priority systems were therefore taken as a starting point for selecting ITS services to be covered in the study:

- eCall
- Real-time travel and traffic information
- Extended environmental monitoring
- Dynamic traffic management
- Speed alert
- Dynamic navigation systems
- Eco-driving coaching
- Local danger warnings
- Adaptive headlights
- Eco-driving assistance
- Blind spot monitoring
- Lane departure warning
- Obstacle and collision warning
- Emergency braking.

In addition to ITS systems in general, CAPITAL project aims to provide information on cooperative ITS (C-ITS) services. The standards of many C-ITS services have been developed during recent years, and discussions on their deployment in Europe have been carried out within the framework of C-ITS Platform supported by the European Commission and the Amsterdam Group. Both Amsterdam Group and C-ITS platform have provided roadmaps for deployment of C-ITS in Europe. The C-ITS Platform has identified a list of C-ITS services which are considered technologically mature and for which relevant standards have been developed. These services are the so-called Day-1 services:

- Hazardous location warning:
  - Emergency brake light
  - Emergency vehicle approaching
  - Slow or stationary vehicle(s) warning

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o Traffic jam ahead warning
o Road works warning
o Weather conditions
o Other hazardous notifications

- Signage applications:
  o In-vehicle signage
  o In-vehicle speed limits
  o Probe vehicle data
  o Shockwave damping
  o Green Light Optimal Speed Advisory (GLOSA)
  o Signal violation/Intersection safety
  o Traffic signal priority request by designated vehicles.

Based on the list of Day1 services defined by C-ITS Platform, the C-Roads platform developed communication profiles for the Day1 services, specifically focusing on communication between roadside units and vehicles. C-Roads is a platform for Member States working on the deployment of harmonized and interoperable C-ITS services in Europe.

In addition, C-ITS Platform has provided a list of services that are less mature from a technological point of view but are still considered a deployment priority. These services are included in the list of Day 1’s services of C-ITS Platform:
- Information on fuelling & charging stations for alternative fuel vehicles
- Vulnerable Road user protection
- On street parking management & information
- Off street parking information
- Park & Ride information
- Connected & Cooperative navigation into and out of the city (1st and last mile, parking, route advice, coordinated traffic lights)
- Traffic information & Smart routing.

It was considered preferable to focus the topic study on services that have been identified as priority in Europe, which have potential to contribute to policy objectives and which are sufficiently mature from technological point of view. Day-1 services of the C-ITS platform were therefore selected for analysis in the study.

2. Objectives

The objective of this topic study is to provide a timely, comprehensive and consistent overview of 1) ITS impact assessments and 2) on the safety, environmental and traffic efficiency impacts of selected ITS and C-ITS systems on the European level.

The study focuses on the safety, environmental and traffic efficiency impacts of the following ITS systems:
- eCall
- Real-time travel and traffic information
- Extended environmental monitoring
- Dynamic traffic management
- Speed alert
- Dynamic navigation systems
- Eco-driving coaching
- Local danger warnings
- Adaptive headlights
- Eco-driving assistance
- Blind spot monitoring
- Lane departure warning
- Obstacle and collision warning
- Emergency braking.

In addition to ITS, the study covers the safety, environmental and traffic efficiency impacts of the following C-ITS services:

- Hazardous location warning:
  - Emergency brake light
  - Emergency vehicle approaching
  - Slow or stationary vehicle(s) warning
  - Traffic ahead warning
  - Road works warning
  - Weather conditions
  - Other hazardous notifications

- Signage applications:
  - In-vehicle signage
  - In-vehicle speed limits
  - Probe vehicle data
  - Shockwave damping
  - Green Light Optimal Speed Advisory (GLOSA)
  - Signal violation/Intersection safety
  - Traffic signal priority request by designated vehicles.

The topic study aims to provide background information for development of CAPITAL study module “Impacts of ITS and C-ITS services”. Chapter 3 describes the scope and the methods used to collect information on the two subtopics. The results on ITS impact assessments is summarised in Chapter 4 and the impacts of the selected services are summarised in Chapter 5. Chapter 6 contains a discussion and conclusion of the topic study.

3. Methods

3.1 ITS impact assessment

A literature study was carried out to collect information on the methods for assessing the impacts of ITS and C-ITS services. The literature study was focused on the material already known to the authors due to their earlier work. When collecting material on ITS impact assessment, priority was set in collecting material that is applicable to a wide range of ITS and C-ITS systems and covering all aspects considered necessary to build an overview of the topic.

The collected material was summarised around six subtopics:
- Evaluation methods
- ITS evaluation frameworks
- The FESTA handbook
- Considerations in ITS service evaluation
- Criteria for an effective ITS and C-ITS evaluation methodology
- Data collection for ITS impact assessment
Finally, the FESTA handbook was summarised and presented as an example.

### 3.2 Impacts of selected ITS and C-ITS systems

The study was performed as a literature study to collect information on the impacts of selected ITS- and C-ITS systems. The data was mainly collected from the:

- iMobility effects database: descriptions of ITS systems, summaries of studies and summaries of the impacts of the systems available in the iMobility effects database, literature study
- Literature study on printed and electronic material.

The information on the ITS systems were mainly collected from the iMobility effects database since it contains an extensive review of available study results. The information of the C-ITS services was mainly collected from publications of the C-ITS platform.

The use of peer-reviewed studies based on empirical data and carried out in the European context has been prioritized. Expert assessment has been used when no assessed impact was available. Attention was also paid on what reference point was used in the studies (e.g. pre-existing ITS services or situation without ITS services).

Because the impacts of different ITS systems depend greatly on the environment and traffic system where the system has been used or tested, studies not relevant for Europe were excluded from the results.

### 4. Impact assessment of ITS and C-ITS systems

#### 4.1 Evaluation methods

There are various methods for evaluating Intelligent Transport Systems (ITS) and Cooperative ITS (C-ITS) projects. The choice of the right method though for the evaluation of such projects is important. The method to be applied must maintain a balance between the complexity and cost of the evaluation and the cost of the potential project (Newman-Askins et al. 2003). Therefore, each responsible authority and the involved developers should define for each specific case if a very broad “all OK” or “all not OK” indicator is efficient or if a very exact benefit/cost assessment to guide a major investment is required.

Another critical factor for choosing the right method for the evaluation of ITS and C-ITS services is the complexity of the evaluation and the complexity of each method. The required complexity of the evaluation depends on the purpose of the evaluation results. For example, the degree of complexity required for determining the net worth65 of the project to society is much higher than for performance measurement (Newman-Askins et al. 2003).

The main problem with ITS and C-ITS services’ evaluation is that all methods of evaluation require significant amount of data, which is difficult to gather because of the evolving nature of ITS projects. ITS projects are usually enhancements to the existing transport infrastructure, and for that reason there is no need for a full economic impact analysis in ITS and C-ITS projects (Newman-Askins et al. 2003).

 Usually, the distributional effects of ITS and C-ITS projects and services are considered in a

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65 according to the Cambridge Dictionary, net worth is “the value of the assets that a business has, after any debts are taken away” [https://dictionary.cambridge.org/dictionary/english/net-worth]
socio-economic analysis such as cost-benefit analysis (CBA) or multi-criteria analysis (MCA) (Newman-Askins et al. 2003). The CBA method is the most commonly used method of the evaluation for ITS and C-ITS projects, while the cost-benefit ratio (i.e. the actual output of the method) is based on several assumptions about the monetary values of benefits.

The cost-benefit ratio can be incorporated into a goal-based evaluation framework, where it will serve as one of the several indicators of the evaluation framework.; this leads to the use of the MCA method. However, it should be noted that such solution may lead to the risk of double counting certain impacts, since some cost- and benefit-related factors may be included in both the cost-benefit ratio and the MCA (Newman-Askins et al. 2003). CBA’s of ITS and C-ITS is discussed further in Topic study 7 (Cost-benefit analyses of ITS and C-ITS services).

Cost-efficiency analysis (CEA) can be used to compare ITS and C-ITS projects when a defined service impact is expected and information is available on the costs of the projects (Bristow et al. 2007). However, no monetary value or valuation techniques are required for service impacts. Cost-efficiency analysis compares the impacts of a project to its costs.

The European Union EVA ITS evaluation manual recommends the use of CBA only when standard monetary values are available, MCA when monetary values are not available for major impacts and CEA in cases where monetary values are available only for costs and a specified impact is achieved (Newman-Askins et al. 2003).

Impacts of various measures affecting the transport system have been studied based on changes in the level of service (LoS) of physical infrastructure such as road links and junctions. In previous ITS and C-ITS services’ evaluation, factors referred to capacity analysis such as traffic volumes, traffic density, road geometry and signal parameters have been used to calculate a Level of Service (LoS). LoS provides qualitative information on operational performance of road links and junctions.Nevertheless, those factors used to calculate the LoS do not include the full benefits of ITS. For example, impacts on environment or safety are not reflected in changes in LoS.

**4.2 ITS Evaluation Frameworks**

There are six (Hills and Junge 2010) or seven (Tarry et al. 2012) steps in order to choose the best approach to evaluate the impacts of ITS and C-ITS services. These steps are presented below (Error! Reference source not found.3):

**Step 1: The clarification of the evaluation background.** This is a preliminary stage that is designed mention which evaluation process is being undertaken, the intended use and users, the intervention objectives to be considered and the resources needed.

**Step 2: Consideration of the intervention’s nature.** This step dabbles with the type of intervention (e.g. policy, programme, package or scheme), and how this will give feedback for the evaluation approach.

**Step 3: Mapping the intervention logic.** This step explains the factors that are likely to shape the delivery of the intervention and therefore influence its success. Step 3 helps to highlight what evidence is required from the evaluation and in particular, indicate where key gaps in the existing evidence base might be.

**Step 4: Defining the evaluation purpose and framing the evaluation questions.** This step is built on the previous steps to ensure that the evidence produced by the evaluation meets the requirements of the stakeholders.
Step 5: Deciding on the most suitable overall approach to the impact evaluation. There are 3 available approaches: the outcome approach which compares the situation before an intervention with the situation after its introduction; the experimental approach which compares the outcome of an intervention with what would have happened in its; and the theory-based approach which articulates and tests the assumed connection between an intervention and anticipated impacts. In this particular step there is the final decision about the most suitable approach, according to what need to be evaluated.

Step 6: Refining the chosen evaluation approach. Depending on the outcome of the previous step and if a decision has been made that there is a need for evidence that is attributable to the scheme, then the next stage is to select an appropriate approach to achieve this.

Step 7: Implementation of the evaluation data collection program. The final step of this process is actually the implementation of the chosen evaluation framework, based on the decisions made in the above described steps.
Figure 1. Steps for evaluating ITS and C-ITS (Hills and Junge 2010 and Tarry et al. 2012).

There are two approaches toward the benefit assessment of ITS deployment: the goal-oriented approach (GOA) and the economic analysis approach (EAA) (Peng et al. 2000, Mehta et al. 2001). The GOA starts with defining the goals and the objectives of the services and setting up specific measurements. This method focuses on whether the output has achieved its original goals (Peng et al. 2000, Mehta et al. 2001).

On the other hand, the EAA method focuses on cost efficient ways to achieve the set goal of the service. If, for example, the goal of a service is the congestion’s reduction the EAA would ask whether this service’s goal is economically beneficial, and how the rate of return on investment compares to that of other projects (Peng et al. 2000, Mehta et al. 2001).

In the next two subchapters, additional information about the GOA method and the EAA method is provided.
4.2.1 Goal-Oriented Approach

The goals of the ITS and C-ITS services are predefined. It is critical though that the final selection of the implemented and deployed ITS and C-ITS services is an iterative approach and with the participation of all stakeholders. That way the defined evaluation framework and the evaluation measures are selected based on desired targets and measures (Turner and Stockton 1999, Lomax et al. 2000, EC 2010).

This method is used for the evaluation of ITS and C-ITS services in order to (Turner and Stockton 1999):

1. Understand their impacts.
2. Quantify their benefits.
3. Help make future investment decisions.
4. Optimize existing system operation and/or design.

This ITS and C-ITS evaluation framework consists of two main elements:

1. Designation of transportation goals and objectives.
2. Enumeration of evaluation measures (Turner and Stockton 1999).

A comprehensive evaluation framework should be able to:

1. Identify the process needed to specify the goals, objectives and potential impacts; and
2. Develop measures to estimate the impacts (Lomax et al. 2000).


1. Improve the safety of the transportation systems by:
   a. Reducing the number of fatalities; and
   b. Reducing the severity of collisions.
2. Increase the operational efficiency and capacity of the surface transportation system by:
   a. Reducing disruptions due to incidents;
   b. Improving the LoS and convenience provided to travellers; and
   c. Increasing the infrastructure’s capacity.
3. Enhance present and future productivity by:
   a. Reducing costs incurred by fleet operators and others;
   b. Reducing travel time; and
   c. Improving transportation systems’ planning and management.
4. Enhance the personal mobility and the convenience and comfort of the surface transportation system by:
   a. Providing access to pre-trip and on-trip information;
   b. Improving the safety and security of the travel; and
   c. Reducing the travellers’ stress.
5. Reduce energy and environmental (external) costs associated with traffic congestion by:
   a. Reducing harmful emissions; and
   b. Reducing energy consumption.

According to the European Commission’s Directive 2010/40/EU though (EC 2010), the used measures in the evaluation phase of ITS services shall:

1. Be effective – make a tangible contribution towards solving the key challenges affecting road transportation in Europe (e.g. reducing congestion, lowering of emissions, improving energy efficiency, attaining higher levels of safety and security including vulnerable road users);
2. Be cost-efficient – optimise the ratio of costs in relation to output with regard to meeting objectives;
3. Be proportionate – provide, where appropriate, for different levels of achievable service quality and deployment, taking into account the local, regional, national and European specificities;
4. Support continuity of services – ensure seamless services across the Union, in particular on the trans-European network, and where possible at its external borders, when ITS services are deployed. Continuity of services should be ensured at a level adapted to the characteristics of the transport networks linking countries with countries, and where appropriate, regions with regions and cities with rural areas;
5. Deliver interoperability – ensure that systems and the underlying business processes have the capacity to exchange data and to share information and knowledge to enable effective ITS service delivery;
6. Support backward compatibility – ensure, where appropriate, the capability for ITS systems to work with existing systems that share a common purpose, without hindering the development of new technologies;
7. Respect existing national infrastructure and network characteristics – take into account the inherent differences in the transport network characteristics, in particular in the sizes of the traffic volumes and in road weather conditions;
8. Promote equality of access – do not impede or discriminate against access to ITS applications and services by vulnerable road users;
9. Support maturity – demonstrate, after appropriate risk assessment, the robustness of innovative ITS systems, through a sufficient level of technical development and operational exploitation;
10. Deliver quality of timing and positioning – use of satellite-based infrastructures, or any technology providing equivalent levels of precision for the purposes of ITS applications and services that require global, continuous, accurate and guaranteed timing and positioning services;
11. Facilitate inter-modality – take into account the coordination of various modes of transport, where appropriate, when deploying ITS; and
12. Respect coherence – take into account existing Union rules, policies and activities which are relevant in the field of ITS, in particular in the field of standardisation.

Those goals/elements can be represented as indicators in the evaluation process.
Another need is the categorization of the evaluation measures. There are two types of categorization. The first type uses the terms of output and outcome evaluation measures. Output (or efficiency) evaluation measures are, in general, aggregate in nature and they correspond to a certain transportation facility. Examples of output evaluation measures are traffic volume per lane and total vehicle delay. Outcome (or effectiveness) evaluation measures are those that typically characterize the transportation effects into certain groups. Some examples of outcome evaluation measures are individual travel times/trip time reliability and travel costs (Turner and Stockton 1999).

The distinction between these two categories is important for three reasons (Turner and Stockton 1999):

1. Output measures are typically aggregate facility statistics; because of that they are unable to dynamically approach the travellers’ responses. On the other hand, outcome measures are structured to typically work that way.
2. Outcome measures are associated with different transportation goals like mobility and accessibility.
3. Output measures are easier to measure (because of their nature). Outcome measures require measures either at the level of individual traveller or at company level.

In order for the proper evaluation of ITS services, it is necessary to balance the output and outcome measures through the evaluation of ITS (Turner and Stockton 1999).

The second categorization type is the one of the “few good measures” as defined in the literature (Lomax et al. 2000, Peng et al. 2000, Mehta et al. 2001). This approach is designed in order to provide some basic consistency between evaluations and offer information on the yearly progress of ITS efforts. The “few good measures” approach is a sound techniques but the need for extensive data sets can increase the project budget (Lomax et al. 2000, Peng et al. 2000, Mehta et al. 2001).

The “few good measures” include:

1. Crashes;
2. Fatalities;
3. Travel time;
4. Throughput;
5. User satisfaction or acceptance; and

A similar performance-based approach is used in the United Kingdom. In this method, performance indicators (including value-for-money indicators), were developed in an evaluation framework to evaluate several ITS projects in the United Kingdom. (Peng et al. 2000)

4.2.2 Economic Analysis Approach
The EAA method for ITS and C-ITS services evaluation uses economic analysis techniques similar to those used for highway project economic analyses. This approach attempts to quantify the specific monetary value of all ITS and C-ITS impacts and it focuses on
quantifying the short-term and long-term economic impacts of ITS projects “on regional and national economies, the users, the private sector, the community and the environment”. This approach attempts to reduce everything to a single cost-benefit ratio (Peng et al. 2000).

ITS and C-ITS services’ evaluation should encompass benefits not only related to transportation system users; it should include other factors relevant to other stakeholders such as transportation infrastructure providers and managers, potential private investors, ITS technology providers etc. taking into account that the evaluation should take into account all different aspects of ITS and C-ITS implementation (economic, social, environmental etc.) as well as that each deployment is an investment that have to be evaluated through CBAs (Peng et al. 2000).

### 4.3 Considerations in ITS services evaluation

Although there appears to be great differences between the GOA method and the EAA method, they are closely related. Some GOA evaluation frameworks incorporate an economic analysis while some EAA frameworks also consider goals and objectives of ITS and C-ITS services. The main difference is that economic benefit is considered to be one of the many components of the GOA evaluation method, while it is considered to be the main measurement in the EAA method (Peng et al. 2000).

Nevertheless, both methods have their limitations. Sometimes the goals of a project are not clear; on the other hand, many benefits are difficult to assign a monetary value, which makes economic analysis challenging. Both approaches are complementary and should be used either together or each method should be used in when the proper prerequisites, as they are described in the above subchapters, are fulfilled.

Regardless of the approaches to be used, the following issues should be considered in the evaluation process (Peng et al. 2000):

**Affected Groups:** The groups affected by deployed ITS services is a critical factor. Despite the effect of those services to the main users, the evaluation framework should investigate the distribution of the impacts to other groups such as various user groups, non-users, public agency operators and private entities should be considered during the evaluation of ITS services (Turner and Stockton 1999, Lomax et al. 2000, Peng et al. 2000).

**Evaluation Time Frame:** In the process of ITS evaluation the time frame of occurrence is of high importance, because through the time frame categories (short-medium-long term benefits and impacts) there is a clear picture of the users’ benefits (Turner and Stockton 1999, Lomax et al. 2000, Peng et al. 2000).

**Specific measures and parameters:** Some ITS benefits can be identified by using specific measures and parameters. The measures mentioned below are commonly used to quantify ITS impacts (Peng et al. 2000).

1. **Safety:** Some measures of the number of incidents, crashes, and fatalities.
2. **Reduction of delay and travel time:** The measure of delays and travel time reliability.
3. **Cost reduction:** A measure of productivity and reduced operating costs from ITS services.
4. Throughput: A measure of passengers or people within a specific unit of time who traverse a portion of the road network.

5. Customer satisfaction: The extent to which passengers and other consumers who rely on transport service feel satisfied. While satisfaction is an abstract term, the quality of a service is often measured by the number of people who continue to use it, as well as comments on customer satisfaction or dissatisfaction.


An overview of impacts and relevant stakeholders and methods is provided in Table 1.

**Table 5. Overview of impact areas and related stakeholders and methods.**

<table>
<thead>
<tr>
<th>Impact</th>
<th>Stakeholder</th>
<th>Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Safety</td>
<td>Society</td>
<td>Statistics</td>
</tr>
<tr>
<td>2. Reduction of delay</td>
<td>Travellers</td>
<td>Simulation</td>
</tr>
<tr>
<td>4. Throughput</td>
<td>Road operators</td>
<td>Measurements</td>
</tr>
<tr>
<td>5. Customer satisfaction</td>
<td>Travellers</td>
<td>Questionnaire</td>
</tr>
<tr>
<td>6. Environmental benefits</td>
<td>Society</td>
<td>Statistics, overall values</td>
</tr>
</tbody>
</table>

**4.4 Criteria for an effective ITS (and C-ITS) evaluation methodology**

The most important criteria which need to be met for the use of an effective ITS and C-ITS evaluation methodology (Newman-Askins et al. 2003), (Econation) are:

1. The evaluation should be transparent and allow for simple updating of impact parameters.
2. The methodology should provide an accurate output, as well as being objective without any positive or negative bias.
3. The methodology should allow comparison of results of evaluation of ITS and conventional transport projects.
4. The evaluation should include rigorous sensitivity testing and not apply false precision to the estimated impacts.
5. The methodology should consider the combined effect of implementing various combinations of ITS.
6. The methodology must be developed to avoid double counting of benefits.
7. The base and project cases studied in the evaluation must be based on the same operational conditions.

Moreover, in all evaluation processes, both internal cost and external costs should be taken into account. Internal costs are easy to foresee, explain and quantify because they are costs that a business bases its price on. External costs are costs that are not included in what the business bases its price on. Even though external costs are not included in the final price of
the product, they still exist and they have significant impacts on the outcome of the evaluation. This has a direct implementation in ITS and C-ITS evaluation as these systems most of the times, apart from their focus environment, they have impacts on their external environment.

4.5 Data collection for impact assessment of ITS and C-ITS
Because of the need to collect and process traffic-related data, traditional on-road sensors were massively installed and collecting methods have been evolving in order to collect, compute, process and transmit traffic data.

Those systems are referred as conventional in-situ technologies. Along the roadway such in-situ technologies, based on intrusive or non-intrusive techniques, have been installed. Despite the necessity to install those systems, experts lead to the conclusion that the in-situ technologies were not sufficient because of their limited coverage and expensive costs of implementation and maintenance (Lopes et al. 2010).

During the last years there are several new alternatives technologies based on sensor technology and its applications to transport engineering (Lopes et al. 2010).


1. Conventional in-site (in-situ) data collection technologies
2. Mobile traffic probes (Floating car data and ITS probe vehicle techniques)
3. Wide-area data collection technology

In the below subchapters, only the in-situ technologies and the mobile traffic probes are further discussed. That is because these two methods are more relative to the object of this Deliverable.

The data collection methods, based on the network coverage have the ability to be adjusted into the current needs. That means that either the area can be limited to a particular site location or it can be stretched to fixed road segments or trips defined by identifying sensors. There is also the ability for the area to be extended to a wide-area network through autonomous on-board equipped vehicles and airborne sensors (Lopes et al. 2010).

Each of these methods has different technical and operational characteristics (Lopes et al. 2010). Below there is a brief description of those technologies.

4.5.1 Conventional in-situ/in-site technologies – Sensor Network technologies

In-situ technologies refer to traffic data measured by detectors located along the roadside. Generally, the conventional technologies can be divided into two categories: the intrusive and non-intrusive methods (Leduc 2008, Lopes et al. 2010).

In technical terms, the intrusive methods consist of a data recorder and a sensor placing along the roadside. On the other hand, the non-intrusive techniques are based on remote observations (Leduc 2008), [Traffic and mobility data collection for real-time applications].
The most important in-situ technologies (Leduc 2008, Lopes et al. 2010) are listed in Error! Reference source not found.:

### Table 6. In-situ technologies for data collection.

<table>
<thead>
<tr>
<th>Intrusive methods</th>
<th>Non-intrusive methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pneumatic road tubes</td>
<td>Manual counts</td>
</tr>
<tr>
<td>Piezoelectric sensors</td>
<td>Passive and active infra-red</td>
</tr>
<tr>
<td>Magnetic loops</td>
<td>Passive magnetic</td>
</tr>
<tr>
<td></td>
<td>Microwave radar</td>
</tr>
<tr>
<td></td>
<td>Ultrasonic and Passive acoustic</td>
</tr>
<tr>
<td></td>
<td>Video image detection</td>
</tr>
</tbody>
</table>

*For further technical details please check the relevant reference (Leduc 2008)

#### 4.5.2 Mobile traffic probes

This category refers to the collection of mobility-related data by locating and recognizing vehicles at multiple points in a network. The use of the mobile traffic probes requires that specific detectors are real or virtually installed in the road network. Some of the installed sensors provide complete transversal of the travel path; this capability leads to information related with route choice analysis and O-D estimation (Lopes et al. 2010).

There are two categories within the family of mobile traffic probes. Those categories are the Floating Car Data (FCD) and the ITS probe vehicle techniques (Turner et al. 1998, Lopes et al. 2010).

**Floating Car Data (FCD)**

FCD refers to real-time traffic and mobility data collection by locating the vehicles through the use of mobile phones or GPS systems over the road network. The principal of the FCD method is the collection of real-time traffic data by locating vehicles equipped with mobile phone or GPS (Leduc 2008, Lopes et al. 2010).

The data derived are vehicle’s location, speed and direction of travel. The data sets produced are sent anonymously to a central processing centre. The data collected is being processed and then it can be redistributed to the drivers on the road (Leduc 2008).

There are two categories of FCD (Leduc 2008, Lopes et al. 2010) which are namely mentioned below:

- GPS-based FCD
- Cellular-based FCD systems (e.g. CDMA, GSM, UMTS and GPRS networks)

*For further technical details please check the relevant references

**ITS probe vehicle techniques**

According to (Turner et al. 1998): “The probe vehicle techniques are ITS applications designed primarily for collecting data in real-time”. Their primary application is to collect data
for a specific purpose (other than travel time data) such as real-time traffic operations monitoring, incident detection and route guidance applications.

However, the ITS probe vehicle techniques' main use is for the collection of travel time data. Since these probe vehicles are used for travel time data collection, they are sometimes referred as "passive" probe vehicles (Turner et al. 1998).

In the case of the ITS probe vehicle techniques, probe vehicles are sampled at fixed location by means of electronic transponders (Turner et al. 1998).

There are five main types of ITS probe vehicle data collection services. These services are suited for large-scale data collection efforts. However, those services typically have a high implementation cost (Turner et al. 1998).

The most common used ITS probe vehicle technologies (Turner et al. 1998, Lopes et al. 2010) are:

- **Signpost-Based Automatic Vehicle Location (AVL):** In this technique probe vehicles communicate with transmitters mounted on existing signpost structures. This technique is mostly used by transit agencies.

- **Automatic Vehicle Identification (AVI):** Probe vehicles are equipped with electronic tags. These tags communicate with roadside transceivers to identify unique vehicles and collect travel times between transceivers.

- **Global Positioning System (GPS):** Probe vehicles are equipped with GPS receivers and two-way communication to receive signals from earth-orbiting satellites. The positional information transmitted to a control centre to display real-time position of the probe vehicles. Travel time information can be determined from the collected data.

- **Ground-Based Radio Navigation:** This system is similar to the global positioning system (GPS). Data are collected by communication between probe vehicles and a radio tower infrastructure.

- **Cellular Geo-location:** This technology has the ability to collect travel time data by tracking cellular telephone call transmissions.

In conclusion, two main categories of system and technologies exist for collection of traffic data. These technologies are the conventional in-situ technologies and mobile traffic probes. The mobile traffic probes are further sub-categorized in FCD technologies and in ITS probe vehicle techniques. Conventional systems were the first to be used, but their weaknesses led to the development of the mobile traffic probes which collect mobility-related data by locating the vehicles in the network through the use of new technologies.

These technologies allow for high quality and trusted traffic-related and mobility-related data to be collected. There is also the ability for further analysis of the collected data and for the transmission of the generated information to the users of the transport infrastructure through V2X technologies, and especially though Infrastructure-to-Vehicle (I2V) technologies.
4.6 The FESTA Handbook

FESTA Handbook is the result of a project aimed at supporting the Field Operational Tests (FOTs) by providing a handbook of good practices. The FESTA handbook was developed under the 7th Framework Programme with the purpose to offer a common methodology for the performance of FOTs in Europe.

FESTA Handbook describes the entire process of planning, preparing, executing, analyzing and reporting a FOT. FOTs are the most common type of tests for evaluating the performance of ITS, when deployed at large scale. A FOT is defined by the FESTA Handbook as “A study undertaken to evaluate a function, or functions, under normal operating conditions in road traffic environments typically encountered by the participants using study design so as to identify real-world effects and benefits.” (FESTA Handbook 2016).

Nevertheless, the FESTA Handbook is not applicable in all Technical Readiness Levels (TRLs). The pre-deployment phase (pilots) and the deployment phase, which are nearer to the market and in a high TRL, are not covered by FOTs, so they are not examined under the FESTA Handbook (Figure 1).

FESTA Handbook also provides information about aspects that differ across the European Union’s member states (FESTA 2016).

In Figure 3 there is a visualization of the process proposed in the FESTA Handbook.
5. Impacts of ITS and C-ITS services

5.1 Introduction
This chapter deals with the provision of information about the main impacts of various ITS and C-ITS services. The choice of the below presented services has occurred both from the iMobility priority systems (iMobility Effects Database) for ITS services and from the C-ITS Platform’s Day 1 services (C-ITS Platform 2016) for the presented C-ITS services.

At first there is need to mention that the impacts have been categorised for their better understanding. According to ESF’s Working Group 2 (ESF Member Organisation Forum on Evaluation of Publicly Funded Research 2012), the categories of impacts are:

- Scientific impact
- Technological impact
- Economic impact
- Social impact
- Political impact
- Environmental impact
- Health impact
- Cultural impact
The impacts presented in the following subchapters are categorised both as social - health impacts and environmental impacts. Social – health impacts deal with the reduction or not of accidents (with or without fatal injuries) and environmental impacts deal with the protection of the environment and the reduction of pollutants.

However, in some services identification of specific impacts upon a category maybe is difficult to be estimated. This due to the difficulty in identifying the exact area of influence that an ITS and C-ITS service affects. For example it is difficult to identify exactly the total length of a road network that is affected by the operation of an ATIS. Another example include ITS that focus on minimization of environmental impacts by transport. Also in this case it is hard to identify the exact area that the system have an impact on and therefore calculate environmental KPIs (e.g. CO$_2$ emissions etc.). Another significant issue is the lack of data. Data collection and processing needed for the provision of some ITS and C-ITS services mainly related to privacy that limit the evaluation methodologies’ potential and therefore no solid results can be produced (Iordanopoulos 2017).

As it is presented in the Annex 5-1, the impacts of the presented services have occurred from studies and analyses of previous studies.

5.2 Impacts of ITS
The below table provides a description of the selected ITS services; the descriptions have been derived from the iMobility Effects Database.
Table 7. iMobility effects Database priority ITS services and their description (iMobility Effects Database).

<table>
<thead>
<tr>
<th>a/a</th>
<th>System</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>eCall</td>
<td>eCall stands for European in-vehicle emergency call system. The function of eCall is to open an emergency call to public safety answering point when sensors in the vehicle detect an accident. The system can also be activated manually. The system sends information about the accident vehicle, for example its location and opens a voice connection between the vehicle occupants and the public safety answering point. eCall is included as one priority actions in the European Commissions’ ITS Directive. (Öörni and Goulart 2017).</td>
</tr>
<tr>
<td>2</td>
<td>Real-Time Travel and Traffic Information</td>
<td>RTTI includes all information which is relevant to organize and to optimize traffic flow and which can give advice to the mobile user, usually the driver, and to contribute to road safety and efficiency. The eSafety goal is to provide the majority of drivers with actual intra-urban traffic information and to get adequate urban traffic information in 50% of all major metropolitan areas in the EU. RTTI systems informs to the user through in-vehicle and nomadic devices about the traffic (congestion) and weather conditions. This helps the driver in choosing the most effective route or for preparing to cope with the foreseeable situation ahead on the route. The actuality of the information about the traffic situation to maintain the credibility of the function.</td>
</tr>
<tr>
<td>3</td>
<td>Dynamic Traffic Management</td>
<td>DTM systems and LDW systems are used to increase the safety and flow of traffic in cases of disturbance caused by incidents, congestion and adverse weather. Dynamic traffic management systems may also be used to implement hard shoulder running to increase road capacity locally during peak hours. The systems are operated automatically, semi-automatically or manually from traffic control centres based on fixed monitoring systems or mobile sensors (FCD etc.) on location. The systems employ Variable Message Signs or VMS to give the information to the drivers. Three categories of VMS exist based on the types of messages given: ‘regulatory messages’, ‘danger warning messages’ and ‘informative messages’. The DTM systems usually use regulatory messages, sometimes accompanied by danger warning and informative messages.</td>
</tr>
<tr>
<td>4</td>
<td>Speed Alert</td>
<td>The system alerts the driver with audio, visual and/or haptic feedback when the speed exceeds the locally valid speed limit. The speed limit information is either received from transponders in speed limit signs or from a digital road map, requiring reliable positioning information.</td>
</tr>
<tr>
<td>5</td>
<td>Dynamic Navigation Systems</td>
<td>Dynamic navigation utilizes current traffic event and transport network status data for adjusting the routing process in electronic navigation systems. This enables users to avoid routes with accidents, roadworks, road closure, and congestion in “real time”. The Traffic Message Channel (TMC) is mostly used to provide the basic traffic event information countries in Europe using RDS radio communications. More enhanced and individually sourced content is used to improve the standard TMC services in terms of accuracy and quality. These kinds of services are being provided via cellular networks.</td>
</tr>
<tr>
<td>6</td>
<td>Local Danger Warnings</td>
<td>DTM systems and LDW systems are used to increase safety and flow of traffic in cases of disturbance caused by incidents, congestion and adverse weather. The systems are operated automatically, semi-automatically or manually from traffic control centres based on fixed monitoring systems or mobile sensors (FCD etc.) on location. The systems employ Variable Message Signs or VMS to give information to the drivers. Three categories of VMS exist based on the types of messages given: ‘regulatory messages’, ‘danger warning messages’ and ‘informative messages’. Local warning systems use danger warning messages.</td>
</tr>
<tr>
<td>7</td>
<td>Adaptive Headlights</td>
<td>The system consists of electromechanical controlled headlights to ensure optimum illumination of the lane in bends. The headlight is directed into the bend as soon as the vehicle begins cornering. A reduction of the glare to the upcoming</td>
</tr>
<tr>
<td>a/a</td>
<td>System</td>
<td>Description</td>
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</tr>
<tr>
<td></td>
<td>vehicles is possible. Vehicle speed, yaw rate and steering wheel angle can be used as input data for the controller of the system.</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Eco-diving Assistance</td>
<td>Eco-driving assistance assists and encourages the driver to eco-driving by providing information to the driver about the current fuel consumption, energy use efficiency and appropriate gear selection taking into account engine and transmission efficiency, vehicle speed and rate of acceleration etc. Apart from displaying instantaneous and mean fuel consumption on the instrument panel (from the on-board computer), there can be an “Eco Drive Indicator”, which indicates when the vehicle is being operated in a fuel-efficient manner with respect to driveline efficiency. The measure also informs the driver when a gear shift is appropriate.</td>
</tr>
<tr>
<td>9</td>
<td>Eco-diving Coaching</td>
<td>Eco-driving coaching provides the driver information on gear change, acceleration behaviour and driving speed for operating the vehicle in an energy efficient manner. Like eco-driving assistance, the system may provide information of current fuel consumption, energy use efficiency and appropriate gear selection taking into account engine and transmission efficiency, vehicle speed and rate of acceleration etc. In addition to parameters internal to vehicle, the system utilizes information from outside the vehicle such as road geometry, mandatory stops and status of traffic lights to provide advice on optimal gear change, driving speed and acceleration behaviour.</td>
</tr>
<tr>
<td>10</td>
<td>Blind Spot Monitoring</td>
<td>At both sides of a vehicle normally there are some blind spots, if using a mirror for back ward view. Different systems can either provide better vision into the blind spot area or supplemental information regarding an obstacle being there, e.g. by warning signals. Wide angle side mirrors reduce the blind spot area. If the mirrors are heated, the vision in bad weather conditions is optimized further on. Camera techniques with image processing or radar sensors can give additional information about the situation in the blind spot. An adequate HMI solution is generally a prerequisite for an effective system.</td>
</tr>
<tr>
<td>11</td>
<td>Lane Departure Warning</td>
<td>Warning is given to the driver in order to avoid leaving the lane unintentionally. Video image processing is the most important technology used to detect lane markings on the road surface. Warnings provided to driver can be acoustic, visual or haptic.</td>
</tr>
<tr>
<td>12</td>
<td>Obstacle and Collision Warning (incl. ACC)</td>
<td>System detects obstacles and gives warnings when collision is imminent. Current solutions with limited performance are a separate feature of Adaptive Cruise Control systems which use information obtained from radar sensors or video image processing to give visual and acoustic warnings. Future systems will likely use long range/near range radar sensors or LIDAR and video image processing.</td>
</tr>
<tr>
<td>13</td>
<td>Emergency Braking</td>
<td>Based on radar (short and long range), LIDAR and/or camera vision, emergency braking support systems provide support in situations with a high risk of a head to tail collision in order to avoid the collision or to reduce the collision speed and the total crash energy. Total crash energy reduction correlates directly to crash injury mitigation. Different levels of support are available: enhancement of driver’s braking if necessary, automatic activation of partial braking, and automatic activation of full braking. Some systems also trigger reversible measures of occupant protection.</td>
</tr>
</tbody>
</table>

In terms of safety almost all the services have positive effects and the percent of the reduction of crashes (both fatal or not) and injuries vary from 1.5 to 30%. The only services with no reliable estimates for their effects in the safety are Real-Time Travel and Traffic Information and Blind Spot Monitoring. Also, in order for some services to achieve the maximum positive effects (Speed Alert) a full fleet penetration of the service is required. In terms of congestion, efficiency and comfort only eCall, Real-Time Travel and Traffic Information and Dynamic Traffic Management have (small) positive effects. Nevertheless no
specific estimations are available for the positive effects in congestion, efficiency and comfort. The environmental effects of the iMobility Effects Database priority ITS services are positive and, in the cases where exact estimates are available, vary from 0.5-11% less CO$_2$ emissions and fuel consumptions.

In the below table there is a synopsis of the social-health and environmental impacts of the iMobility Effects Database priority ITS services. The results presented below have derived from using various methods. From the variety of existing evaluation methods the most appropriate was used each time based on the characteristics of the services. Further information and details about the methods used in the impact assessment of each are provided in the Annex 5-1.
Table 8. Impacts of ITS services for the sectors of society-health and environment (iMobility Effects Database).

<table>
<thead>
<tr>
<th>a/a</th>
<th>Safety</th>
<th>Accidents</th>
<th>Congestion</th>
<th>Efficiency</th>
<th>Comfort</th>
<th>Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-</td>
<td>3.6 - 7.3% less fatalities</td>
<td>Small</td>
<td>-</td>
<td>-</td>
<td>Small</td>
</tr>
<tr>
<td>2</td>
<td>No reliable estimates</td>
<td>10% less</td>
<td>Positive</td>
<td>Positive</td>
<td>Positive</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>Improve</td>
<td>Reduction of injury crashes (5-20%) and fatal crashes (10-25%)</td>
<td>Positive</td>
<td>Improved</td>
<td>Positive</td>
<td>Decreased energy consumption - greenhouse gas emissions</td>
</tr>
<tr>
<td>4</td>
<td>Improve</td>
<td>Reduced fatalities in urban areas by 20% - 13-30% less fatal accidents (full fleet penetration)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Contradictory regarding energy consumption and emissions</td>
</tr>
<tr>
<td>5</td>
<td>Positive</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Reduced fuel consumption and CO₂ emissions by 2%</td>
</tr>
<tr>
<td>6</td>
<td>Positive</td>
<td>1.5% less injury crashes</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Slightly positive</td>
</tr>
<tr>
<td>7</td>
<td>Positive</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>8</td>
<td>Safety effects similar to speed alert (improved safety because of lower speeds)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3-11% less CO₂ emissions</td>
</tr>
<tr>
<td>9</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Potential for reduced fuel consumption</td>
</tr>
<tr>
<td>10</td>
<td>No reliable estimates</td>
<td>Less side collisions</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>11</td>
<td>-</td>
<td>10% less accidents and not so severe</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>12</td>
<td>Less rear-end collisions and not so severe</td>
<td>2.2-5.8% less injury accidents</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Probably 0.5-5% less CO₂ emissions</td>
</tr>
<tr>
<td>13</td>
<td>Reduction of crash speeds/ prevent rear-end crashes and collisions</td>
<td>7% less fatalities and injury risks</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Positive effects on emissions and fuel consumption</td>
</tr>
</tbody>
</table>
### 5.3 Impacts of C-ITS

The below table provides a description of the Day 1 C-ITS services, as derived from the C-ITS Platform (C-ITS Platform 2016).

**Table 9. C-ITS services and their descriptions (C-ITS Platform 2016).**

<table>
<thead>
<tr>
<th>a/a</th>
<th>Service</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hazardous Location Warning</td>
<td>The emergency electronic brake light is a service aimed at preventing rear end collisions by informing drivers of hard braking by vehicles ahead. Using this information, drivers will be better prepared for slow traffic ahead and will be able to adjust their speed accordingly.</td>
</tr>
<tr>
<td>1</td>
<td>Emergency Electronic Brake Light</td>
<td>This service aims to give an early warning of approaching emergency vehicles, prior to the siren or light bar being audible or visible. This should allow vehicles extra time to clear the road for emergency vehicles and help to reduce the number of unsafe manoeuvres.</td>
</tr>
<tr>
<td>2</td>
<td>Emergency Vehicle Approaching</td>
<td>Slow or stationary vehicle(s) warning is intended to deliver safety benefits by warning approaching drivers about slow or stationary/broken down vehicle(s) ahead, which may be acting as obstacles in the road. The warning helps to prevent dangerous manoeuvres as drivers will have more time to prepare for the hazard. This service can also be referred to as car breakdown warning.</td>
</tr>
<tr>
<td>3</td>
<td>Slow or Stationary Vehicles</td>
<td>The Traffic Jam Ahead Warning (TJW) provides an alert to the driver on approaching the tail end of a traffic jam at speed - for example if it is hidden behind a hilltop or curve. This allows the driver time to react safety to traffic jams before they might otherwise have noticed them themselves. The primary objective is to avoid rear end collisions that are caused by traffic jams on highways.</td>
</tr>
<tr>
<td>4</td>
<td>Traffic Jam Ahead Warning</td>
<td>This service gives drivers an advance warning of upcoming hazardous locations in the road. Examples of these hazards include a sharp bend in the road, steep hill, pothole, obstacle, or slippery road service. Using this information, drivers will be better prepared for upcoming hazards and will be able to adjust their speed accordingly.</td>
</tr>
<tr>
<td>5</td>
<td>Road Works Warning</td>
<td>Roadworks warnings enable road operators to communicate information about roadworks and restrictions to drivers. This allows drivers to be better prepared for upcoming roadworks and potential obstacles in the road, therefore reducing the probability of collisions.</td>
</tr>
<tr>
<td>6</td>
<td>Weather Conditions</td>
<td>The objective of this service is to increase safety through providing accurate and up-to-date local weather information. Drivers are informed about dangerous weather conditions ahead, especially where the danger is difficult to perceive visually, such as black ice or strong gusts of wind.</td>
</tr>
<tr>
<td>7</td>
<td>In-vehicle Signage</td>
<td>In-vehicle signage is a vehicle-to-infrastructure (V2I) service that informs drivers of relevant road signs in the vehicle's vicinity, alerting drivers to signs that they may have missed, or may not be able to see. The main purpose of this service is to provide information, give advance warning of upcoming hazards and increase driver awareness.</td>
</tr>
<tr>
<td>8</td>
<td>In-vehicle Speed Limits</td>
<td>In-vehicle speed limits are intended to prevent speeding and bring safety benefits by informing drivers of speed limits. Speed limit information may be displayed to the driver continuously, or targeted warnings may be displayed in the vicinity of road signs, or if the driver exceeds or drives slower than the</td>
</tr>
</tbody>
</table>
The purpose of probe vehicle data is to collect and collate vehicle data, which can then be used for a variety of applications. For example, road operators may use the data to improve traffic management.

Shock wave damping aims to smooth the flow of traffic, by damping traffic shock waves.

GLOSA provides speed advice to drivers approaching traffic lights, reducing the likelihood that they will have to stop at a red light, and reducing the number of sudden acceleration or braking incidents. This is intended to provide traffic efficiency, vehicle operation (fuel saving) and environmental benefits by reducing unnecessary acceleration.

The primary objective of this service is to reduce the number and severity of collisions at signalised intersections.

The traffic signal priority request by designated vehicles allows drivers of priority vehicles (for example emergency vehicles, public transport, HGVs) to be given priority at signalised junctions.

The impacts of the C-ITS services have been categorised in social-health and environmental impacts. In terms of safety almost all the services have positive effects and the percent of the reduction of crashes (both fatal or not) and injuries vary from 0.1 to 7.8%. The only service with no exact estimations estimates for its effects in the safety is Traffic Signal Request by Designated Vehicles. In terms of congestion, efficiency and comfort none of the services have significant effects upon this sectors. The environmental effects of the described C-ITS services are positive (but small) and, in the cases where exact estimates are available, vary from 0.005-3.5% less CO₂ emissions and fuel consumptions. The below table provides a synopsis about the impacts of Day 1 C-ITS (Malone et al. 2014), (Asselin-Miller et al. 2016), (Kulmala et al. 2012), (eSafety Forum 2010) as presented in the C-ITS Platform (C-ITS Platform).

For some of the presented C-ITS services there is information about the willingness to use the system, the willingness to pay for the system and the usefulness of the system. More specific:

- For Traffic Jam Ahead Warning service, the willingness to use the system is 79%
- For Shockwave Damping service, the willingness to pay for the system is 50% and the usefulness of the system is 86%
- For Weather Conditions service, the usefulness of the system is 76%.

In the below table there is a synopsis of the social-health and environmental impacts of the C-ITS Platform’s Day1 C-ITS services. As in the previous chapter the results presented below have also derived from using various methods. From the variety of existing evaluation methods the most appropriate was used each time based on the characteristics of the services. Further information and details about the methods used in the impact assessment of each are provided in the Annex 5-1.

<table>
<thead>
<tr>
<th>a/a</th>
<th>Safety</th>
<th>Accidents</th>
<th>Congestion</th>
<th>Efficiency</th>
<th>Comfort</th>
<th>Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hazardous Location Warning</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Improvement of safety and driver’s awareness</td>
<td>2.5% less injuries - 2.7% less fatalities</td>
<td>-</td>
<td>Small</td>
<td>-</td>
<td>Small</td>
</tr>
<tr>
<td>2</td>
<td>Less accidents</td>
<td>2.5% less injuries 2.7% less fatalities</td>
<td>-</td>
<td>Small</td>
<td>-</td>
<td>Small</td>
</tr>
<tr>
<td>3</td>
<td>Less accidents</td>
<td>0.7-1.1% less fatalities and injuries</td>
<td>-</td>
<td>Small</td>
<td>-</td>
<td>Small</td>
</tr>
<tr>
<td>4</td>
<td>Less accidents</td>
<td>2.4-2.5% less injuries - 1.7-2.4% less fatalities</td>
<td>-</td>
<td>No</td>
<td>-</td>
<td>No</td>
</tr>
<tr>
<td>5</td>
<td>Less accidents</td>
<td>4.1-4.2% less injuries and 3.1% less fatalities</td>
<td>Less congestion</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>Positive</td>
<td>1.9% less fatalities and 1.5% less injuries</td>
<td>-</td>
<td>Small</td>
<td>-</td>
<td>Small</td>
</tr>
<tr>
<td>7</td>
<td>Positive</td>
<td>2.5% less fatalities and 1-3% less injuries</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.005% less fuel consumption and 0.01-0.02% less emissions</td>
</tr>
</tbody>
</table>

Signage applications

<table>
<thead>
<tr>
<th>a/a</th>
<th>Safety</th>
<th>Accidents</th>
<th>Congestion</th>
<th>Efficiency</th>
<th>Comfort</th>
<th>Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Less accidents</td>
<td>0.5-1% less fatalities and injuries through the use of &quot;children&quot; and “pedestrian crossing ahead” signs</td>
<td>-</td>
<td>Small</td>
<td>-</td>
<td>Small</td>
</tr>
<tr>
<td>9</td>
<td>Less accidents</td>
<td>2.7% less fatalities and injuries</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>2.4-2.8% less fatalities and injuries</td>
<td>-</td>
<td>Small</td>
<td>-</td>
<td>0.001-0.006% less fuel consumption and emissions</td>
</tr>
<tr>
<td>11</td>
<td>Better safety</td>
<td>7.8% less fatalities and injuries by 5.0% less injuries (on motorways)</td>
<td>-</td>
<td>Small</td>
<td>-</td>
<td>Small</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td>0.1-0.3% less fatalities and injuries</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.1-0.7% less fuel consumption and 0.0-0.8% less emissions</td>
</tr>
<tr>
<td>13</td>
<td>Improved safety</td>
<td>1-4% less fatalities and 2-7% less injuries</td>
<td>-</td>
<td>Small</td>
<td>-</td>
<td>Small</td>
</tr>
<tr>
<td>14</td>
<td>Small</td>
<td>-</td>
<td></td>
<td>Improved</td>
<td>-</td>
<td>Less</td>
</tr>
</tbody>
</table>
6. Discussion and conclusions

This topic study addressed impact assessment and impacts of ITS and C-ITS services. First a general overview of the evaluation and impact assessment process was given. Common methods and frameworks are important to allow for comparisons and meta-analyses of different studies. The FESTA handbook provides a framework for assessing FOTs.

The evaluation can either apply a goal oriented approach or an economic analysis approach or a combination of both approaches. Whichever approach is chosen, the evaluation should consider the following aspects: targeted groups, evaluation time frame and measures. In addition to the target group, the service also affects e.g. non-users and public agency operators. The evaluation time frame is important for using the correct expected penetration rates. The impacts should be defined through the commonly used measures such as the number of incidents and fatalities for the safety impacts.

Data collection for impact assessments can be done in three different ways: by using detectors installed on the roadside, by using mobile traffic probes and by using wide area data collection.

The second objective of the topic study was to present impacts of different ITS and C-ITS services. The ITS services include: eCall, RTTI, Extended environmental monitoring, dynamic traffic management, speed alert, dynamic navigation systems, eco-driving assistance, lane keeping support, obstacle and collision warning and emergency braking. They were chosen because they have been recognized as iMobility priority systems (iMobility Effects Database) and because there are estimates available of their impacts. The systems with the most promising impact on safety were lane departure warning, speed alert, eCall and Dynamic Traffic Management. For the impacts on emissions and environmental, eco-driving assistance has been assessed to reduce CO₂ emissions by 3–11%.

The C-ITS services consisted of Day 1 applications which have been identified as priority C-ITS applications (C-ITS Platform 2016). The C-ITS services included hazardous location notifications: emergency brake light, emergency vehicle approaching, slow or stationary vehicle(s), traffic jam ahead warning, hazardous location notification, road works warning, weather conditions and signage applications: in-vehicle signage, in-vehicle speed limits, probe vehicle data, shockwave damping, green light optimal speed advisory, signal violation/intersection safety and traffic signal priority request by designated vehicles. Due to the un-matureness of the technologies, the impacts of the services have in general been assessed through impact assessments of ITS. For services providing information of hazardous location or conditions, the impact reduction fatalities and injuries has been estimated to be between 0–5%.
7. References


Annex 5:


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### Annex 5-1

Table 1. Studies on the impacts eCall (Kulmala and Öörni 2012, iMobility Effects Database)

<table>
<thead>
<tr>
<th>Impacts</th>
<th>Methods</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reducing accident notification time to one minute or less from the values in the sample selected from the US Fatality Analysis Reporting System (FARS) was estimated to reduce road traffic fatalities by approximately 1.84%.</td>
<td>Accidents involving fatalities, and the survival of accident victims as a function of time was compared for two groups: accidents with notification time of one minute or less and all other accidents.</td>
<td>Wu et al. 2013</td>
</tr>
<tr>
<td>The impact of the reduced rescue time on fatalities as a result of eCall was found to be different in different countries due to geography, rescue service performance etc. For Finland, a saving of 4-8% of road fatalities was estimated but the reduction in the UK was estimated to be considerably smaller (1%). The environmental impacts of eCall were found to be negligible or at least very small. For Finland, 0.02–0.05% reduction of vehicle hours spent in congestion was estimated which corresponds to reduction of 0.04–0.10% in emissions of CO2, PM and NOx.</td>
<td>The results are based on a questionnaire sent at the European level and in-depth studies carried out for four European countries. The impacts have been estimated on the basis of a literature study, expert interviews and information collected with the questionnaire.</td>
<td>Francics et al. 2009</td>
</tr>
<tr>
<td>eCall was estimated to reduce the number of road traffic fatalities by 5.8% (3.6-7.3%) in EU25 countries. A small increase (~0,1%) in the number of serious injuries was expected because eCall changes fatalities to injuries and serious injuries to less severe injuries.</td>
<td>The expected percentage changes in the number of fatalities and serious injuries on different accident categories were mostly based on the Finnish AINO study. The percentages obtained with Finnish data were then transformed into EU-25 accident data.</td>
<td>Wilmink et al. 2008</td>
</tr>
<tr>
<td>eCall was estimated to reduce the annual number of road traffic fatalities by 1-2% in the Netherlands. The severity of injuries will also be reduced for about 1% of the injured people brought into hospitals.</td>
<td>Accident analysis of all fatal accidents on the road involving potentially eCall equipped vehicles the authors looked at all accidents in which the fatal cases were not killed instantly but died shortly after the accident.</td>
<td>Donkers and Scholten 2008</td>
</tr>
<tr>
<td>eCall was estimated to reduce the annual number of road fatalities in UK by 3%.</td>
<td>The effects of eCall on the number of fatalities and serious injuries were estimated on the basis of the reduction in the time between accident and notification of emergency services, classification of accidents on the basis of road type and time of accident and classification of casualties potentially benefiting from eCall or not. A 66% fleet penetration was assumed.</td>
<td>McClure and Graham 2006.</td>
</tr>
<tr>
<td>The eCall system could very probably have prevented 4.7% of the fatalities in accidents involving motor vehicle occupants. In the accidents involving a fatally injured unprotected road user, however, the system could probably have prevented no fatality. In all, the eCall system was estimated to be able to reduce 4-8% of road fatalities in Finland.</td>
<td>The results are based on Finnish accident data collected by in-depth accident investigation teams. The data was analysed by medical experts having long experience of treating accident trauma.</td>
<td>Virtanen 2005.</td>
</tr>
<tr>
<td>From 5 to 10% of road fatalities would be changed to severe injuries in EU. In addition, 10 to 15% of severe injuries would be changed to slight injuries.</td>
<td>Based on official European accident statistics, traffic analyses, available market reports, and other sources. Effectiveness estimates were based on results from surveys of the E-MERGE project.</td>
<td>Abele et al. 2004</td>
</tr>
<tr>
<td>The foreseen live savings are estimated on an average between 5-10% which means 2000 to 4000 lives given the current number of fatalities of approx. 40000 and the reduction of the severity of injuries is estimated at the same number 5-10%.</td>
<td>The results are based on a questionnaire targeted to public safety answering point operators in E-MERGE test sites.</td>
<td>Cap Gemini Ernst &amp; Young. 2004</td>
</tr>
</tbody>
</table>
The influence of route suggestions was found not to change when the quality of information provided to test subjects declined. However, perceived inaccuracy of travel time information was found to have an impact on route selection. After receiving inaccurate information on travel time, test subjects switched to longer and more reliable routes in terms of travel time.

1.5% of trips were reported by road users to be cancelled or changed departure time in response to pre-trip information on road closure in urban environment. More frequently reported changes in travel behaviour were route changes, mode shifting and change of destination. For on-trip information, driving experience, travel time, trip purpose and desire for pre-trip information were found to have statistically significant effects on rerouting decisions after getting on-trip information through VMS.

Participants with access to smartphone providing real-time traffic information such as travel time and incident information reacted more strongly to variations in daily travel times than they did when they were monitored but no RTTI was provided in the pre-trial period. Another group of participants was not given access to a smartphone displaying RTTI. This group also reacted to daily variations in travel times. These users were expected to have used traffic information from other sources or have been better capable of processing information available into predicted travel times.

Low acceptance of the system functionality was experienced in a field test carried out in Berlin. The causes of this were found to be traffic conditions which limited the ways the test drivers could adapt their behaviour, quality of the human machine interface of the system, quality of service (the information provided by the system was also available via VMS) and absence of added value to driver.

“Slow traffic ahead” warnings were found to improve drivers’ situation-awareness when approaching the end of the queue.

The most ecological routes in terms of fuel consumption may be different from time-priority routes for the same origin-destination pair. For the most ecological route between two points, the fuel consumption was 9% less than for the time-priority route.

Real-time information on slipperiness and other road weather related problems has been estimated to reduce the risk of injury accidents in adverse conditions by 8% on main roads and 5% on minor roads in Nordic conditions.

45% of drivers with an RDS-TMC receiver had changed route due to on-trip RDS-TMC messages at least once. On the basis of information received before the trip, 23% of the drivers had changed their plans.

**Table 2. Studies on the impacts of RTTI (Kulmala and Öörni 2012, IMobility Effects Database).**

<table>
<thead>
<tr>
<th>Impacts</th>
<th>Methods</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>The influence of route suggestions was found not to change when the quality of information provided to test subjects declined. However, perceived inaccuracy of travel time information was found to have an impact on route selection. After receiving inaccurate information on travel time, test subjects switched to longer and more reliable routes in terms of travel time.</td>
<td>The results are based on a laboratory experiment with a stated preference method. In total, 36 participants were involved in the experiment and 20 route selections were analysed for each participant. The participants were given a route planning task.</td>
<td>Ben-Elia et al. 2013</td>
</tr>
<tr>
<td>1.5% of trips were reported by road users to be cancelled or changed departure time in response to pre-trip information on road closure in urban environment. More frequently reported changes in travel behaviour were route changes, mode shifting and change of destination. For on-trip information, driving experience, travel time, trip purpose and desire for pre-trip information were found to have statistically significant effects on rerouting decisions after getting on-trip information through VMS.</td>
<td>The results are based on a data set collected with a survey and development of a logistic regression model for impacts of traffic information. The survey was answered by 430 respondents.</td>
<td>Kattan et al. 2013</td>
</tr>
<tr>
<td>Participants with access to smartphone providing real-time traffic information such as travel time and incident information reacted more strongly to variations in daily travel times than they did when they were monitored but no RTTI was provided in the pre-trial period. Another group of participants was not given access to a smartphone displaying RTTI. This group also reacted to daily variations in travel times. These users were expected to have used traffic information from other sources or have been better capable of processing information available into predicted travel times.</td>
<td>The COOPERS system has been tested in a simulator study and was demonstrated in five test sites spanning four different countries. The focus of the research agenda was on user behaviour and acceptance tests.</td>
<td>Gilka and Richter 2011</td>
</tr>
<tr>
<td>Low acceptance of the system functionality was experienced in a field test carried out in Berlin. The causes of this were found to be traffic conditions which limited the ways the test drivers could adapt their behaviour, quality of the human machine interface of the system, quality of service (the information provided by the system was also available via VMS) and absence of added value to driver.</td>
<td>The results are based on a field test which involved 108 drivers using RTTI, and a total duration of the trial of 13 weeks.</td>
<td>Tseng et al. 2013</td>
</tr>
<tr>
<td>“Slow traffic ahead” warnings were found to improve drivers’ situation-awareness when approaching the end of the queue.</td>
<td>The results are based on a field test carried out on a single transport corridor in the Netherlands. The data collection was based on observation of vehicle passages with license plate recognition cameras and electronic vehicle identification beacons and a travel diary filled in by the participant. The participants were also asked to complete a series of surveys. The field operational test involved 108 drivers using RTTI, and a total duration of the trial of 13 weeks.</td>
<td>Nowakowski et al. 2011</td>
</tr>
<tr>
<td>The most ecological routes in terms of fuel consumption may be different from time-priority routes for the same origin-destination pair. For the most ecological route between two points, the fuel consumption was 9% less than for the time-priority route.</td>
<td>Field test with one instrumented vehicle trip.</td>
<td>Kono et al. 2008</td>
</tr>
<tr>
<td>Real-time information on slipperiness and other road weather related problems has been estimated to reduce the risk of injury accidents in adverse conditions by 8% on main roads and 5% on minor roads in Nordic conditions.</td>
<td>Literature study and expert interviews. The literature study contained a number of roadside pilot system evaluations.</td>
<td>Rämaå et al. 2003</td>
</tr>
<tr>
<td>45% of drivers with an RDS-TMC receiver had changed route due to on-trip RDS-TMC messages at least once. On the basis of information received before the trip, 23% of the drivers had changed their plans.</td>
<td>To assess the user and behavioural attitudes to RDS TMC (reaction to messages) interviews were conducted.</td>
<td>Tarry and Pyne 2003</td>
</tr>
</tbody>
</table>
Table 3. Studies on the impacts of Dynamic traffic management (Kulmala and Öörni 2012, iMobility Effects Database).

<table>
<thead>
<tr>
<th>Impacts</th>
<th>Methods</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Opening an extra lane on the hard shoulder reduced traffic density and</td>
<td>The results are based on observations made on a French urban motorway east of Paris. The study</td>
<td>Aron et al. 2013.</td>
</tr>
<tr>
<td>the number of accidents in the road stretch where the extra lane was</td>
<td>included a before and after analysis and a comparison site (the same site when hard shoulder</td>
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<td>available. This positive effect was partly compensated by migration of</td>
<td>running was not active). The extra lane was created with a moveable barrier.</td>
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<td>accidents to road stretch downstream of the site. In total, the number</td>
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<td>of accidents was reduced by 3% although this result was not statistically</td>
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<td>significant.</td>
<td>The study analysed the impacts of ramp metering. Travel times were reduced by 12-17% for the</td>
<td>Bhouri et al. 2013</td>
</tr>
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<td></td>
<td>motorway and metered on-ramps depending on the control strategy employed. The standard deviation</td>
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<td></td>
<td>of the travel time was reduced by 34-35%.</td>
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<td></td>
<td>The study analysed the impacts of ramp metering. Travel times were reduced by 12-17% for the</td>
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<td></td>
<td>motorway and metered on-ramps depending on the control strategy employed. The standard deviation</td>
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<td></td>
<td>of the travel time was reduced by 34-35%.</td>
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<td></td>
<td>Hard shoulder running reduced travel time by 14% on a 3 km road stretch on a motorway in France</td>
<td>Bhouri et al. 2012</td>
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<td></td>
<td>(2.3 km of motorway in with hard shoulder and 0.7 km of downstream).</td>
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<td></td>
<td>The results are based on a before and after study. Measurement of travel times was based on</td>
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<td></td>
<td>inductive loops.</td>
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<td></td>
<td>Dutch cabinet decided to increase the maximum speed limit to 130 km/h. Variable speed limits</td>
<td>Loot et al. 2012</td>
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<tr>
<td></td>
<td>were used to implement new speed limits and to reduce travel times. The average speed of cars</td>
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<td></td>
<td>increased by 2-3 km/h on freeways with two lanes. The average speed difference between vehicles</td>
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<td>increased by 0.5-2.5%. The frequency of short following distances increased on freeways with two</td>
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<td></td>
<td>lanes by 2%. On freeways with three or four lanes, short following distances were reduced.</td>
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<td></td>
<td>Variable speed limits were used to reduce the speed of vehicles approaching an unprotected</td>
<td>Sevefelt and Wessel 2012</td>
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<tr>
<td></td>
<td>intersection on a single carriageway main road. Variable speed limits reduced the average speed</td>
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<td>of vehicles approaching an unprotected intersection by 3-9 km/h when compared to situation with</td>
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<td>static speed limits.</td>
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<td>When implemented in heavy trucks, an advisory ISA system reduced the time travelled over the</td>
<td>Fitzharris et al. 2011</td>
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<td>speed limit. The odds of travelling over the posted speed limit was 21% lower when ISA was</td>
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<td></td>
<td>active. This result was statistically significant.</td>
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<td></td>
<td>Both deployments of hard shoulder running analysed in the study improved road capacity locally.</td>
<td>Aron et al. 2010.</td>
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<tr>
<td></td>
<td>However, extra traffic was induced and congestion migrated to downstream in the first of the</td>
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<td></td>
<td>analysed deployments.</td>
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<td></td>
<td>Effect of hard shoulder running on road capacity was estimated on the basis of traffic flow</td>
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<td></td>
<td>theory, calibrated general exponential model and data collected on two test sites in France.</td>
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</table>

Annex 5: 47/72
<table>
<thead>
<tr>
<th>Impacts</th>
<th>Methods</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>The safety of road users was influenced by the increased maximum...</td>
<td>The safety effects were estimated on the basis of accident statistics...</td>
<td>Lind and Lindkvist 2009.</td>
</tr>
<tr>
<td>methods were used to lower speed limit in dense traffic conditions...</td>
<td>to estimate the effects of the study with a before-and-after study.</td>
<td></td>
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<tr>
<td>to obtain more harmonised traffic flow. The study indicated that...</td>
<td>The effects on traffic flow were studied by measuring vehicle speed...</td>
<td></td>
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<tr>
<td>variable speed limits decreased the number of injury accidents...</td>
<td>and traffic counts. The environmental effects were calculated on the...</td>
<td></td>
</tr>
<tr>
<td>per million vehicle kilometres by 20%. However, the results of the...</td>
<td>basis of changes in vehicle speed. Cost-benefit analysis was...</td>
<td></td>
</tr>
<tr>
<td>the study were not statistically significant. Variable speed limits...</td>
<td>used to assess the socio-economical profitability.</td>
<td></td>
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<tr>
<td>increased speed limits were also found to improve travel times...</td>
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<tr>
<td>by 5% in dense traffic conditions. If queue situations are...</td>
<td>A before-and-after study with speed measurements on a highway in...</td>
<td>Lind 2007.</td>
</tr>
<tr>
<td>included in calculation, the reduction in travel time is 15%. Increase</td>
<td>Measurements on a highway in Southwestern Sweden</td>
<td></td>
</tr>
<tr>
<td>in speed of vehicles was found to increase petrol consumption and...</td>
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<tr>
<td>carbon dioxide emissions. Socio-economic benefit-cost calculations...</td>
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<td>were carried out for the Malmö test site in which the socio-economical</td>
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<tr>
<td>benefit-cost ratio was found to be more than 10. Of the four...</td>
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<tr>
<td>evaluated test sites two were estimated to be socio-economically...</td>
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<td>profitable and in one case the cost were found to be larger than...</td>
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<td>estimated benefits.</td>
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<td>Free flowing traffic along the motorways consumes on average...</td>
<td>Literature study</td>
<td>Reinhardt and Kompfner 2007</td>
</tr>
<tr>
<td>60% less fuel than when traveling on the local urban network (Greece).</td>
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<tr>
<td>By penalizing left-hand turns in route planning (trucks) the...</td>
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<tr>
<td>ROADNET software generated savings on fuel and emissions.</td>
<td></td>
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<tr>
<td>Variable speed limits reduced average speed of vehicles by...</td>
<td>Methods of the study: traffic speed measurements and telephone interviews</td>
<td>Rämä 2001</td>
</tr>
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<td>13-14 km/h during severe or very severe road surface conditions. The...</td>
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<td>respect for the normal speed limit (120 km/h) has also increased.</td>
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<td>A variable speed limit system integrated with a slippery road warning...</td>
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<tr>
<td>system reduced injury accidents on a Finnish motorway by around 10%.</td>
<td></td>
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<tr>
<td>Route information and management systems employing VMS in Germany...</td>
<td>Evaluation of traffic management systems with accident data</td>
<td>Siegener et al. 2000</td>
</tr>
<tr>
<td>decreased the risk of road accidents by 15% and the risk of severe...</td>
<td></td>
<td></td>
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<tr>
<td>injury accidents by somewhat more, between 9 and 36 %. The impacts of</td>
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<td>the system depend on the quality of the traffic management system and...</td>
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<td>the level of traffic volumes. On roads with high traffic volumes,...</td>
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<td>the numbers of accidents were 22 – 64 % lower than before the...</td>
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<td>implementation of the system. On roads with low or moderate volumes,...</td>
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<td>the changes in accident numbers were statistically insignificant.</td>
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<tr>
<td>Rear-end injury accidents have decreased as a result...</td>
<td>A compilation of the results of accident studies</td>
<td>Elvik et al. 1997</td>
</tr>
<tr>
<td>queue warning systems on motorways whereas the number of rear-end...</td>
<td></td>
<td></td>
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<tr>
<td>accidents resulting in property damage only have increased.</td>
<td></td>
<td></td>
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<tr>
<td>Safety can be improved not only by just reacting swiftly to...</td>
<td>Based on earlier accident studies</td>
<td>Bandmann and Finsterer 1997</td>
</tr>
<tr>
<td>incidents but also by preventing them through harmonisation of the...</td>
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<td>traffic flow via ramp control (or ramp metering), lane control,...</td>
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<tr>
<td>route diversion schemes, and in general traffic management.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lane control has little effect on injury accidents. Ramp control is...</td>
<td>Literature review compiling results from accident studies.</td>
<td>Perrett and Stevens 1996</td>
</tr>
</tbody>
</table>
Table 4. Studies on the impacts of Speed alert (Kulmala and Öörni 2012, iMobility Effects Database).

<table>
<thead>
<tr>
<th>Impacts</th>
<th>Methods</th>
<th>Reference</th>
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<tbody>
<tr>
<td>Three types of ISA were analysed: informative ISA, warning ISA and intervening ISA. Informative ISA did not have a significant effect on driver behaviour. Warning ISA was found to improve driver behaviour by reducing average and maximum driving speed and speeding frequency for a substantial share of drivers. Intervening ISA reduced maximum and average speed as well as standard deviation of speed. When driving with intervening ISA, some drivers misused the system by pressing the accelerator continuously and therefore delegating speed control to the system.</td>
<td>The results are based on a simulator study with 23 participants. The study involved four simulated drives: no system use, informative ISA, warning ISA and intervening ISA.</td>
<td>Spyropoulos et al. 2014</td>
</tr>
<tr>
<td>The study analysed the effects of informative ISA on drivers who had received at least two traffic infringement notices for violating the speed limit. ISA reduced the mean driving speed by 1.22 km/h, the time spent driving over the speed limit by almost 40% and the time taken to return to the speed limit by 4.61 s after exceeding it. The effects of ISA did not persist after the ISA functionality was removed.</td>
<td>The results are based on a field operational test carried out in Australia. The study involved 86 participants divided into four groups (two “Speed Alert” groups with ISA and two “Speed Data” groups with no ISA) and two periods (with ISA and baseline after driving with ISA).</td>
<td>Stephan et al. 2014</td>
</tr>
<tr>
<td>The study analysed the effect of a feedback-reward system on speed limit compliance and headways maintained by drivers. A cluster analysis revealed two driving styles: more speed and headway compliant (Cluster A) and less speed and headway compliant (Cluster B). For cluster A, the speed compliance rate increased from 89.1% to 96.4% of the driving time. For cluster B, the speed compliance rate increased more, from 79.4% to 94.7%. The results were statistically significant</td>
<td>The study was a field operational test carried out in Canada, and it involved 37 participants. Cluster analysis was applied to identify differences between users’ driving behaviour. The study included baseline, intervention and post-intervention periods. Mixed linear models were built to analyse the results of the study.</td>
<td>Merrikhpoor et al. 2014</td>
</tr>
<tr>
<td>A field operational test was organised to investigate ISA as a penalty system for drivers with serious speeding offences. Two types of intervening ISA were tested, and the test drivers had the possibility to override the system. The system reduced the mean speed and 85th and 95th percentile speeds on all of the tested road types and reduced the standard deviation of driving speed. When driving with the system, relatively small speed violations were still observed but violations over 20 km/h were few. After the systems were turned off, the users mostly returned to their old speeding behaviour.</td>
<td>The results are based on a field test which involved 51 test drivers. The field trial included three periods: the ‘before’ period without the system, the period when the system was active and the ‘after’ period.</td>
<td>van der Pas et al. 2014</td>
</tr>
<tr>
<td>The study analysed the effectiveness of three types of intelligent speed adaptation (ISA): advisory ISA, differential ISA and mandatory ISA. In terms of conforming to the speed limit, older drivers (over 60 years) would benefit most from mandatory ISA, but this may include a greater risk of lane deviations than other types of ISA. In terms of lane keeping performance, advisory ISA was found to be most beneficial for older drivers.</td>
<td>The study was performed in a driving simulator. The analysed data set included data of 26 drivers aged over 60 (experimental group) and data of 16 drivers aged 60 or less (control group). The tests involved four scenarios for each participant: no ISA systems available, advisory ISA, differential ISA system and mandatory ISA system.</td>
<td>Guo et al. 2013</td>
</tr>
<tr>
<td>An advisory ISA reduced mean driving speeds, and it was estimated to reduce accidents involving serious injury by 13-18%. The system was found to have no significant effect on speed after it had been removed.</td>
<td>This estimate is based on reduction in mean driving speed on the analysed road links and the power model for relationship between accidents and driving speed. The data was collected with a field test in Malaysia which included baseline, treatment and post baseline periods and it involved 11 test drivers.</td>
<td>Ghadiri et al. 2013</td>
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<td>Impacts</td>
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<td>The test group significantly reduced the proportion of distance driven over the speed limit.</td>
<td>The results are based on a field test of an informative ISA system combined with financial incentives. The study involved a test group and control group but no before and after analysis of test and control groups. The field test was carried out in Sweden and it involved 128 drivers in the test group and 68 drivers in the control group.</td>
<td>Stigson et al. 2013</td>
</tr>
<tr>
<td>The results suggest that mandatory ISA may affect the safety of overtaking manoeuvres unless the driver has adapted to the limitations of vehicle equipped with mandatory ISA or other driver support functions supporting safe overtaking are provided.</td>
<td>The results are based on simulator tests with 26 test drivers. The drivers participated in two separate trials: one with mandatory ISA and one with voluntary ISA. Both of the trials included 12 overtaking situations (6 with ISA and 6 without).</td>
<td>Jamson et al. 2012</td>
</tr>
<tr>
<td>The study analysed the impact of informative ISA combined with economic incentives. The proportion of distance travelled over the speed limit was reduced from 13% in the baseline period to 4% during the first period with ISA. During the latter periods with ISA, there was a small gradual increase in the proportion of distance travelled over the speed limit. No increase in travel time because of ISA was found in the study. During the post baseline period when ISA was turned off, the drivers returned to their old speeding habits.</td>
<td>The results are based on a field operational test organised in Denmark. The field test involved 153 drivers and it was conducted during 2007-2009.</td>
<td>Lahrmann et al. 2012</td>
</tr>
<tr>
<td>Speed alert improved compliance to speed limit. The frequency of speeding events was reduced by up to 50% depending on the speed limit value. Average driving speed increased by 0.75-2.33 km/h except on motorways. The probability of strong jerk events was reduced but the likelihood of observing critical time gaps was increased by 13%. Hard braking events were reduced by approximately 30%. The results on incident occurrence (near crash events) were partly inconclusive.</td>
<td>The results are based on data collected with a field operational test in France. The study involved a baseline period of three months and a test period of nine months.</td>
<td>Malta et al. 2012</td>
</tr>
<tr>
<td>The percentage of time driving at or slower than the 70 miles per hour speed limit was larger (54.83%) in the group equipped with an informative ISA system than in the control group (48.78%). However, this result was not statistically significant. No statistically significant difference was observed in mean speed driven on roads with 25 miles per hour speed limit.</td>
<td>The results are based on a field test carried out with 50 participants. The study involved a one-week baseline period, two weeks of system usage and a one week return to baseline period.</td>
<td>Reagan et al. 2013</td>
</tr>
<tr>
<td>The paper analysed two scenarios: a market-driven scenario and authority-driven scenario. In the authority-driven scenario, ISA was predicted to reduce the number of fatal accidents by 30% and 25% serious accidents over the analysis period of 60 years. Voluntary ISA and mandatory ISA were also predicted to reduce CO2 emissions by respectively by 3.4% and 5.8% on 70 mph (113 km/h) roads.</td>
<td>Impacts of ISA on the number of different types of accidents were estimated on the basis of speed profiles measured in a field test and theoretical models which describe the relation between driving speed and accident risk. Impacts on CO2 emissions were estimated by using an emissions model available from earlier research.</td>
<td>Lai et al. 2012</td>
</tr>
<tr>
<td>The study analysed the relative effects of informative and actively supporting ISA system on experienced and inexperienced drivers. The ISA systems seemed to be more effective at reducing speeds for experienced drivers on some road types. No evidence of negative behavioural adaptation or increased subjective workload levels was found in the study.</td>
<td>The results are based on tests carried out in a driving simulator. The study involved 30 test drivers divided into two groups (experienced and inexperienced). The simulated drives consisted of a familiarisation drive, a practice drive and nine test drives divided into three blocks: ISA system not active, informative ISA active and actively supporting ISA active.</td>
<td>Young et al. 2010</td>
</tr>
<tr>
<td>Impacts</td>
<td>Methods</td>
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<td>Mandatory ISA was found to reduce CO2 emissions on average by about 6% on motorway-type roads. For most other types of road, speed control was found to have very little impact on CO2 emissions, and in some cases it may result in increased emissions on urban roads with low speed limit.</td>
<td>The impact of speed control on emissions was estimated on the basis of measurements of vehicle speed and acceleration and generalised additive models for vehicle emissions. The data collection was carried out in a field test which included 20 instrumented vehicles and 79 test drivers.</td>
<td>Carslaw et al. 2009.</td>
</tr>
<tr>
<td>An advisory ISA system reduced fuel consumption by 14%. The share of distance driven above the speed limit was reduced by about one third from 25% to 14%.</td>
<td>The results are based on a field test conducted in Göteborg, Sweden with 26 vehicles owned by the City of Göteborg. Fuel consumption was calculated on the basis of odometer reading and actual amounts of fuel filled in tank.</td>
<td>Andersson 2009</td>
</tr>
<tr>
<td>The results showed that voluntary limited mode of the ISA system where the system controls speed but the driver can override the system leads to a significant increase in average fuel consumption, with less significance for the trips in inter-urban and motorway areas. However, a significant increase in fuel consumption was observed only within 30km/h zones (8% of the experimental zone). Drivers’ gear choices under active modes of the LAVIA system were found to be slightly different from those corresponding to inactive modes in respect to vehicle speed. The active modes of the LAVIA system were shown to probably induce diminished attention, especially in the gear choice.</td>
<td>The results are based on a field test which involved 44 drivers during 8 weeks test period. Fuel consumption was estimated on the basis of the position of accelerator pedal and engine rpm.</td>
<td>Saint Pierre et al. 2008</td>
</tr>
<tr>
<td>Drivers’ overriding behaviour varied from one speed zone to another. The drivers were found to have a strong tendency to override the ISA in urban environment, where they are most likely to have conflicts with vulnerable road users such as pedestrians. On 20 mph roads ISA was overridden for 13% of distance travelled, while on the 30 mph roads and 40 mph roads the ISA was overridden for 8% of the distance travelled. The results also showed that the overriding behaviour was different in different driver categories. Male and young drivers were found to override the ISA system more often than other drivers. Both speed limit warning and local danger warnings improve traffic safety by reducing driving speed, quantities of speed limit violations and exposure time of speed limit violations. The results presented in the paper are not statistically significant.</td>
<td>The conclusions are based on data collected in four field tests which involved 79 drivers. The ISA vehicles were given to test drivers for six months of which the ISA was active for four months. The ISA system used in the trials was an overridable voluntary ISA system.</td>
<td>Lai and Carsten 2008</td>
</tr>
<tr>
<td>The Driver Warning System providing speed limit warning and hot spot warning features was analysed in the study. The field tests showed that the system reduces driving speed by about 5%. The system was found to have potential to reduce the number of fatalities by 2.1-10.7%, fatal accidents by 1.7-8.7% and serious injury accidents by 0.7-3.6% depending on the expected market penetration between 13-65% in 2016 and the quality of implementation.</td>
<td>The results are based on a field test carried out in Germany which involved 64 test drivers separated into control and experimental groups. The results of the field tests and models describing the relation between speed and accidents and speed variation and accidents were used to estimate the safety impact of the system.</td>
<td>Heinig et al. 2007a.</td>
</tr>
<tr>
<td>Both speed limit warning and local danger warnings improve traffic safety by reducing driving speed, quantities of speed limit violations and exposure time of speed limit violations. The results presented in the paper are not statistically significant.</td>
<td>The results were obtained by recording and analysing the driving behaviour of 64 test persons.</td>
<td>Heinig et al. 2007b</td>
</tr>
<tr>
<td>The social representations of LAVIA (the French ISA system) and its a priori acceptability were found to be determined by social representations of speed. The most accepted mode by drivers was the advisory mode. Using LAVIA has a major impact on a posteriori acceptability of the system, but representations still continue to have an effect on it.</td>
<td>The results are based on two surveys targeted to drivers before and after using different styles of LAVIA (the French ISA system). The theoretical framework of the studies was the theory of social representations.</td>
<td>Pianelli et al. 2007</td>
</tr>
<tr>
<td>Impacts</td>
<td>Methods</td>
<td>Reference</td>
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<tr>
<td>The time the vehicle travels over the speed limit was reduced by 30%. The effect depends on the functionality of ISA system and incentives connected to driving and speed behaviour.</td>
<td>A field test with 20 vehicles</td>
<td>Myhrberg 2007</td>
</tr>
<tr>
<td>The active acceleration pedal type speed alert affected speed the most in 90 km/h zone where speeding decreases by almost 10%. At lower speed limits effects were smaller although speeding was more frequent. In the 30 km/h zone, distance speeding decreased from 45.9% to 42.8%, which means that the counter pressure was overridden in a vast amount of distance. Differences between drivers were large. Speeding without the system varied between 6% and 61%. Distance speeding with the system varied between 3% and 50%. For most drivers speeding reduced with the system. Average speed of less frequent speeders tended to increase as drivers accelerated faster to the speed limit and drove exactly at the speed limit instead of safely below. Average speed of more frequent speeders tended to decrease.</td>
<td>Data was collected with in-vehicle data logging device from 37 vehicles (34 cars, 3 buses) in Ghent, Belgium. For 21 out of 37 vehicles enough data were available from both periods, with and without the system. The effects on speed concern differences between driving data with the active accelerator pedal system and data after deactivation of this system. Speeds were analyzed on two levels: time-based and distance-based. Time based speeds include also idling. Distance-based speeds were calculated based on average speeds at which people travel per meter, and this means exclusion of idling. Only distance-based results are reported in this paper.</td>
<td>Broekx et al. 2006</td>
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<td>The speed alert with audio alert and active gas pedal for speeds more than 2 km/h above the speed limit reduced mean, maximum and 85th percentile speeds, and reduced speed variability in most speed zones. ISA also reduced the percentage of time drivers spent travelling above the speed limit, and did not increase travel times. The systems were effective only while they are active. There was little evidence of any negative behavioural adaptation to the system. A significant reduction in fuel consumption was found, but only in 80km/h zones with active ISA and FDW. Carbon Dioxide emissions also decreased significantly, when both ISA and FDW were jointly active in 80 km/h zones. A significant reduction in Nitrogen Oxide and Hydrocarbonates emissions was found in 80 km/h zones when the ISA system alone was active. Significant reductions in Nitrogen Oxide and Hydrocarbonates emissions were also found in 60 km/h (Nitrogen Oxide only) and 80 km/h zones when both the ISA and FDW systems were jointly active. The ISA system by itself is expected to reduce the incidence of fatal crashes by up to 8 percent and serious injury crashes by up to 6 percent. When combined with FDW, the ISA system is expected to reduce fatal and serious injury crashes by 9 and 7 percent, respectively.</td>
<td>The results were based on an on-road evaluation of four ITS technologies equipped to 15 Ford passenger cars (referred to as 'SafeCars'). The four technologies were: Intelligent Speed Adaptation (ISA); Following Distance Warning (FDW); Seatbelt Reminder (SBR) and Reverse Collision Warning (RCW). Each SafeCar was also equipped with Daytime Running Lights. Twenty-three fleet car drivers (15 treatment and 8 control drivers) participated in the on-road trial. Each participant drove a SafeCar for at least 16,500 kilometres. During the trial, the treatment drivers were exposed to all four ITS technologies, while the control drivers were exposed to the SBR and RCW systems only. Each SafeCar was equipped with a data logging system which automatically recorded a range of driving performance measures. This report presents the findings that derived from the logged driving data and from the subjective data on drivers' perceived acceptability and usability of the SafeCar systems.</td>
<td>Regan et al. 2006</td>
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<td>If everyone had Intelligent Speed Adaptation (speed alert as the main type studied), there could be 20% fewer road injuries in urban areas.</td>
<td>Results are based on large-scale field studies made in Sweden including accident and behavioural studies</td>
<td>Biding and Lind 2002</td>
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<td>Speed alert systems signalling with light and sound if the driver exceeds the speed limit are expected to reduce the number of injury accidents by ca. 10% and fatalities by ca. 18%. A voluntary system, where the driver can enable or disable control by the vehicle of the maximum speed has been estimated to affect safety in a similar fashion. A dynamic version of the compulsory speed control (limiter) would reduce injury accidents by 36% and fatal accidents by 59%.</td>
<td>User trials, simulator studies and simulation modelling were the methods of the study.</td>
<td>Carsten and Fowkes 2000</td>
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<tr>
<td>Automatic speed limiting on rural roads would reduce the total number of injury accidents in Sweden by about 10%. Dynamic ISA in conditions of low friction would decrease the total number of injury accidents by ca. 12% and ISA in darkness by 12%.</td>
<td></td>
<td>Várhelyi 1997</td>
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## Final results: Impacts on traffic safety

<table>
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<tr>
<td>In general, drivers reduced speed before interacting with a navigation system and maintained a longer distance to the lead vehicle during system inputs. Reduction in the lane keeping performance was found for the nomadic system but not for the integrated system. No overall increase in critical driving situations could be found during or after integrating with a navigation system.</td>
<td>The results are based on data collected in a field operational test done in Germany. The field operational tests lasted three months, and the resulting data was analysed for 99 participants.</td>
<td>Metz et al. 2014.</td>
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<td>Simple auditory route guidance could be followed without a significant interference to a simulated driving task. However, more complex auditory route instructions were found to cause interference.</td>
<td>The results of the study are based on simulator tests with 25 participants (undergraduate students from 19 to 21 years).</td>
<td>Dalton et al. 2013</td>
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<td>According to a driver survey, trust in navigation systems is generally high with 73% of drivers being at least somewhat trusting of the systems (67% “somewhat” trusting, 6% were “very” trusting). The results of the carrier survey indicated that the most of the carriers (62%) were “very” trusting or “somewhat trusting on navigation system accuracy.</td>
<td>The results are based on a survey answered by truck drivers and a survey aimed at freight carriers conducted in the US. However, no statistical tests were carried out nor confidence intervals calculated.</td>
<td>Park and Fender 2013</td>
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<td>When driving with a navigation system the relative frequency of incidents (crash related events) near intersections was reduced (built-in in-vehicle device: - 5.4% and mobile device : -21.5%). Because of the lack of information on the impact mechanisms between use of navigation systems and traffic safety, the results related to the safety impacts were not fully conclusive.</td>
<td>The results are based on data collected with a field operational test in Germany. The study involved a baseline period of three months and a test period of nine months.</td>
<td>Malta et al. 2012</td>
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<td>Final results: Impacts on traffic safety</td>
<td>The analysis of the results has shown that differences exist between the user acceptance and service impacts measured in simulator and field tests in real traffic environment. The user acceptance survey answered by drivers involved in simulator tests presented a more negative attitude towards the system. Analysis of driver behaviour showed no difference in the field test before and after receiving the service even though this was visible in results of simulator tests.</td>
<td>Valero Mora et al. 2012</td>
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<td>The project tested an in-vehicle traffic map device (TrafficGauge) using 2 215 participants from the Puget Sound region. Three rounds of surveys took place between November 2007 and May 2008 in which participants used the TrafficGauge for six months. The project also analyzed a roadway corridor to determine, in instances of unusual freeway congestion, how traveller’s behaviour affects congestion on alternative roadways.</td>
<td>Valero Mora et al. 2012.</td>
<td>Cerbe et al. 2009.</td>
</tr>
<tr>
<td>Participants who changed their routines saved time a mean number of 1.6 times. The mean amount of time saved on those instances was a little over 30 minutes. 32% of participants indicated that they did not save any time by using the device. Over 59% of the participants indicated that the information provided by the device reduced their level of stress. The corridor analysis confirmed that many travellers diverted either on the basis of what they see on the roadway or what they get from en-route traffic information sources. Even the modest levels of diversion observed in this study increased arterial congestion, especially near freeway ramps. This visible arterial congestion near the freeway discouraged diversion.</td>
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<td>Valero Mora et al. 2012.</td>
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<td>Two routes were compared in the test: the fast and short route. The short route offered an average fuel saving of 21% compared to the fast route and travel time longer by 6%.</td>
<td>The results of the study are based on data collected in a field operational test done in Germany. The field operational tests lasted three months, and the resulting data was analysed for 99 participants.</td>
<td>Metz et al. 2014.</td>
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### Table 5: Studies on the impacts of Dynamic navigation systems (Kulmala and Öörni 2012, iMobility Effects Database).

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<td>The results are based on a survey answered by truck drivers and a survey aimed at freight carriers conducted in the US. However, no statistical tests were carried out nor confidence intervals calculated.</td>
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<td>When driving with a navigation system the relative frequency of incidents (crash related events) near intersections was reduced (built-in in-vehicle device: - 5.4% and mobile device : -21.5%). Because of the lack of information on the impact mechanisms between use of navigation systems and traffic safety, the results related to the safety impacts were not fully conclusive.</td>
<td>The results are based on data collected with a field operational test in Germany. The study involved a baseline period of three months and a test period of nine months.</td>
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<td>Participants who changed their routines saved time a mean number of 1.6 times. The mean amount of time saved on those instances was a little over 30 minutes. 32% of participants indicated that they did not save any time by using the device. Over 59% of the participants indicated that the information provided by the device reduced their level of stress. The corridor analysis confirmed that many travellers diverted either on the basis of what they see on the roadway or what they get from en-route traffic information sources. Even the modest levels of diversion observed in this study increased arterial congestion, especially near freeway ramps. This visible arterial congestion near the freeway discouraged diversion.</td>
<td>The project tested an in-vehicle traffic map device (TrafficGauge) using 2 215 participants from the Puget Sound region. Three rounds of surveys took place between November 2007 and May 2008 in which participants used the TrafficGauge for six months. The project also analyzed a roadway corridor to determine, in instances of unusual freeway congestion, how traveller’s behaviour affects congestion on alternative roadways.</td>
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<td>Two routes were compared in the test: the fast and short route. The short route offered an average fuel saving of 21% compared to the fast route and travel time longer by 6%.</td>
<td>The results of the study are based on data collected in a field operational test done in Germany. The field operational tests lasted three months, and the resulting data was analysed for 99 participants.</td>
<td>Metz et al. 2014.</td>
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Route optimisation on the basis of fuel economy was estimated to reduce fuel consumption and CO2 emissions by 4% (total reduction of 1%) in urban areas and 1% on motorways and rural roads (total reduction of 0.7%). In other words, the reduction in fuel consumption and CO2 emissions because of improved route choice was estimated to be 1.7% in EU27 countries. The system was also estimated to reduce CO2 emissions and fuel consumption by relieving congestion. The impact of reduced congestion was estimated to be 0.4% in EU27 countries. When both of these impacts are combined, dynamic navigation systems were found to have potential to reduce CO2 emissions by 2.1% in EU27 countries.

The results revealed that the drivers performed better when using a portable navigation system compared to those using a paper map, in terms of efficiency to destination and driving performance. In addition, drivers could save time and gasoline using a portable navigation system when in an unfamiliar region, and driving performance may be safer, despite the fact that the display screen of the phone used in the test was small.

The most ecological routes in terms of fuel consumption may be different from time-priority routes for the same origin-destination pair. For the most ecological route between two points, the fuel consumption was 9% less than for the time-priority route.

The study showed a reduction of 16% in kilometres when travelling in an unfamiliar area with a navigator compared to driving with conventional navigational aids in a similar situation. The mean speed used by drivers increased somewhat and the occurrence of inappropriate behaviour was reduced from 1.3 remarks per run when using conventional navigation aids to 0.56 with a TomTom navigation system. The statistical analysis of damages of a car lease company showed that the drivers having a navigation system registered less damages and per kilometres driven. The claimed damage costs of lease car drivers without a navigator were found to be 5% higher than drivers having a navigator. As a conclusion, the results of all four research methods indicated a positive effect of navigation systems on traffic safety.

### Table 6. Studies on the impacts of Eco-driving coaching (Kulmala and Öörni 2012, iMobility Effects Database).

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<td>The results of the study showed that the reduction in fuel consumption achieved with an anticipatory eco-driving assistance system is not dependent on the complexity of the traffic scenario.</td>
<td>The results are based on a simulator study with 27 participants.</td>
<td>Rommerskirc hen et al. 2014</td>
</tr>
<tr>
<td>The results of the study showed that the reduction in fuel consumption achieved with a system for anticipatory eco-driving assistance system is not dependent on the complexity of the traffic scenario.</td>
<td>The results are based on a literature study and estimates made by the authors.</td>
<td>Klunder et al. 2009</td>
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<tr>
<td>The results revealed that the drivers performed better when using a portable navigation system compared to those using a paper map, in terms of efficiency to destination and driving performance. In addition, drivers could save time and gasoline using a portable navigation system when in an unfamiliar region, and driving performance may be safer, despite the fact that the display screen of the phone used in the test was small.</td>
<td>Thirty-two drivers participated in field experiments carried out in both urban and rural environments. A smart phone was adopted as the portable navigation system in the study.</td>
<td>Lee and Cheng 2008</td>
</tr>
<tr>
<td>The most ecological routes in terms of fuel consumption may be different from time-priority routes for the same origin-destination pair. For the most ecological route between two points, the fuel consumption was 9% less than for the time-priority route.</td>
<td>Field test with one instrumented vehicle</td>
<td>Kono et al. 2008</td>
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<tr>
<td>The study showed a reduction of 16% in kilometres when travelling in an unfamiliar area with a navigator compared to driving with conventional navigational aids in a similar situation. The mean speed used by drivers increased somewhat and the occurrence of inappropriate behaviour was reduced from 1.3 remarks per run when using conventional navigation aids to 0.56 with a TomTom navigation system. The statistical analysis of damages of a car lease company showed that the drivers having a navigation system registered less damages and per kilometres driven. The claimed damage costs of lease car drivers without a navigator were found to be 5% higher than drivers having a navigator. As a conclusion, the results of all four research methods indicated a positive effect of navigation systems on traffic safety.</td>
<td>Four different methods were used in the study: a statistical analysis of damages of a car lease company with a database of 115197 lease car drivers; driving experiment with 36 test drivers with a navigator or conventional navigation aids; an user survey targeted to 4000 drivers and an international literature quick scan.</td>
<td>Vonk et al. 2007</td>
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An eco-driving support system with the capability to communicate with and detect the status of traffic lights provided acceleration, deceleration and gear shifting advice. The system was found to have the potential to reduce fuel consumption between 15.9% and 18.4% and to slightly increase travel time. No negative impacts on safety were found although it was found to necessary reduce the distraction caused by the system.

The results are based on a simulator study with 30 participants. Staubach et al. 2014

Table 7. Studies on the impacts of Local danger warnings (Kulmala and Öörni 2012, iMobility Effects Database).

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<td>An informative message about an accident on a freeway did not seem to have any immediate and significant impact on diversion to an alternative route. This conclusion applies only to the time period and the three sites analysed in the paper.</td>
<td>The result was obtained by comparing diversion rates on a freeway off-ramp before and after displaying a message informing drivers of an accident. The data collection was carried out in California in the US.</td>
<td>Xuan and Kanafani 2014</td>
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<td>Secondary crashes were found to represent approx. 5.5% of all primary incidents on interstate road 5 in California, USA. Mild statistical evidence that variable message signs reduce the number of secondary accidents was found in the study.</td>
<td>The results are based on analysis of 9524 incidents including 528 secondary accidents which took place on Interstate road 5, California, USA during 2008. A logistic regression model was used in analysis of results.</td>
<td>Kopitch and Saphores 2011</td>
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<td>The Driver Warning System providing speed limit warning and hot spot warning features was analysed in the study. The field tests showed that the system reduces driving speed by about 5%. The system was found to have potential to reduce the number of fatalities by 2.1-10.7%, fatal accidents by 1.7-8.7% and serious injury accidents by 0.7-3.6% depending on the expected market penetration between 13-65% in 2016 and the quality of implementation.</td>
<td>The results are based on a field test carried out in Germany which involved 64 test drivers separated into control and experimental groups. The results of the field tests and models describing the relation between speed and accidents and speed variation and accidents were used to estimate the safety impact of the system.</td>
<td>Heinig et al. 2007a</td>
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<td>Warned drivers reduced their speed in the first 10 seconds by about 18 %. Drivers in unequipped vehicles also benefit from the wireless local danger warning system, when the penetration rate of the system reaches 30 %.</td>
<td>Driver simulator tests with 41 test persons</td>
<td>Malone et al. 2007</td>
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<td>A sign warning about slippery road conditions reduced the mean speeds. In addition, the variable safety margin sign extended the headways and reduced mean speeds. The variable safety margin sign decreased the proportion of the drivers in queues with headways of less than 1.5 seconds by 28-38% during good road conditions and by 31-37% during slippery road conditions.</td>
<td>Field studies employing automated measurements of speeds and headways connected to road weather information</td>
<td>Rämä et al. 1996</td>
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<tr>
<td>A Dutch fog warning system including a text warning (&quot;fog&quot;) and dynamic speed limit VMS signs on a motorway, reduced speeds in fog by 8 to 10 km/h, although in extremely dense fog, the system had an adverse effect on speed. This was due to the too high &quot;lowest possible speed limit&quot; display in the VMS (60 km/h). A more uniform speed behaviour was obtained due to the introduction of the system.</td>
<td>Driving simulator studies</td>
<td>Hogema et al. 1996</td>
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Table 8. Studies on the impacts of Adaptive headlights.
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<td>Adaptive high intensity discharge (HID) headlights helped drivers to detect low reflectance targets in low light conditions on a rural road. The system reduced driver's detection time of the target. The benefit of adaptive headlights over fixed headlights was found to be 200-380 ms depending on the driving scenario. No benefit was observed on straight road sections.</td>
<td>The results are based on a field test carried out on a two-lane rural road in night conditions with 20 participants. The test involved three scenarios: driving with fixed halogen headlights, fixed HID headlights and adaptive HID headlights. The results were analysed with linear mixed modelling approach.</td>
<td>Reagan et al. 2015</td>
</tr>
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<td>Fixed halogen low beam headlights were rated as less glaring than fixed and adaptive high intensity discharge (HID) headlights. The study results did not indicate an increase in perceived glare with the adaptive HID low beam headlights when compared to fixed HID low beams.</td>
<td>20 test participants rated the glare from vehicle headlights when a test driver drove towards them on a test track. The visual discomfort caused by the vehicle headlights was measured with the DeBoer visual discomfort response scale.</td>
<td>Reagan et al. 2014</td>
</tr>
<tr>
<td>Adaptive headlights (Volvo Active Bending Lights system) reduced the number of property damage liability insurance claims by 9.0% and bodily injury liability insurance claims by 16.8%. Both results were statistically significant.</td>
<td>The results are based on a regression analysis made for a data set collected from insurance companies in USA. Vehicles of the same make and model year were used as a control group.</td>
<td>Highway Loss Data Institute 2012a</td>
</tr>
<tr>
<td>Adaptive headlights (Mercedes-Benz Active Curve Illumination) reduced the number of property damage liability claims by 4.7%, bodily injury liability claims by 9.9% and medical payments claims by 14.0%. All of the results were statistically significant.</td>
<td>The results are based on a regression analysis made for a data set collected from insurance companies in USA. Vehicles of the same model year not equipped with the system were used as a control group.</td>
<td>Highway Loss Data Institute 2012b.</td>
</tr>
<tr>
<td>Adaptive headlights were found to have potential to prevent or mitigate 2,484 fatal accidents and 29,000 injury accidents annually in USA.</td>
<td>Databases of accidents reported by the police were used to identify accidents which could have been prevented or mitigated. The study analysed only the potential the systems have to prevent accidents but not their effectiveness.</td>
<td>Jermakian 2011</td>
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<tr>
<td>A general increase in speed was noticed in both AFS and non-AFS groups during the six days of testing. The speed increase was significantly higher in the non-AFS group in city scenario representing urban environment. Drivers with AFS technology did change their driving pattern, but only in terms of driving speed, and no change in lateral distance or steering wheel measures was found.</td>
<td>The results are based on a literature study and a driving test lasting six days. A group of drivers with AFC system was compared with a control group of drivers with no AFS system.</td>
<td>Jenssen et al. 2007</td>
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<tr>
<td>The extent of road safety impact of such a system will rely on how drivers will adapt their behaviour to the increased visibility conditions.</td>
<td>The results of the study are based on review of earlier results and personal opinions of the author.</td>
<td>Rumar 1997</td>
</tr>
<tr>
<td>Drivers were found to compensate for the improved vision by increasing their speed, which in some circumstances even led to increased accident risks when compared to before the deployment of the reflector posts.</td>
<td>Analysis of accident statistics and automated measurement of vehicle speeds</td>
<td>Kallberg 1991.</td>
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Table 9. Studies on the impacts of Eco-driving assistance (Kulmala and Öörni 2012, iMobility Effects Database).

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<td>An eco-driving assistance system providing feedback to bus drivers on average fuel consumption, harsh deceleration, speeding, idling and rollout reduced fuel consumption by 6.8%.</td>
<td>The results are based on a before and after comparison for data collected in a field experiment carried out in Sweden on an urban bus line. The field test involved a baseline period of three weeks and three weeks of driving with the system. 54 bus drivers participated in the study.</td>
<td>Strömberg and Karlsson 2014</td>
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<tr>
<td>An in-vehicle information system providing frontal collision warning, lane departure warning, gear change advice and braking and acceleration advice was found to reduce fuel consumption by 3.7% (miles per gallon of fuel spent increased by 4.1% between control and experimental conditions, from 54.8 to 57.0). The mean headway to the vehicle in front increased from 2.05 s to 2.33 s. The time spent traveling closer than 1.5 s to the vehicle in front was reduced by two thirds. These results were statistically significant. No increase in travel time, reduction in average speed or adverse impacts on distraction related parameters, such as lane deviations, were observed. The mean number of lane deviations and near deviations reduced from 17.7 in control condition to 15.5 in experimental condition. However, this difference was not statistically significant.</td>
<td>The results are based on a field test with an instrumented vehicle on a fixed driving route in central England with 33 participants. The test route included three different road categories: &quot;motorway&quot;, &quot;urban&quot; and &quot;inter-urban&quot;. The test results were recorded for each participant both in control and experimental conditions.</td>
<td>Birrell et al. 2014</td>
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<tr>
<td>The study analysed the impact of eco-driving assistance system installed in city buses on a frequent bus line in Helsinki. The system was found to reduce fuel consumption by 3.8% in the long term on average. A 6.8% reduction in fuel consumption was achieved with a combination of eco-driving training and eco-driving advice provided by an in-vehicle system.</td>
<td>The results are based on a field test carried out in Helsinki with 23 bus drivers using the system and 120 drivers as a reference group. The duration of the field test was 16 months.</td>
<td>Innamaa and Penttinen 2014</td>
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<td>The study analysed the impact of eco-driving assistance system providing real-time information on vehicle energy use and enforcing the advice provided by a gear shift indicator. Fuel consumption was reduced by 7.6 % on average in a test fleet of 15 light commercial vehicles.</td>
<td>The results are based on a field test which involved 15 light commercial vehicles operated in the UK. The test consisted of two-week baseline period and two-week data collection period.</td>
<td>Vagg et al. 2013</td>
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<tr>
<td>An informative eco-driving assistance system was found to have a statistically significant impact on fuel consumption while an intervening system was found to have no statistically significant impact. The results suggest that an informative system may be more effective in influencing driver behaviour.</td>
<td>The results are based on driving simulator tests carried out during three days with 12 test drivers. The test drivers were divided into two groups: the group using an informative eco-driving assistance system and the group using an intervening system.</td>
<td>Nozaki et al. 2012</td>
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<td>Eco-driving system implemented as a mobile application was used by drivers using a company car. Fuel consumption was reduced by 2.2% on average. At the same time, fuel consumption in the control group increased by 1.03%. The difference in fuel consumption between treatment and control groups was statistically significant.</td>
<td>The results of the study were obtained in a field test which involved 50 corporate car drivers and a data collection period of eight weeks. Fuel consumption data recorded before the field test was used as a baseline. The participants were divided into treatment and control groups (25 drivers each). The system under analysis was an eco-driving assistance system implemented as a mobile application.</td>
<td>Tulusan et al. 2012</td>
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<td>Drivers’ mental workloads were found to be higher when changing CDs and or during a navigation task than in a scenario in which the driver was receiving eco-driving messages to a PDA mounted in the vehicle. The authors concluded that the eco-driving message presents a distraction risk to drivers but the risk is lower than for tasks which involve both manual and cognitive demands.</td>
<td>The results are based on a simulator study with 22 participants and comparison of baseline, eco-driving and two other distraction scenarios using repeated measures mixed ANOVA tests.</td>
<td>Rouzikah et al. 2012</td>
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<tr>
<td>Eco-driving strategies involving smooth acceleration may increase emissions and travel times in urban intersections in high-demand conditions because of slower queue discharge rate and interactions between eco-driving and other vehicles.</td>
<td>The results are based on a simulation model which was calibrated with real traffic data. The simulation model was applied to a four-leg junction.</td>
<td>Qian and Chung 2011</td>
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</table>
Drivers will be less able to use eco-driving style when the traffic environment is highly demanding such as in residential areas and during critical situations. Time pressure was also found to reduce the performance in fuel consumption was observed on only one of the four test routes and a reduction in NOx, CO and HC emissions on two of the four test routes.

Gear shift indicator reduced CO2 emissions of two test vehicles by 4.16% and 6.68%. For the third test vehicle, a negligible increase in the emissions (0.07%) was observed.

An in-vehicle acceleration advisory tool was found to have an impact on accelerating behaviour of drivers. However, a statistically significant reduction (-4%) in fuel consumption was observed on only one of the four test routes and a reduction in NOx, CO and HC emissions on two of the four test routes.

Gear shift indicator has been found to reduce fuel consumption and CO2 emissions by 3–5% over the standard legislative driving cycle (MVEG-B). Impacts on CO2 emissions and fuel consumption were significant also over the real-world driving cycles (CADC urban and rural): reduction in fuel consumption and CO2 emissions was 7% for petrol cars over the urban part of the CADC and 11% over the rural part of the CADC (4% and 6% for diesel cars). For some petrol cars, the shifting according to gear shift indicator increased NOx emissions. For diesel cars with no particle filter, particle emissions increased by 15–30%. Eco-driving was found to reduce CO2 emissions and fuel consumption by 7% for petrol cars and by about 8–10% for diesel cars.

Table 10. Studies on the impacts of Blind spot monitoring (Kulma and Öörni 2012, iMobility Effects Database).

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<th>Impacts</th>
<th>Methods</th>
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<tr>
<td>No direct statistical relationship between implementation of eco-driving by the followed cars and overtaking behaviour of the following car was found in this study. However, following cars were found to be more likely to overtake when the followed vehicle implementing eco-driving was marked with a sticker.</td>
<td>A field experiment with 15 vehicles implementing eco-driving was carried out in Japan to study the effect of eco-driving on overtaking behaviour of the following car.</td>
<td>Ando and Nishihori 2011</td>
</tr>
<tr>
<td>Drivers will be less able to use eco-driving style when the traffic environment is highly demanding such as in residential areas and during critical situations. Time pressure was also found to reduce the performance in fuel saving goal for the group which had to manage both time saving and fuel saving goals. No adverse effects on safety were observed.</td>
<td>The results of the study are based on tests carried out in a driving simulator with 36 participants. A group of drivers with safety and fuel saving goals was compared with drivers with safety, fuel saving and time saving goals.</td>
<td>Dogan et al. 2011</td>
</tr>
<tr>
<td>Gear shift indicator reduced CO2 emissions of two test vehicles by 4.16% and 6.68%. For the third test vehicle, a negligible increase in the emissions (0.07%) was observed.</td>
<td>The results are based on measurement of CO2 emissions in a dynamometer test over the new European driving cycle (NEDC). The reduction in emissions was studied by taking the test with gear shift points defined in NEDC and gear shift points recommended by the gear shift indicator.</td>
<td>Norris et al. 2010</td>
</tr>
<tr>
<td>An in-vehicle acceleration advisory tool was found to have an impact on accelerating behaviour of drivers. However, a statistically significant reduction (-4%) in fuel consumption was observed on only one of the four test routes and a reduction in NOx, CO and HC emissions on two of the four test routes.</td>
<td>The results of the study are based on a before and after study which involved four cars driven by 20 drivers during six weeks. The test was carried out with postal vehicles in Southern Sweden.</td>
<td>Larsson and Ericsson 2009</td>
</tr>
<tr>
<td>Gear shift indicator has been found to reduce fuel consumption and CO2 emissions by 3–5 % over the standard legislative driving cycle (MVEG-B). Impacts on CO2 emissions and fuel consumption were significant also over the real-world driving cycles (CADC urban and rural): reduction in fuel consumption and CO2 emissions was 7% for petrol cars over the urban part of the CADC and 11% over the rural part of the CADC (4% and 6% for diesel cars). For some petrol cars, the shifting according to gear shift indicator increased NOx emissions. For diesel cars with no particle filter, particle emissions increased by 15–30%. Eco-driving was found to reduce CO2 emissions and fuel consumption by 7% for petrol cars and by about 8–10% for diesel cars.</td>
<td>The results are based on field tests carried out in the Netherlands. The reduction in CO2 mentioned in the results was achieved when eco-driving tips were applied correctly under average Dutch urban and rural traffic conditions. The driving cycle representing eco-driving was recorded in real traffic environment, and emission measurements were carried out in laboratory environment.</td>
<td>Vermeulen 2006</td>
</tr>
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</table>

The results suggest that the effects of the system may be dependent on the drivers age. Older vehicle owners reported checking side mirrors while changing lanes with blind spot monitoring more often than younger vehicle owners.

The system reduced driving speed when negotiating curves. Lane choice and lane changes also improved when the system was active. No effects on speed limit compliance or driving speed in general were found. When the system was active, test drivers made turns at intersections with too high speeds. More errors with dangerous distance to the side were also observed when the system was active. The only difference in drivers’ emotional state was the increased level of irritation when driving with the system active.

The system reduced measuring driving speed when negotiating curves. Lane choice and lane changes also improved when the system was active. No effects on speed limit compliance or driving speed in general were found. When the system was active, test drivers made turns at intersections with too high speeds. More errors with dangerous distance to the side were also observed when the system was active. The only difference in drivers’ emotional state was the increased level of irritation when driving with the system active.

The impacts of the system were measured with test drives in which 24 drivers participated. The test drivers drove the test route twice serving as their own controls. In addition to automated driver monitoring, driver behaviour was observed using the Wiener Fahrprobe method. The drivers’ comprehension of the system and reactions to the functions were studied with a questionnaire.
<table>
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<th>Impacts</th>
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<tr>
<td>The study analysed the impact of a blind spot monitoring system installed in heavy trucks. The average number of safety critical events per 10,000 miles was reduced from 3.50 to 2.55 (-27%). The results were statistically significant at the p-level=0.0539.</td>
<td>The results are based on a field test carried out with heavy trucks in the US (N=19). The number of safety related events (e.g. conflicts and hard braking manoeuvres) was compared between the baseline (two months) and intervention periods (four months).</td>
<td>Schaudt et al. 2014</td>
</tr>
<tr>
<td>The results suggest that a haptic blind spot warning through steering wheel would be more effective than a haptic warning through seat belt.</td>
<td>The results are based on a simulator experiment with 24 participants and statistical analysis of collision prevention rate and the minimum distance by which a collision was avoided.</td>
<td>Chun et al. 2013</td>
</tr>
<tr>
<td>Use of turn signal was reduced by approximately 10% when a blind spot information system was in use. Only few relevant incidents (near-crash events) could be identified during the field test, and no statistically significant difference between baseline (driving without the system) and treatment period (driving with a blind spot information system) could be found.</td>
<td>The results are based on data collected with a field operational test in Sweden. The study involved a baseline period of three months and a test period of nine months.</td>
<td>Malta et al. 2012</td>
</tr>
<tr>
<td>Blind spot monitoring system was found to reduce the frequency of injury claims from insurance company (-3.6% for bodily injury liability, -26.5% for medical payments and -7.2% for personal injury protection) but the reductions of the frequencies of various types of claims were not statistically significant.</td>
<td>The results are based on a regression analysis made for a data set collected from insurance companies in USA. Vehicles of the same model year not equipped with the system were used as a control group.</td>
<td>Highway Loss Data Institute 2012b</td>
</tr>
<tr>
<td>Blind spot monitoring system was found to reduce the frequency of property damage liability claims by 2.4% although the result was not statistically significant. The results indicated a 1.3% increase in the frequency of collision insurance claims and a reduction of 159$ in the average severity of the claims. The reduction in the severity of claims was statistically significant. Results for impacts on injuries were partly contradictory and not statistically significant.</td>
<td>The results are based on a regression analysis made for a data set collected from insurance companies in USA. Vehicles of the same make and model year were used as a control group.</td>
<td>Highway Loss Data Institute 2012a</td>
</tr>
<tr>
<td>Blind spot monitoring systems were found to have potential to prevent or mitigate 393 fatal accidents and 20,000 injury accidents annually in USA.</td>
<td>Databases of accidents reported by the police were used to identify accidents which could have been prevented or mitigated. The study analysed only the potential the systems have to prevent accidents but not their effectiveness.</td>
<td>Jermakian 2011</td>
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<tr>
<td>The integrated crash warning system increased turn signal use in the treatment period. No negative behavioural adaptation effects related to involvement in secondary tasks were observed.</td>
<td>The impacts of an integrated driver assistance system were studied with a field test. The field operational test involved 108 passenger car drivers and a testing period of 40 days of which the first 12 days served as baseline.</td>
<td>Sayer et al 2011a</td>
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<tr>
<td>The integrated warning system was found to have a statistically significant but small effect on lateral offset (distance between lane centreline and vehicle centreline). On limited access roads, drivers maintained a position slightly closer to the centre of the lane.</td>
<td>The results are based on a field test in which a fleet of 10 heavy trucks was equipped with an integrated warning system. The field test involved 18 drivers and included a testing period of 10 months of which two months served as baseline period.</td>
<td>Sayer et al. 2010</td>
</tr>
<tr>
<td>Blind spot detection/Lane change warning was found to have potential to prevent 5.0% of crashes involving large trucks included in the LTCCS database</td>
<td>The estimates are based on the Large Truck Crash Causation Study (LTCCS), 2001–2003, which conducted on-scene investigations for real-world crashes. This data (N=1070) was used to make case by case estimations of the applicability of crash avoidance countermeasures for each crash.</td>
<td>Kingsley 2009</td>
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Table 11. Studies on the impacts of Lane keeping support (Kulmala and Öörni 2012, iMobility Effects Database).

<table>
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<tr>
<th>Impacts</th>
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<tr>
<td>An in-vehicle information system providing frontal collision warning,</td>
<td>The results are based on a field test with an instrumented vehicle on</td>
<td>Birrell et al. 2014</td>
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<td>lane departure warning, gear change advice and braking and acceleration</td>
<td>a fixed driving route in central England with 33 participants. The test</td>
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<td>advice was found to reduce fuel consumption by 3.7% (miles per gallon</td>
<td>route included three different road categories: &quot;motorway&quot;, &quot;urban&quot; and</td>
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<td>of fuel spent increased by 4.1% between control and experimental</td>
<td>&quot;inter-urban&quot;. The test results were recorded for each participant both</td>
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<td>conditions, from 54.8 to 57.0). The mean headway to the vehicle in</td>
<td>in control and experimental conditions.</td>
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<td>front increased from 2.05 s to 2.33 s. The time spent traveling closer</td>
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<td>than 1.5 s to the vehicle in front was reduced by two thirds. These</td>
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<td>results were statistically significant. No increase in travel time,</td>
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<td>reduction in average speed or adverse impacts on distraction related</td>
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<td>parameters, such as lane deviations, were observed. The mean number of</td>
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<td>lane deviations and near deviations reduced from 17.7 in control</td>
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<td>condition to 15.5 in experimental condition. However, this difference</td>
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<td>was not statistically significant.</td>
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<td>The results are based on a field operational test in Sweden. The study</td>
<td>Malta et al. 2012</td>
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<td>involved a baseline period of three months and a test period of nine</td>
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<td>months.</td>
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<td>Lane departure warning system was implemented together with an</td>
<td>The study results are based on a field test with before-and-after</td>
<td>Nodine et al. 2011a</td>
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<td>impairment warning system (system which attracts the attention of</td>
<td>setting. The field test lasted six weeks for each participant (two</td>
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<td>the driver when he or she starts to drive less consistently e.g.</td>
<td>weeks of baseline and four weeks of driving with the system active). The</td>
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<td>because of distraction or drowsiness). The combined system was</td>
<td>field test involved 108 test subjects and a fleet of 16 passenger cars</td>
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<td>found to increase turn signal usage by 10% and reduce crash relevant</td>
<td>equipped with the system. A statistical analysis was performed for the</td>
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<td>events by about 9%. The system was also concluded to improve drivers'</td>
<td>test results. The estimation of safety impacts is based on the</td>
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<td>lateral control of vehicle: mean steering wheel angle was reduced by</td>
<td>observed number of near accident events during baseline and test</td>
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<td>15%.</td>
<td>periods.</td>
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<td>The lane departure warning would reduce the number of fatalities by</td>
<td>Robinson et al. 2011</td>
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<td>15-60 in a year in UK with 100% fleet penetration. Reduction in the</td>
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<td>number of serious injuries was estimated to be between 578 and 1,581 in</td>
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<td>a year.</td>
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<td>Jermakian 2011</td>
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<td>Databases of accidents reported by the police were used to identify</td>
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<td>accidents which could have been prevented or mitigated. The study</td>
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<td>analysed only the potential the systems have to prevent accidents but</td>
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<td>not their effectiveness.</td>
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### Impacts

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<td>The integrated system was found to have statistically significant effect on the number of lane departures (decrease from 14.6 to 7.6 departures per 100 miles) and the mean duration of lane departures (decrease from 1.98 to 1.66 seconds). Drivers were also found to be less likely to make unsignaled lane changes and more likely to make lane changes (12.6% increase) when the system was active.</td>
<td>The impacts of an integrated driver assistance system were studied with a field test. The field operational test involved 108 passenger car drivers and a testing period of 40 days of which the first 12 days served as baseline.</td>
<td>Sayer et al. 2011b.</td>
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<tr>
<td>Reduction in the number of lane excursions (partial or incomplete lane changes) was observed. The number of lane changes was reduced by 9% at lower speeds and by 15% with higher speeds. Lane departure warning functionality included in the system was found to have potential to prevent at most 8,000 truck crashes annually in the USA if fully deployed in truck fleet.</td>
<td>The results are based on a field test in which a fleet of 10 heavy trucks was equipped with an integrated warning system. The field test involved 18 drivers and included a testing period of 10 months of which two months served as baseline period.</td>
<td>Nodine et al. 2011b</td>
</tr>
<tr>
<td>Lane departure warning systems were estimated to reduce the number of fatalities by 7% in Australia and reduce the number of injuries by 4,177 in a year.</td>
<td>The proportion of relevant accidents was estimated by analysing police-reported crash data in New South Wales between 1999–2008. The benefit estimates were then applied to all crashes in Australia.</td>
<td>Anderson et al. 2011</td>
</tr>
<tr>
<td>An adaptive lane departure warning system was compared against non-adaptive lane departure warning system. In the adaptive LDW mode, 13 test drivers (13%) either experienced delayed activation of the system or received no warning at all when they should have received one.</td>
<td>The results are based on a test in a driving simulator with 40 drivers.</td>
<td>Tijerina et al. 2010</td>
</tr>
<tr>
<td>Drivers equipped with the system maintained lane positions slightly closer to the centre of the lane. The integrated crash warning system was found to have no statistically significant effect on, turn signal use on lane changes or frequency of lane changes. A reduction in lane departure frequency was observed for most of the drivers but the reduction was not statistically significant. No increase in the frequency of involvement in secondary tasks was observed.</td>
<td>The results are based on a field test in which a fleet of 10 heavy trucks was equipped with an integrated warning system. The field test involved 18 drivers and included a testing period of 10 months of which two months served as baseline period.</td>
<td>Sayer et al. 2010</td>
</tr>
<tr>
<td>Lane departure warning was found to have potential to prevent 6.1% of crashes involving large trucks included in the LTCCS database.</td>
<td>The estimates are based on the Large Truck Crash Causation Study (LTCCS), 2001–2003, which conducted on-scene investigations for real-world crashes. This data (N=1070) was used to make case by case estimations of the applicability of crash avoidance countermeasures for each crash.</td>
<td>Kingsley 2009</td>
</tr>
<tr>
<td>A collision mitigation braking system which is able to collect information about the environment around the vehicle, warn the driver, and perform a braking manoeuvre could have prevented 17.8% of all accidents involving personal injury in the data sample. The corresponding safety potential of a lateral guidance system consisting of lane keeping assistant and lane change assistant was estimated to be up to 7.3%. It was estimated that a car fleet equipped with both lateral guidance and collision mitigation braking system could have avoided up to 25.1% of all accidents included in the data sample.</td>
<td>The results are based on an in-depth analysis of a sample of 2 025 accidents taken from a database maintained by German Insurers Accident Research (UDV).</td>
<td>Kuehn et al. 2009</td>
</tr>
<tr>
<td>Lane departure warning systems reduce the number of accidents and accident-related congestion. The impact on the CO2 emissions was estimated to be 0.008% in Europe.</td>
<td>The impact on the CO2 emissions has been estimated on the basis of safety impact estimates provided by the eIMPACT project and assumptions made by the authors.</td>
<td>Klunder et al. 2009.</td>
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</table>
Lane keeping support would reduce the number of fatalities by 15.2% and number of injuries by 8.9% in Europe if fully deployed in the vehicle fleet. The results are based on the analysis of expected impacts on driver behaviour, identification of relevant accidents on the basis of accident statistics available and estimation of the most probable safety impact of these two sources. Wilmink et al. 2008

Intelligent vehicles with automatic cruise control and lane departure warning system reduce the number of accidents by 8% save 3% of fuel. When driving with ACC and LDW, emissions were reduced up to 10%. The report is a literature study. The results have been obtained in a Dutch field test. Reinhardt and Kompfner 2007

The number of unintentional lane crossings decreased with 35 % on secondary roads and on highways because of lane departure warning. Drivers also kept better course to prevent warnings. A field operational test with 20 cars conducted in the Netherlands Alkim et al. 2007

Lane departure warning system was estimated to reduce the number of single vehicle road departure crashes by 17-19 % and the number of rollover crashes by 17-23 % when applied in large trucks (> 10 000 lbs). The results are based on a 12 months long field operational test involving 22 trucks. Orban et al. 2006

25% reduction in accident number and 25% reduction of accident severity in head-on collisions. 25% reduction in accident number and 15% reduction of accident severity in left-roadway accidents. 60 % reduction in the number of accidents and a 10 % reduction in accident severity for side collisions. Estimates are based on accident statistics assuming a 0.5 sec quicker reaction to lane departure. Abele et al. 2004

Lane departure warning systems installed in heavy goods vehicles would decrease the number of accidents involving heavy goods vehicles by 10% Trial involving 40 professional drivers and 36 heavy duty vehicles. Korste 2003

Table 12. Studies on the impacts of Obstacle and collision warning (Kulmala and Öörimä 2012, iMobility Effects Database).

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<th>Impacts</th>
<th>Methods</th>
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<td>The study analysed the impact of drivers' expectations on brake reaction time when using a forward collision warning system. The brake reaction time was about 0.48 s shorter when the warning system provided information that fulfilled the driver’s expectation in comparison to a situation with no information. When the warning system provided misleading or incomplete anticipatory information, brake reaction time was about 0.19 s longer. When the warning system failed to indicate a danger, brake reaction times were about 0.29 s longer.</td>
<td>The study was carried out with an instrumented vehicle on a test track. The study involved 32 participants and six experimental conditions. The results were analysed with the repeated measure ANOVA method.</td>
<td>Ruscio et al. 2015</td>
</tr>
<tr>
<td>A larger share of younger drivers reported benefits of the system and experiencing at least one situation in which the system prevented a collision than older drivers. Younger drivers also more frequently reported to follow the leading vehicle less closely and to look away from the road less frequently.</td>
<td>The results are based on a questionnaire disseminated to owners of vehicles equipped with the system in the US. 215 responses were received and analysed.</td>
<td>Cicchino and McCartt 2015</td>
</tr>
<tr>
<td>The system reduced driving speed when negotiating curves. Lane choice and lane changes also improved when the system was active. No effects on speed limit compliance or driving speed in general were found. When the system was active, test drivers made turns at intersections with too high speeds. More errors with dangerous distance to the side were also observed when the system was active. The only difference in drivers' emotional state was the increased level of irritation when driving with the system active.</td>
<td>The impacts of the system were measured with test drives in which 24 drivers participated. The test drivers drove the test route twice serving as their own controls. In addition to automated driver monitoring, driver behaviour was observed using the Wiener Fahrprobe method. The drivers’ comprehension of the system and reactions to the functions were studied with a questionnaire.</td>
<td>Várhegyi et al. 2015</td>
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<tr>
<td>An in-vehicle information system providing frontal collision warning, lane departure warning, gear change advice and braking and acceleration advice was found to reduce fuel consumption by 3.7% (miles per gallon of fuel spent increased by 4.1% between control and experimental conditions, from 54.8 to 57.0). The mean headway to the vehicle in front increased from 2.05 s to 2.33 s. The time spent traveling closer than 1.5 s to the vehicle in front was reduced by two thirds. These results were statistically significant. No increase in travel time, reduction in average speed or adverse impacts on distraction related parameters, such as lane deviations, were observed. The mean number of lane deviations and near deviations reduced from 17.7 in control condition to 15.5 in experimental condition. However, this difference was not statistically significant.</td>
<td>The results are based on a field test with an instrumented vehicle on a fixed driving route in central England with 33 participants. The test route included three different road categories: motorway, urban and inter-urban. The test results were recorded for each participant both in control and experimental conditions.</td>
<td>Birrell et al. 2014</td>
</tr>
<tr>
<td>Drivers having experience of using Adaptive Cruise Control (ACC) responded more quickly to cut-in events than drivers having no experience with the system. Both experienced and unexperienced users responded more slowly to cut-in events when driving with the system compared to manual driving.</td>
<td>The study was carried out in a driving simulator with two driver groups; drivers experienced with using ACC and drivers with no experience. The analysed results included data from 31 drivers, of whom 29 drove all the included scenarios: manual driving, intentional car following, ACC and ACC with assisted steering.</td>
<td>Larsson et al. 2014</td>
</tr>
<tr>
<td>A system providing congestion tail warnings on motorways was found to increase maximum driving speed, decrease minimum time-to-collision when following a vehicle in free-flow traffic and increased intensity of performing secondary task when compared to driving without assistance. The results concerning speed and headways were not considered critical, because the values of these variables did not cross critical safety thresholds. The increased secondary task involvement was considered potentially critical to safety.</td>
<td>The results are based on a simulator study which involved 16 participants and comparison of driving with and without assistance.</td>
<td>Bueno et al. 2014</td>
</tr>
<tr>
<td>ACC increased average time-headways by about 16% on motorways. The system also reduced fuel consumption on motorways by 2.77% when activated and by 1.37% on average (with 49.4% usage rate).</td>
<td>The results have been obtained in a field operational test done in Germany. The field operational test involved 100 vehicles, baseline period of three months and test period of eight months.</td>
<td>Benmimoun et al. 2013a</td>
</tr>
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<td>Warning of a forward collision was found to reduce the reaction time of the driver when braking was necessary. The results suggested that the reduction in driver reaction time was due to reduction of the time needed to process the visual target at higher cognitive level.</td>
<td>The results are based on a study in a simplified driving simulator with 12 test subjects, recording of the driving manoeuvres of the test drivers and analysis of electrophysiological data collected during the test.</td>
<td>Buenoa et al. 2013</td>
</tr>
<tr>
<td>The paper analysed the effect of ACC and FCW on safety and environment. Combined system including both ACC and FCW increased average time-headways between vehicles by 16% on motorways. Correspondingly, the number of critical time-headways (less than 0.5 s) was reduced by 73% and number of harsh braking events by 67%. ACC was also found to reduce fuel consumption by 2.77% on motorways for equipped vehicles and when the system was active. With the usage rate (49.4%) observed in the study, ACC was estimated to have potential to reduce fuel consumption of passenger cars by 1.37% on motorways.</td>
<td>The results have been obtained in a field operational test which involved 100 passenger cars, baseline period of three months and treatment period of nine months. No conclusions on the statistical significance of the results are made, and no confidence intervals have been calculated.</td>
<td>Benmimoun et al. 2013b</td>
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<td>ACC has been estimated to reduce the number of injury accidents in EU27 countries by 2.2 - 5.8% on motorways, 0.47 - 0.65% on rural roads and 0.14% in urban environments.</td>
<td>The results are based on data obtained in two field operational tests organised in Sweden and in Germany. The study involved a baseline period of three months and a test period of nine months.</td>
<td>Malta et al. 2012</td>
</tr>
<tr>
<td>The study analysed the braking behaviour of car drivers: whether the driver lets the ACC to brake or whether the driver intervenes by braking manually. The use of the automatic braking feature of ACC was found to be more frequent with longer headway settings. The drivers also intervened less frequently on roads with higher speed limit than roads with a lower one.</td>
<td>The results are based on a data set which includes data of 66 drivers. The data set was collected with a field test lasting three weeks.</td>
<td>Xiong and Boyle 2012</td>
</tr>
<tr>
<td>Adaptive cruise control system including a forward collision warning and collision mitigating braking functionality (Mercedes-Benz Distronic Plus) was found to reduce the frequency of collision insurance claims by 7.1% and reduce property damage liability claims by 14.3%. Both results were statistically significant. The system also reduced the frequency of injury claims (for example, 16% reduction in the frequency of bodily injury liability claims) but these results were not statistically significant.</td>
<td>The results are based on a regression analysis made for a data set collected from insurance companies in USA. Vehicles of the same model year not equipped with the system were used as a control group.</td>
<td>Highway Loss Data Institute 2012b.</td>
</tr>
<tr>
<td>An integrated warning system including a forward collision warning, curve speed warning, lane change/merge warning and lane departure warning was implemented and tested. A small reduction in the time headway was observed when driving over 40 km/h in non-freeway conditions and the system was active. Drivers showed a statistically significant increase in proportion of lane changes where the turn signal was used (62% during baseline and 75% during test period). Lane excursions decreased by 21% and the duration of lane excursions was also shorter. There was no statistically significant difference in drivers' involvement of secondary tasks. A statistically significant decrease in near accident events was observed: there was a 33% reduction in the rate of lane change near accidents and 19% reduction in road departure near accidents. The functions involved in the system were estimated to reduce the corresponding types of relevant accidents by 6-29%.</td>
<td>The study results are based on field test with before-and-after setting. The field test lasted six weeks for each participant (two weeks of baseline and four weeks of driving with the system active). The field test involved 108 test subjects and a fleet of 16 passenger cars equipped with the system. A statistical analysis was performed for the test results. The estimation of safety impacts is based on the observed number of near accident events during baseline and test periods.</td>
<td>Nodine et al. 2011a</td>
</tr>
<tr>
<td>The SASPENCE system evaluated in the study had both obstacle and collision warning and speed alert features. The system was found to have positive effect in terms of traffic safety on driver reaction times, increased headway and interactions with vulnerable road users at intersections. The system had negative effects on driver performance, facilitating behaviour and braking behaviour at traffic lights, and it increased the number of centre line crossings. Improvements achieved with the system were considered to outweigh the observed negative behavioural adaptation effects.</td>
<td>The results are based on field test with 19 test drivers, and each of them driving a test route with length of 50 km. Information was collected with in-vehicle observations, logging of driver reactions and system status and a questionnaire answered by test drivers.</td>
<td>Adell et al. 2011.</td>
</tr>
<tr>
<td>Forward collision warning/mitigation system was found to have potential to prevent or mitigate up to 20% of 5.8 million police-reported crashes each year in USA. The system could potentially prevent or mitigate 66,000 non-fatal serious and moderate injury accidents and 879 fatal accidents each year.</td>
<td>Databases of accidents reported by the police were used to identify accidents which could have been prevented or mitigated. The study analysed only the potential the systems have to prevent accidents but not their effectiveness.</td>
<td>Jermakian 2011</td>
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<td>For passenger vehicles, the integrated system was found to have no effect on forward conflict levels when approaching preceding vehicles, and no effect on hard braking manoeuvres was observed. For heavy trucks, a positive effect on driver reaction times and brake reaction times to forward conflicts was observed.</td>
<td>The impacts of an integrated driver assistance system were studied with a field test. The field operational test involved 108 passenger car drivers and a testing period of 40 days of which the first 12 days served as baseline.</td>
<td>Sayer et al. 2011b</td>
</tr>
<tr>
<td>Adaptive cruise control system with automatic braking functionality was estimated to reduce the number of fatal accidents by 7% and the number of injury accidents by 4% in case of cars. When this estimate was calculated, the system was assumed to be effective only for accidents happening with speeds larger than 60 km/h. Corresponding accident reductions for a system effective across all vehicle speeds were estimated to be 12% and 25%.</td>
<td>The proportion of relevant accidents was estimated by analysing police-reported crash data in New South Wales between 1999 and 2008. The system was assumed to prevent a large share of narrowly defined relevant accidents and a smaller share of other possibly relevant accidents. The benefit estimates were then applied to all crashes in Australia.</td>
<td>Anderson et al. 2011</td>
</tr>
<tr>
<td>Forward collision warning was found to have potential to prevent 23.8% of crashes involving large trucks included in the LTCCS database.</td>
<td>The estimates are based on the Large Truck Crash Causation Study (LTCCS), 2001–2003, which conducted on-scene investigations for real-world crashes. This data (N=1070) was used to make case by case estimations of the applicability of crash avoidance countermeasures for each crash.</td>
<td>Kingsley 2009</td>
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<tr>
<td>Reduction of 5-10% of CO2 emissions for cruise control systems is mentioned in the literature. For automatic cruise control, reductions of 0.5-5% in CO2 emissions have been reported.</td>
<td>The results are based on a literature study.</td>
<td>Klunder et al. 2009</td>
</tr>
<tr>
<td>A normal driver is able to avoid a collision with a vehicle in front in 8 percent of all cases thanks to Brake Assist (classic). A normal driver is able to avoid a collision with a vehicle in front in 20 percent of all cases and to reduce the severity in an additional 25 percent thanks to DISTRONIC PLUS (ACC, collision warning) and BAS PLUS (enhanced braking assist). A normal driver is able to avoid or mitigate each second collision with a vehicle in front respectively each fourth with a vehicle behind thanks to the DRISTONIC PLUS (ACC, collision warning, brake assist, emergency braking, parking support) package.</td>
<td>Accident causation study based on German GIDAS statistics as well as data mining of spare parts logistics for Daimler.</td>
<td>Schittenhelm 2009</td>
</tr>
<tr>
<td>Both unadaptive and adaptive forward colliding warning (FCW) systems benefited driver safety in rural conditions. When the system was functional, brake reaction time was reduced and during the braking events, drivers remained further from a collision with a lead vehicle. Neither sensation seeking nor an individual driver’s brake reaction time affected the speed of their response to the traffic events. Benefits of the adaptive system were demonstrated for aggressive drivers (high sensation seeking, short followers). The aggressive drivers rated each FCW more poorly than their non-aggressive contemporaries. However, this group, with their greater risk of involvement in rear-end collisions, reported a preference for the adaptive system as they found it less irritating and stress-inducing. Achieving greater acceptance and hence likely use of a real system is fundamental to good quality FCW design.</td>
<td>A driving simulator study involving 45 drivers.</td>
<td>Jamson et al. 2008</td>
</tr>
</tbody>
</table>
A statistically significant 28% reduction in rear-end crashes related to the deployment of the three analysed safety systems was found. However, the largest share of this benefit came from the effect of collision warning system (CWS).

The safety effects were based on the frequency and severity of rear-end conflicts encountered during the field operational test. The field operational test involved a baseline fleet of 20 vehicles, the control fleet of 50 vehicles equipped with a collision warning system (CWS) and the test fleet of 50 vehicles equipped with both CWS, adaptive cruise control (ACC) and electronically controlled brake system (ECBS).

Intelligent vehicles with automatic cruise control and lane departure warning system reduced accidents by 8% (Dutch Field test) and saved 3% of fuel. The system reduced emissions by up to 60% less pollution in specific situations. In general, emissions decreased by up to 10% when driving with ACC and LDW.

The report is a literature study. The results are based on a Dutch field test.

Automatic collision avoidance system, as an integrated system of forward collision warning and automatic cruise control functions, has the potential to prevent about 6 to 15 percent of all rear-end crashes depending on the source of crash data used for safety benefits estimation. This system effectiveness ranges between 3 and 26 percent according to 95 percent confidence bounds.

The results are based on data collected from a field operational test involving 10 vehicles and 66 drivers and on a system characterization test.

The possibilities of current ACC systems in improving traffic safety and reducing congestion seem limited: although positive effects on driver safety and traffic safety were found, some negative effects are a cause for concern. The ACC systems should be extended with a Stop-and-Go functionality and preferably also with collision warning or collision avoidance capabilities.

The results presented were based on a literature study on subject.

Effectiveness of Forward Obstacles Collision Warning Systems using the in-vehicle information and the roadside information was evaluated introducing the velocity at 100m point forward the obstacle as a new evaluation criteria. As the results, it was clarified that the integrated road side/in-vehicle information has significant effectiveness.

Simulator studies

A collision warning system based on the prediction of driver's braking action was developed. Results of the study are based on field experiments with 18 people.

Results of the study are based on measurements of reaction time and some measurements in real traffic situations.

Without warning, the braking time increases as the awareness level decreases. A warning system that can compensate for a decline in driver perceptual ability caused by sleepiness is effective.

Table 13. Studies on the impacts of Emergency braking (Kulmala and Öörni 2012, iMobility Effects Database).

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<tr>
<td>Autonomous emergency braking was estimated to reduce the number of rear-end accidents by 38%.</td>
<td>The results are based on analysis of real-world accident data with a meta-analysis approach combined with the induced exposure method. The study involved analysis of accident data in six countries of which most were located in Europe.</td>
<td>Fildes et al. 2015</td>
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<tr>
<td>Impacts</td>
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<td>According to a preliminary benefit estimate of NHTSA, a system including forward collision warning, dynamic brake support and crash imminent braking functionalities will reduce the number of fatalities by 100 and the number of serious injuries by 4,000 in the US, if installed in all light vehicles.</td>
<td>The reduction in injuries and fatalities was estimated by combining the expected reduction in collision speed for various types of accidents achieved with the system with the statistics of police reported accidents in the US.</td>
<td>US DOT 2014.</td>
</tr>
<tr>
<td>Automatic emergency braking system combined with brake assist was estimated to reduce fatal pedestrian accidents by 15.3% and pedestrian accidents with serious injury by 38.2% in France. This corresponds to 1.3% of all fatal accidents and 3.8% of accidents with a serious injury in France. This estimate applies to a system with 100% fleet penetration in passenger vehicles and a system with 100% reliability.</td>
<td>The results are based on a case-by-case analysis of pedestrian accidents in six European countries. The results were extrapolated to French conditions using French data on pedestrian accidents. The system analysed in the study was assumed to operate with reliability of 100% and be effective for all road types and weather conditions.</td>
<td>Chauvel et al. 2013</td>
</tr>
<tr>
<td>The analysis showed that drivers allocated their attention towards the roadway and braked immediately after receiving a forward collision warning. After a few seconds after the warning, drivers’ eye movements directed away from the roadway towards the source of the warning in the instrument cluster.</td>
<td>The results are based on analysis of 60 naturally occurred collision warning events, 27 valid events during the baseline period and 33 valid events during the treatment period. The data analysed in the paper was collected in naturalistic setting collected in the EuroFOT project. The analysed data consists of 20 Dutch truck drivers.</td>
<td>Wege et al. 2013</td>
</tr>
<tr>
<td>The results of forward collision warning were partly inconclusive. However, the results indicated a negative automation effect: the test drivers maintained higher mean speeds with the forward collision warning (with emergency braking) when no unexpected events (such as the lead car braking hard) were present.</td>
<td>The results are based on driving simulator tests with 30 participants and statistical analysis of test results.</td>
<td>Muhrer et al. 2012</td>
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<tr>
<td>Automatic emergency braking system was estimated to reduce the number of fatalities by 30% in accidents in which the front of the car impacts another vehicle.</td>
<td>The result is based on an in-depth analysis of a sample of 100 fatal accidents involving the front of a car impacting another vehicle.</td>
<td>Robinson et al. 2011</td>
</tr>
<tr>
<td>Brake assist system was found to reduce the stopping distance during panic braking on average by 1.43 ft (0.436 m) when braking was initiated at speed of 45 mph (72 km/h).</td>
<td>The results are based on test track trials with 64 test drivers.</td>
<td>Klunderet al. 2009</td>
</tr>
<tr>
<td>A collision mitigation braking system which is able to collect information about the environment around the vehicle, warn the driver, and perform a braking manoeuvre could have prevented 17.8% of all accidents involving personal injury in the data sample. The corresponding safety potential of a lateral guidance system consisting of lane keeping assistant and lane change assistant was estimated to be up to 7.3%. It was estimated that a car fleet equipped with both lateral guidance and collision mitigation braking system could have avoided up to 25.1% of all accidents included in the data sample.</td>
<td>The results are based on an in-depth analysis of 2,025 accidents taken from a database maintained by German Insurers Accident Research (UDV).</td>
<td>Kuehn et al. 2009</td>
</tr>
<tr>
<td>Autonomous braking systems like Volvo’s City Safety have been found to have potential to prevent annually 263,250 crashes, mitigate 87,750 and prevent 151,848 injuries corresponding to savings of 2 million euro in a year in repair costs and insurance claims in the UK if standard fleet wide fitment is assumed.</td>
<td>The results are based on data collected on insurance claims, average values of insurance claims and assumptions made by the authors.</td>
<td>Avery and Weeke 2009</td>
</tr>
<tr>
<td>The emergency braking was found to reduce both fatalities and injuries by 7% in EU25, considering also likely behavioural adaptation effects of the system. The system especially addresses rear-end-collisions and collisions against fixed obstacles.</td>
<td>The estimates for the safety impacts are based on synthesis of earlier studies, the power model presented by G&quot;oran Nilsson and assumptions made by the authors.</td>
<td>Wilmink et al. 2008</td>
</tr>
</tbody>
</table>
Emergency brake assist was found to reduce the number of fatalities and injuries by 7.8% and the number of severe injuries and fatalities by 14.6% in case of cars with four stars in Euro NCAP classification. Effectiveness of emergency brake assist in preventing accidents or mitigating their consequences was estimated on the basis of police-reported accident data collected in France for vehicles having four stars in Euro NCAP classification. Cuny et al. 2008

Brake assistance system reduced rear-end collisions by 8%. The system also reduced the severity of accidents involving pedestrians: the proportion of severe accidents of all accidents involving pedestrians was reduced from 36.4% to 31.7%. The estimates are based on a comparison on the numbers of accidents involving Mercedes Benz vehicles registered in years 1996-1997 and 1997-1998. The accident figures were compared for years 1998-1999 for the former and 1999-2000 for the latter group of vehicles. The figures were compiled on the basis of samples of all accidents reported by the police in Germany. Breuer et al. 2007

A statistically significant 28% reduction in rear-end crashes related to the deployment of the three analysed safety systems was found. However, the largest share of this benefit came from the effect of collision warning system (CWS). The safety effects were based on the frequency and severity of rear-end conflicts encountered during the field operational test. The field operational test involved a baseline fleet of 20 vehicles, the control fleet of 50 vehicles equipped with a collision warning system (CWS) and the test fleet of 50 vehicles equipped with both CWS, adaptive cruise control (ACC) and electronically controlled brake system (ECBS). Lehmer et al. 2007

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<td>Effectiveness of emergency brake assist in preventing accidents or mitigating their consequences was estimated on the basis of police-reported accident data collected in France for vehicles having four stars in Euro NCAP classification.</td>
<td>Cuny et al. 2008</td>
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<tr>
<td>Brake assistance system reduced rear-end collisions by 8%. The system also reduced the severity of accidents involving pedestrians: the proportion of severe accidents of all accidents involving pedestrians was reduced from 36.4% to 31.7%.</td>
<td>The estimates are based on a comparison on the numbers of accidents involving Mercedes Benz vehicles registered in years 1996-1997 and 1997-1998. The accident figures were compared for years 1998-1999 for the former and 1999-2000 for the latter group of vehicles. The figures were compiled on the basis of samples of all accidents reported by the police in Germany.</td>
<td>Breuer et al. 2007</td>
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### Table 14. Studies on the impacts of Emergency brake light.

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<th>Impacts</th>
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<tr>
<td>The estimated annual effect on traffic accidents was a decrease of 25–304 fatalities (2.7%) and 1322–16219 injuries (2.5%) (EU-28 year 2030).</td>
<td>Field operational test.</td>
<td>Malone et al. 2014</td>
</tr>
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</table>

### Table 15. Studies on the impacts of Emergency vehicle approaching.

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<th>Impacts</th>
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<tr>
<td>The service was expected to prevent 14–84 fatalities and 933–4954 injuries by 2030 in the EU-28. This corresponds to a 0.8% reduction in both fatalities and injuries. The service was rated to increase the feeling of safety by 5.6-6.0 (on a scale of 1 to 7). The service was viewed as useful by 92% of the participants and 41% had a willingness to pay for the service.</td>
<td>Field operational test. The application was tested in Germany, Italy and Spain. French accident statistics was used for the estimations.</td>
<td>Malone et al. 2014</td>
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### Table 16. Studies on the impacts of Slow or stationary vehicle(s) warning.

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<th>Impacts</th>
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<td>The service was expected to prevent 12–125 fatalities and 427–2794 injuries by 2030 in the EU-28. This corresponds to a 1.1% reduction in fatalities and a 0.7% reduction in injuries</td>
<td>Field operational test. The applications obstacle and roadworks warning was tested in Finland, Sweden, Italy and Spain.</td>
<td>Malone et al. 2014</td>
</tr>
</tbody>
</table>
The estimated average effect on traffic accidents was a 4.5% reduction of fatalities and 2.8% reduction of injuries.

Application "wireless location danger warning". For the safety effects, expert estimations were applied to the accident statistics to scale up the effects on EU-25 level. Penetration rate: 100%.

Wilmink et al. 2008

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<tr>
<td>The estimated average effect on traffic accidents was a 4.5% reduction of fatalities and 2.8% reduction of injuries.</td>
<td>Application &quot;wireless location danger warning&quot;. For the safety effects, expert estimations were applied to the accident statistics to scale up the effects on EU-25 level. Penetration rate: 100%.</td>
<td>Wilmink et al. 2008</td>
</tr>
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</table>

Table 17. Studies on the impacts of Traffic jam ahead warning.

The study showed no impact on traffic efficiency. The estimated annual effect on traffic accidents was a prevention of 193 fatalities (1.7%) and 16 619 injuries (2.5%) (EU-28 year 2030).

Field operational test combined with expert assessments. The effect on traffic efficiency was studied with traffic simulation.

Malone et al. 2014

The estimated average effect on traffic accidents was a 2.4% reduction of fatalities and 2.8% reduction of injuries. When differentiating different road types the reduction on motorways was: 4.9% in injuries and 3.3% in fatalities, on interurban and urban roads: 4.1% in injuries and 2.8% in fatalities and urban roads: 2.0% in injuries and 1.6% in fatalities.

Cost-benefit analysis based on gathered national statistics. Penetration rate: 100%.

Kulmala et al. 2012

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<td>The study showed no impact on traffic efficiency. The estimated annual effect on traffic accidents was a prevention of 193 fatalities (1.7%) and 16 619 injuries (2.5%) (EU-28 year 2030).</td>
<td>Field operational test combined with expert assessments. The effect on traffic efficiency was studied with traffic simulation.</td>
<td>Malone et al. 2014</td>
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Table 18. Studies on the impacts of Hazardous location notification.

The estimated average effect on traffic accidents was a 4.2% reduction of fatalities and 3.1% reduction of injuries.

Impacts assessed for EU-25 for 2030. Based on literature review and data collected in the eIMPACT project.

Kulmala et al. 2008

The impact on traffic efficiency and traffic accidents was estimated to be 2–10% reduction in congestion, fatalities and injuries. No specific scenario or penetration rate was defined.

Literature review

eSafety Forum 2010

The estimated average effect on traffic accidents was a 4.1% reduction of fatalities and 3.1% reduction of injuries. When differentiating different road types the reduction on motorways was: 5.3% in injuries and 5.2% in fatalities, on interurban and urban roads: 5.3% in injuries and 5.3% in fatalities and urban roads: 1.9% in injuries and 1.7% in fatalities.

Cost-benefit analysis based on gathered national statistics. Penetration rate: 100%.

Kulmala et al. 2012

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<th>Impacts</th>
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<tr>
<td>The estimated average effect on traffic accidents was a 4.2% reduction of fatalities and 3.1% reduction of injuries.</td>
<td>Impacts assessed for EU-25 for 2030. Based on literature review and data collected in the eIMPACT project.</td>
<td>Kulmala et al. 2008</td>
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</table>

Table 19. Studies on the impacts of Road works warning.

The estimated effect on traffic accidents was a prevention of 209 fatalities (1.9% decrease) and 9 939 injuries (1.5% decrease) (EU-28 year 2030).

Field operational test combined with expert assessments. Assessed through the applications "obstacle warning" and "car breakdown warning". Penetration rate: 76%.

Malone et al. 2014

<table>
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<tr>
<td>The estimated effect on traffic accidents was a prevention of 209 fatalities (1.9% decrease) and 9 939 injuries (1.5% decrease) (EU-28 year 2030).</td>
<td>Field operational test combined with expert assessments. Assessed through the applications &quot;obstacle warning&quot; and &quot;car breakdown warning&quot;. Penetration rate: 76%.</td>
<td>Malone et al. 2014</td>
</tr>
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</table>

Table 20. Studies on the impacts of Weather conditions warning.

The service was assessed to have an effect on traffic efficiency by increasing the time spent on the road (0.01%). The impact on fuel consumption was a 0.005% decrease (all vehicle and road types, EU-27). This would decrease the NOx emissions by 0.02% and PM emissions by 0.01%.

Impacts assessed for EU-25 for 2030. Based on literature review and data collected in the eIMPACT project. Application assessed: local danger warning due to poor weather, penetration rate: 100%.

Kulmala et al. 2008

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<tbody>
<tr>
<td>The service was assessed to have an effect on traffic efficiency by increasing the time spent on the road (0.01%). The impact on fuel consumption was a 0.005% decrease (all vehicle and road types, EU-27). This would decrease the NOx emissions by 0.02% and PM emissions by 0.01%.</td>
<td>Impacts assessed for EU-25 for 2030. Based on literature review and data collected in the eIMPACT project. Application assessed: local danger warning due to poor weather, penetration rate: 100%.</td>
<td>Kulmala et al. 2008</td>
</tr>
</tbody>
</table>
The estimated average effect on traffic accidents was a 4.5% reduction of fatalities and 2.8% reduction of injuries. For the safety effects, expert estimations were applied to the accident statistics to scale up the effects on EU-25 level. Wilmink et al. 2008

The impact on traffic accidents was estimated to be 2–4% reduction in fatalities and injuries. No specific scenario or penetration rate was defined. Literature review. eSafety Forum 2010

The road departure warning was expected to decrease fatalities by 1.6% and injuries by 0.7%. The corresponding effect for hazard incident warning was a decrease of 16.4% in fatalities and 8.6% in injuries. Field operational test which included two applications: (1) road departure which warned e.g. for slippery road and (2) hazard and incident warning which included warnings e.g. for bad visibility. SAFESPO T 2010

The estimated average effect on traffic accidents was a 16.5% reduction of fatalities and 8.5% reduction of injuries. The magnitude of the effect depended on the weather condition. Cost-benefit analysis based on gathered national statistics. Penetration rate: 100%. Kulmala et al. 2012

The estimated average effect on traffic accidents was a 3.4% reduction of fatalities and injuries. The impact on traffic accidents was estimated to be 2–4% reduction in fatalities and injuries. No specific scenario or penetration rate was defined. Literature review. eSafety Forum 2010

Table 21. Studies on the impacts of In-vehicle signage.

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<tr>
<td>The estimated average effect on traffic accidents was a 1.04% reduction of fatalities and 0.46% reduction of injuries, EU28 year 2030.</td>
<td>Field operational test combined with expert assessments. Tested two different signs: (1) children and (2) pedestrian crossing ahead</td>
<td>Malone et al. 2014</td>
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Table 22. Studies on the impacts of In-vehicle speed limits.

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<th>Impacts</th>
<th>Methods</th>
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<tr>
<td>The estimated average effect on traffic accidents was a 8.7% reduction of fatalities and 6.2% reduction of injuries</td>
<td>Impacts assessed for EU-25 for 2030. Based on literature review and data collected in the eIMPACT project. Penetration rate: 100%.</td>
<td>Kulmala et al. 2008</td>
</tr>
<tr>
<td>The impact on traffic accidents was estimated to be 2–10% reduction in fatalities and injuries. No specific scenario or penetration rate was defined.</td>
<td>For the safety effects, expert estimations were applied to the accident statistics to scale up the effects on EU-25 level. Penetration rate: 100%.</td>
<td>Wilmink et al. 2008</td>
</tr>
<tr>
<td>The estimated average effect on traffic accidents was a decrease of 6.9% in fatalities and a decrease of 3.9% in injuries (EU-28 year 2030).</td>
<td>Literature review.</td>
<td>eSafety Forum 2010</td>
</tr>
<tr>
<td>The system was expected to decrease fatalities by 7.1% and injuries by 4.9%.</td>
<td>Field operational test. Penetration rate 100% in 2020.</td>
<td>SAFESPO T 2010</td>
</tr>
<tr>
<td>The estimated average effect on traffic accidents was a decrease of 6.9% in fatalities and a decrease of 3.9% in injuries</td>
<td>Field operational test combined with expert assessments. Penetration rate: 76%.</td>
<td>Malone et al. 2014</td>
</tr>
<tr>
<td>Based on the results, the service could lead to a 1.4% reduction in vehicle speed and reduce fuel consumption by 2.3% on motorways and 3.5% on non-motorway non-urban roads. The service would decrease NOx, PM and CO emissions by 0.1-0.5% on motorways whereas VOC emissions would increase by 0.1%. On non-motorway non-urban roads PM, CO and VOC would increase by 0.2–4.2% whereas NOx would decrease by 0.4%.</td>
<td>Combination of the ASTRA model and results from the eIMPACT and DRIVE C2X projects</td>
<td>Asselin-Miller et al. 2016</td>
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</table>
### Table 23. Studies on the impacts of Probe vehicle data.

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<th>Impacts</th>
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<tr>
<td>The estimated average effect on traffic accidents was a 2.4% reduction of fatalities and 2.8% reduction of injuries. When differentiating different road types the reduction on motorways was: 4.9% in injuries and 3.3% in fatalities, on interurban and urban roads: 4.1% in injuries and 2.8% in fatalities and urban roads: 2.0% in injuries and 1.6% in fatalities.</td>
<td>Cost-benefit analysis based on gathered national statistics. Penetration rate: 100%.</td>
<td>Kulmala et al. 2012</td>
</tr>
<tr>
<td>Based on the results, the service could lead to a 0.006% reduction in fuel consumption (EU-27). The service would decrease NOx emissions by 0.003% and PM emissions by 0.001%</td>
<td>Combination of the ASTRA model and results from the CODIA and DRIVE C2X projects</td>
<td>Asselin-Miller et al. 2016</td>
</tr>
</tbody>
</table>

### Table 24. Studies on the impacts of Shockwave damping.

<table>
<thead>
<tr>
<th>Impacts</th>
<th>Methods</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamic speed adaptation is expected to reduce fuel consumption by 0.005% and emissions (NOx and PM) by less than 0.1%. The estimated effect on traffic accidents on motorways was a 7.8% reduction of fatalities and 5.0% reduction of injuries.</td>
<td>Impacts assessed for EU-25 for 2030. Based on literature review and data collected in the eIMPACT project.</td>
<td>Kulmala et al. 2008</td>
</tr>
</tbody>
</table>

### Table 25. Studies on the impacts of GLOSA.

<table>
<thead>
<tr>
<th>Impacts</th>
<th>Methods</th>
<th>Reference</th>
</tr>
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<tbody>
<tr>
<td>The system was assessed to decrease fuel consumption by 0.1% on rural roads and 0.7% on urban roads. The effect on emissions were a decrease of 0.3–0.8% in CO, 0.1%–0.2% in NOx, 0.5–0.6% in VOC and 0.0–0.1% in PM. The estimated effect on traffic accidents on was a 0.1% reduction of fatalities (rural and urban roads) and a 0.1% reduction of injuries on rural roads and a 0.3% reduction of injuries on urban roads, EU-28, year 2030.</td>
<td>Field operational test combined with expert assessments.</td>
<td>Malone et al. 2014</td>
</tr>
</tbody>
</table>

### Table 26. Studies on the impacts of Signal violation/Intersection safety.

<table>
<thead>
<tr>
<th>Impacts</th>
<th>Methods</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>The estimated average effect on traffic accidents was a 3.7% reduction of fatalities and 6.9% reduction of injuries.</td>
<td>Impacts assessed for EU-25 for 2030. Based on literature review and data collected in the eIMPACT project.</td>
<td>Kulmala et al. 2008</td>
</tr>
<tr>
<td>The estimated average effect on traffic accidents was a 3.9% reduction of fatalities and 7.3% reduction of injuries.</td>
<td>For the safety effects, expert estimations were applied to the accident statistics to scale up the effects on EU-25 level. Included GLOSA/TTG.</td>
<td>Wilmink et al. 2008</td>
</tr>
<tr>
<td>The estimated average effect on traffic accidents for the first application was a 0.7% reduction of fatalities and 2.2% reduction of injuries. For the second application 3.1% reduction of fatalities and 4.8% reduction of injuries</td>
<td>Field operational test which included two applications: (1) V2V left-turn assist (2) V2I red light violation, left and right-turn assist. Penetration rate: 100%</td>
<td>SAFESPO T 2010</td>
</tr>
</tbody>
</table>
Table 27. Studies on the impacts of Traffic signal priority request by designated vehicles.

<table>
<thead>
<tr>
<th>Impacts</th>
<th>Methods</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>The expected impact on traffic efficiency was a 9.2% reduction in travel time for buses. The corresponding reduction in fuel consumption and CO\textsubscript{2} emissions was a 8.3% decrease. NOx, PM, CO and VOC emissions were expected to decrease by between 8.0–8.3%.</td>
<td>Based on the results UITP Working Group study and the ASTRA model.</td>
<td>Asselin-Miller et al. 2016</td>
</tr>
</tbody>
</table>
Annex 6: Financial incentives, business models and procurement models for C-ITS deployment

Grant Agreement Number: 724106

Project acronym: CAPITAL

Project full title: Collaborative cApacity Programme on Its Training-educAtion and Liaison

**Topic study 6: Financial incentives, business models and procurement for C-ITS deployment**

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<th>PP</th>
<th>RE</th>
<th>CO</th>
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<td></td>
<td>Public</td>
<td>Restricted to other programme participants (including the GSA)</td>
<td>Restricted to a group specified by the consortium (including the GSA)</td>
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This project has received funding from the European Union's Horizon 2020 research and innovation programme under the European Union's Horizon 2020 research and innovation programme under grant agreement No 724106
This document presents the content for CAPITAL project’s WP3. It includes TOPIC STUDY ITS-6: Financial incentives, business models and procurement for C-ITS deployment.
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Abbreviations and Acronyms

<table>
<thead>
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<th>Definition</th>
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<tbody>
<tr>
<td>CAPITAL</td>
<td>Collaborative cApacity Programme on Its Training-educAtion and Liaison</td>
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<tr>
<td>C-ITS</td>
<td>C-operative ITS</td>
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<tr>
<td>EC</td>
<td>European Commission</td>
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<td>EU</td>
<td>European Union</td>
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<td>GA</td>
<td>Grant Agreement</td>
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<td>ITS</td>
<td>Intelligent Transport System</td>
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<td>PO</td>
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1. Introduction

This is deliverable covers CAPITAL project’s Topic Study no. ITS-6: Financial incentives, business models and procurement for C-ITS deployment. More specifically, the topic study aims to cover several sub-topics that are relevant for the topic. These are defined by the CAPITAL project as follows:

- Business model frameworks
- Stakeholder perspectives on business models
- Governance schemes and data exchange
- Engagement of public and private stakeholders.

Each of these sub-topics are covered in this document that is structured into four main sections that follow closely (but not entirely) to sub-topic division: i) business models and their frameworks (section 4), ii) stakeholder perspectives (section 5), iii) procurement (section 6), and iv) ecosystem for C-ITS and its management (section 7). All these aspects are crucial in the deployment of C-ITS, since the adoption of C-ITS presents a multi-actor and multi-dimensional challenge due to the dynamics not only between the supply and demand for C-ITS, but also due to investment, technology and user-acceptance risks that are prevalent in the mobility context.

The motivation for the topic study springs partly from the abovementioned risks. Providing appropriate tools – both at conceptual and practical level – the risks are reduced and there is a more clear perception on the prerequisites of C-ITS deployment.

The road towards co-operative, connected and automated mobility (CCAM) requires new modes of operation, new business models and new ways of procuring mobility solutions. Much of the grounding work has been carried out by the C-ITS Platform, the work of which is reported in C-ITS Platform Phase II Final Report, issued in September 2017. A number political, technological, organisational and regulatory issues are on the way of full-scale successful deployment of C-ITS. This deliverable seeks to provide starting point information and tools to manage C-ITS deployment from the financial and economic point of view, which in turn are intertwined with the aforementioned question. It goes without saying that the topical area and challenges are so extensive and far-reaching that a single study can make only a marginal contribution. However, these small steps are needed as the critical questions as well as prospective answers start to diffuse in the stakeholder community.

This study first takes a look at the question of individual business model framework, that is needed by each of the actors that are planning their business and services within the context of C-ITS. The critical questions include first and foremost the value propositions that an actor is able and willing to make. To understand if this value proposition actually involves value, business model tools and value assessment methods are needed. Secondly, there is a need to understand the wider context of the service and value network. The stakeholder perspectives and in particular the business and service ecosystem structures give the framework and boundary conditions for individual actor’s business model and value proposition, as no single actor is able to operate in a vacuum – mobility system is complex and has many externalities that are critical for socio-economic and environmental acceptability.

Procurement process is one way of bringing actors together and to build business ecosystems that would not perhaps build up without some external push – at least the build-up could be delayed and important competitive advantages and opportunities lost. Managing and governing C-ITS ecosystems is something that is yet to be learned. The final section of this study covers this essential management function, which is still very much in its infancy.
2. Objectives, Methods and Approach

The objective of this topic study is to provide a timely, comprehensive and consistent overview of the financial incentives, business models and procurement models of selected C-ITS systems. The topic study aims to provide background information for the development of CAPITAL study module “Financial models, business models and procurement models for C-ITS deployment”. Hence the objective is not to create ready-to-use learning or teaching modules, but rather the necessary building blocks and foundation to be able to build those modules.

This topic study makes use of several methods. First, it uses a constructive and collaborative design of the modular structure of the topic study. Constructive approach is used by utilizing the experience and know-how of the authors, who have in addition to research experience also some teaching experience within and outside the EU. Secondly, the literature included in sub-topics is gathered through traditional inquiries of scholar and professional databases (e.g. Google Scholar). Also the literature drawn by the authors of this deliverable has been utilized as far as possible. The additional materials, such as videos, case studies, etc. are sought also through desk inquiries via the internet or via personal networks. The introductory texts are provided by the authors of this deliverable and cross-refered.

An important source of material is the final report on C-ITS platform phase II (C-ITS Platform 2017) with its Annexes 1-3. These reports are utilised as a starting for many sections.
3. Business Model Frameworks for C-ITS

Definitions and Key Concepts

A business model is simplistically defined as the plan (as well as realization of the plan) “how a firm makes money”. However, both the academic research and practitioners have gone much beyond the simplistic view on business models. Business model definitions are multiple and they can be found in business economics literature in abundance. There follows few examples demonstrating the variety of definitions:

- The business model concentrates on value creation. It describes a company's or organisation's core strategy to generate economic value, normally in a form of revenue. (Bryony Rochester, Financial Times)

- An abstract representation of an organization, be it conceptual, textual, and/or graphical, of all core interrelated architectural, co-operational, and financial arrangements designed and developed by an organization presently and in the future, as well all core products and/or services the organization offers, or will offer, based on these arrangements that are needed to achieve its goals and objectives. (Al-Debei & Avison 2010)

- Business model is a method of doing business, by which a company sustains itself and generates value. (Chesbrough & Rosenbloom 2002)

A business model can be also something that can be defined as a construct rather than semantic model. Osterwalder's ontology [structure] of a business model is called the business model canvas (BMC). It shows the different elements of the business model with which a company can do the aforementioned: generate value and make it profitable for itself. The canvas allows a design of different types of business models by splitting the critical questions in to separate issues that build up the ontological structure.

The generation of value is the crucial element. Unless somebody finds value in the service or product, then it will not be used and certainly not paid for. It is value that makes the service or product worth something. The BMC's key partners, key activities and channels by and large define the value chain that is needed to create value. Customer segments, channels and value propositions are part of the marketing management functions of any firm or organization. Managing cost and resources are part of production management functions. Revenue management falls between financial and marketing management functions.

In a C-ITS context the business model canvas is useful in number of ways. It provides tool with which the services can be designed in a way that the needed value chains can be constructed, pricing and revenue logic can be considered, and key partners needed to build-up C-ITS services can be identified and invited. For example automotive industry, public authorities, and digital and physical infrastructure providers belong to the actors that are needed to realize C-ITS. Therefore, note that C-ITS context requires planning of entirely new business models and hence the need for the canvas is obvious.

The value propositions in C-ITS context not only include revenues in monetary terms. The value includes also socio-economic impacts such as safety and reduction in emissions and energy consumption. Therefore the puzzle of the canvas becomes more complex and demanding.

We adopted the definition from Osterwalder & Pigneur which stated: “a business model describes the rationale of how an organisation creates, delivers, and captures value.” (2010)
It can be said “that value proposition, value architecture, value finance, and value network articulate the primary constructs or dimensions of business models.” (Al-Debei and Avison, 2010).

Figure 1. Business model canvas for generic business model engineering

The BMC, shown in Figure 1 above contains nine building blocks – the different elements that could be used to define a proposed operations and value configuration. The figure shows demand side on the right: customer segments, relationships, and channels, and supply side on the left: key partners, activities and resources. The revenue streams generated from the business are found in the bottom right, with the cost structure to the bottom left. The value proposition - the accrued goods, services and benefits, - sit in the centre,,, being the meeting point of the ongoing transaction between supply and demand.

To develop a BMC requires a collaborative stakeholder workshop, at which those with an interest, mandate and resources to plan a new sustainable business organization can help populate the BMC with an eye to people, planet and profit.

- Key partners
  - Identify who are the key partners in each pilot, what is their aim and what is their role
- Key activities
  - Identify the key activities that are needed to deliver the measure/solution
- Key resources cost structure
  - Identify the resources needed to “produce” the measure/solution
- Cost structure
  - Identify the cost categories (give figures if known)
- Value proposition
  - Identify what is the value proposition/added value that is being offered by this measure/solution
- Customer relationships
  - Identify the type of relationship that is being used
- Customer segments
  - Identify the customer segment that it is being addressed with this. For whom are we creating value
- Channels
  - Identify how we are reaching the customer in terms of communication channels
- Revenue streams
  - Identify the revenues to be achieved

Examples of the key questions that arise when using the canvas aiding in devising C-ITS business model for the individual actor:

- **REVENUE STREAMS**: How can we price the reduction in emissions? Who is willing to pay for increased safety and how much?
- **KEY RESOURCES**: How do we ensure interoperability between different systems of different manufacturers? Who hosts the needed databases and registers?
- **COST**: who is paying for the needed standardization work and interoperability engineering?
- **CHANNELS**: what fixed or nomadic devices are feasible and how different apps are certified?
- **CUSTOMER RELATIONSHIPS**: How do we engage people to use C-ITS related services and ensure feedback in unsatisfactory service cases or other conflicts?
- Etc.

The business model canvas is a step towards the concept of a business ecosystem. Business ecosystems work for incorporating innovations (Moore 1993) and strengthening their market position by bringing synergies of different companies and public actors together towards a common innovation and share benefit. The common grounding of an ecosystem is the shared fate of the involved actors (market players, customers, regulators) and the need to understand an organization’s own role in the ecosystem (Iansiti and Levien 2004).

**Non-monetary value**
Value in Porter (Porter, 1985) and early business model literature was focused on monetary value and indeed profit generation. Combined with a value chain focus on cost reduction, this limited any focus on value that was not inherently monetary, or where the capture and reward to value was complex. Arend addressed this clearly in 2013, identifying that business models needed to address more than simple monetary outcomes, consider the gains and losses of all affected parties, and that better business models should be not be a contest but instead a collaboration (Arend, 2013). This holistic view, that control may be more likely shared among participants, had already been incorporated into the Business Model CANVAS (BMC) by Osterwalder and Pigneur (Osterwalder and Pigneur, 2010). In short, value need not be monetary. It is possible to generate value that doesn't affect profit margins, or is difficult to assess in a traditionally defined cost benefit analysis. This does not exclude it from a CANVAS, if it is seen by the participants as part of the value proposition, and there is a reward in the capturing of that proposition, then it clearly has value and should be stated and seen as part of the business model.

**Service business model CANVAS**
Of note for C-ITS is the alternative Service Model CANVAS (Zolnowski, Weiβ and Böhmann, 2014) which adopts the core building blocks of the BMC but adopt a parallel vertical approach which can encompass the different perspectives of partner, customer and company.
Figure 2. Starting point for design (Zolnowski, Weiß and Böhmann, 2014)

Figure 3. Service Business Model Canvas

However, the business model canvas is meant to work primarily only in a single-actor context, i.e. it is able to capture business model prerequisites and boundary conditions regarding one actor only; the one who is doing the business model design.

The Working Group – Business Models in C-ITS, which was formed as part of the C-ITS Platform of the European Commission DG MOVE, stated that business model canvas is too static and too focused on individual stakeholders to describe C-ITS business models capturing the C-ITS framework. So in that case a cluster of canvas models for each stakeholder would be needed. But the different models are often not complementary, but in conflict and do not represent the whole ecosystem. Therefore the Working Group determined that the value chain model and the value network model (and their combination) are most useful to describe and discuss C-ITS business models covering multiple stakeholders. Nevertheless the canvas model was considered as good support to highlight internal and external components of a C-ITS business model. So the Working Group used the canvas model as a checklist in order to ensure the capturing of the whole relevant ecosystem.

Generic value chain or network models are illustrations or visualizations of the network, sometimes of the entire ecosystem. For the project SCOOP@F a Value Network Model was developed. It is a result of a negotiation process between the different stakeholders. Due to the different technologies covered by SCOOP@F several combinations are possible and adjustments are very likely. Due to this fact the representation of the SCOOP@F business model form of the Value Network model is only a current snapshot of the ongoing activities.
The model represents the organization and flows between the different stakeholders. Figure 4 includes the global organization. With additional Value Network models the different aspects (like legacy situation, service provider organization, G5-based organization, etc.) are detailed in further steps.

What Do We Know? - Brief Review of Literature and Relevant Findings
Business models are revenue generating logical structures, where the supplier receives money and customers receive benefits. This applies to ITS services too. ITS services do not function without data and from thereon information is refined from the data. Data and information are the core “produce” delivered to intermediate and end users. When consumed and used in the right way, we will enhance safety, increase efficiency of operations and productivity of the transport system as a whole as well as cut the harmful effects of transport, such as emissions. In other words, information and data create value.

There are two different angles relevant to information value: the perceived value and the realized value (Ahituv 1989). Typically the first is associated with design and decision-making (we think and anticipate the value to be realized), whereas the latter is an empirical observation (we have witnessed how the value has realized). Perceived value is hence always speculative in nature, while the realistic value is empirical and observable (Fig. 5). This is particularly important to notice when thinking of deployment of new technological solutions in transport, when the empirical experiences are often limited both in terms of scope and time.
The outcomes, i.e. the impacts, of information on the decisions and actions of users are mostly uncertain or at least stochastic: the impacts do not always manifest in exactly the same ways, and different users react differently even in identical situations with the same information (Leviäkangas 2011).


The attributes can be linked to the concept of value chain or network, since at each stage of the service production process the attributes’ value is (in the best case) added thus increasing the aggregate value of the information. This is exemplified in Figure 6.
Figure 7. Information value chain and value creation

The value chain highlights one of the main problems in making ITS services work: there are a number of actors that need to contribute to the value creation process and make transactions. The multitude of transactions that have to be agreed and framed beforehand, increase the risks of having problems and disturbances in the chain - the longer and more complex the chain, the lower the resilience against failures.

Modern business models in digital (information) services are more than chains, rather they are dynamic networks. The value capture becomes more challenging, the revenue logic more complex, and the value creation process multi-dimensional. To manage the value creation process and the network, a strong actor is needed. Usually large companies, even if lacking the required expertise to cover all aspects of the value creation process have the resources to mobilize and manage these value networks, and even business ecosystems.

This might be even more complex when focusing on C-ITS and some basic facts need to be considered:

As the final report of the C-ITS platform phase II related to Business Models in C-ITS showed clearly pointed out is that deployment of C-ITS requires the involvement of a number of stakeholders from public sector but also from different industries, as stated before. Furthermore the cost-benefit analysis of the first phase of the C-ITS platform showed that the potential benefits of C-ITS will outweigh the costs, but the benefits will also materialize over time, but depend strongly on the harmonized and coordinated, but also accelerated deployment. In addition it has to be considered that large parts of the benefits will directly affect the users or the society at large, while the costs of investment are assigned to the road operators or car manufacturers.

As another issue the deployment of C-ITS and other related technologies (e.g. Mobile Internet, Internet of Things, Cloud Technology, Automated Vehicles) are relevant in moving towards connected, cooperative and automated mobility, and can be transformative and disruptive to existing business processes.

So a business model for C-ITS needs to consider these facts and reduce uncertainties and to create value for all stakeholders that need to invest in C-ITS.

C-ITS is a dynamic market that will need progressive investment over several years. At this moment it is not yet feasible to fully integrate quantitative financial features (revenues, costs, profitability) when describing the business model. So business models for C-ITS need to be adaptable to its environment as the system scope needs to be adapted over time so that new stakeholders can be integrated and the relations between the stakeholders updated. Having
this in mind the value chain model or the value network model, or a combination of both is most useful in this context.

The Value Chain model focuses on activities, processes and roles in the whole ecosystem. It can be used to describe the C-ITS ecosystem, by aggregating different value chains for different C-ITS use cases (e.g. V2V services, I2V services, V2I services or P2V services). The Value network approach on the other hand is more systematic and in a way more open to new stakeholders that can join at any moment. Therefore it is also adaptable to the evolvement of the C-ITS ecosystem.

The Working Group - Business Models of the C-ITS platform used the combination of both approaches. Value chain models have been developed for various use cases in different C-ITS projects and the Value network approach was used to describe the Scoop@F business model. Based on this key issues were identified to further define business models for C-ITS. Figure 8 shows one example for the Value chain model for a C-ITS use case.
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#### Figure 8. Road Works Warning (Short Term) - Germany - ETSI ITS G5

<table>
<thead>
<tr>
<th>Role</th>
<th>Example Actors</th>
<th>Generic value chain for traffic information incl. detailed process steps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road Infrastructure Operator</td>
<td>Hessens Mobil</td>
<td>Content provision: Detection X Data reception X Data pre-processing X Data delivery X Content creation X Data fusion X Data processing X Data delivery X Content creation X Internet of Things X Service creation X Service generation X Service delivery X Service presentation X End User</td>
</tr>
<tr>
<td>Road Infrastructure Operator</td>
<td>Hessens Mobil</td>
<td>Service provision: Content reception X Content fusion X Service generation X Service delivery X Service presentation X</td>
</tr>
<tr>
<td>TCC Operator</td>
<td>Hessens Mobil</td>
<td>Content provision: Detection X Data reception X Data pre-processing X Data delivery X Content creation X Data fusion X Data processing X Data delivery X Content creation X Internet of Things X Service creation X Service generation X Service delivery X Service presentation X End User</td>
</tr>
<tr>
<td>TCC Operator</td>
<td>Hessens Mobil</td>
<td>Service provision: Content reception X Content fusion X Service generation X Service delivery X Service presentation X</td>
</tr>
<tr>
<td>ITS-G Operator</td>
<td>Volkswagen, Opel</td>
<td>Content provision: Detection X Data reception X Data pre-processing X Data delivery X Content creation X Data fusion X Data processing X Data delivery X Content creation X Internet of Things X Service creation X Service generation X Service delivery X Service presentation X End User</td>
</tr>
<tr>
<td>ITS-G Operator</td>
<td>Volkswagen, Opel</td>
<td>Service provision: Content reception X Content fusion X Service generation X Service delivery X Service presentation X</td>
</tr>
</tbody>
</table>

(see: C-ITS platform Phase II - Final report, p. 70)
The Working Group on Business Models also identified some key motivations and issues for the different stakeholder groups deploying C-ITS and developed – based on that – a description of business models from various stakeholder perspectives. As these are based on discussions with a small group of C-ITS stakeholders the results are not representative from a statistical point of view. Nevertheless the results of the Working Group summarize some main aspects in regard to C-ITS business models.

The analysis of the Value Chains for the different projects or C-ITS use cases showed that – from the perspective of the public authorities – it is very likely that different business models will operate in parallel in the EU and no single business model can be prescribed, but it will be influenced by the different phases of deployment. Main motivations for public authorities to invest in C-ITS are improving the road safety, making the traffic management more efficient and optimizing infrastructure management costs. In general the motivations like road safety, fluent traffic flow, reliability of journey and the reduction of environmental impacts are the key motivations for all stakeholder groups. Whereas for the individual user the added value of the service is in the focus, the increase of revenues and the enhanced profitability of operations are the key motivations of private sector stakeholders.

The Working Group also formulated some key issues in relation to the business models for C-ITS followed by some recommendations and further actions. One of the major issues the involved stakeholders, especially from the public sector, have to deal with are the determination of costs and benefits of C-ITS. What is stated is that there is a progression from determining the costs and benefits to the calculation of benefit-cost ratios and in a later step the development of shared business models for public and private stakeholders. Therefore concrete evidence is needed on the investment, operation and maintenance costs and cost savings due to the use of C-ITS. Furthermore similar evidence will be necessary for the impacts and social benefits.

So summarizing the information provided in the C-ITS platform Phase II final report the C-ITS market is constantly evolving and changing. Due to the nature of C-ITS the framework is complex and a multitude of stakeholders from public side or private sectors are involved. There is no clear business model at the moment. Depending on the implementation specific framework different business models will be possible. Also the different roles will be covered differently, depending on national or project specific requirements and framework conditions. Models like the Value chain or the Value network enable the analysis of different approaches and reveal similarities, but also differences. The increased use of cost-benefit analysis or impact assessment will be necessary in order to develop the specific business model.
4. Stakeholder Perspectives on Business Models

Definitions and Key Concepts
The Merriam-Webster web-dictionary\(^{66}\) gives three definitions for a *stakeholder*:
- A person entrusted with stakes of bettors
- One that has a stake in an enterprise
- One who is involved in or affected by a course of action.

It is easy to see that the last definition applies to C-ITS deployment context – or in fact in any systemic context where a large number of actors are affected by an investment, decision or action. *Stakeholder theory* is an important concept as well. Introduced by Edward Freeman (1984) the theory states that business ethics and moral values play an important role in the management of business. The idea is not just to make money, but to satisfy the needs and aspirations of larger group of actors, the stakeholders. This theory is actually quite new and confronts the traditional view of agent theory, where the idea of a firm is just to make money for the shareholders. Since its introduction it has spread widely and seems to dominate the modern perception of managing business.

Practically everything in C-ITS context relies on stakeholder theory. Alone the fact that successful C-ITS deployment requires multiple commitments of different stakeholders, that there are some conflicting interests that need to be managed, and that there is a substantial socio-economic public good justification for C-ITS makes this context a fruitful application ground for stakeholder theory.

An *actor* is someone that has role to play in the form of action, be that an investment or an operational activity. Stakeholders always include all actors, but not necessarily vice versa. Sometimes a stakeholder may not be an active party, but still is affected e.g. by the externalities created by a system, e.g. C-ITS. C-ITS Platform (2017) identifies four main types of actors that are needed for the successful incorporation of C-ITS:
- Public authorities (state, regional, city/local)
- Private road operators
- Service providers
- Vehicle manufacturers.

However, there are many other stakeholders that are either a part of the C-ITS deployment or affected by it, such as:
- End users (drivers)
- Public transport operators
- Other mobility system end-users, e.g. cyclists, pedestrians
- Insurance companies
- Other mobility service providers (rental companies, MaaS providers, parking services, etc.)
- Technology and system suppliers.

These all stakeholders are affected by C-ITS and hence they need to be appropriately engaged in the development and deployment of C-ITS. Some of the stakeholders are motivated by business potential, some are motivated by the opportunity to provide better public service and create more sustainable mobility systems. In this sense, these stakeholders have their ‘own’ business models they are trying to realise. The challenge in C-ITS deployment is to bring these ‘business models’ in to *congruence*, so that on aggregate level the benefits are maximised without making any stakeholder seriously worse-off than before. Using the value

chain and value network models it is possible to identify both the actors and the stakeholders as well as to identify which type of motivations (benefits, costs or impacts) these stakeholders might have with regard to the particular C-ITS service or service bundle. Table 1 gives an example of such a depiction.

Table 1. Stakeholder view added to a value chain

<table>
<thead>
<tr>
<th>Actors</th>
<th>Stakeholders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actor</td>
<td>Passive actor</td>
</tr>
<tr>
<td></td>
<td>Actor1</td>
</tr>
<tr>
<td></td>
<td>Actor2</td>
</tr>
<tr>
<td></td>
<td>Actor3</td>
</tr>
<tr>
<td></td>
<td>End-user</td>
</tr>
<tr>
<td></td>
<td>Affected Non-users</td>
</tr>
<tr>
<td>Function</td>
<td>Raw data gathering</td>
</tr>
<tr>
<td></td>
<td>Raw data purchase and distribution</td>
</tr>
<tr>
<td></td>
<td>Data refining</td>
</tr>
<tr>
<td></td>
<td>Distribution and service packaging</td>
</tr>
<tr>
<td></td>
<td>Service consumption</td>
</tr>
<tr>
<td>Benefit</td>
<td>Revenue from Actor1</td>
</tr>
<tr>
<td></td>
<td>Revenue from Actor2</td>
</tr>
<tr>
<td></td>
<td>Revenue from Actor3</td>
</tr>
<tr>
<td></td>
<td>Revenue from End-user</td>
</tr>
<tr>
<td></td>
<td>Private benefits from the service</td>
</tr>
<tr>
<td>Cost</td>
<td>No direct additional cost</td>
</tr>
<tr>
<td></td>
<td>Payments for data</td>
</tr>
<tr>
<td></td>
<td>Payments to Actor1</td>
</tr>
<tr>
<td></td>
<td>Payments to Actor2</td>
</tr>
<tr>
<td></td>
<td>Payments to Actor3</td>
</tr>
<tr>
<td></td>
<td>Externalities</td>
</tr>
</tbody>
</table>

Actors 1-3 and End-users are the active stakeholders, whereas the passive actor (raw data source) and other users have passive roles but yet are affected. The business model for the entire service is not sustainable if for example the raw data is not available or if Non-users suffer from negative externalities. On the other hand, if there are significant positive externalities for the Non-users, for example in terms of less congestion, there are possibilities for supplement revenues for Actors 1-3 with public-funded subsidies.

What Do We Know? - Brief Review of Literature and Relevant Findings

C-ITS is about creating value. The value should be created not only for the carmakers but also to stakeholders around C-ITS context. The value creation questions have been discussed in number of academic and professional works (e.g. Harrison & Wicks 2013, Argandona 2011, Crane et al. 2009, Kochan & Rubinstein 2000, Flak & Rose 2005). The common message is by and large (excluding the criticism towards stakeholder theory) that modern, systemic challenges such as climate change, social justice, equity, environmental concerns, etc. require businesses to adopt a stakeholder approach in their business planning and engineering.

For C-ITS the simple fact is that stakeholder approach is no less than absolutely necessary, regardless whether one views the business potential or the socio-economics of the system or service under consideration.
5. Procurement of C-ITS

Topics from the ToC regarding Procurement models for C-ITS:

- PPI-Model (Public Procurement of Innovation)
- PPP-Model (Public-Private-Partnership)
- Alliance-model
- PCP - model (Pre-Commercial Procurement)
- Procurement of a single system / Standard procurement

Definitions and Key Concepts

Introduction to procurement in general

In many sectors, as in the ITS sector, public authorities are the key players and therefore also the principal buyers of goods and services. According to the data available from the European Commission around 250,000 public authorities in the EU spend around 14% of GDP on the purchase of services, works and supplies every year. These public authorities are subject to public procurement. Public procurement refers to the process by which public authorities, such as government departments or local authorities, purchase work, goods or services from companies. The European law sets out some minimum rules that are harmonized around the European Union and transposed into national legislation. The core principles of these directives are transparency, equal treatment, open competition, and sound procedural management. They are designed to achieve a procurement market that is competitive, open, and well regulated. For tenders below a certain amount only the national procurement laws apply. For higher amounts the European laws have to be applied. However, national rules also have to respect the general principles outlined in the European legislation.

The European legal framework consists of three directives that had to be transposed into national law:

- Directive 2014/24/EU on public procurement
- Directive 2014/25/EU on procurement by entities operating in the water, energy, transport and postal services sectors
- Directive 2014/23/EU on the award of concession contracts

In addition European guidelines for contracts not covered by the above directives, either fully or in part, can be found in this Commission interpretative communication from 2006. This communication applies to:

- Low-value contracts below the Directives’ thresholds that still have cross-border interest;
- Contracts above EUR 207 000 for which the Directives only provide limited rules (e.g. health and legal services).

It interprets existing case-law from the European Court of Justice and suggests best practice to comply with internal market requirements. This includes the minimum transparency and non-discrimination provisions required when awarding low-value contracts.

In October 2017 the European Commission adopted a public procurement strategy COM(2017) 572 that focuses on six strategic policy priorities in order to improve EU public procurement practices in a collaborative manner by working with public authorities and other...

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stakeholders, like new guidance for ensuring the wider uptake of innovative procurement, specific measures for further professionalization of public buyers, enabling better access to procurement markets, boosting digital transformation and foster cooperation between procurers. The EC communication furthermore mentioned the encouraging steps that have already been taken in several European Member States to reform procurement practices and procurement structures. But one crucial, hampering factor is also depicted in the EC communication: Strategic procurement possibilities are not sufficiently used, as more than half of the procurement procedures still use the lowest price as the only award criterion although the public procurement directives leave public buyers entirely free to opt for purchases based on cost-effectiveness, quality-based criteria.

The EC communication also related to the study on “Strategic use of public procurement in promoting green, social and innovation policies” which showed that on the innovation side the innovation procurement is hampered by various barriers, like enhanced risk on side of the buyers, increased workload, lack of maturity of goods and services demanded and last but not least a lack of flexibility in the procurement process.\(^69\)

The primary goal of a purchasing manager is to achieve best value for money within the context of legal requirements and sustainability commitments made, such as the EU directives on public procurement and sustainability standards, e.g. SA8000 (Baily, 2005, pp. 112–124, 484–503).

**Procurement of Innovation tools**

To deal with challenges different approaches different approaches were developed, which should foster the further procurement of innovative solutions namely PPI, PCP, Innovation Partnerships, or the PPP model:

- **Public Procurement of Innovative solutions (PPI)** is used when challenges can be addressed by innovative solutions that are nearly or already in small quantity in the market and don't need new Research & Development (R&D).

- **Pre-Commercial Procurement (PCP)** can be used when there are no near-to-the-market solutions yet and new R&D is needed. PCP can then compare the pros and cons of alternative competing solutions approaches. This will in turn enable to de-risk the most promising innovations step-by-step via solution design, prototyping, development and first product testing. PCP is based on the exemptions for procurement of R&D services currently included in the Procurement Directives.\(^70\)

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By developing a forward-looking innovation procurement strategy that uses PCP and PPI in a complementary way, public procurers can drive innovation from the demand side.  

- **Innovation partnerships** were defined in Article 49 of the European procurement directive of 2014 (2014/24/EU) for the first time to enable public authorities to create structured partnerships with a supplier with the objective to develop an innovative product, service or works, with the subsequent purchase of the outcome. The innovation partnership should be based on the procedural rules that apply to the competitive procedure with negotiation and contracts should be awarded on the sole basis of the best price-quality ratio, which is most suitable for comparing tenders for innovative solutions. Whether in respect of very large projects or smaller innovative projects, the innovation partnership should be structured in such a way that it can provide the necessary ‘market-pull’, incentivising the development of an innovative solution without foreclosing the market. Contracting authorities should therefore not use innovation partnerships in such a way as to prevent, restrict or distort competition. In certain cases, setting up innovation partnerships with several partners could contribute to avoiding such effects.

In addition to the tools available for procurement of innovation also PPPs can be considered in this context.

- **Public-private partnerships (PPPs)** are long-term contracts between two units, whereby one unit acquires or builds an asset or set of assets, operates it for a period and then hands the asset over to a second unit. Such arrangements are usually between a private enterprise and government but other combinations are possible, with a public corporation as either party or a private non-profit institution as the second party (according to Article 15.41 of Regulation (EU) No 549/2013). So PPP provides a legal structure to pool resources and to gather critical mass and to make research and innovation funding across the EU more efficient by sharing financial, human and infrastructure resources. Furthermore an internal market is created for innovative products and services. This construct enables innovative technologies to get faster to the market. PPPs can provide the right framework for international companies to anchor their research and innovation investments in Europe and last but not least

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enable the scale of research and innovation effort needed to address critical societal challenges and major EU policy objectives.\(^2^2\)

**C-ITS and the specific requirements for procurement**

C-ITS is a complex framework, as it requires the involvement of a number of stakeholders from public sector but also from different industries. Especially the public authorities play a major role in funding of new services and foster the deployment of new innovations.

Fast developments in the C-ITS sector in the last years allowed moving relatively quickly from basic research to a maturity level of the technology that is (very) close to the market. The legal framework is adapting slower than the development of the technology. Various funding initiatives and programs have fostered the deployment of C-ITS, by public authorities. Nevertheless C-ITS solutions are not available as “off-the-shelf” solutions on the market. In the frame of C-ITS the procurer has typically a good understanding of needs, functional requirements and also the technical specifications of the solution to be procured (as it is stated in the P4ITS final recommendations). Nevertheless the commercial off-the-shelf (COTS) solutions are often missing, which leads to the fact that even if the technology framework can be defined, there are no products and services available on the market that can match it.

As public authorities (transport authorities, ministries, cities, etc) are important drivers for the C-ITS implementation it has to considered that they are subject to the public procurement law - also when we it comes to the deployment of an innovative solution. So the constraints of the procurement directives have to be considered for the deployment of C-ITS. This means that for “buying” innovative solutions, like C-ITS services, public authorities need to make use of innovative or alternative approaches for procurement, like PPI (as a very general term used in this context), PCP, innovation partnership or certain open or restricted procedure.

In general there is not only “one procedure” that is adequate, but different procurement procedures that have advantages and disadvantages, depending on the general framework for the procurement, the maturity level of the procured solution, etc.

The P4ITS project developed a scheme to illustrate the correlation between the technology readiness level and the actions according to the EU procurement directives, which is depicted earlier in Figure 10. Link between technology readiness level (TRL) and procurement actions (see P4ITS consortium, 2016, P4ITS - D6.2. - final recommendations, p.22)

Figure 10. Link between technology readiness level (TRL) and procurement actions (see P4ITS consortium, 2016, P4ITS - D6.2. - final recommendations, p.22)

What Do We Know? - Brief Review of Literature and Relevant Findings

The relevance for innovative procurement approaches for C-ITS deployment

As summarized by the SPICE project, “the fast development of technologies creates many challenges for traditional public procurement. In many cases the innovative solutions are difficult to be purchased within the traditional procurement framework. The EU directives (e.g. Directive 2014/24/EU) provide the legal framework for public procurement procedures, such as:

- Wide possibilities of market consultation prior to the procurement actions (art. 40);
- Competitive procedures with negotiation (art. 29) or dialogue (art. 30);
- Innovation Partnership (art. 31) – the “commercial extension” of PCP;
- Design contest (art. 78);
- Competition based on innovative characteristics (art. 67) or life-cycle costing/total cost of ownership (art. 68).

These possibilities can help procuring innovations.”

In addition to the different tools mentioned by SPICE Pre-Commercial Procurement (PCP) should be considered as one additional approach, which is based on the exemptions for procurement of R&D services currently included in the Procurement Directives.

The use of innovative procurement tools - especially in the area of C-ITS- has also been stressed in the Final Report of the C-ITS platform published in 2016. The C-ITS platform recommends that the European Commission should support public investment, by means of harmonized C-ITS pre-commercial procurement schemes and practical tools such as investment guidelines for infrastructure managers. Furthermore the report included the following recommendation: “Facilitating procurement and providing guidance to city authorities are some actions that need to be taken in order to facilitate C-ITS investment in cities”. The promotion of innovative public procurement processes and the stimulation of the sharing of knowledge among stakeholders, especially among public stakeholders were also addressed by the C-ITS platform. The WG9 of the C-ITS platform (Implementation issues) recommended “To support public investment, by means of harmonised C-ITS pre-commercial procurement schemes, which could be as well an effective tool to help bridging this gap”. Furthermore it

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73 SPICE project (2017)- D5.2. SPICE Stakeholder Group Launch, p. 17
stated, the European Commission should contribute together with other actors, to develop practical tools to support C-ITS deployment (like pre-commercial procurement) that could stimulate the roll-out of C-ITS at local, regional and national levels.\(^8\)

In the Phase II of the C-ITS platform, which published the final report in September 2017, procurement issues were of minor relevance. Nevertheless the report included a separate recommendation regarding the Urban C-ITS standardisation:

- **Support for procurement and deployment**
  
  Launch a dedicated activity to describe required functional requirements, technical specifications and communication profiles for C-ITS services and equipment for operators. Extend described supporting actions to build up technical/financial capacity to develop and improve test standards and field operational testing as a whole. Accelerate the development process of conformance tests for infrastructure-based messages, e.g. SPaT/MAP. Common definitions to be addressed. To be potentially addressed within relevant on-going projects - in particular the development of an 'urban specification profile' based on common functional requirements.\(^76\)

So at the moment we can see that specifications and profiles are in development that will hopefully simplify the procurement of C-ITS in the future. Nevertheless the relevance of innovative procurement approaches is uncontested.

Although these procurement tools are enablers for the deployment of C-ITS by public procurers the knowledge about the tools and the implementation of these innovative approaches is often lacking, as e.g. the iMobility Support Report 2013\(^76\) has shown.

The following will provide a short overview of PPI and PCP in the relation of (C-ITS) deployment to provide a basic understanding of the tools. A number of platforms and projects have developed guidelines, recommendations and supporting material that will help public procurers to dig deeper into the topic.

**Pre-commercial procurement (PCP) as a tool for (C-)ITS deployment**

Within iMobility Support project a specific “PCP for ITS Guide” was developed that summarized the key issues of Pre-Commercial Procurement:

The deployment of ITS solutions has started some years ago. Nevertheless, the deployed solutions are often isolated proprietary systems ending at geographical or institutional borders. Harmonised solutions and deployment of innovations are the key prerequisites for ITS to have an impact. Interoperability, harmonisation and cross-border cooperation are main aspects for this, but furthermore broad deployments of harmonised systems and services require the involvement of several stakeholders (e.g. operators) in the public sector resulting in the need of new and innovative ways of procurement. Research and Development (R&D) activities must be followed up by further instruments which transcend these, including also the development of innovation-oriented procurement strategies and the use of new instruments to encourage deployment. On European level, the European Commission fosters additional financial instruments to support the demand for innovation and innovative procurement. Pre-commercial procurement (PCP) has been identified as one promising tool for public authorities and entities in charge of public services to support the deployment of innovative products and services. For all organisations that by law have to follow the European Public Procurement Directives, it is a way to finance the Research and Innovation (R&I) tasks necessary to develop innovative solutions to their problems. As a preceding step before the actual purchase of
goods, it offers an alternative to the traditional financial means for the support to innovation, based on risk-benefits sharing according to market conditions, and giving the possibility to procurers to act as innovation demanding first buyers.

PCP can be seen as an approach to support the public authorities to answer these complex needs for mobility solutions and ensure the development and deployment of innovations for crucial areas as in the mobility sector.

The definition of Pre-Commercial Procurement differs from source to source and from organisation to organisation. In principle it can be stated that Pre-Commercial Procurement is a demand-side oriented innovation policy instrument. The aim of PCP is to solve socio-economic needs and challenges of a public procurer, which require R&D to get new solutions developed. PCP is adequate if the problem can be clearly defined, but either no adequate solutions are available or the pros and cons of several potential competing solutions have not been compared or validated yet. Therefore the public sector buys R&D from several suppliers in parallel (comparing alternative solution approaches), in form of competition. An evaluating process takes place after each critical milestone (design, prototyping, test phase). The risks & benefits of R&D (e.g. IPRs) are shared with suppliers to maximise incentives for wide commercialisation. According to the PCP model of the European Commission, it can be distinguished between a preparation phase and the PCP process itself consisting of three main phases (solution design, prototype development and first test products development). Ideally the PCP process is followed by the commercial procurement of the developed products or services.

The PCP process itself does NOT include the actual procurement of the developed solution.

According to the EC definition, Pre-Commercial Procurement (PCP) is an approach “for procuring R&D services which enables public procurers to:
- share the risks and benefits of designing, prototyping and testing new products and services with the suppliers; in a way that is in-line with international WTO legislation and relevant EU legislation on public procurement without involving State aid;
- create optimum conditions for wide commercialisation and take-up of R&D results through standardisation and/or publication;
- pool the efforts of several procurers.

Pre-commercial Procurement is based on the special exemption from the Procurement Directives related to research and development services formulated in article 14 of the 2014/24/EC and article 32 in 2014/25/EC. These exemptions apply to public contracts for R&D services only, not for R&D supplies or R&D works.


The document defined the concept of PCP based on the application of risk-sharing according to procuring of R&D services to the market conditions so “that does not constitute State aid. As a rule, the relationship between the public purchaser and the company within the pre-commercial procurement should not include an aid element, and this should be excluded through the appropriate design of the contract. Where public authorities buy R&D from companies at market price, there is no advantage and consequently no element of State aid.”

COM(2007) 799 defined the process of Pre-Commercial Procurement in 3 phases as it is defined by the European Commission to ensure a competitive development in phases:

![Diagram of Pre-commercial Procurement phases]

**Figure 11. The phases of PCP (source: EUROPEAN COMMISSION (2007) - COM(2007) 799: "Pre-commercial Procurement: Driving innovation to ensure sustainable high quality public services in Europe", p.8)**

The iMobility Support “PCP for ITS Guide” developed a step-by-step Guidance for PCP, which is a helpful basis for creating a better understanding of the tool. Furthermore the Guide is complemented by a number of case studies and recommendations for the use of PCP.

A number of PCP projects have been supported by the European Commission. Information on these projects is available on the platform of the European Commission dedicated to Pre-Commercial Procurement.

It has to be stated the PCP is one tool that has advantages and disadvantages. Especially in relation to the tool of “Innovation partnership” all potential options have to be compared to identify the right solution for the procurer.  

**Public Procurement of Innovation (PPI) as a tool for (C-)ITS deployment**

Based on the key aspects given in the P4ITS final recommendations document, the information provided on the Procurement of Innovation Platform as well as on the dedicated platform.

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79 P4ITS consortium (2016) - P4ITS - D6.2. - final recommendations

80 [http://www.innovation-procurement.org/home/?no_cache=1](http://www.innovation-procurement.org/home/?no_cache=1)
website of the European Commission. PPI can be defined as follows:

**Public procurement of innovation (PPI) occurs when public authorities act as a launch customer for innovative goods or services. These are typically not yet available on a large-scale commercial basis and may include conformance testing.**

The legal bases for PPI build the European procurement directives that were mentioned earlier in this document.

Within the update of the Directives in 2014 changes to the procurement procedures have been included which are expected to increase the uptake of PPI. These include:

- Increased **flexibility and simplification** on the procedures to follow, negotiations and time limits;
- Clearer conditions on how to established collaborative or **joint procurements** which, through bulk purchasing, can provide the necessary demand to launch new solutions;
- Strengthening the use of **life cycle costing**, which describes all the phases through which a product passes from its design to its marketing and the discontinuation of its production;
- The creation of **innovation partnerships** which enable a public authority to enter into a structured partnership with a supplier with the objective of developing an innovative product, service or works, with the subsequent purchase of the outcome;
- The exemptions for procurement of R&D services currently included in the new Directives (which are the basis for PCP) will be maintained. Public procurers can therefore continue to undertake **pre-commercial procurement**.

The European Commission defined PPI as “Public Procurement of Innovative solutions”. According to the EC definition “PPI facilitates wide diffusion of innovative solutions on the market. PPI provides a large enough demand to incentivise industry to invest in wide commercialisation to bring innovative solutions to the market with the quality and price needed for mass market deployment. This enables the public sector to modernise public services with better value for money solutions and provides growth opportunities for companies. Public Procurement of Innovative solutions (PPI) happens when the public sector uses its purchasing power to act as early adopter of innovative solutions which are not yet available on large scale commercial basis”.

In the context of PPI the official definition of the term “innovation” has to be considered:

**“Innovation” means the implementation of a new or significantly improved product, service or process, including but not limited to production, building or construction processes, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations inter alia with the purpose of helping to solve societal challenges or to support the Europe 2020 strategy for smart, sustainable and inclusive growth**.

So as stated in the P4ITS final recommendations document the “implementation of a new or significantly improved product, service or process” is the key aspect of the definition of innovation in the context of PPI. When it comes to “traditional” procurement award criteria like the lowest price do not foster the procurement of new and significantly improved solutions, as the price will be in many cases higher than for other solutions as they are not available on a large scale commercial basis.

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83 Directive 2014/24/EU, Article 2 (1), n. 22
large scale basis yet. So PPI provides the path to procure new, innovative solutions.  

PPI is procedure-neutral and in principle any procedure within the procurement directives is applicable in a PPI action, although some Member States in national legislation or guidelines may require procuring authorities to follow specific procurement procedures or procedural steps when procuring new, innovative solutions. Therefore, and conversely to PCP, PPI actions can be understood as supporting initiatives enhancing procurement of innovation.  

According to P4ITS PPI can be understood as:

- "European, national, regional or local programmes/strategies/policies supporting procurement of innovation, such as strategies on making daily procurement more innovation friendly (e.g., target to carry out with a PPI approach 20% of all procurement actions) or multi authority cooperation with a certain economic mass, allowing market penetration of new (yet undiscovered) innovative solutions in grand joint procurement projects or 

- The technical or legal approaches one can adopt to enhance the possibilities of new innovative solutions to win a tender (in this document also referred to as ‘PPI approaches’). Hence, on an operational level the PPI approaches are the very fundamental preconditions for PPI actions and the principles behind PPI approaches can be used in any public procurement procedure, including day-to-day ‘conventional’ procurement, to enhance the possibilities for obtaining new solutions for the needs of the procuring authority.

PPI might therefore be part of a mix of policies aiming to encourage the procurement of both R&D and innovation in the performance of public tasks or to address societal challenges and needs. Such a policy mix can therefore comprise both PCP and PPI strategies.  

The Procurement of Innovation Platform developed practical guidance on PPI which will facilitate preparation and implementation of public procurement of innovative goods and services, which is online available.

The P4ITS consortium had especially a deeper look on the aspects related to C-ITS: "PPI does not necessarily include R&D. However, especially in the area of C-ITS, PPI might very well contain elements of R&D for adapting / modifying / integrating a solution already available on the market, so as to make it meet the requirements, insofar as this adaptation, etc. has not been developed during the initial market dialogue phase. This is mainly due to the fact that standardised and interoperable C-ITS solutions are still not available on a large commercial scale, or are not yet ready for implementation.

The choice of the tender procedure should always be based on market investigations / consultations. Supplementary R&D might be carried out by suppliers themselves during a market dialogue phase. However, if the procurer cannot reasonably anticipate the need for such supplementary R&D to be carried out outside a tender procedure, the procurer must choose a tender procedure for the PPI action. As depicted in Figure 10. Link between technology readiness level (TRL) and procurement actions (see P4ITS consortium, 2016, P4ITS - D6.2. - final recommendations, p.22) different approaches are available, based on the maturity level of the relevant service”.  

The P4ITS consortium prepared an overview of different PPI approaches, including pros and cons of each approach (e.g. market

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84 P4ITS consortium (2016) - P4ITS - D6.2. - final recommendations, p. 11
85 P4ITS consortium (2016) - P4ITS - D6.2. - final recommendations, p. 20
86 P4ITS consortium (2016) - P4ITS - D6.2. - final recommendations, pp.21-22
consultation, early announce of procurement intentions, forward committment procurement, functional/open specifications, total cost of ownership, life-cycle costing, using "innovative characteristics" as evaluation criteria, remuneration for participation, free test sites/living labs, joint procurement...). Guidance like this can help procurers to identify their appropriate procurement approach, based on the related C-ITS solution.

Especially some of the C-ITS Day 1 services have a significant level of maturity or are even ready on the market, so commercial solutions will be in some cases already available on the market. Other services are already piloted in operational environments. Therefore "standard" procurement procedures could be the appropriate tool. For other C-ITS services, or especially those services summarized under Day 1.5 services with a lower maturity level different approaches may be needed so that the means of PPI are relevant.

"PPI strategies and actions shall not be considered as a complex set-up, difficult to implement, but rather as - as already mentioned, strategies and procurement approaches enabling decision makers and public procurers to communicate on a large scale the needs / problems of public transport authorities, and to make the requirements acknowledged by the market players. This way, PPI actions are also an opportunity for new cooperation between procurers and suppliers to find solutions together while gathering knowledge important for both sides". 87

"Depending on the complexity of the need or problem, the procurement of innovative C-ITS solutions may require a multidisciplinary team including ITS specialists, procurement specialists, lawyers, and strong project management. However, this should not require heavy bureaucratic procedures regulating PPI, but rather a new cultural approach to procurement of innovation. In this way, different experts sit together and cooperate first to achieve common understanding and mutual learning with open minds, then to implement procurement actions of C-ITS solutions based e.g. on life cycle costing or total cost of ownership". 88

As emphasized by P4ITS it is important "for a successful large scale deployment and market rollout of innovative C-ITS solutions to include reflections about procurement as from the very early phases of development and implementation, i.e. already when formulating the problem or needs to be communicated to the market. Planning a PPI approach well ahead, and communicating the PPI approach to the market, is a way to give to both procurer and the suppliers a clear vision of the project and to make it easier to define the main tasks and milestones.

In the specific field of C-ITS, thanks to the level of maturity of technologies, short-term targeted PPI actions may therefore be a better support action than long-term R&D activities as regards the challenges related to the last steps of deployment, when objectives, roles and responsibilities of different actors on specific tasks can be defined more in detail as compared to exploratory research and highly risky developments." 89

Finally it has to be concluded that "Public Procurement of Innovation is much more than a simple buying and tendering process; it requires strategic and cross-sectorial, long-term thinking" 90 13

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87 P4ITS consortium (2016) - P4ITS - D6.2. - final recommendations, p. 31
88 P4ITS consortium (2016) - P4ITS - D6.2. - final recommendations, p. 32
89 P4ITS consortium (2016) - P4ITS - D6.2. - final recommendations, pp. 32-33
90 P4ITS consortium (2016) - P4ITS - D6.2. - final recommendations, p. 45
**PCP and PPI and the deployment of innovative solutions**

As the Procurement of Innovation Platform concludes: “While much of the PPI and PCP discussion relates to scientific research and development, there is more to it than this alone. Innovation in the public procurement context very much takes into account:

- Innovation in the design and delivery of public services
- The procurement of innovative goods and services
- Innovative procurement processes and models

Therefore, PPI and PCP cover a large range of the industrial market through all development phases – from research to the final stage of the product – giving public buyers the opportunity to influence the market towards innovative solutions”\(^\text{14}\).
6. The Governance and Management of the C-ITS Ecosystem

Definitions and Key Concepts
As business ecosystems are networks of firms which collectively produce a holistic, integrated technological system that creates value for customers (Bahrami and Evans, 1995; Basole, 2009; Lusch, 2010; Teece, 2007; Agerfalk and Fitzgerald, 2008) the management and governance of the ecosystem is the function that facilitates and enables this network to deliver the value – in simple words, make sure that the ecosystem is a) coming to existence and being formed, b) once in place, creating value. The first step to make is to make the ecosystem actors aware that they belong to an ecosystem and that they are aware of the other ecosystem actors’ existence. After this ‘self-realisation’ it is easier to start building links between the ecosystem actors. Partly this link-building may be evolutionary and partly it may be deterministic. If there is a general aspiration to boost the ecosystems and their readiness in value creation, the deterministic, goal-oriented work is required. Hence there is a need to govern and manage the network of actors.

Governance means action or manner of governing a state or an organisation (Oxford Dictionary). It means also the highest level of management and the systems for exercising the management (Cambridge Dictionary). Hence governance can be regarded as the strategic system of managing an organisation, be that organisation large (e.g. a state or multinational corporation) or small (e.g. an SME). Different types of organisations require different type of governance system. The same applies to business ecosystems. And since a business ecosystem is usually associated with particular service or set of services, the service systems require different types of governance, i.e. system of management.

Governance is not operational management, but strategic. The management system is built on strategic level and is therefore more permanent, meaning that it has strategic dimensions on a chronological scale, but that it also is implemented by the high-level management of the organisation(s). The management system is the tool for the strategic management to set guidelines, priorities, and modus operandi for the entire organisation. In ecosystem management and governance, the ecosystem actors’ strategic management dictate the governance models. The clarity and functionality of the governance depends on three things: 1) how complex is the ecosystem, 2) how dominant are the key actors, and 3) how the actors are able to build a consensus among themselves about the governance.

Since ecosystem governance can be regarded as ‘agreements’, ‘set of rules’ or ‘operating principles’, the tools for governance must explicitly include for example:
- Framework contracts between actors
- Strategic agreements and memorandums of intent
- Alliances and partnership agreements
- Commonly agreed standards and performance criteria
- Etc.

In C-ITS and CCAM context, the above tools must be available or they must be constructed before scalable implementation is possible. Otherwise the C-ITS services are built on case-by-case basis that may vary from one place and one context to another. This in turn may result in market islands and lack of economies of scale. On the other hand, however, natural evolutionary competition between companies (technology, services) and even ecosystems requires overlapping and differing experiments and market trials.

Successful governance system takes into account also external effects, that is those impacts and consequences that fall outside the ecosystem and are faced by stakeholders external to the ecosystem. Managing side effects – externalities – is in many cases mandatory and
particularly so in mobility context where the requirements for safety and environment are strict.

Figures 12.

What Do We Know? - Brief Review of Literature and Relevant Findings

The research body of knowledge starts to be extensive. A good literature overview is to be found from Mäkinen & Dedehayir (2012). The literature has identified a number of different types of ecosystems:

- Industrial ecosystems (Desrochers, 2010; Sharma and Henriques, 2005)
- Product ecosystems (Frels et al., 2003)
- Service ecosystems (Lusch, 2010)
- Technology-oriented ecosystems (Santos and Eisenhardt, 2005, Zulkarnain et al 2014)
- Innovation ecosystems (Autio & Thomas 2014)
- Spatially-oriented business or innovation ecosystems (Majava et al. 2016, Aapaoja & Leviäkangas 2015)
- Etc.

This means that markets where the value is delivered are different for various ecosystems and that these markets may overlap, as may the ecosystems. Also for some ecosystems the word ‘business’ might be misleading. It would actually be more correct to talk about ‘value creation systems’ than business networks or business ecosystems.

For C-ITS, all the aforementioned ecosystems may apply, depending on the perspective one adopts. A C-ITS service may appear in a particular city or region with particular features and it may thus be regarded as a spatial system. It may also be that only certain vehicles are capable of offering some services and the functionality is either service- or product-oriented, or both. At an early stage of C-ITS development there are surely innovation ecosystems that are involved in the research, development and innovation.

The art is to understand that which ecosystem actors are the most relevant around which the ecosystem can be built. These are called the **keystone** actors (Iansiti & Levien 2004). Without
the keystone actors, be they companies or other organisations, the ecosystem will not evolve. For example, if a city is launching a call for tenders for a C-ITS and uses the tools of innovation procurement, one of the keystone actors is definitely the city itself. The other actors, depending on the type of service that is called for, may comprise vehicle manufacturers, vehicle fleet owners, or specialised mobility service providers.
7. References


iMobility Support. (2013) - iMobility Support D3.4a – Status report on PCP at EU level 2013

iMobility Support. (2014) - iMobility Support D3.4b – Status report on PCP at EU level 2014

iMobility Support. (2015) - iMobility Support D3.4c – Status report on PCP at EU level 2015


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P4ITS consortium. (2016) - P4ITS - D6.2. - final recommendations, p.22


SPICE project (2017). D5.2. SPICE Stakeholder Group Launch, p. 17


URL references:


Materials and Further Readings

**Business model frameworks**

Alexander Osterwalder’s presentation on business model canvas on YouTube: [https://www.youtube.com/watch?v=2FumwkBMhLo](https://www.youtube.com/watch?v=2FumwkBMhLo)

Australian Road Research Board on C-ITS on YouTube: [https://www.youtube.com/watch?v=3AKCkK4h0ck](https://www.youtube.com/watch?v=3AKCkK4h0ck)


**Stakeholder perspective**
Professor Freeman explains stakeholder theory:  

Professor Freeman explains “who are stakeholders?”:  
https://www.stakeholdermap.com/what-are-stakeholders-video.html

Professor T. Jones tells “what’s next for stakeholder theory?”  

**Procurement**


iMobility Support Reports on Pre-Commercial Procurement

iMobility Support Report on PCP at European Level 2013  
https://ertico.assetbank-server.com/assetbank-ertico/action/viewAsset?id=11986&index=9&total=65&view=viewSearchItem

iMobility Support Report on PCP at European Level 2014  
https://ertico.assetbank-server.com/assetbank-ertico/action/viewAsset?id=13195&index=2&total=65&view=viewSearchItem

iMobility Support Report on PCP at European Level 2015  
https://ertico.assetbank-server.com/assetbank-ertico/action/viewAsset?id=13407&index=7&total=65&view=viewSearchItem

iMobility Support “PCP for ITS Guide”  
https://ertico.assetbank-server.com/assetbank-ertico/action/viewAsset?id=13419&index=8&total=65&view=viewSearchItem

Webpage of the European Commission on Pre-Commercial Procurement  
https://ec.europa.eu/digital-single-market/pre-commercial-procurement

The Procurement Innovation Platform  
http://www.innovation-procurement.org/home/?no_cache=1

Guidance for public authorities on Public Procurement of Innovation  
P4ITS Final recommendations

Webpage of the European Commission on Innovation Procurement

European Assistance For Innovation Procurement
http://eafip.eu/

Business ecosystems:
https://www.youtube.com/watch?v=-nl7RnfB2GM from Deloitte
https://www.youtube.com/watch?v=VsOfcRAbhow from Stanford University by Rahul Basole
https://www.youtube.com/watch?v=l6d7ALmFKMg from Harvard BS by prof. Shapiro
Annex 7: Cost-benefit analyses of ITS services

Grant Agreement Number: 724106

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<td>RE Restricted to a group specified by the consortium (including the GSA)</td>
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<td>CO Confidential, only for members of the consortium (including the GSA)</td>
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Abstract

This document presents topic study 7: Cost benefit analyses of ITS and C-ITS services.

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<th>Definition</th>
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<tr>
<td>BCR</td>
<td>Benefit-Cost Ratio</td>
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<tr>
<td>CBA</td>
<td>Cost-Benefit Analysis</td>
</tr>
<tr>
<td>C-ITS</td>
<td>Cooperative Intelligent Transport System</td>
</tr>
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<td>EC</td>
<td>European Commission</td>
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<tr>
<td>EEI</td>
<td>Energy Efficiency Intersection</td>
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<td>GA</td>
<td>Grant Agreement</td>
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<td>GLOSA</td>
<td>Green Light Optimal Speed Advisory</td>
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<tr>
<td>I2V</td>
<td>Infrastructure to Vehicle</td>
</tr>
<tr>
<td>IRR</td>
<td>Internal Return Rate</td>
</tr>
<tr>
<td>ITS</td>
<td>Intelligent Transport System</td>
</tr>
<tr>
<td>KPI</td>
<td>Key Performance Indicator</td>
</tr>
<tr>
<td>NPV</td>
<td>Net Present Value</td>
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<td>PO</td>
<td>Project Officer</td>
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<td>RHW</td>
<td>Road Hazard Warning</td>
</tr>
<tr>
<td>RVW</td>
<td>Red Violation Warning</td>
</tr>
<tr>
<td>SCBA</td>
<td>Social Cost-Benefit Analysis</td>
</tr>
<tr>
<td>TTG</td>
<td>Time To Green</td>
</tr>
<tr>
<td>V2I</td>
<td>Vehicle to Infrastructure</td>
</tr>
<tr>
<td>V2V</td>
<td>Vehicle to Vehicle</td>
</tr>
<tr>
<td>V2X</td>
<td>Vehicle to other transport participants</td>
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<td>WP</td>
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1. Introduction

The topic study ITS-7: Cost-benefit analysis of ITS of the CAPITAL project was designed by the partners of the CAPITAL project to prepare a study module on cost-benefit analyses (CBA) for the cooperative intelligent transport system services (C-ITS). It provides a consistent and comprehensive overview of the recent developments of the CBA previously applied to transport projects, in particular, on the deployment of C-ITS services. It briefly discusses methodology (how to conduct a CBA) and what are the indispensable ingredients for such analysis. It also explains key terminology and provides some relevant case studies to understand the advantages as well as limitations of the CBA. This topic study is supported by relevant literature and other materials that can be used in the study module.

1.1 Scope and objectives

The main objective of this topic study on the cost-benefit analysis for the C-ITS services is to provide background information on the CBA and how it is applied in the projects dealing with C-ITS services in transport. The study provides building blocks and a basis to be used to create a CAPITAL study module on “Cost-benefit analysis for ITS services.”

Through the systematic approach of the CBA, the goal of this study is also to understand the strengths and weaknesses of the analysis. The CBA explained in this chapter is based on the well-known procedure that consists of comparing the identified costs with the benefits so that the profitability of the project can be easily analysed. The measurement of the benefits is based on a selection of Key Performance Indicators (KPIs). The correct identification of KPIs is crucial in order to identify the gaps between current and desired performance of the services. It is also important to carefully detect the correct indicators able to measure and assess precisely the impact of the services. Based on these considerations, a set of indicators needs to be introduced to translate the KPIs into monetary values.

By calculating the costs necessary for deployment operation and maintenance of the C-ITS services and calculating their benefits for all stakeholders, the viability of a business model needs to be determined. To identify this viability a CBA tool is utilised. The results of this analysis is basis for further financial, cost-effectiveness, break-even analyses, amongst others.

1.2 Rationale

The CBA discussed in this topic study is based on findings of previous research, namely scientific publications and projects that focused on CBA of ITS services in transport sector. In particular, it considers several projects, i.e.: COMPASS4D, FREILOT, SmartCEM and CO-GISTICS.

COMPASS4D was an EU-founded project on deployment of Cooperative Intelligent Transport Services. Its main focus was on three services that aimed to increase driver’s safety and reduction of road accidents: the Energy Efficiency Intersection (EEI), the Road Hazard Warning (RHW) and the Red Violation Warning (RVW).

FREILOT was also an EU-funded project intended to demonstrate how the FREILOT services could contribute to save ca. 25% of the fuel consumption.

SmartCEM (Smart Connected Electro Mobility) project aimed to demonstrate the fundamental role of ICT solutions for improving the electro mobility for cities and people.
The NEWBITS project (ongoing) that is a Coordinated and Support Action project funded under the EC Programme Horizon 2020. NEWBITS tries to understand the changing conditions and dynamics that affect and/or influence C-ITS innovations (http://cordis.europa.eu/project/rcn/205765_en.html). The gained knowledge will help to understand how to minimise the failures inherent to ITS innovation deployment. It will also define business models for C-ITS.

CO-GISTICS project focused on improvement of the transport systems through deployment of five ITS services in 7 logistics hubs across Europe. These services were: Intelligent Truck Parking and Delivery Area Management, Cargo Transport Optimisation, CO₂ Footprint Monitoring and Estimation, Priority and Speed Advice and Eco-Drive Support. The services aimed to bring benefits in terms of reduction of CO2 emissions, fuel consumption or waiting time.

1.3 Structure of the document

In order to make this deliverable well organised and easily usable, it was structured into four main sections, which correspond to four key questions defined and tackled by the CAPITAL project, namely:

- Definition of the costs and benefits of C-ITS
- Financing of C-ITS services
- Identification of the costs for instalment, operation and maintenance of C-ITS services
- Building C-ITS on existing investments

The first section contains a definition of a CBA. It also presents a review of recent approaches on CBA, together with the description of their methodologies to assess the existing C-ITS services. The second section focuses on a brief presentation of the C-ITS services and models for their financing. The third part of this document is dedicated to identification of the costs related to instalment, operation and maintenance of various C-ITS services and how these costs can be measured. The fourth chapter presents an analysis of the existing investment schemes and how these can be utilised for deployment of ITS services.

1.4 Context

Before starting a discussion on CBA, it is necessary to briefly explain what ITS is. From a very outset, it is worth mentioning that there is no homogeneous definition that can explain ITS. This can be explained through the fact that ITS have a very fast exponential development and highly cross-cutting and interdisciplinary nature. ITS is a still young discipline.

The term ‘ITS’ stands for ‘Intelligent Transport Systems’ or ‘Intelligent Transportation Systems.’ In a wider sense, ITS means a system related to mobility that is increased in development through information technology (IT).

ITS applies advanced technologies of electronics, communications, computers, control and sensing and detecting in all kinds of transportation system in order to improve the management of the transport system, increase safety, efficiency and service, and traffic situation through transmitting real-time information. It can help to tackle congestion, pollution, poor accessibility and even social exclusion (https://deltasoftwaresolutions.net/2014/03/31/intelligent-transportation-system/).

According to the EC “ITS are advanced applications which – without embodying intelligence as such – aim to provide innovative services relating to different modes of transport and transport management and enables various users to be better informed and make safer, more
coordinated and ‘smarter’ use of transport networks” (European Commission, 2010b). 

Mathew (2014) explains the ITS as “the application of computer, electronics, and communication technologies and management strategies in an integrated manner to provide traveller information to increase the safety and efficiency of the surface transportation systems. These systems involve vehicles, drivers, passengers, road operators, and managers all interacting with each other and the environment, and linking with the complex infrastructure systems to improve the safety and capacity of road systems.”

Rye (2006) defines the ITS as “the application of computer technology to the transport sector. ITS systems gather data about the transport system, process it, and then use the processed data to improve the management of the transport system, and/or to provide the transport user with more and better information on which to base their transport decisions.”

Another term that is extensively used in this topic study is ‘C-ITS,’ which stands for the ‘Cooperative Intelligent Transport Systems.’ C-ITS focuses on the communication between intelligent transport systems, whether it is a vehicle communicating with another vehicle, with the infrastructure, or with other C-ITS systems (\url{http://etsc.eu/briefing-cooperative-intelligent-transport-systems-c-its}).

The NEWBITS project (NEWBITS Project Deliverable 2.1: “Overview of ITS initiatives in the EU and US”, 2017) defines ITS and C-ITS, as follows: “C-ITS are considered a subset of the overall ITS that communicates and share information between ITS stations to give advice or facilitate actions with the objective of improving safety, sustainability, efficiency and comfort beyond the scope of stand-alone system.” It also considers ITS main function as the increased efficiency in the transport system, with special focus on the service and information provision for the full spectrum of users (drivers, passengers vehicle owners, network operators…) which involves a diversity of stakeholders (network operators, public authorities, OEMs, service providers, technology developers…).

With C-ITS communication is happening between vehicles (vehicle to vehicle, V2V), between vehicles and infrastructure (vehicle to infrastructure, V2I; infrastructure to vehicle I2V) and/or between vehicles and other transport participants (V2X), for instance pedestrians or cyclists.

The figure 1 below shows how various C-ITS (safety systems, warning systems, travel assistance, traffic signals, navigations, fleet management etc.) communicate and interact between themselves by using different communication networks, such as MAN, Mobile, WLAN, ITS-G5, and satellite to exchange the information and data (\url{http://www.manutencionyalmacenaje.com/es/notices/2015/01/50-m-de-la-ue-para-instalar-sistemas-inteligentes-de-transporte-en-vias-europeas-37821.php#WnwY7YTytEY}).
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Figure 1. Intelligent Transport Systems

It is indispensable to retain that ITS as well as C-ITS are not limited to only one mode of transport, i.e. road, but they also include other modes of transport such as rail, aviation and waterways and communication between them. Because of numerous benefits and relatively moderate costs related to deployment of C-ITS, there is a big interest and need in the society towards a fast introduction of these services.

1.5 Methodology

The ITS-7 topic study employs several methods for development of the studying programme on the CBA for ITS services. A cooperative approach is based on bringing together an academic research on the CBA and practical experience in designing, development and deployment of various ITS services. The benefits of synergy of both academic as well as business environments allows to estimate the costs and benefits of the ITS services as precisely as possible, taking into account various models, factors, approaches, investment conditions, etc. This knowledge will be transferred and structured in the study module.

A relevant scholarly literature and various audio-visual online materials that have been used in preparation of this chapter were gathered in the course of preparation of this topic study through personal network or desk research via Internet. All these materials can be used in the course of the study programme on the CBA.

A list of bibliography on the CBA for ITS services and related topics was proposed by the chapter contributors to the reader as a studying materials.
2. Cost-benefit analysis

Before entering into discussion on the CBA for C-ITS, first of all, the key terminology needs to be defined and explained.

2.1 Definition of cost-benefit analysis

There are numerous publications that endeavour to define the cost-benefit analysis (CBA), or as it is also called benefit costs analysis (BCA). However, all of them have four key elements in common, namely:

- this is a process or technique
- it aims at quantifying or calculating both costs and benefits
- it aims at evaluation of costs and benefits
- the results of this evaluation are used in decisions on financing projects.

Schulz and Geis, (1993) says that “the cost-benefit analysis (CBA) is a systematic and well-proven technique of economic evaluation. It is a process of comprehensively contrasting benefits and costs associated with the introduction or implementation of a project. The results allow an assessment of the desirability of a project. It, therefore, provides a helpful component for decision making, e.g. in the public sector.”

A CBA that consider not only financial effects of the developed project, but also takes into account its social impacts is also called a social cost-benefit analysis (SCBA).

The SCBA (http://decisio.nl/en/research/social-cost-benefit-analysis/) can be defined as “a systematic and cohesive method to survey all the impacts caused by a development project or other policy measure. It comprises not just the financial effects (investment costs, direct benefits like profits, taxes and fees, et cetera), but all the societal effects, like: pollution, efficiency, environment, safety, travel times, spatial quality, health, indirect (i.e. labour or real estate) market impacts, legal aspects, et cetera. The main aim of a SCBA is to attach a price to as many effects as possible in order to uniformly weigh the above-mentioned heterogeneous effects. As a result, these prices reflect the value a society attaches to the caused effects, enabling the decision maker to form an opinion about the net social welfare effects of a project.”

In the CO-GISTICS project, the CBA is defined as “a procedure aimed at quantifying and evaluating the costs and the benefits of an investment project in order to determine its feasibility. It is usually carried out to support decisions on investment projects. The analysis provides information on the predicted time to return an investment taking into account environmental and social factors. This is done by comparing the scenario with the project versus a scenario without project.”

The CBA is one of a set of tools of assessing efficiency of investment decision, i.e. it helps to identify how to allocate resources to obtain the maximum possible benefits from invested resources. It necessary to keep in mind that CBA is rather an approach than a methodology that helps to compare benefits and costs that are states in monetary terms.

While applying CBA for the C-ITS services in transport, it is important to keep in mind the social aspects as well as the environmental impact and how they can be calculated. Many agree that the CBA still contains many limitations and a number of enhancement are possible to be included in the process that can increase the reliability of the results.
2.2 Calculation

A standard CBA consists of four steps, namely identification of cost, calculation of benefits, comparison of alternatives and, finally, report and planning the action.

In the first step of determination of the costs, a list of all possible costs needs to be prepared. It has to include initial or capital costs; ongoing costs (planned costs in the coming months and years), labour costs, contactor costs (it also include any external labour costs), supply or input costs and non-monetary costs (it includes the impact on safety, environment and other less tangible things. It has to be kept in mind that not all impacts can be assessed, but they need to be listed and taken into consideration).

In the second step the benefits needs to be calculated. It is prepared for the same dimensions as it was done for the cost. All benefits are divided into two groups, i.e. monetary: time saved, energy saved, supply saving, etc. and non-monetary: quality, reputation, safety, environment, morale, etc. This calculation should considered the immediate, yearly, long-term as well as ongoing benefits.

The third step is dedicated to comparison of all costs and benefits prepared in the previous two steps for every option or scenario. In case there is only one scenario or alternative, it has to be compared with the status quo. There are four steps to compare options, namely: costs need to be subtracted from each benefit for each option/solution; then they are compared with status quo; then each solution is compared with each other and, finally, the non-monetary values need to be taken into consideration.

Table 1 is an example of a simple CBA prepared for several scenarios, including a status quo. In some of the rows it can be difficult to provide monetary values. In this case a description of the cost or benefits is indicated.

<table>
<thead>
<tr>
<th></th>
<th>Status Quo</th>
<th>Solution 1</th>
<th>Solution 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial costs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ongoing costs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time saving</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supply saving</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy saving</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reputational</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morale</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quality</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comfort</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In the final step, a report and action plan are prepared which are based on the previously conducted CBA. After assessing all options, a recommendation is prepared, which include a brief plan of actions for the recommendation. It also needs to include other influencing factors. In some cases it is possible to have a compelling argument that still needs to be postponed for other reasons. A good example of it can be competing priorities, availability or resources, cash flow, etc.

It is indispensable to keep in mind that non-monetary conditions can have a significant influence. For instance, safety can outperform all other criteria in determining action. Also time-value of money needs to be taken into account, for each capital has its cost. In case the CBA becomes complicated, then more detailed financial analysis is needed.
In the transport sector, before starting any project related to C-ITS, a CBA also needs to be prepared. However, it is more complex and needs some explanation, because it considers various elements and conditions.

The “Guide to Cost-Benefit Analysis of Investment Projects, Economic appraisal tool for Cohesion policy 2014-2020” (http://ec.europa.eu/regional_policy/sources/docgener/studies/pdf/cba_guide.pdf) in detailed manner explains the methodology to carry out a CBA on investment on transport, energy and research and development infrastructure. Following the analytical framework to carry out described in the Guideline, a CBA consists of three main characteristics. The first characteristic is related to the analysis of the investment and the costs for the execution of the project. The second characteristic is that the CBA should be carried out in a long term perspective. Finally, the economic performance expressed in monetary terms aims to present quantitative figures on the value of the investment and on its economic return.

There are three main indicators that can be estimated to evaluate an investment and that need to be computed to carry out the CBA to evaluate the C-ITS services:

- **Internal Return Rate** (IRR), which refers to the measurement of the profitability of potential investments;
- **Net Present Value** (NPV), which computes the benefit and cost cash flow;
- **Benefit-Cost Ration** (BCR) that aims to discover the relationship between qualitative and quantitative benefits and costs.

The IRR is used to measure the efficiency of an investment. The higher the value of the IRR, the higher is the desirability of the project because higher is the rate to reach the break even. The IRR is closely related to the NPV, which is a measure of the performance of an investment.

The NPV is evaluated as the sum of discounted costs minus the sum of discounted benefits:

\[
\text{NPV} (N) = \sum_{i=1}^{N} \frac{B_i - C_i}{(1 + d)^i}
\]

\(B_i\) = benefits of the project in year \(i\)
\(C_i\) = costs of the project in year \(i\)
\(d\) = discount rate
\(N\) = number of time periods.

It is important to keep in mind that the \((B_i - C_i)\) denotes the cash inflow, outflow of year \(i\) and may be positive or negative.

If the value NPV \((N)\) is positive, then it indicates that a positive return from the project in \(N\) years and it is worthwhile to invest on the basis of this time horizon. In case the NPV is negative then the project will bring losses. It is important to look as well at the investments necessary for the project. If there are two scenarios with the same NPV, but one of them requires less investments and another way more, then it worth considering the project with less investments, unless the amount of investment is not an issue.

The IRR represents the value of discount rate nullifying the NPV in the formula; it is computed setting NPV equal to zero and solving the relation with respect to \(d\). IRR is a discount rate where NPV turns from positive to negative. The higher IRR would mean the higher costs.
However, the IRR is not the indicator for higher benefits, but the value of the NPV with higher value indicates higher return.

The IRR is a discount rate that makes the NPV of all cash flows from a project equal to zero. It is an expected rate of return which will be earned on a project or investment. The IRR calculations rely on the same formula as NPV does. When calculation IRR, investment (cash flows) are given, and the NPV equals zero. The initial investment for starting period will be equal to the present value of the future cash flows of the investment. Investment = present value of future cash flow. Hence, the NPV = 0.

\[
0 = NPV = \sum_{n=0}^{N} \frac{CF_n}{(1 + IRR)^n}
\]

\(CF_n\) = Cash flow/investment in each period
\(N\) = holding period
\(n\) = each period

In case IRR is greater than or equal to the cost of capital, the project would be accepted, if not, then it will be rejected.

The BCR compares the discounted benefits to the discounted costs as follows:

\[
BCR (N) = \frac{\sum_{i=1}^{N} \frac{B_i}{(1 + d)^i}}{\sum_{i=1}^{N} \frac{C_i}{(1 + d)^i}}
\]

The BCR formula includes absolute costs and discounted benefits. Both costs and benefits can be situated on micro- and macroeconomic levels. The result of this calculation is an objective economic-based indicator for the cost-effectiveness of the project.

When the results of the formula on BCR show >1 then it worth investing into the project. Schulz and Geis, (2014) indicate that by applying BCR for the decision making in investment in ITS-projects, it can be ensured that decisions are taken under objective criteria instead of being solely interest driven.

### 2.3 Applying cost-benefit analysis

It is not an easy task to evaluate the various transport projects and calculate immediately their costs and benefits. The difficulties appear from the variety of areas that an implementation of a project involves. Besides the visible economic effects, which are easier to calculate, transport projects touch many social and environmental aspects, which are difficult to estimate and predict. The CBA seems to be so far a unique tool that allows to assess to a certain degree a social or environmental impact of a project.

The main principle that stands behind the CBA is to make different types of effects, including benefits and costs, comparable in monetary way. It is relatively easy to conduct it for the cost, whereas the total benefits require more efforts to be calculated. Since the CBA does not attempt to calculate the total improvement to the society, the individual benefits can be summed up together, and, when combined with occurring externalities, present a comprehensive assessment. Therefore, CBA is a standard tool in evaluation of both economic and socio-economic impact of a transport project (Čiapas and Rinkevičius, 2014)
A study conducted by Leviäkangas and Lähesmaa, (2002) on CBA acknowledges the limitations of the traditional CBA to evaluate investments in C-ITS services. The standard CBA (Leviäkangas, 2002) currently used for transport projects insufficiently recognises the special characteristics of C-ITS investments. Therefore, a new multi-criteria approach needs to be proposed to assess the qualitative risks that have not a monetary value which can include all investments needed, cost and benefits.

Also Schulz and Geis, (2014) indicate in their analysis of CBA carried out to evaluate investments on C-ITS in the context of several FP5 and FP6 European projects (CHAUFFEUR I and II, RESPONSE II, SeiSS, eIMPACT, PRE-DRIVE C2X and DRIVE C2X) that CBA generates important results that shed new light on C-ITS projects. It overcomes the purely business relevant perspective and touches the areas that have not been yet considered. There is a small number of research projects that takes into account the assessment of socio-economic impacts compared to the number of purely scientific publications. The authors underline that C-ITS have special requirements comparing to other projects on infrastructure. They also indicated a number of challenges, which are not considered in the calculation CBA in purely infrastructure projects.

According to Schultz and Geis, the analysed projects have shown that the CBA is often faced with incomplete information, especially, it refers to the costs. So far, the CBA has focused on benefits due to transport efficiency, emission savings, safety increase, etc., but it has not yet taken into account other elements, for instance, such as comfort. It can influence the quality of travelling that might increase for driver or traveller by application of ITS. The authors also argue that macroeconomic variables, especially economic growth need to be included into the calculation of CBA. Therefore, CBA needs to comprise a number of improvements that can increase the reliability of the results. “The higher the reliability of the results, the more likely it is that CBA is increasingly applied in ITS research and can thus contribute to a successful implementation of technologically enhanced projects.”

The European Commission has acknowledged that ITS can significantly contribute to reduce the impact of transport on the environment as well as improve the efficiency of the transport systems. The Directive 2010/40/EU (http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32010L0040) of the European Parliament and the Council of 7th July 2010 on the framework for development of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport was issued. It sets a legal framework to speed-up the introduction of ITS on the European market. Currently, there are no standards procedures how to perform CBA on ITS investments, however, there is a common agreement on benefits that ITS services can provide in terms of performance in transport (e.g. reduction of waiting time, improvement of delivery time), impact on society (e.g. reduction of CO2 emissions) and on the economy (e.g. reduction of fuel consumption).

2.3 C-ITS Platform’s methodology for CBA

The C-ITS Platform Working Group on Cost Benefit Analysis proposed to analyse various scenarios of deployment of C-ITS in Europe that would lead to widespread and coordinated deployment of the C-ITS services. The study was conducted for the EU MSS in the period between 2015 and 2030. At the first stage the Group identified a list of C-ITS-services that are likely to be deployed first. Then, a baseline scenario was agreed. It described the possible deployment roadmap of C-ITS services in all EU. In the next step the Group identified the most promising scenario in terms of quick and widespread uptake. Finally, it was decided to produce the highest possible quality of detailed input data to feed the CBA.

The Group prepared a list of defined C-ITS services of Day 1 applications for EU to be
deployed in the short-term. The list of indicates which services are to be deployed first and it serves a basis for aligning funding and investment priorities. The list of services was split into Day 1 and Day 1.5, based on technical readiness in the short-term (See Table 2 and 3).

The second step is the scenario building. The Group decided to bundle some services together in the process of deployment. There are two reasons:

- Some services will rely on the same hardware investment
- It is unlikely that many business cases can be found for individual services.

It was also agreed to consider two additional criteria when assessing the both list of services (Day 1 and Day 1.5), namely:

1. V2V, V2I or V2X communication (V=vehicle, I=infrastructure, X=anything, e.g. pedestrian)
2. The primary purpose of the service (e.g. road safety, traffic information, freight services, etc.)

The services were grouped in 9 service bundles, where each bundle has its particular communication type and purpose (See Table 2 and 3).

### Table 2. List of Day 1 C-ITS services

<table>
<thead>
<tr>
<th>#</th>
<th>Day 1 Services</th>
<th>Bundle</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Emergency electronic brake light</td>
<td>V2V</td>
</tr>
<tr>
<td>2</td>
<td>Emergency vehicle approaching</td>
<td>V2V</td>
</tr>
<tr>
<td>3</td>
<td>Slow or stationary vehicle(s)</td>
<td>V2V</td>
</tr>
<tr>
<td>4</td>
<td>Traffic jam ahead warning</td>
<td>V2V</td>
</tr>
<tr>
<td>5</td>
<td>Hazardous location notification</td>
<td>V2I</td>
</tr>
<tr>
<td>6</td>
<td>Road works warning</td>
<td>V2I</td>
</tr>
<tr>
<td>7</td>
<td>Weather conditions</td>
<td>V2I</td>
</tr>
<tr>
<td>8</td>
<td>In-vehicle signage</td>
<td>V2I</td>
</tr>
<tr>
<td>9</td>
<td>In-vehicle speed limits</td>
<td>V2I</td>
</tr>
<tr>
<td>10</td>
<td>Probe vehicle data</td>
<td>V2I</td>
</tr>
<tr>
<td>11</td>
<td>Shockwave damping</td>
<td>V2I</td>
</tr>
<tr>
<td>12</td>
<td>Green Light Optimal Speed Advisory (GLOSA) / Time To Green (TTG)</td>
<td>V2I</td>
</tr>
<tr>
<td>13</td>
<td>Signal violation/Intersection safety</td>
<td>V2I</td>
</tr>
<tr>
<td>14</td>
<td>Traffic signal priority request by designated vehicles</td>
<td>V2I</td>
</tr>
</tbody>
</table>
### Table 3. List of Day 1.5 services

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

In the first table all 14 services were combined into 3 bundles, where the first group concentrated on safety based on V2V, whereas 2 and 3 based on V2I services are associated with motorways and services related to traffic lights.

In the following step the all 9 service bundles were approached from two perspectives:

- Transport type (personal, public, freight)
- Geographical environment (TEN-T corridor, TEN-T core network, TEN-T comprehensive network, extra-urban, urban).

Finally, deployment scenarios were defined with two characteristics:

1. They are additive, i.e. scenario B contains all of scenario A, scenario C contains all of scenario B and A, etc.
2. They are chronological, e.g. scenario A will be developed before B, scenario B will be deployed before C, etc.
The five main scenarios proposed by the group are:

Scenario A:
- Deployment of all safety based V2V services (Bundle 1) starts on all roads (as V2V is road independent, the determining factor is the uptake rate in vehicles)
- Traffic information & smart routing (Bundle 5) is deployed on TEN-T corridors and core roads first and initially for passenger cars only

Scenario B
- The (mainly) motorway-focused V2I services from Bundle 2 (such as road works warning and shockwave damping) are deployed on TEN-T corridors and core roads
- Traffic information & smart routing extends to comprehensive network and now includes freight vehicles

Scenario C
- Urban deployment of the applicable services from Bundle 2 and the very urban focused services from Bundles 3 (e.g. GLOSA, traffic signal priority) and 4 (Parking information)
- Traffic information & smart routing extends to all other equipped roads
- Safety based V2V services (Bundle 1) extend to buses
- Motorway-focused V2I services (Bundle 2) are further deployed to all equipped roads

Scenario D
Loading zone management is deployed to freight vehicles and equipped roads

Scenario E

- All additional Day 1.5 V2X services (e.g. motorcycle approaching indication or VRU protection) are deployed across all vehicle types and equipped roads

2.6. Limitations of cost-benefit analysis

As it was already mentioned that CBA is an approach rather than a rigid methodology. Therefore, the main focus of this chapter is identification of possible limitations of CBA. Three main groups of limitation is going to be discussed here, namely limitation related to choice of CBA, uncertainty related to cost and uncertainty related to benefits.

2.6.1. Choices in CBA

There are several initial explicit or implicit choices in CBA which can not only increase uncertainty in CBA, but also change their results.

2.6.1.1. Level of analysis

The European project EVA (EVA, 1991) identifies three levels of analysis which is relevant for deployment of C-ITS:

- Operational analysis: it deals with technical performance of the system
- Socio-economic evaluation: it estimates the gains or losses for society that come from deployment of C-ITS
- Strategy assessment: it provides a long-term political analysis of all ITS applications.

The technical performance of C-ITS is still under study. Many research projects showed that C-ITS provides a strategy-level assessment. As for the social-economic assessment requires more precise deployment data and it often needs to be estimated, which, in its turn, leads to uncertainty in CBA.

2.6.1.2. Geographical area

It is indispensable to establish the geographic area where CBA is to be carried out, for different regions have different provision of roads, type of traffic, road services, safety characteristics, etc., which need to be taken into account. Therefore, to invest in particular system, a geographic context needs to be considered and its specific context.

2.6.1.3. Political context

The political context includes various support and subsidies as well as the legal situation and it can have a serious influence on costs and benefits if they are not considered properly.

2.6.1.4. Lifecycle or snapshot CBA

There are two common approaches of CBA, i.e. the “lifecycle” and “snapshot.” The former approach sets the discounted value of benefits against the discounted values of costs over the timescale of interest, whereas the latter approach selects a year in the future and calculates the BCR for the year. In this approach the cost are transformed to annual values and are compared to the discounted selected year benefits. The selection of “lifecycle” or “snapshot” approach depends on the information needs. The lifecycle approach focusses
more on the timeline for market success of an intervention and it is closely linked with “year zero” investment decisions.

2.6.1.5. **Point of time consideration**

The important question in CBA is the start time and duration period during which costs and benefits are calculated. It is important to keep in mind that the cost for new technologies are reduced over time, namely the new system become cheaper. In this case CBA needs to choose a time and estimate costs as well as benefits at future times.

2.6.1.6. **Technology issues**

A choice for new technology also contains certain risks and there are not easy reflected in CBA. Technology affect both the cost and benefits of C-ITS. Without solid data, they have to be estimated, which increase uncertainty.

2.6.1.7. **Human factors**

Another risk that cause uncertainty in CBA is the human factor. It is know that ITS have less impact than theoretical estimation. As an example, some ITS technologies installed on board of a vehicle make drivers feel safer, then they start driving faster. This negates part of benefit. Therefore, the behaviour of equipped with new technologies drivers and unequipped road users need to be also considered. In order to calculate benefits, special mechanisms to assess expected impacts need to be developed and human response incorporated to determine real benefits.

2.6.1.8. **Discount rate**

For some projects the discount rate is applied for a specific period of time. Once it is applied, it needs to be reflected in calculation of costs and benefits for different years with different discount rate, which is not always the case.

2.6.2. **Uncertainty over costs**

There is some uncertainty related to the costs. The cost within a CBA can depend on the actual situation or scenario that is considered. In some cases, certain C-ITS requires specific hardware. However, in a more complex situation, when hardware is already available, incremental cost may be applied. Therefore, for each case the costs will be different, depending on various scenarios.

Another uncertainty is related to the included costs. The final cost of a product is based on a total sum of a number of costs included (e.g. cost of deployment, distribution, cost of installation and maintenance, insurance, training, communication, energy, etc.) that need to be estimated.

It is believed that bundling cooperative services together is the only way to introduce the new technology in transport and would also allow to share the costs across services. However, this approach needs to be proved through development of business models that involve appropriate stakeholders.

2.6.3. **Uncertainty over benefits**

There is also some ambiguity to the benefits from the C-ITS. To estimate the future benefits from the deployment of C-ITS the future context needs to be taken into account. In this case
it is indispensable to analyse and forecast the future traffic situation, which can be affected both by developments in other technologies as well as by the various economic and social factors. It is important to identify which benefits are expected, whether they are related to safety, to efficiency or to environment.

Other risks linked to the expected benefits are related to valuing outcomes. To have a complete CBA it is important to have a data obtained from experience of actual implementation, which would include cost of implementation, maintenance and measures of the actual benefits achieved. However, such data do not exist and often needs to be estimated.

### 2.6.4. Moral and ethical limitation of CBA

Since the CBA needs to estimate and evaluate the cost and benefits in monetary values, many argues that it is ethically wrong to assign monetary values to human life or injury. CBA’s ethical limitation, as Husseim says, are “apparent in areas of environment, safety and health regulation, in which case, there may be many instances where a certain decision might be right even though its benefits do not outweigh its costs.” ([http://www.icrp.org/docs/6/11.%20Philosophical%20Critique%20of%20Limitations%20of%20Cost%20Benefit%20Analysis-Stuck.pdf](http://www.icrp.org/docs/6/11.%20Philosophical%20Critique%20of%20Limitations%20of%20Cost%20Benefit%20Analysis-Stuck.pdf)) He proposes to use multi-criteria analysis (MCA). He provides several advantages why MCA is preferred to CBA.

One of the advantages is that MCA is able to take into account the distribution of costs and benefits amongst the population unlike a standard CBA. It rationalizes problems with number of components beyond the ability of the human brain to process conventionally. He says that through sensitivity analysis, enables exploration of alternatives and robustness of final solutions.

The Swedish parliament adopted a “Vision Zero” ([Whitelegg and Haq, 2006](http://www.icrp.org/docs/6/11.%20Philosophical%20Critique%20of%20Limitations%20of%20Cost%20Benefit%20Analysis-Stuck.pdf)) according to which decisions related to road safety need to go beyond the concerns regarding economic aspects and also take into account moral obligation of saving lives. It clearly shows that there is a complex interaction between economic, moral, social and political factors which change depending on the context.

### 2.7. Concluding remarks

CBA is an analytic tool that endeavours to express the most important effects in monetary values, which is not always possible. It measures efficiency, yet decision makers sometime will have other objectives that have nothing to do with efficiency.

Regarding C-ITS services, these are more likely to be delivered when a number of organisations with different business cases and models are involved. However, it is a very difficult task to quantify and understand within a CBA all individual costs and benefits, which will vary with each link in the delivery chain, the consumer and society. This leads us to the conclusion that CBA provides, at the best regard, the first general overview of the potential of cooperative systems to address society needs. However, its support to build a business case for a specific implementation of cooperative system is very limited. Transportation Economics Committee of the Transportation Research Board (TRB) summarises the main topics on performing Transportation Benefit-Cost Analysis on their webpage ([http://bca.transportationeconomics.org/](http://bca.transportationeconomics.org/))
3. Investing in C-ITS services

As it was identified by the C-ITS Platform, providing the significant added value of the C-ITS in the transport sector, their deployment are considered to be slow and fragmented (NEWBITS Project Deliverable 2.1 “Overview of ITS initiatives in the EU and US.”, 2017). The main reason for it is that in their nature the ITS services are public oriented. It leads to the fact that the innovative business models that would support the deployment of the C-ITS services are often missing. Therefore, it is indispensable that stakeholders that invest in ITS services see the benefits of their investments in the C-ITS services and new technologies.

3.1 Definition of cost and investment

This chapter of the topic study on CBA of ITS services focuses on the analysis on the investment and operational costs that are needed for implementation of the C-ITS services. Before starting the discussion, key terms such as ‘cost’ and ‘investment’ need to be defined.

Under the ‘cost’ we understand a certain amount of money that is required to be paid to install, run and maintain the ITS service.

‘Investment’ refers to the decision of allocation of money with perspective of having economic benefits.

In order to conduct the CBA for the ITS services two values need to be properly calculated and analysed, i.e. costs and benefits. Therefore, in the next section we will briefly focus on costs and investments.

3.1.1. Costs

The initial step in CBA is identification of the costs. There are two types of information that are collected in two different stages of the project and are indispensable for calculation of CBA, i.e. the initial investment costs and operational costs. The initial investment costs comprise the costs of fixed assets (e.g. ICT platform, devices, etc.) as well as non-fixed assets (e.g. project management, technical assistance, etc.), whereas the operational costs includes all entailed costs necessary to maintain the implemented services, such as labour costs for the employer, fuel, subscriptions, etc.

The CO-GISTICS project proposes to group all costs of the ITS services into three sets related to three implementation phases of the project:

- The value of pre-existing equipment that is needed to run the existing services used to deploy the new services;
- The current operational costs that should be taken into account in the CBA. It also includes the investment needed for the deployment of the services;
- The operational costs needed to run and maintain the ITS services.

The breakdown of the costs needs to be prepared for a certain period of time (5-10 years). This the time needed to cover the costs for the implementation of the services and obtain benefits. In the case of the CO-GISTICS project, 5-years period was chosen to cover the implementation costs and receive benefits in terms of fuel consumption and efficiency.

3.1.2. Benefits

Another value that is needed for the CBA is identification and calculation of the benefits. The evaluation of benefits is based on the monetisation of a subset of KPIs identified by any project. The process of monetisation of the benefits is natural for quantitative indicators such
as fuel consumption, for it can be easily measured and calculated. However, it is not that easy to quantify benefits for the society, such as environmental emissions, saved time, improved efficiency, etc. In this case for such costs standard values are employed to convert them into monetary values. In the CO-GISTICS project, for instance, services that have been assessed through the identification of additional KPIs that are not deployed to evaluate the benefits in monetary terms. The identified benefits by the project are the reduction of the average number of stops for vehicles and go per route or the average number of hard breaks which lead to the improvement of the logistic services. These qualitative benefits are transformed into quantifiable values and make a part of total benefits of the C-ITS services.

Another example of qualitative benefits from C-ITS services that are transformed into quantitative values is ROADIDEA project (Leviäkangas and Öörni, 2010). The project developed the fog warning system. The benefits from the developed ITS come mainly from the accident cost saving, i.e. the reduced number of accidents in foggy road traffic conditions. The outcome of the calculation of the fog pilot project shows that the investment is very profitable and worth making, because many of the benefit assumptions are on the safe side. The BCR calculated for the project is above 9 and NPV is €1.6mn. The IRR for nominal flows (i.e. non-discounted) is 77%. It is also indicated in the project that other potential benefits, such as those resulting in from re-routing and avoiding parts of road network with reduced visibility and lower than expected speeds could be calculated, but they were not included. However, there are still many uncertainties related to CBR. The most significant is the forecasted traffic growth and reduction of traffic accident numbers, where the former increases the future benefits and the later one decreases them.

Therefore, it is very important to take into account not only the benefits that provide economic value to the stakeholders who take the decision on investment, but also include the factors that can significantly improve the quality of life, e.g. environmental factors and can be quantified as a part of total benefits. It is also important to keep in mind that various stakeholders involved in the project that aims at deployment of ITS and C-ITS pursue different benefits, namely public authorities are interested more in the social benefits (e.g. reduction of accidents, emissions, increasing safety, etc.), whereas transport operators are looking at the benefits linked to costs saving (e.g. reduction of petrol consumption, better lead time, safety of freight, etc.) While preparing CBA, the interests and benefits of all stakeholders needs to be taken into account and thoroughly calculated in order to have a complete picture of deployment of ITS and C-ITS services.

### 3.2 Risks related to investment in C-ITS

A major risk related to C-ITS deployment are the significant upfront investments (Schulz and Geis, 2015) needed on both, the infrastructure level as well as on the vehicle level. Both are required to be set up in order to enhance cooperation before any benefits will occur (European Commission, 2016). Therefore, it is vital that the projects aiming at deployment of C-ITS obtain sufficient financial support from both private and public sectors. The European Commission plays a key role in financing C-ITS projects. Through the framework of the Connecting Europe Facility (CEF) it provides financial support for such projects as well as incentivises and stimulates private and professional end-users and infrastructure owners or operators to invest in vehicle and infrastructure equipment.

The EC has created the C-ITS Platform (discussed earlier) by means of which it promotes the interoperable deployment of C-ITS in the EU. On the basis of various studies and conducted projects on C-ITS, it was identified that the timeframe for assessing the impact of deployment was set up to 2018-2030. Significant benefits are to be expected within 5 to 10 years after initial investments, taking into account the deployment scenario and uptake risks. It was also identified that benefits significantly outweigh costs on an annual basis, and – depending on
the scenario – by a ratio of up to 3:1 when evaluated over the whole 2018-2030 period (European Commission, 2016). Therefore, the expected benefits from deployment of C-ITS services are very large, but they are not expected to appear in a short-term.

An important condition to achieve large benefits and create interoperability is to deploy C-ITS services across the EU and to deploy a maximum of services in a short period of time in order to ensure the quickest possible positive return on investment.

Each C-ITS is a meta-system (i.e. system of systems), as Leviäkangas, (2002) explains, that brings benefits not only to their owners, but also to the users of the transport system. To measure the capability to bring the benefits, a CBA is applied, as it is typically done to assess transport system investments. However, there are many challenges to perform an accurate analysis. First of all, it is difficult to draw a clear comparison between ITS investments (Leviäkangas and Lähesmaa, 2002) and traditional transport infrastructure investment, due to the nature of ITS and conventional transport engineering solutions. Secondly, there is a difference on returns required on ITS investments and other types of infrastructure improvements that depends on different life span of the investments (P. Leviäkangas, 2011). The third challenge, as Leviäkangas says, is the build-up of sustainable ITS services is more difficult, because stability of the revenue logic and business ecosystem is risky since there is not too much relevant experience within the transport sector.

Although the ITS investment differ in various ways from traditional investments in infrastructure engineering, both investments pursue the same goals, namely time saving, reduction maintenance costs, safety, higher reliability in transport operations, etc. The differences are in the volume of investment and cost efficiency. In this case, ITS can be more realistic solution for postponing larger projects that require larger capital involvement and higher expenditures.

Leviäkangas (2013) identified 4 main risks that can jeopardise the investments into C-ITS. He brought together investment as it is shown in the Table 4.

<table>
<thead>
<tr>
<th>Type of risk or benefit</th>
<th>ITS investment</th>
<th>Infrastructure investment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technological risks</td>
<td>High; may delay ITS projects</td>
<td>Medium, as infrastructure engineering is based mostly on mature technologies</td>
</tr>
<tr>
<td>Demand risk (is there enough traffic?)</td>
<td>Low, since the service life span of any ITS investment is probably not greater than 10 years</td>
<td>High, as the infrastructure will be in place for about half a century; during this time period, any demand risk may materialise</td>
</tr>
<tr>
<td>Financial risk</td>
<td>Low, as investment are typically not as capital-intensive as traditional infrastructure projects</td>
<td>High; projects are usually very capital-intensive</td>
</tr>
<tr>
<td>Flexibility with regard to the whole system</td>
<td>High, as the technologies could be replaced and the whole system disassembled or replaced if needed</td>
<td>Low, as the infrastructure will be in place for many decades and the investment is irreversible</td>
</tr>
</tbody>
</table>

As for required return on investment, it should be reflected in the discount rate applied to investments. As the Table 3 shows that required return on investment (i.e. the discount rate
used in the investment appraisal) should be lower for ITS investments than for traditional infrastructure investment, for the former carry fewer risks.

To create any ITS service several actors need to be involved to ensure its delivery. It is not easy to form such business environment or ecosystem. In such system an information service supply chain is vital where the raw data is collected, refined and finally sent to the end-user as a service. Adding actors for the ecosystem and service supply chain, as Leviäkangas, (2011) believes, can create more risks. It may lead to overpricing of services because of multiplication in risk accounting in the service supply chain (i.e. all actors endeavour to shield their cash flow).

3.3 Considerations on C-ITS investments

In this chapter there is a reference in some critical points for C-ITS investments. A major obstacle for C-ITS deployment is that significant upfront investments are required both on the vehicle and the infrastructure level and that enhanced co-operation needs to be established before any benefits will occur. So it is obvious that synchronisation of actions is key, considering existing inter-dependencies (European Commission, 2016).

Furthermore, any new investment constitutes a burden upon tight public budgets. For that reason, local authorities develop urban transport and mobility policies that can achieve the best return on investment, and ensure consistency and continuity with other local and regional solutions (European Commission, 2017).

Another point is that significant benefits will start to accumulate between 5 and 10 years after initial investments, depending on deployment scenario and uptake rates. For that reason it is recommended to deploy C-ITS services through a Master Plan where the goals, objectives and actions will be clear (Hadjidimitriou, 2017).

Taking into account the long-term existence of benefits, it is quite important to have some “quick win” cases and ambassadors for C-ITS projects. That way C-ITS projects and services will start gain initial infrastructure investments. Transport often competes with education and health care from the same scarce budget and thus investment projects need to demonstrate immediate benefits and strong added value. In particular, such investments need to directly show how the citizen will benefit and sometimes it is difficult to quantify the benefits of ITS applications and services (Hadjidimitriou, 2017, Barmpas et al., 2016).

In order to have benefits right after the implementation of C-ITS services it is of high importance to choose the right C-ITS service. According to C-ITS Platform Final report, at some point it was suggested that initial deployments of C-ITS might well focus on using cellular communications and on specific V2V C-ITS application sets. Nevertheless, that would lead to the result that certain benefits of Vehicle-to-Infrastructure communication might never come to fruition (Hadjidimitriou, 2017).

The existing infrastructure and the area of the infrastructure are an important factor for C-ITS investments. The complexity of investments in city-environments is that a set of applications (not a single application) would fully demonstrate the benefits of C-ITS. The deployment of C-ITS services in urban areas must therefore support strong local policy objectives and demonstrate how it can improve and build on top of existing ITS investments. On the other hand, for motorway environments there are the same difficulties to initiate C-ITS investment as in urban areas, but the purchasing process seems less complex (Hadjidimitriou, 2017, Barmpas et al., 2016).
4. Implementation of Cost Benefit Analysis in deployed C-ITS services

4.1 Cost-benefit analysis in pilot and full scale services

In the past years four European projects FREILOT, COMPASS4D, Smart-CEM and CO-GISTICS employed a CBA to assess the implementation of the piloted ITS services in transport sector. In all these projects the NPV is calculated on a time horizon of 10 years and virtual city, as proposed by the French National Metallisation and Organisation of Urban Freight Distribution funded in 2011 by the French National Research Agency (http://www.agence-nationale-recherche.fr/Project-ANR-10-VILL-0003), is created on the basis of a set of assumptions.

The COMPASS4D project identifies that a virtual city is the result of set of parameters extracted from the characteristics of several medium sized areas, where investments are assumed to be made by a public authorities. There is a perfect penetration in the market of ITS services and the operating costs and revenues are constant over the years. The virtual city is a base scenario to which pilot sites are compared.

In calculation of CBA, the projects apply different approaches that are based on various perspectives. For instance, in FREILOT project, CBA is calculated on the basis of each piloted service, whereas the COMPASS4D performs the CBA on a pilot site basis. Smart-CEM project carries out the analysis on two different perspective, i.e. public authorities and private operators. In the FREILOT the CBA intends to quantify the initial investments (i.e. software, computers machine for servers, infrastructure and civil work, on-board units) and operational costs (i.e. functional costs related to man power, software updates maintenance, enforcement, such as unit cost of policemen, number of hours needed for control and maintenance of the on-board unit). In this case, the NPV provides an overview of the time needed for the payback with the introduction of fees for utilisation of the ITS service. Each scenario is evaluated and compared to the virtual city. The following step foresees the analysis of the benefits brought by the services in terms of fuel consumption, distance travelled, travel time and CO2 savings. Then the best combination of ITS services is determined by considering several scenarios (Hadjidimitriou et al., 2017).

In COMPASS4D project, which is based on FREILOT methodology, different categories of vehicles used to test the ITS services are evaluated. The socio-economic benefits are evaluated in terms of total number of trips, travel time, fuel consumption and share of trips. The project value of the deployed services is based on the benefits expressed in monetary terms (a set of standards values is introduced to monetise social, environmental and efficiency benefits). These benefits are measured before and after the services are deployed. The aggregated costs (initial investment, operational and maintenance costs) are calculated on annual basis.

CO-GISTICS project proposes a different approach in the CBA, i.e. to provide an overview of the costs and benefits from different perspective. This approach allows different types of stakeholders who considering the possibility to invest in ITS services to improve efficiency of the logistic chain. In this approach the costs and the benefits are presented from two perspectives, i.e. from a point of view of public stakeholders and from a point of view of private stakeholders during three phase project implementation:

1. ‘AS-IS’ situation which includes the assessment of pre-existing equipment and the analysis of the current scenario
2. The investment phase where investments are required to introduce the ITS services
3. The execution phase where the services are adopted. In this phase the cost entailed
to usage and maintenance are taken into account.

The CO-GISTICS project explains that the benefits are monetised on the basis of the KPIs defined in the project and measured by the partners during the execution phase.

The C-ITS Platform Working Group on Cost Benefit Analysis proposed to establish a matrix of different geographical environmental and time horizons. The purpose of it is to identify for each of them the possible applications to be deployed indifferent time frame. It also suggested that CBA takes into account different categories of users and how they can benefit from application of C-ITS, namely what are the benefits for individual and the society.

The CO-GISTICS project developed a CBA which consists of four stages. It intends to present the results from three different perspectives. (See Figure 3)

![Figure 3. CO-GISTICS cost-benefit analysis methodology](image)

In the first phase, the key stakeholders of the ITS services are identified. This stage also includes the identification of the main measures of the costs and benefits for both private and public stakeholders. This data is collected from the pilot sites leaders in the next stage.

The assembled data in the second phase refers to three different scenarios: the ‘AS-IS’ situation, the investment needed to deploy the ITS services, and the costs and benefits identified to deploy and maintain the services. The data collected in this phase is kept separately for each stakeholder and service.

The third phase is dedicated to the CBA which uses the data collected in the previous phase. The CBA is carried out from the point of view of different stakeholders (i.e. public and private) and for each service. Different levels of deployment of the services can be applied, considering the availability of pre-existing assets, the size of the stakeholder and the need for new investments.

In the last fourth stage the date is aggregated by pilot sites. In this phase the CBA has the objective to present different business solutions. This stage shows the results of the CBA performed on a number of ITS services and as a final goal of it is to show the advantages of the ITS services when they are deployed together.

Finally, the CBA prepared for each pilot site where the NPV is calculated by aggregating the costs and the benefits collected by all stakeholders, both private and public and the BCR is present. This phase also considers different scenarios which consists in the introduction of fees for utilisation of the services.

The CO-GISTIC’s model of evaluation of the costs and benefits is based on the NPV over 5-10 years to evaluate the time needed for payback the investment. In the phase III, the CBA consists of the presentation of the NPV calculated for each service and using different type of
cost categories (existing assets, new investments on equipment, back-office costs, etc.) provided by private stakeholders. The same analysis is prepared for other stakeholders (i.e. public stakeholders). The CBA that is prepared at stakeholder and service levels takes into account the size of public organisation, whether it is small, medium or large.

The CO-GISTICS CBA shows that, most of the times, the deployed services bring benefits in terms of reduction of CO₂ emissions, fuel consumption or waiting time. For most of the services and pilot sites the BCR is greater than "0", which means that the investment spent on the ITS services in the project will bring economic benefits.

4.2 Costs related to instalment, operation and maintenance of C-ITS related projects

An issue regarding the CBAs of C-ITS services is the instalment, operational and maintenance costs. In general, the operating cost is one of the two main types of information related to the CBA. In Deliverable 6.4 of CO-GISTICS Project is mentioned that the operational costs “include all costs needed to maintain the service such as labour costs for the employer, subscriptions, fuel, etc” (Hadjidimitriou, 2017).

In COMPASS4D Deliverable 6.4 it is stated that the instalment, annual maintenance and operational costs are among the first steps to be utilized during the CBA of C-ITS services (F. Barmpas et al., 2016). Also, in CO-GISTICS Project Deliverable 6.4 it is mentioned that when C-ITS are examined, the majority of the costs involve the purchase of devices and tools to be installed in the vehicles and platforms to set up. For that reason, when someone examines the costs related to C-ITS pilot sites, an important factor is the number of the vehicles in which the equipment is going to be installed (Hadjidimitriou, 2017).

A factor which plays a leading role in the final costing of C-ITS services is the cost breakdown. By this term we mean the set time horizon in order to cover the costs for the implementation of the C-ITS services and obtain the expected benefits. The costs, especially those regarding the implementation of the equipment, can be varied depending on the existence or not of pre-existing equipment in the services’ implementation area (Hadjidimitriou, 2017).

When examine the implementation of C-ITS services in pilot sites estimates may have to be made when data for those pilots is missing for e.g. the fuel consumption and the time travelled (Barmpas et al., 2016).

The investment needed is then described as well as an estimate of the yearly operational costs needed to maintain the service. It should be noted that in Compass4D Project and FREILOT Project, the costs of disruption during installation and maintenance were not estimated and hence they have not been considered in the CBAs. On the other hand, in the CO-GISTICS Project, these parameters have been estimated and they have been included in the CBA of the project (Hadjidimitriou, 2017, Barmpas et al., 2016, Gonzalez-Feliu et al., 2012).

Below there is a table from the CBA of the CO-GISTICS Project (Hadjidimitriou, 2017) for the costs of Thessaloniki’s pilot test area, which presents an overview of the costs for each service based on the costs and investments and by evidencing the type of stakeholder (public and private) and its size (Small, Medium or Large). It should be mentioned that according to CO-GISTICS Project Deliverable 6.4: “the size of the organization is defined based on the EU recommendation 2003/361 for which a small enterprise has less than 25 employees, a medium company has a number of employees included between 50 and 250 and, finally, a large company has more than 250 employees.”.
Table 5. Thessaloniki’s pilot test area overview of the costs for each implemented service

<table>
<thead>
<tr>
<th>Service</th>
<th>Stakeholder</th>
<th>Organisation size</th>
<th>Pre-existing equipment</th>
<th>Pre-existing equipment description</th>
<th>Current operational costs [€/year]</th>
<th>Investment Costs [€]</th>
<th>Operational Costs Value [€/year]</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Priority and Speed Advice (2 vehicles)</td>
<td>Fleet Operator</td>
<td>Small</td>
<td>No</td>
<td>n/a</td>
<td>-</td>
<td>340€</td>
<td>600€</td>
<td>SIM card per tablet (~1GB data packet) for 12 months’ operations Yearly subscription to service</td>
</tr>
<tr>
<td>Region</td>
<td>Large</td>
<td>Yes</td>
<td>Traffic lights connected to the TMC</td>
<td>50.000€</td>
<td>10.000€</td>
<td>5.000€</td>
<td>Maintain connection to TMC</td>
<td></td>
</tr>
<tr>
<td>CO2 Monitoring and Eco-Drive Support (10 vehicles, 4 of which with CANbus)</td>
<td>Fleet Operator</td>
<td>Small</td>
<td>No</td>
<td>n/a</td>
<td>-</td>
<td>3.900€</td>
<td>4500€</td>
<td>SIM card per tablet (~1GB data packet) Yearly subscription to service</td>
</tr>
<tr>
<td>Cargo Transport Optimization (2 vehicles)</td>
<td>Fleet Operator</td>
<td>Large</td>
<td>No</td>
<td>n/a</td>
<td>-</td>
<td>2.840€</td>
<td>450€</td>
<td>SIM card per tablet (~1GB data packet) Yearly subscription to service</td>
</tr>
</tbody>
</table>
5. Conclusion

This topic study provides an overview of the recent developments of the CBA methodology. It briefly discusses the methodology and the main elements for this analysis. It also provides some information about the limitations of the CBA methodology. This topic study also provides information on the investments for C-ITS services, such as some main risks that can jeopardise the investments into the C-ITS services. There is also a brief reference in some key factors which can affect the investments (especially the initial investments) for C-ITS services. Finally there are some information about CBAs previously applied to transport projects, in particular, and information about the instalment, operation and maintenance costs of C-ITS services.
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https://www.youtube.com/watch?v=0kakVKN1mi8
https://www.youtube.com/watch?v=DOJHJtZtuMl
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https://www.youtube.com/watch?v=gxK3e-REaUM

CBR
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IRR
https://www.youtube.com/watch?v=zfk3HhkXC_I

NPV
https://www.youtube.com/watch?v=2HXwiCoYM8o
Annex 8: Guidance in deploying ITS and C-ITS

Grant Agreement Number: 724106
Project acronym: CAPITAL

Project full title: Collaborative cApacity Programme on Its Training-educAtion and Liaison

Topic study 8: Guidance in deploying ITS (C-ITS)

<table>
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<td>PU</td>
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<td>PP</td>
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<td>RE</td>
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**Abstract**

This document aims to provide a guidance when deploying ITS and C-ITS services including policy frameworks, deployment, implementation strategies, and roadmaps. It includes a description of services implementation during Baseline and Operational periods; service implementation characteristics of the employed hardware and software; Information on the local stakeholders and their role during operation and continuous engagement; Best practices from projects and pilots and lessons learnt.

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## Abbreviations and Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>EC</td>
<td>European Commission</td>
</tr>
<tr>
<td>PO</td>
<td>Project officer</td>
</tr>
<tr>
<td>GA</td>
<td>Grant Agreement</td>
</tr>
<tr>
<td>WP</td>
<td>Work Package</td>
</tr>
<tr>
<td>ITS</td>
<td>Intelligent Transport System</td>
</tr>
<tr>
<td>C-ITS</td>
<td>Cooperative-Intelligent Transport System</td>
</tr>
<tr>
<td>C-Roads</td>
<td>Cooperative-Roads</td>
</tr>
<tr>
<td>SUMP</td>
<td>Sustainable Urban Mobility Plan</td>
</tr>
<tr>
<td>SULP</td>
<td>Sustainable Urban Logistics Plan</td>
</tr>
<tr>
<td>GDPR</td>
<td>General Data Protection Regulation</td>
</tr>
<tr>
<td>SIRI</td>
<td>Standard Interface for Real-Time Information</td>
</tr>
<tr>
<td>NeTEx</td>
<td>Network and Timetable Data Exchange</td>
</tr>
<tr>
<td>TN-ITS</td>
<td>Transport Network ITS Spatial DATA</td>
</tr>
<tr>
<td>TM 2.0</td>
<td>Traffic Management 2.0</td>
</tr>
<tr>
<td>CEDR</td>
<td>Conférence Européenne des Directeurs des Routes</td>
</tr>
<tr>
<td>EU EIP</td>
<td>European ITS Platform</td>
</tr>
<tr>
<td>UITP</td>
<td>Union Internationale des Transports Publics</td>
</tr>
<tr>
<td>ASECAp</td>
<td>Association Européenne des Concessionnaires d´Autoroutes et d´Ôuvrages à Péage</td>
</tr>
<tr>
<td>ACEA</td>
<td>European Automobile Manufacturers Association</td>
</tr>
<tr>
<td>NAP</td>
<td>National Access Point</td>
</tr>
<tr>
<td>TRT</td>
<td>Transporti e Territorio srl</td>
</tr>
<tr>
<td>ETSI</td>
<td>European Telecommunication Standards Institute</td>
</tr>
<tr>
<td>CCAM</td>
<td>Cooperative, connected and automated mobility</td>
</tr>
<tr>
<td>INEA</td>
<td>Innovation and Networks Executive Agency</td>
</tr>
<tr>
<td>EIP-SCC</td>
<td>European Innovation Partnership Smart Cities and Communities</td>
</tr>
<tr>
<td>ADAS</td>
<td>Advanced Driver Assistance Systems</td>
</tr>
<tr>
<td>IFOPT</td>
<td>Identification of Fixed Objects on Public Transport</td>
</tr>
<tr>
<td>API</td>
<td>Application Programming Interface</td>
</tr>
<tr>
<td>CEN</td>
<td>European Committee for Standardisation</td>
</tr>
<tr>
<td>OJP</td>
<td>Open Journey Planning API</td>
</tr>
<tr>
<td>UML</td>
<td>Unified Modelling Language</td>
</tr>
<tr>
<td>XML</td>
<td>eXtensible Mark-up Language</td>
</tr>
<tr>
<td>HTTP</td>
<td>HyperText Transfer Protocol</td>
</tr>
<tr>
<td>SOAP</td>
<td>Simple Object Access Protocol</td>
</tr>
<tr>
<td>KPI</td>
<td>Key Performance Indicator</td>
</tr>
<tr>
<td>GHG</td>
<td>Green House Gas</td>
</tr>
<tr>
<td>RSU</td>
<td>Roadside Unit</td>
</tr>
<tr>
<td>SME</td>
<td>Small and Medium Enterprise</td>
</tr>
<tr>
<td>UFT</td>
<td>Urban Freight Transport</td>
</tr>
<tr>
<td>HMI</td>
<td>Human Machine Interface</td>
</tr>
</tbody>
</table>
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1. Introduction

This document is intended to serve as the basis for developing a practical guide for assisting local and regional government authorities deploying ITS and C-ITS services across Europe.

8.1 Objectives

The main objective of this report is to serve as the basis for developing a practical guide for assisting local and regional authorities on ITS and C-ITS services across Europe. When deploying ITS/C-ITS services, it is important to consider the relevant legal framework, the related policy framework, policy driven initiatives, as well as the technical framework, standards and technical specifications. Based on this information, it support in building a city strategic master plan aligned with local policy goals, legal and organisational framework conditions and also main challenges. There are various methodologies for building a city strategic master plan such as SUMP, SULP, C-ITS, Smart City and the city can choose the one that is most relevant to its own vision, challenges, needs, stakeholders and budget. A city strategic guide serves in defining the roadmap for implementing ITS (C-ITS) or other technologies in the mobility of a city. Implementing C-ITS in the city is also a challenging task. It includes a description of how the services should be used during baseline and operational periods; service implementation characteristics of the hardware and software; information on the role of local stakeholders during operation and their continued engagement. Finally transfer of knowledge could be a very important task especially for neighbouring cities or the greater region. The document is divided into ITS and C-ITS policy guide, C-ITS strategic guide, C-ITS implementation guide and C-ITS transferability guide.
2. ITS and C-ITS policy guide

In the following section, European legal acts which form the legislative framework for ITS, and have been designed with the goals defined in the vision-related documents of the European Commission in mind, are described. All of them are binding (Directives and Regulations) and serve as a basis for deployment, mainly at a technical level.

In addition, the PSI Directive 2003/98/EC (related to the amended version 2013/37/EU) and the INSPIRE Directive (2007/2/EC) are covered, as each of the Delegated Regulations refers to compliance with these Directives when it comes to the use of data collected by the public sector. Furthermore, the General Data Protection Regulation (GDPR) 2016/679/EU must be taken into account.

2.1 EU Directives

Directive 2010/40/EU (ITS Directive)

The ITS Directive has emerged from the Action Areas defined in the 2008 ITS Action Plan of the European Commission. It provides a legal framework for deployment of Intelligent Transport Systems and has been transposed into national law by all European Member States.

The main elements of the Directive are the four Priority Areas, within which six Priority Actions have been defined. The Priority Areas are the following:

- Optimal use of road, traffic and travel data,
- Continuity of traffic and freight management ITS services,
- ITS road safety and security applications,
- Linking the vehicle with the transport infrastructure [2, Art. 2].

The Priority Actions are the following:

a) the provision of EU-wide multimodal travel information services;
b) the provision of EU-wide real-time traffic information services;
c) data and procedures for the provision, where possible, of road safety related minimum universal traffic information free of charge to users;
d) the harmonised provision for an interoperable EU-wide eCall;
e) the provision of information services for safe and secure parking places for trucks and commercial vehicles;
f) the provision of reservation services for safe and secure parking places for trucks and commercial vehicles [1, Art. 3].

In accordance with the Lisbon Treaty, the Commission has a mandate to adopt specifications of functional, technical, organisational, or service provision-related nature under the ITS Directive in order to improve compatibility, interoperability, and continuity of Intelligent Transport System applications throughout the whole European Union. This has happened in the form of Delegated Regulations supplementing this Directive, each of those for one Priority Action. Five specifications (for priority action a) – e)) have already been adopted. A list of the related Delegated Regulations is included in the next chapter.

There is no specification for Priority action f) (the provision of reservation services for safe and secure parking places for trucks and commercial vehicles) expected in the near future as those reservation services would mean the reservation of public space (i.e. a parking space) which
contradicts national law in many European Member States and would therefore be difficult to implement.

The Directive established a reciprocal information flow between the Commission and the Member States, consisting of mechanisms for reporting, consulting and expertise provided to the European Commission. The Commission then issues specifications in accordance to the knowledge acquired, as indicated by the figure below:

![Diagram of the circular information flow of the ITS Directive](image)

**Figure 7. The circular information flow of the ITS Directive.** Error! Reference source not found.

**Delegated Regulations related to the Priority Actions**
Although the primary responsibility for implementing European law lies with the Member States, in some cases uniform conditions for the implementation are needed. In these cases the European Commission adopts an implementing act. The Commission adopts them on the basis of a delegation granted in the text of an EU law, in this case a legislative act. To do so the Commission has to consult expert groups, including representatives from each Member State, and prepare a draft text of the delegated act. After a four week period for feedback the Commission can adopt the act. Once the Commission has adopted the act, the Parliament and the Council generally have two months to formulate any objections. If they do not, the delegated act enters into force [4].

**2.2 European policy framework for ITS**
European and national level policy frameworks can significantly impact the deployment of ITS services in general and C-ITS services in particular. When talking about the deployment of ITS
and C-ITS services there are a handful of European strategic activities and documents to be considered such as the C-ITS Platform, as they influence the deployment of ITS services. Furthermore, these are relevant guidance strategies and documents for any deployment of ITS or C-ITS services. This policy initiative was highly innovative at that time and kick-started numerous deployments on European level. Initiatives like C-Roads could heavily affect the deployment of ITS services.

2.2.1 Guidance for ITS deployment

Policy driven initiatives aimed at the ITS sector can provide major input and guidance for European ITS stakeholders when it comes to the deployment of ITS services. One activity which produced highly important guidance for the harmonised deployment of ITS services was the EasyWay initiative (EasyWay 1 and EasyWay2), followed by the EU EIP and EU EIP+ and finally the EU ITS Platform. The EasyWay project (phase 1 from 2007-2009, phase 2 from 2010-2012) was established in response to the need for accelerated and co-ordinated ITS (Intelligent Transport Systems) deployment in Europe and the call for deployment of core European ITS services. The deployment guidelines developed within the frame of this initiative are still in use by European road operators. The EasyWay ITS-Core Service Deployment Guidelines include:

![Set of EasyWay Deployment Guidelines](image)

*Figure 8. Set of EasyWay Deployment Guidelines (see [15])*

In 2012 the EasyWay ITS Deployment Guidelines were adopted by the Member States and many ITS Implementation Corridors are now applying the Guidelines in their projects [15]. The “EU ITS Platform” (EU EIP) follows on from projects already supported by the Commission’s TEN-T programme, “European ITS Platform” (2013-2015) and “European ITS Platform+” (2014-2015), which were successors of the EasyWay initiative. The “EU ITS Platform” brings together the majority of the European players to cooperate and establish an open “forum”. The forum aims to providing valuable contributions to the future strategy and policy recommendations for the development of ITS services along European road Corridors. As well as the guidance available in the ITS Deployment Guidelines, road operators and other stakeholders deploying ITS services are supported by a dedicated ITS Deployment Guidelines website, a professional helpdesk and a user support facility produced by the EIP+ project and now managed by the EU ITS Platform.
In order to improve the 2012 ITS Deployment Guidelines, road operators took the initiative to monitor and collect feedback on the application of the guidelines in national projects. As a first step, the EIP project provided essential post-processing steps to improve the usability of the Guidelines for ITS deployments and to reflect the initial experiences and feedback gained since their publication at the end of 2012. The following EIP+ work programme had the goal of monitoring and collecting feedback on the application of the guidelines in the ITS Corridors and in other co-funded implementation projects. It was also responsible for consolidating the reporting of the results, lessons learned and best practices concerning the requirements in the guidelines across Europe. The guidelines are available here: https://dg.its-platform.eu/DGs2012

2.2.2 European ITS related Platforms as guidance for harmonised deployment in Europe

Platforms and associations of public authorities, transport operators and related stakeholders provide not only guidance on the deployment of ITS, they also support stakeholders in their activities and help to harmonise ITS deployment activities at European level. The number of platforms and associations involved in the CAPITAL project is quite large and dynamic. C-ITS related platforms will be covered by the next chapter. The following section summarises the ITS related platforms that could be of interest to public authorities and transport operators:

ERTICO – ITS Europe:
ERTICO was founded in 1991 as a platform to develop and deploy ITS across Europe. The ERTICO Partnership is a public/private Partnership consisting of over a hundred partners across eight different sectors, all working towards bringing intelligence into the mobility of people and goods in Europe. http://ertico.com/

POLIS – European Cities and Region Networking for Innovative Transport Solutions:
Polis is a network of European cities and regions working together to develop innovative technologies and policies for local transport. The network provides on a regular basis networking events, which can offer guidance on best-practices for the deployment of innovative solutions in the mobility sector, working groups and position papers. Polis communicates their messages to the European Institutions on issues relating to urban and regional mobility using position papers and responses to consultations. https://www.polisnetwork.eu/

CEDR – Conférence Européenne des Directeurs des Routes:
CEDR is a platform for cooperation between national road to cooperate and promote improvements to the road system and its infrastructure. The members of CEDR are the respective national road authorities or equivalents. CEDR publishes reports and studies on related mobility topics on a regular basis. [18] http://www.cedr.eu/

UITP - Union Internationale des Transports Publics:
UITP is the International Association of Public Transport and a worldwide network bringing together all public transport stakeholders and sustainable transport modes. The UITP also offers relevant policy briefs, toolboxes and related information that can serve as guidance for
Annex 8: Association Européenne des Concessionnaires d’Autoroutes et d’ Ouvrages à Péage:
ASECAP is the European Association of Operators of Toll Road Infrastructures. The purpose of the associations is to defend and develop the system of motorways and road infrastructures in Europe applying tolls as a means to ensure the financing of their construction, maintenance and operation. ASECAP provides Fact Sheets as well as position papers on a regular basis.

EU ITS Platform
The EU ITS Platform brings together the majority of the European key players, cooperating to establish an open “forum”, aiming at providing valid contribution for the future strategy and policy recommendation for better development of ITS service along European road Corridors. Next to the guidance through the ITS Deployment Guidelines, that define explicit criteria for fulfilling harmonisation requirements and provide best practice examples, road operators who are deploying ITS services as well as interested stakeholders are supported via a dedicated ITS Deployment Guideline website, a professional helpdesk and a user support facility.

ACEA – European Automobile Manufacturers Association
The European Automobile Manufacturers’ Association (ACEA) represents 15 major European based car, van, truck and bus manufacturers. ACEA represents the common interests, policies and positions of the European Automobile Industry and engages in dialogue with European (public) institutions to foster discussion regarding industry-related issues and contributes to the related policy initiatives. ACEA also provides a number of factsheets and guidance.

2.2.3 European Standards as guidance for deployment of ITS services
International standards are the common denominator that allows cities to put in place interoperable platforms where private and public stakeholders are able to develop needed solutions. They are essential enablers that ensure an expected performance level and compatibility between technologies. They embody strong technical and process expertise and facilitate the replication of outcomes. Standards propose common metrics that permit comparative analysis and benchmarking of solutions. International Standards open the door to a larger choice of products and because many suppliers around the world use them in manufacturing they also facilitate long-term maintenance and repair of city infrastructure. This benefits both cities and their citizens. Moving cities to greater smartness and sustainability also requires broad collaboration between stakeholders, including standards organizations. In fact, no single standards organization will be able to develop all the different standards cities will need.

As can be seen from the previous chapters of this report, data and access to data are the most crucial issues for the deployment of ITS services. When looking deeper into the legal and
policy frameworks, these are core issues which are also tackled in all of the guidance documents. To ensure harmonised access to data standards, technical specifications and quasi standards play a major role. When it comes to the deployment of ITS services, one should know in detail the requirements and definitions specified in the related standards regarding access, exchange and reuse of traffic and travel data. The topic of European Standards, as well as the National Access Points (as defined in the Delegated Regulations), is closely related to this topic of data and data access and relevant for deployment.

As providers of travel and traffic information mainly use IT based systems for the provision of relevant data (e.g. timetables, real-time information about delays, information on tariffs, etc.), these data are combined from different data sources. For the automatic exchange of data, different standardised interfaces and exchange formats exist as well as some proprietary solutions. To foster the harmonised provision of data related to ITS services and or the provision of multimodal traveller information at European level, the Delegated Regulations (see chapter 2) provide requirements regarding interoperable exchange formats and data protocols. The defined National Access Points, as Single Point of Entry, should use these formats (e.g. DATEX II, NeTEx…).

**DATEX II (CEN/TS 16157)**

DATEX II has been developed to provide a standardised way (e-language) for communicating and exchanging traffic information and travel data between traffic control centres, traffic information centres and service providers all over Europe. The specification provides a harmonised way for exchanging data across boundaries, at system level, to enable better management of the European road network. DATEX II is a multi-part Standard, maintained by CEN Technical Committee 278, CEN/TC278, (Road Transport and Traffic Telematics). The focus of DATEX II standardisation is on the information content. Part 1 defines the modelling methodology and rules for extension, while the remaining parts (2-7) define the content according to the methodology.

The DATEX II content model provides a common terminology and ontology used in IT systems. This enables and improves the European wide harmonisation and coordination of ITS measures and ITS developments. The DATEX II modelling approach is based on the Unified Modelling Language (UML). In order to be implemented, a platform independent model needs to be transformed into one or several platform specific models. Thus, the DATEX II community has chosen to stick to the most popular and non-exclusive Internet specifications, i.e. XML (eXtensible Mark-up Language), HTTP and SOAP. [23]

**NeTEx - Network and Timetable Data Exchange (CEN/TS 1664)**

NeTEx is a European CEN Standard for the exchange of static data. It is based on Transmodel EN 12896:2006 (a reference model for public transport), as well as on national and European standards like IFOPT (CEN-EN 28701) and SIRI (CEN-EN 15531-1/2/3/4/5 and standards in the different Member States e.g. VDV 452 in Germany, BISONS in the Netherlands or TransXChange in the UK).

NeTEx specifies the exchange of traffic and travel information for public transport. To assure interoperability across borders, EU Member States are currently developing a common European minimum profile for NeTEx. This is done within a specific CEN-working group and
with the participation of delegates from different Member States. The work on the minimum profile started in 2017 and should be finalised by the end of 2018. [22]

TN-ITS
TN-ITS (Transport Network ITS Spatial DATA) is a technical exchange specification to facilitate the provision and exchange of static road data between public road authorities (data providers) and ITS map providers or other potential ITS service providers (data receivers). Such static data are often referred to as "digital map data" and include road network attribute data such as traffic signs, traffic regulations, speed limits, but also road infrastructure data such as parking, gas stations or charging points. The goal of the data exchange concept TN-ITS is to make up-to-date, static road data of a reliable and “trusted” source available to ITS service providers, who can include that information for example in navigation devices. Currently, a Technical Specification is being prepared on behalf of CEN/NEN on TN-ITS entitled "Intelligent transport systems - ITS spatial data - Data exchange on changes in road attributes”.

The availability of accurate and up-to-date information about static road data is critical for providing up-to-date traffic information services. A harmonised framework is needed for the provision of a seamless data supply chain used by both public authorities and the private sector. The purpose of TN-ITS is to provide rapid and automated information about changes of any kind of static spatial data (e.g. road signs or speed limits) to end users, for example through in-vehicle devices such as navigation systems or advanced driver assistance systems (ADAS). Hence, it is crucial to support the data collection and data updating on the part of the ITS map provider.

SIRI – Standard Interface for Real-Time Information (CEN/TS 15531)
According to the SIRI Whitepaper, published by the CEN TC 278 Working Group 3, Sub Group 7 “the Service Interface for Real Time Information (SIRI) specifies a European interface standard for exchanging information about the planned, current or projected performance of real-time public transport operations between different computer systems”. [35, 1 p.]

SIRI comprises a modularised set of discrete functional services for operating public transport information systems. Services cover planned and real time timetable exchange, as well as vehicle activity at stops, the vehicle movement and information to assist in the provision of reliable connections between vehicles. SIRI uses a modern XML schema and TransModel terminology and modelling concepts.

Public transport - Open API for distributed journey planning (CEN/TC 278)
A CEN standard “Public transport – Open API for distributed journey planning” has recently been published for distributed journey planning of public transport by the Technical Committee CEN/TC 278, which opens the way for a unified and standardised solution in Europe. This specification is now progressing towards a final vote within CEN. [2]

The Open API standard is a technical specification which defines a plan for establishing an Open API for distributed journey planning that can be implemented by any local, regional or national journey planning system in order to exchange journey planning information with any other participating local, regional or national journey planning system. Open API is
underpinned by the main existing standards for public transport operations, i.e. IFOPT (Identification of Fixed Objects in Public Transport), NeTEx (Network and Timetable Exchange), SIRI (Service Interface for Real-time Information), and Transmodel (Public Transport Reference Data Model).

A review of three long established Distributed Journey Planning Systems that have been working in Europe over the past 10 years (EU-Spirit, JourneyWeb and DELFI) found that, while the architecture of each of these systems was different, the nature of the enquiries sent between the systems, and the content of the responses sent in return, were essentially the same. This suggested that it would be possible to define a single Open Journey Planning API to support all distributed journey planning systems. The Open Journey Planning API (OJP) will therefore allow a system to engineer just one interface that it can make widely available (to authorised users or openly as they so choose) rather than having to engineer separate APIs for each bipartite exchange arrangement that may be required with other systems. The Delegated Regulation (EU) 2017/1926 of the ITS Directive with regard to the provision of EU-wide multimodal travel information services, which provides the necessary requirements to make EU-wide multimodal travel information services accurate and available across borders recommends the use of the Open API standard in relation to the requirements specified in Article 7 “Linking Travel information Services”. [24]

**National Access Point**
The national access point is defined as a term in the Delegated Regulations 2017/1926/EU, 885/2013/EU, 886/2013/EU and 2015/962/EU a little differently. The National Access Point is an important requirement of the Commission to ensure interoperability and exchange of data across the borders of EU Member States.

Summarising the common elements in the definitions of the aforementioned Delegated Regulations, the National Access Point is a digital interface where data (either static travel and historic traffic data, static road data, dynamic road status data and traffic data, both together with corresponding metadata, or information on parking places) is made accessible for reuse to users. This does not automatically mean that the data itself will be available on the National Access Points, but in most Member States the National Access Points are set up as catalogue services where metadata services provide links and descriptions of data existing with the single data-owners. Transport authorities, transport operators, infrastructure managers and transport on demand service providers shall provide the data through a National Access Point (NAP). For safety related data in accordance to 886/2013/EU access to data shall even be given by all data owners, including private entities as well. National Access Points are an important framework for the deployment of ITS and should be considered when planning a new deployment.

### 2.3 The European policy framework for C-ITS
In line with the adoption of the Delegated Regulations based on Priority Area IV (Linking the vehicle with the transport infrastructure) of the ITS Directive 2010/40/EU, the Commission is currently preparing a legal framework for C-ITS. The adoption of the appropriate legal framework at EU level needs to ensure legal certainty for public and private investors, the availability of EU funding for projects, the continuation of the C-ITS Platform process as well as international cooperation with other key regions of the world on all aspects related to
cooperative, connected and automated vehicles. In this respect the Commission considers, where appropriate, making use of its mandate under the ITS Directive to adopt a Delegated Act for C-ITS by 2018. This Act will ensure continuity of C-ITS services, will lay down rules for security of C-ITS communications, ensure the practical implementation of the General Data Protection Regulation for C-ITS, ensure a hybrid communication approach and specify rules on interoperability and the compliance assessment processes.[27]

2.3.1 C-ITS Strategy of the European Commission


This C-ITS Strategy aims to facilitate the convergence of investments and regulatory frameworks across the EU, in order to see deployment of mature C-ITS services in 2019 and beyond. This includes the adoption of the appropriate legal framework at EU level by 2018 to ensure legal certainty for public and private investors, the availability of EU funding for projects, the continuation of the C-ITS Platform process as well as international cooperation with other main regions of the world on all aspects related to cooperative, connected and automated vehicles. It also involves continuous coordination, in a learning-by-doing approach, with the C-Roads platform, which brings together deployment activities being carried out in EU Member States.

This Communication COM (2016) 766 is the result of intensive work with experts, from both the public and private sectors, done within the C-ITS platform. In November 2014 the Commission launched the C-ITS platform to identify remaining barriers and propose solutions for C-ITS deployment in Europe. The first phase of the C-ITS platform resulted in an expert report published in January 2016 and was – together with Cost-Benefit Analysis finalised in February 2016 by Ricardo Energy and Environment and Trasporti e Territorio srl (TRT) and a public consultation done by the Commission between June and September 2016 – the basis for the C-ITS Strategy. The Communication defines priorities for the deployment of C-ITS services, and identified issues that should be tackled at EU level to ensure that deployment is coordinated, in 2019.

The C-ITS Strategy also states that the availability of C-ITS services across Europe for end-users is highly important for the swift deployment of C-ITS. So available C-ITS services should be as widely as possible. To do this, the Commission has set priorities for the coordinated deployment of Day 1 services (which are technologically-mature and highly-beneficial C-ITS services), so that it can be achieved quickly and, as a result, end-users can benefit from them as soon as possible.

Table 11. Day 1 C-ITS services list (COM (2016) 766)

| Day 1 C-ITS services list
| Hazardous location notifications: |
| Slow or stationary vehicle(s) & traffic ahead warning; |
| Road works warning; |
| Weather conditions; |
Emergency brake light;
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;
- Shockwave damping (falls under European Telecommunication Standards Institute (ETSI) category 'local hazard warning').

In addition, a list of C-ITS services was defined, for which full specifications or standards might not be completely ready for large scale deployment in 2019, even though they are considered to be generally mature. These are the Day 1.5 C-ITS services.

Table 12. Day 1.5 C-ITS services list (COM (2016) 766)

<table>
<thead>
<tr>
<th>Day 1.5 C-ITS services list</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information on fuelling &amp; charging stations for alternative fuel vehicles;</td>
</tr>
<tr>
<td>Vulnerable road user protection;</td>
</tr>
<tr>
<td>On street parking management &amp; information;</td>
</tr>
<tr>
<td>Off street parking information;</td>
</tr>
<tr>
<td>Park &amp; ride information;</td>
</tr>
<tr>
<td>Connected &amp; cooperative navigation into and out of the city (first and last mile, parking, route advice, coordinated traffic lights);</td>
</tr>
<tr>
<td>Traffic information &amp; smart routing.</td>
</tr>
</tbody>
</table>

In addition specified some specific actions regarding the deployment of Day 1 and Day 1.5 services:

Table 13: List of specific actions (COM (2016) 766)

**Specific actions**

EU Member States, local authorities, vehicle manufacturers, road operators and the ITS industry should implement C-ITS and ensure that at least the Day 1 C-ITS services listed are fully supported.

The Commission will support EU Member States and industry deploying Day 1 C-ITS services, notably through the Connecting Europe Facility, European Structural and Investment Funds and the European Fund for Strategic Investments.

The Commission will provide funding for research and innovation through H2020, and possibly the European Structural & Investment Funds, for Day 1.5 C-ITS services and beyond, including higher levels of automation.

The Commission will encourage the update of the Day 1.5 service list and future C-ITS
2.3.2 C-ITS Deployment Platform

The Commission decided in early 2014 to take a more prominent role in the deployment of connected driving, by setting up a C-ITS Deployment Platform. The Platform consists of national authorities, C-ITS stakeholders and the Commission. The aim of the platform was to develop a shared vision on the interoperable deployment of C-ITS in the EU and to provide policy recommendations for the development of a roadmap and a deployment strategy for C-ITS in the EU as well as identifying potential solutions to some critical cross-cutting issues. The first phase of the C-ITS Deployment Platform was finalised in January 2016, with the publication of the Final Report: https://ec.europa.eu/transport/sites/transport/files/2017-09-c-its-platform-final-report.pdf

Based on the results of Phase I of the C-ITS Deployment Platform the European Commission prepared the C-ITS strategy (COM(2016) 766). The second phase of the platform further developed a shared vision on the interoperable deployment of Cooperative Intelligent Transport Systems (C-ITS) towards cooperative, connected and automated mobility (CCAM) in the European Union. Phase II focused more on tangible progress towards the definition of implementation conditions and requirements. The Working Groups on Security, Data Protection, Compliance Assessment and Hybrid Communication have all worked on issues that are essential to the interoperability of C-ITS deployment and hence relevant for the preparation of Delegated Act(s) on C-ITS. The final report of Phase II was published in September 2017. https://ec.europa.eu/transport/sites/transport/files/2017-09-c-its-platform-final-report.pdf.

2.3.3 C-Roads – The Platform of Harmonised C-ITS Deployments in Europe

The C-Roads Platform is a joint initiative of EU Member States and road operators, which are in the phase of installing C-ITS for the testing and operation of “C-ITS Day-1 services” (as defined in the C-ITS strategy). Pilot installations are harmonised, in light of cross-border interoperability based on cooperation within the C-Roads Platform. Key elements are the joint development of technical specifications which are to provide the basis for all pilot deployments, as well as commonly prepared cross-site tests to demonstrate cross-border interoperability of the deployed C-ITS services.

In accordance with the C-ITS Platform recommendations, harmonised specifications are being developed and the first harmonised communication profile for C-ITS services is already finalised. All developed specifications are publicly available and form the basis for pilot installations on the road network. The Commission and the Innovation and Networks Executive Agency (INEA) are closely linked to the C-Roads Platform. They follow and actively participate in the C-Roads Platform which provides the legislative framework to ensure the link to other C-ITS relevant stakeholder groups. They also provide the policy support needed for a pan-European and harmonised deployment of C-ITS, provided by these partners. With 16 European States currently participating as core members, the C-Roads Platform approach pursues cooperation on a holistic level in order to cover all dimensions linked with the deployment of C-ITS, such as sharing experiences and knowledge regarding deployment and implementation issues as well as user acceptance. It as well follows a bottom-up approach that includes national pilots. These form basic elements for a later pan-European C-ITS
implementation. The national pilot initiatives move on to cross-site testing, which will allow them to grow together and achieve transnational interoperability.

Harmonisation is the core asset of the C-Roads Platform, since it ensures sustainable and efficient deployment. [28] All C-Roads Member States have committed themselves to use the elaborated C-Roads specifications for any C-ITS related deployments undertaken in their territory. The communication profiles, as well as the learnings and the outcomes of the pilots, form the basis for the deployment of C-ITS in Europe and are followed by EU Member State authorities.
3. C-ITS city strategic guide

There are a number of elements that a public authority needs to take into consideration before preparing the C-ITS strategic guide in a city or region or an EU Member State. A Strategic Plan is the road map for public authority decision-making so it is important to involve the whole transportation and mobility value chain, match policy goals versus emerging trends and see which one is more applicable, analyse at the same time existing conditions within a city and finally ensure commitment and resources. This chapter contains different methodologies of city strategic plans and it is up to the City’s local policy objectives and challenges to choose the most relevant one.

![Figure 9. C-ITS city strategic guide](image)

3.1 Develop a City Strategic Plan based on SUMP

The City Strategic Plan needs to link strategic plans with performance measurement goals by converting strategic objectives into measures and targets. Key stakeholders who will measure the success of the vision, strategic priorities and outcomes and strategic initiatives that support the achievement of objectives, are linked to the budget process, and are measured using targets and metrics contained in the City’s plan.

As part of the City Strategic Plan, the Strategic objectives on Transportation and Mobility pillar based on Sustainable Urban Mobility Plan (SUMP), Sustainable Urban Logistics Plan (SULP) and C-ITS are addressed and established. The correct strategic initiative for implementing emerging technologies (C-ITS vs Policy goals) is chosen and a separate ITS Vision to guide the ITS implementation for the City is established.

Sustainable Urban Mobility Plan (SUMP)
A Sustainable Urban Mobility Plan (SUMP) is a ‘strategic plan designed to satisfy the mobility needs of people and businesses in cities and their surroundings for a better quality of life. It builds on existing planning practices and takes due consideration of integration, participation, and evaluation principles’. The Sustainable Urban Mobility Plan concept considers the functional urban area and foresees that plans are developed in cooperation across different policy areas and sectors, across different levels of government and administration and in cooperation with citizens and other stakeholders.

Guidelines are developed to provide local authorities with a clear framework for the development and implementation of such a plan. However, EU Member States need to promote these practices at national level to ensure the right legislative support conditions for their local authorities are in place.

The Sustainable Urban Mobility Plan (SUMP) is a "strategic plan designed to satisfy the mobility needs of people and businesses in cities and their surroundings for a better quality of life. It builds on existing planning practices and takes due consideration of integration, participation, and evaluation principles" (ELTIS 2013).

The Urban Mobility Package puts forward specific recommendations for coordinated action between all levels of government and between the public and the private sector in four additional areas: (i) urban logistics; (ii) urban access regulation; (iii) deployment of intelligent transport system solutions; (iv) and urban road safety.
3.2 Develop a City Strategic Plan based on SULP

Although the SUMP, in principle, addresses the issue of efficient and effective distribution of goods in cities, there are no concrete guidelines for how this can be achieved. The complexity of organising the urban freight distribution is driven by the vast range of activities resulting from relationships among a variety of actors with different and often conflicting needs and goals and by a number of negative environmental and social effects like congestion, air and noise pollution, and safety. This makes it difficult for a policy planner to propose standard measures that could be suitable for different urban contexts as well as to develop a common understanding about future expectations. In parallel, the science and practice of UFT and city logistics has been developing, with novel solutions to address issues caused by UFT traffic being introduced. The NOVELOG project is filling the gap of the current SUMP approach by suggesting specific guidelines for how a local authority could incorporate UFT measures and policies in their sustainable mobility planning. These guidelines can be described as a Sustainable Urban Logistics Plan (SULP).

The SULP is defined, mirroring the SUMP definition, as a “holistic planning strategy for urban freight that ensures efficient and sustainable logistics operations within urban areas”. The development of the SULP also mirrors the development of the SUMP, except that special focus is given to the movement of freight and the use of UFT solutions.

<table>
<thead>
<tr>
<th>Phase II: Rational and transparent goal setting</th>
<th>Phase I: Prepare well</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.1. Identify and develop effective package of measures</td>
<td>1.1. Identify UFT key stakeholders and organize the SULP Multi-stakeholder platform</td>
</tr>
<tr>
<td>6.2. Learn from other experience</td>
<td>1.2. Assess &amp; improve city’s knowledge on its UFT profile</td>
</tr>
<tr>
<td>6.3. Consider value for money</td>
<td>1.3. Review availability of resources</td>
</tr>
<tr>
<td>5.1. SULPs objectives definition</td>
<td>2.1. Look beyond boundaries</td>
</tr>
<tr>
<td>Setting priorities and measurable targets</td>
<td>2.2. Involve the stakeholders in the planning process</td>
</tr>
<tr>
<td>4.1. Develop a common vision among UFT stakeholders and define the future UFT scenarios</td>
<td>2.3. Finalize the work plan and the management arrangements</td>
</tr>
<tr>
<td>Development of effective package of measures</td>
<td>3.1. Analyze the current UFT situation</td>
</tr>
<tr>
<td>Development of a common vision &amp; future improvement scenarios</td>
<td></td>
</tr>
<tr>
<td>Analysis of the city’s current UFT situation</td>
<td></td>
</tr>
<tr>
<td>Definition of the development process and scope of plan</td>
<td></td>
</tr>
<tr>
<td>Determination of the city’s potential for a successful urban freight planning</td>
<td></td>
</tr>
</tbody>
</table>

![Figure 11. SULP cycle (NOVELOG project)](image)

It is recommended that the SULP process be implemented separately from the SUMP procedure, and that it starts after the definition of the overall sustainable mobility vision of the city. In this way, the city approach for sustainable distribution and service trips that will result from the SULP development process will be in line with the SUMP vision and will focus on serving its general objectives.
3.3 Develop a City Strategic Plan based on ITS

The goal of an ITS Strategic Plan is to identify strategies and tools to allow a city to manage its multimodal transportation network more efficiently using Intelligent Transportation Systems (ITS) while integrating SUMP and SULP.

**Mission & Vision**

- To assist a city’s infrastructure in meeting its mandate of providing a safe and effective transportation system through the planning, deployment and integration of intelligent transportation systems technologies;
- And to position the city’s infrastructure to take advantage of the rapid development of technology and to maintain and improve city’s competitiveness in a fast-moving knowledge-based economy.

The Vision for the future of ITS in city’s transportation system is to have well-developed and integrated systems in place for:

- The travelling public to make and adjust their travelling plans;
- Infrastructure and partners to better manage, operate and maintain the transportation infrastructure and improve the safety of the travelling public;
- Commercial transport operators to improve their productivity, efficiency and competitiveness.

**The Objectives of this plan are to:**

- Bring an articulated and systematic approach to planning, deployment and integration of ITS technologies that conform to the ITS architecture; and serve as a roadmap for infrastructure to set the direction and strategies for future ITS investment and deployment.

**Guiding Principles and Strategies**

- ITS are developed and deployed in a coordinated, systematic and cost effective manner.
  - Establish a permanent City ITS Committee, to coordinate all ITS initiatives within City. This Committee will be responsible for coordinating all ITS initiatives, updating the ITS strategic plan, keeping abreast and advising the city of new ITS technologies and opportunities, and representing the department in coordinating with other levels of government and external stakeholder groups on all ITS related matters.
  - Stage the development and deployment of ITS to build on past experiences (both successes and failures) and existing accepted architecture in an incremental manner. It is important that the costs and benefits of ITS deployment be evaluated and that the performance and effectiveness of existing and future ITS initiatives be closely monitored and measured.
- ITS applications should be seamlessly integrated, compatible with systems in TEN-T corridors, and meet ETSI ITS architecture standards.
  - Cooperate and participate with Ministry (National ITS Action) and also with ITS Nationals to ensure interoperability and integration of ITS technologies, and work with industry and other stakeholder groups to develop ITS architecture.
and technical standards.

- ITS are well integrated in the planning, design, construction and maintenance of the transportation infrastructure.
  - Integrate ITS early in the planning and design process, and make provisions for future ITS installations. Installation of ITS devices should be coordinated with construction and maintenance activities to minimise traffic interruption and costs.
- ITS development and deployment is sustainable
  - With the increasing awareness of ITS, the ITS city committee should include ITS initiatives in their program budgets. ITS deployment should continue to be funded by funding opportunities (H2020, CEF, interreg and other). The ITS committee should actively pursue opportunities for cost-sharing through partnerships with government, other neighbouring cities and regions with the same country, and the private sector.
- A city needs to be open to ITS technologies, partnerships, new knowledge, innovation and awareness.
  - The ITS city committee will keep abreast of the latest technological developments, and promote ITS development and deployment by entering into partnerships with the private sector, stakeholder groups, municipalities and other governments in undertaking joint projects. Raise the awareness of ITS in conferences, demos, posting information on ITS initiatives and latest developments and with links to other ITS sites.

**Strategy Timeframes**

Timeframes play a vital role in determining the feasibility of growing the ITS Program and achieving the program goals. The City’s recommended strategies will be categorised into immediate, near-term, and long-term timeframes. The various timeframes allow interim steps for large or extensive effort projects to be completed in a near-term timeframe.

- **Immediate (0 Years)** implementation strategies are those that can (and should) be started right away and do not require additional funding or infrastructure to complete. Some immediate projects are low hanging fruit that have no associated costs and require minimal effort but are important steps towards developing a City ITS strategy. Other projects that are categorised as immediate are those that should be started now, but that may require a greater amount of time and coordination to accomplish. These more involved projects are still considered immediate because there are no constraints to initiating the project now.

- **Near-Term (2-5 Years)** strategies represent projects that may require funding, time for integration or planning, assistance or participation from interdepartmental or regional partners, and/or a moderate amount of effort to implement. The goal is to implement near-term strategies within two to five years of finalising the Strategic Plan.

- **Long-Term (5-10 Years)** strategies represent those that will require funding, a planned implementation process, extensive support, and/or external support. External support could be comprised of consortium partners. Most of the strategies with a long-term timeframe are large projects which require a combination of extensive planning, partnerships and funding, and are likely dependent on the successful implementation of immediate and near-term projects.
3.4 Develop a City Strategic Plan based on smart cities

There is a wide range of highly divergent plans available which can serve as points of departure for the development of concrete projects. These plans often have different scopes and cover different fields of expertise. However, what they all have in common is that they all aim to reduce the carbon footprint of cities by using advanced ICT-based solutions in combination with measures addressing the physical energy, transport infrastructure and building stock of cities and the behaviour of its users. The European Innovation Partnership Smart Cities and Communities (EIP-SCC), established in 2012 as an initiative from the European Commission, has strived to build a broad community of cities, industries, SMEs, banks, knowledge institutes, citizens, NGO’s, and other smart city actors. It intends to improve citizens’ quality of life and reach energy and climate targets, while increasing the competitiveness of Europe’s industry and innovative SMEs. Knowledge sharing to prevent the repetition of mistakes, and facilitating connections between people and solutions, are essential to achieve these goals. To this end, the EIP-SCC Market Place brings together those who are active in the field of Smart Cities and willing to know more about ongoing and foreseen activities throughout Europe. Networking, partnering, and exchanges of information help to develop and implement smart city solutions at the intersection of Energy, ICT and Transport. The below methodology excludes ICT software development projects.
### 3.5 Identifying City Needs and Priorities

- Meet the current and future transportation needs of residents and visitors and also depending on the objectives (reduce greenhouse gas (GHG) emissions, reduce traffic congestion, expand travel choices, enhance transit or better manage freight) prepare strategic initiatives (ITS).
- Needs and priorities need to be identified through evaluation of existing conditions of the city’s infrastructure with the city’s traffic engineers. Examples are: upgrading the communication system, providing a traffic surveillance and real time traffic management centre and others.

Involving stakeholders and the public is one of the fundamental requirements of sustainable urban mobility planning. Care should be taken to understand and recognise what may be needed from stakeholders at subsequent stages of project development and also what
stakeholders may want in return. Some needs may be mutually beneficial such as: developing strategic relationships or using standard commercial terms and others which are not (such as vendor locking). Citizens and commuters/visitors portray actual needs for mobility solutions so there are many ways to collect and address these through surveys on public transport modes or other ways. The development of a stakeholder management plan helps to manage expectations and associated risks as well as keeping stakeholders engaged throughout the development of a project. It is important to identify key stakeholders, and then approach them to test the initial vision, and afterwards start the engagement process. The type of stakeholders to involve will vary depending on the level of innovation and/or change that the project is anticipated to create. However, typically stakeholder consultation should include a representative group of those who will be involved and/or directly affected by the project, either during its development or once it has been delivered. With good engagement, these stakeholders will assist in flushing out further high level requirements and, importantly, identifying any constraints that will need to be actively managed and future training/support requirements, as well as developing ‘lessons learnt’ feedback.

Table 14. Example of stakeholder list and roles

<table>
<thead>
<tr>
<th>Stakeholder</th>
<th>Stakeholder role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mayors/ politicians</td>
<td>Road-safety/mobility regulations of cities, budgets for infrastructure and operation</td>
</tr>
<tr>
<td>City administration &amp; planning</td>
<td>Planning, implementation of e.g. traffic lights and RSUs, traffic control, mobility management, infrastructure operation and management, provision of traffic information and Infrastructure-2-Vehicle services</td>
</tr>
<tr>
<td>Transport ministries</td>
<td>Safety/mobility regulations for the overall road network, budgets for infrastructure and operation</td>
</tr>
<tr>
<td>Road authorities</td>
<td>Planning, implementation of RSUs, management infrastructure operation</td>
</tr>
<tr>
<td>Road operators</td>
<td>Traffic management and infrastructure operation, provision of traffic information and Infrastructure-2-Car services</td>
</tr>
<tr>
<td>Automotive industry</td>
<td>Implementation of on-board equipment, HMI, Car-2-Car services, in-vehicle signage of Infrastructure-2-Car services, provision of Car-2-Car and Car-2- Infrastructure data</td>
</tr>
<tr>
<td>Service and content providers</td>
<td>Data aggregation, data enrichment and data / service distribution</td>
</tr>
<tr>
<td>Drivers/ inhabitants</td>
<td>Final users, consumers, providers of cooperative information</td>
</tr>
<tr>
<td>Personal and goods Transport (Ports, Public transport, railways)</td>
<td>Traffic management and Management of hub infrastructure Mobility of people and goods around hubs</td>
</tr>
<tr>
<td>Logistics &amp; delivery industry (parcel companies)</td>
<td>Management and delivery of goods flow in the cities</td>
</tr>
<tr>
<td>Chamber of commerce (SMEs, shops)</td>
<td>Receivers of goods flows in the cities</td>
</tr>
</tbody>
</table>

As participation is still a novel task for many cities, it needs to be integrated into the overall management of planning processes, requiring a clear allocation of resources in terms of budget and staff time as well as a communication strategy.
3.6 Policy goals versus emerging trends
A city should specify its objectives and identify its problems before embarking on measure selection. The next step is then to identify the policy measures, projects and packages which could contribute to achieving the objectives or overcoming the problems. City transport policy across Europe is remarkably consistent. The four almost-universal policy goals are:

- To reduce congestion
- To improve the environment – specifically regarding air pollution
- To maintain safety on the network
- To promote excellent public transport (partly to support the above goals) and support commercial activities within the city.

Managing the road network, so that it flows efficiently and effectively for all road users, is a key transport concern for most cities. Weight of traffic, incidents, poorly designed road layouts and junctions all contribute to congestion and require management. These are the areas where technology can help and is helping. However, it is important to choose a strategic initiative for implementing emerging services. A feasibility study on which emerging technologies are needed should be carried out, with opportunities, challenges and how these technologies meet the policy goals of a public authority, identified. These include the following:

- The potential advantages or benefits and risks of the emerging technology.
- A high level description of city challenges compared to the present (baseline) position.
- What business outcomes can the project be expected to deliver (and at what stage).
- How those business outcome(s) contribute to the goals, strategic objectives or business priorities of the organisation.
- A high level plan, including any interim stages to achieving that vision.
3.7 Analysing existing conditions

Before considering emerging technologies, it is worthwhile considering if a public authority is making the most of the current infrastructure and resources and any works being planned. There is on-going budgetary pressure to reduce operating costs and expenditure even when grant funding is available to procure and implement new schemes and initiatives. There are several areas where local authorities are already doing this:

- **Needs versus specifications**
  Too often specifications from local authorities are focused on the solution, resulting in technology suppliers not being able to innovate or provide the latest solutions. Demanding the level of performance (KPI), is more important than how it is implemented.

- **Local authority equipment**
  It may be that some existing local authority equipment is not obsolete and is capable of upgrading to C-ITS. There are many ways to utilise the existing infrastructure capacity and equipment.

- **Making data available to service providers**
  By making data from variable message signs, car parking etc. available to the private industry, maintenance of local authority websites can be avoided.

- **Sharing infrastructure with the cloud and economies of scale**
  Cloud hosting now offers ways to remove the need for a computer server room. Traffic systems hosted on the cloud can be shared amongst local authorities and joined together seamlessly. The new Traffic Management Technology “TM 2.0” framework provides access to a host of suppliers, but it is important to check with neighbouring local authorities if they have the same requirements, and see if money can be saved by working together.
Exchanges of best practices
There are many forums, working groups and suppliers at ITS national level who are all keen to share knowledge.

3.8 Ensure commitment and resources
The next step is to look inwardly at the organisation of a public authority and its business drivers to determine its capability and/or desire to deliver the project, for example:

- Who needs to be involved within the administration?
- Are there sufficient resources with the right skills?
- What impact will the project delivery have on the organisation?
- What transformational steps might be required to undergo the proposed change?

The successful implementation of strategies within the ITS Strategic Plan will require the participation and buy-in from a variety of stakeholders, both internal to and external to the City. Departments are identified as leads for a strategy when the implementation of the strategy is dependent on the commitment of staff time and resources from that department or when the benefits of the strategy are most prominently realised by that department. Many traditional functions undertaken by government, such as road design, traffic management, network operations, pavement design, and transport modelling, will substantially change, reduce or may even disappear or be replaced with new functions. Within any department, there are a broad range of possible impacts on funding, planning, construction, maintenance and operations. It is important to identify key stakeholders and then approach them to test the initial vision and start the engagement process. The type of stakeholders to involve will vary depending on the level of innovation and/or change that the project is anticipated to create. However, typically, stakeholder consultation should include a representative group of those who will be involved and/or directly affected by the project, either during its development or once it has been delivered (e.g. operations staff, maintainers, representative user groups, finance/procurement staff and human resources).

Potential Key responsibilities of the lead department for each recommended strategy/project include:

- Making sure the project receives recognition and endorsement from political leadership/corporate management and any constraints (e.g. budget, programme).
- Identifying the key partners within the department and in other departments that should be involved;
- Setting up of a meeting with identified partners to garner commitment and gain a shared understanding of the strategy/project and the desired results; this may include representatives from departments such as the finance department or City Manager’s Office if it is deemed appropriate;
- Setting up of recurring meetings with project partners, if applicable;
- When the strategy/project is defined, costs for initiating the project and the most promising funding sources, if applicable; should be identified. Ongoing costs (operating, maintenance, management) that may be required after the strategy/project is implemented should also be identified.
Strategy implementation management:

- A contract with a subcontractor, if necessary, to support project and manage contractor’s work should be established;
- Any requirements (meetings, documentation) related to grants or external funding sources that may have been acquired for the project should be completed;
- Periodic check-in meetings with project partners to provide project updates or to make sure participating partners are following up on their project-related responsibilities should be conducted;
- Updates to management (department directors, Mayor, Council), as required; should be provided;
- If a project requires multiple years to implement, budgets should be in place to support project continuation.

Project close-out management (if applicable):

- If the project is stand-alone, a final meeting with project partners should be held to ensure the project is completed satisfactorily (some strategies may involve ongoing recurring meetings);
- Final update to management or council, if necessary should be provided;
- Proper expectations should be set for continuing operations and maintenance costs for the resulting project/program. Depending on where costs will be incurred, the lead department should either make sure they are budgeted properly or provide support to the department in which the cost is incurred to make sure it is budgeted.
- In addition to the lead department for a strategy/project, many projects require participation from other departments to successfully address and implement the strategy.

Key responsibilities of other involved departments for each recommended strategy/project:

- Attending of project meetings set up by the lead department, especially the kick-off meeting where the strategy/project will be defined and clarified as a group;
- Considering ways that a department can financially participate, which might include:
  - Providing some funding (and budget for future costs) for strategy implementation or any ongoing costs, such as procurement of new software or hardware.
  - Applying for funding through a grant or other source to support the project,
  - Providing staff time for project management, development or review,
  - Undertaking a small project in a department to support the larger project (example: set up a server in a department to centralise data collection so that it can feed a larger, City-wide server);
  - Providing input during the project, as requested; and
- Working within an department to update existing processes to support the implementation or ongoing needs of the project, if necessary (example: if data is needed in a different form from how it is currently provided, ways to update collection or processes to provide the data in the format needed for the strategy/project should be considered).

Outreach to additional staff who have not been involved in the ITS City Strategic Plan process
can take two forms. First, staff who have been involved can share the information that they acquired with their peers to raise awareness and make sure that there is not just a single person in each department who understands ITS and the ITS Plan. Second, the City should make consistent information available to staff about the ITS functions or data that can be most useful to them, where and how they could contribute to the system, and who they can contact for information or questions. One way that this could be accomplished is by creating a one-page flyer or other communication material that summarises important information on the ITS activities and impacts for city management. Outreach to Elected Officials and Public Outreach campaigns about ITS are also important and should entail different communication and public relation strategies.

3.9 Learn about ITS city strategy planning from the City of Helmond

With about 90,000 inhabitants, the city of Helmond, located in the South-East of the Netherlands, is considered a medium-sized city on a Dutch scale, but a very small city at a European level. Nevertheless, the City of Helmond government believe that the deployment of Cooperative ITS (C-ITS) services is something not just for large cities. C-ITS fits very well within Helmond’s mobility policy, and it has the potential to offer smart solutions for urban freight challenges. The involvement of Helmond in C-ITS activities goes back more than a decade. In 2003, the City had to decide how to solve the problem of large volumes of vehicles, especially heavy freight trucks on the main urban corridor, passing through the city centre. Plans were made for large investments in new road infrastructure, including tunnels. Finally, the City Council decided to change the mobility policy towards better use of existing infrastructure instead of building new infrastructure. Moreover, the City Council made a very clear statement, establishing that Helmond would not just wait for the market to come up with smart solutions, but was willing to actively support smart mobility pilots and showcases. This policy shift, laid down in the mobility policy paper “Helmond Mobiel 2015”, marked the beginning of Helmond’s involvement in C-ITS pilots and deployment (Figure 9).

**Figure 15. Helmond Mobiel 2015.**
4. C-ITS implementation guide

Looking on the diagram below, it is important to work on a particular path especially after the development of the ITS city strategy plan.

**Figure 16. C-ITS city implementation guide**

4.1 Initiate the Project Planning Process

It is needed to prepare and initiative a project plan & schedule to prepare for the implementation and deployment of different C-ITS services in the city and as well as the area of implementation. During this initial phase, roles and responsibilities of each party are identified.

4.2 Working with the public and private stakeholders

It is important to distinguish between:

- Stakeholders involved in the installation of the C-ITS services at pilot sites, both hardware and software, for the road side and on-board elements
- Users of the systems: drivers, traffic managers, data analysts…

The interests and motivation of each stakeholder can be different. Road authorities typically emphasise their policy objectives, which can be to move people and goods as efficiently and effectively as possible in terms of travel time, emissions and fuel use, and traffic safety. Fleet operators typically express a more economic perspective. They are typically interested in reducing travel time and fuel use to bring down costs or increase revenues. All stakeholders are likely interested in performance indicators that help them build a cost-benefit analysis for each of the services. Examples of the most important performance indicators are: reduction in travel time, reduction in fuel use and/or emission, and reduction of accidents. Interestingly,
stakeholders can recognise that operating multiple services simultaneously brings them economy of scope and improves their business case.

First of all it is necessary to identify stakeholder needs in the context of the pre-defined services selected and if applicable beyond. Capturing these needs could be done through questionnaires, stakeholder workshops and consultations. Secondly to collect user requirements related to the services following the requirement categories (technical, economical, policy etc.). Finally, to identify the general expectancy of the pilot as well as the desired evaluation output.

4.3 Adapting the ITS architecture for the local needs

A system architecture, or systems architecture, is the conceptual model that defines the structure, behaviour, and more viewpoints of a system. An architecture description is a formal description of a system, organised in a way that supports reasoning about the structural properties of the system. It defines the system components or building blocks and provides a plan from which products can be procured, and systems developed, that will work together to implement the overall system. This may enable one to manage investment in a way that meets business needs.

The systems engineering process is often depicted using the V-model system lifecycle. This model emphasises the need to ensure that the system is both built correctly, and that it satisfies the aspirations of all its stakeholders. One methodology which could be used for creating an ITS Architecture is the use of FRAME Architecture, which incorporates the V-model system lifecycle (an example of which is illustrated in the figure below). The FRAME Architecture (originally called the European ITS Framework Architecture) was developed as a result of recommendations from the High Level Group on transport telematics, which were supported by a resolution of the Council of Ministers. ITS Architectures can be created at national, regional or city level, or relate to specific sectors or services and developed taking into consideration needs and requirements as defined above.
C-ITS can be delivered through several different fundamental architectures, which imply very different approaches to designing city projects. Technically, the two key alternatives are:

- Approaches based on short range communication links – ETSI G5, but also Wi-Fi, Bluetooth, etc.
- Approaches based on long range communications – cellular systems, but also Tetra, DMR, etc.
- Approaches based on Hybrid Architecture (combining the above) which is still in the design and development phase.
The CIMEC project diagram depicted illustrates the following C-ITS Business Architectures:

- The first model shows the city providing its C-ITS services directly to the road user, using its own technology.
- The second model shows the city working with a specialist external entity to provide the C-ITS service. This could be a national/regional service, a fleet owner, a vehicle manufacturer, or a specialist distributor of in-vehicle equipment (like TomTom).
- The third model shows the city using a third party to provide services to road users while continuing to collect its own data from them. For instance, the city could publish its network data as open data, and rely on developer innovation to construct solutions (perhaps mobile apps).
- The final model shows a data aggregator, using its own channels to collect live vehicle data which is then provided to the city (perhaps as bought-in data), while the city then provides relevant information back through other channels. This option is perhaps most suited to “uplink focussed” services like gaining floating vehicle data for improving traffic management.

For both technical and commercial architectures, “hybrid” networks, using a suitable mixture of these approaches for different services, are of course possible. And the optimisation will naturally change over time, as they undergo continuous technical and commercial improvement. While there are some advantages of cost, management effort in a single unified approach, these may not always outweigh the benefits of a mixed approach. But one of the biggest technical concerns for cities, and their suppliers, is “interoperability” and this needs to be ensured at the principles phase during the ITS city strategy plan. Standards can have a significant impact on the effectiveness of ITS, provided they are well-designed, managed openly and impartially, and are well supported by market products. From a city perspective, the use of standardised systems, interfaces and processes can significantly reduce the cost of buying equipment; in addition, it can enhance confidence and trust in system reliability and safety, as well as the quality of products and services.

Standardisation activities (and associated legislation where relevant) also directly support the European Union’s policy of a single transport market. Interoperability standards specifically
aim to enable competitive markets and procurement processes, and prevent vendor lock-in problems that can lead to excess cost and risk for cities.

Building a flexible architecture is important but this can make it difficult to determine what performance will be expected when exchanging data between the different parts of the system.

4.4 Description of the services

The coverage for each of the different technologies and services varies area by area leading to different organisational and business decisions country by country and city by city. The table below is an extract of the C-ITS Platform Working List of Services description.
### Table 15. Services Description (source: C-ITS Platform Phase I)

<table>
<thead>
<tr>
<th>Application</th>
<th>Service</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hazardous location notifications</td>
<td>Emergency brake light</td>
<td>This use case occurs when any vehicle abruptly slows down, it switches on emergency electronic brake lights. The application warns the local followers, in due time, so they can adopt their speed to avoid collision with the vehicle.</td>
</tr>
<tr>
<td>Hazardous location notifications</td>
<td>Emergency vehicle approaching</td>
<td>This system uses information provided by the emergency vehicle to help the driver on how to clear the road even when the siren and light bar may not yet be audible or visible.</td>
</tr>
<tr>
<td>Hazardous location notifications</td>
<td>Road works warning</td>
<td>A service whereby the road operator can communicate with drivers through I2V communication about road works, restrictions and instructions.</td>
</tr>
<tr>
<td>Hazardous location notifications</td>
<td>Slow or stationary vehicle(s)</td>
<td>A slow/stationary vehicle can signal its presence to other vehicles. This improves traffic fluidity by encouraging other vehicles to take an alternative route</td>
</tr>
<tr>
<td>Hazardous location notifications</td>
<td>Traffic jam ahead warning</td>
<td>A Self-Organising Traffic Information System (SOTIS) uses Car-2-Car Communication to collect information on the local traffic situation and this information is exchanged between vehicles by wireless ad hoc communication</td>
</tr>
<tr>
<td>Hazardous location notifications</td>
<td>Weather conditions</td>
<td>The use case refers to increasing traffic safety by informing drivers about critical weather conditions ahead especially where the danger can hardly be visually perceived</td>
</tr>
<tr>
<td>Signage applications</td>
<td>Green Light Optimal Speed Advisory (GLOSA)</td>
<td>Traffic lights are connected to a roadside unit. Via this connection, information can be broadcast to nearby vehicles informing them of the traffic light phase schedule. This will enable vehicles to calculate optimal speed of approach. Time to green information may also be presented to drivers.</td>
</tr>
<tr>
<td>Signage applications</td>
<td>In-vehicle signage</td>
<td>Via V2I communication, information on relevant road signs is given to the driver. Roadside units may be mounted on traffic signs and key points along roads, informing drivers of potentially dangerous road conditions ahead, speed limits and upcoming junctions.</td>
</tr>
<tr>
<td>----------------------</td>
<td>-------------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Signage applications</td>
<td>In-vehicle speed limits</td>
<td>Roadside units at key points along roads can broadcast information to drivers about speed limits.</td>
</tr>
<tr>
<td>Signage applications</td>
<td>Probe vehicle data: CAM aggregation</td>
<td>Also known as Floating Car Data (FCD), PVD is data generated by vehicles. Contains vehicle positional information, time stamp and motion. Driver actions e.g. steering, braking, flat tyre, windscreen wiper status, air bag status, weather and road surface conditions can also be transmitted. Probe data is used to manage traffic flows, maintain roads and to alert users in hot spots, where the danger of accidents accumulates.</td>
</tr>
<tr>
<td>Signage applications</td>
<td>Shockwave Damping (also has other names, falls under the general ETSI category “local hazard warning”)</td>
<td>Shock wave damping aims to smooth the flow of traffic, by damping traffic/shock waves. Real-time traffic data is used to feed advisory speeds to cars to smooth out speed variations.</td>
</tr>
<tr>
<td>Signage applications</td>
<td>Signal violation / Intersection Safety</td>
<td>Also known as the Red Light Violation Warning (RLVW), this service’s primary objective is to reduce the number and severity of collisions at signalized intersections. Drivers are warned when they are in danger of violating a red light, or when it is probable that another vehicle is going to make a red light violation.</td>
</tr>
<tr>
<td>Signage applications</td>
<td>Traffic signal priority request by designated vehicles</td>
<td>Different levels of priority can be applied, e.g. extension or termination of current phase to switch to the required phase. What level of green priority is appropriate depends on the vehicle type (e.g. HGV or emergency vehicle) and status (e.g. public transport vehicle on-time or behind schedule).</td>
</tr>
</tbody>
</table>
4.5 Geographical zones of the Implementation sites

When considering the best use of C-ITS for an individual city, a number of factors will need to be considered. What are the particular problems that require solving in a particular area? How will a city in the mountains approach C-ITS compared to a city in the valley or one on a plain? Does it matter that a city is on the coast or inland? To what extent do the range of weather conditions faced by cities affect how what they need from C-ITS? Does size matter? How does local population influence which C-ITS systems and services a city pursues? Does population distribution within a city present special requirements? A city which is faced with very cold weather conditions, with a lot of snow or ice, may be expected to need very different C-ITS systems and services when compared to a city which is more likely to experience temperate conditions or very hot conditions. However, fundamentally, whatever the weather, the city will want to make road users aware of the conditions they will face on the roads. Regardless of the specific conditions, a system which alerts drivers to hazards is a universal requirement; the specific weather conditions do not change the need for the technology.

The table below shows the overview of the planned C-Roads pilot sites and their services and technologies covered. This included also city oriented services demonstrated during COMPASS4D/CO-GISTICS projects. C-Roads consist of different C-Roads pilots operated in different national/urban environments.
Table 16. Geographical Zones of the C-ITS implementation sites (source C-ROADS Detailed pilot overview report)

<table>
<thead>
<tr>
<th>SERVICES</th>
<th>COMMUNICATION TECHNOLOGIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergency electronic brake light</td>
<td>X</td>
</tr>
<tr>
<td>Slow or stationary vehicle(s)</td>
<td>X</td>
</tr>
<tr>
<td>Traffic jam ahead warning</td>
<td>X</td>
</tr>
<tr>
<td>Hazardous location notification</td>
<td>X</td>
</tr>
<tr>
<td>Road works warning</td>
<td>X</td>
</tr>
<tr>
<td>Weather conditions</td>
<td>X</td>
</tr>
<tr>
<td>In-vehicle speed limits</td>
<td>X</td>
</tr>
<tr>
<td>Probe vehicle data</td>
<td>X</td>
</tr>
<tr>
<td>Shockwave damping</td>
<td>X</td>
</tr>
<tr>
<td>Green Light Optimal Speed Advisory</td>
<td>X</td>
</tr>
<tr>
<td>Signal violation/Intersection safety</td>
<td>X</td>
</tr>
<tr>
<td>Traffic signal priority request by ETSI G5</td>
<td>X</td>
</tr>
<tr>
<td>Cellular Communication</td>
<td>X</td>
</tr>
<tr>
<td>DAB</td>
<td>X</td>
</tr>
<tr>
<td>RDS</td>
<td>X</td>
</tr>
<tr>
<td>WiFi and Bluetooth</td>
<td>X</td>
</tr>
<tr>
<td>Other (DATEX II)</td>
<td>X</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Austrian Pilot site</th>
<th>Belgium (Flanders) Pilot site</th>
<th>Czech Pilot site</th>
<th>French Pilot site (C-Roads)</th>
<th>French Pilot site (InterCor)</th>
<th>German Pilot site</th>
<th>Dutch Pilot site</th>
<th>Slovenian Pilot site</th>
<th>UK Pilot site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergency</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Communication</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Technologies</td>
<td></td>
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</tr>
</tbody>
</table>

Annex 8: 40 / 54
<table>
<thead>
<tr>
<th>SUBPILOTS</th>
<th><strong>Belgium</strong> (Wallonia) Pilot site</th>
<th><strong>Danish</strong> Pilot site</th>
<th><strong>Finnish</strong> Pilot site</th>
<th><strong>Hungarian</strong> Pilot site</th>
<th><strong>Italian</strong> Pilot site</th>
<th><strong>Norwegian</strong> Pilot site</th>
<th><strong>Portuguese</strong> Pilot site</th>
<th><strong>Spanish</strong> Pilot site</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X</td>
<td>X X X X</td>
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<tr>
<td>DGT 3.0</td>
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<tr>
<td>SISCOGA Extended</td>
<td></td>
<td>X X X X X X X X X X X</td>
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<tr>
<td>MADRID</td>
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<td>X X X X X X X X X X X</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>CANTABRIAN. País Vasco</td>
<td></td>
<td>X X X X X X X X X X X</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>CANTABRIAN. Asturias</td>
<td></td>
<td>X X X X X X X X X X X</td>
<td></td>
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</tr>
<tr>
<td>CANTABRIAN. A8 Galicia</td>
<td></td>
<td>X X X X X X X X X X X</td>
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</tr>
<tr>
<td>MEDITERRANEAN. CATALAN</td>
<td></td>
<td>X X X X X X X X X X X</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>MEDITERRANEAN. ANDALUSIAN</td>
<td></td>
<td>X X X X X X X X X X X</td>
<td></td>
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</tr>
</tbody>
</table>
4.6 Description of implementations traits

Road side installations guides

An ITS-G5 roadside unit installation consists of a radio unit, a processing platform and connections to the outside world (for example to existing infrastructure devices or a back office).

Antennas: the communication antennas have to be mounted in a location with clear line of sight to the relevant vehicles; for intersections this means the antenna should be close to the centre of the intersection, for example on top of a signal pole. Special attention should be given to trees because the used radio frequency is easily hindered by leaves. Based on an unobstructed 1st Fresnel zone the optimal height for the antenna is at least four meters above the ground (see http://en.wikipedia.org/wiki/Fresnel_zone).

For optimal radio wave transmission, the first Fresnel zone must be unobstructed by objects like trees, houses and the ground itself. To avoid the ground, the radius (R) of the Fresnel zone should not touch point P. When the distance (D) between the antennas increases the zone increases too and must be larger.

Power connection: the RSU power comes from an infrastructure power source; when the radio unit is placed away from the processing unit Power over Ethernet (PoE) is a practical way to combine power and communication into one cable.

Back office connection: a connection to the back office can be created via the cellular network or via a fixed connection like DSL or optical fibre.
Infrastructure system connection: the connection to existing infrastructure like traffic controllers is based on proprietary protocols, depending on the type and brand of the system. Modern traffic controllers provide connections over Ethernet, which is a convenient way to connect.

Cables: the cabling used in the open air or underground must be fit for this purpose, e.g.: UV radiation resistant, metal shielded and waterproof. Cables outside cabinets must be protected against high voltage via surge protectors.

Cabinet: in many cases the processing unit of the RSU can be placed in an existing (traffic controller) cabinet. This saves a lot of work and cost.

**On-board installations**

![Diagram of on-board installations](image)

**Figure 20. On-board installations guides**

Antennas: place the communication antennas in a location with clear line of sight, preferably on the roof top or at least just behind the windscreen.

Power connection: connect the OBU to a power source in the vehicle, usually the cigarette plug. It is highly recommended that this power source is taken after the ignition, so that the vehicle battery is not drained with the OBU staying up while the engine is shut down.

HMI fixation: install the HMI device in a location convenient for the driver. The location can differ depending on the type of vehicle and the presence of existing equipment. Suction cups are convenient to hold a screen or smartphone onto the windscreen.

OBU fixation: the OBU in itself can be hidden somewhere in the vehicle, e.g. side compartment, beneath a seat, in the trunk. To avoid drilling holes, Velcro or e.g. 3M Dual Lock fasteners can be used: it is enough to keep the box steady as the OBU is not under a lot of mechanical stress.

Cables: it is important to hide as much as possible the different cables (antennas, power, etc.) in the vehicle installation both for safety reasons but also to prevent operational issues.
(cable being unplugged because the driver got his foot stuck in it). Pass the cable below the floor carpeting or hide them behind plastic covers.

### 4.7 Operational issues

Piloting new technologies require a careful planning of operation indicators (KPIs), which a city needs to work together with the service provider and also piloting into different stages “Base line” and “Operation”. These operation indicators are strongly linked to the data quality process and allow for checking that the involved systems are working correctly, both in the vehicles and on the roads. One of the reasons behind this approach is that it allows the early results from the first baseline pilot stage to be made available, as soon as possible, so they can be used to support demonstrations of the benefits of these technologies to decision makers at each pilot.

It is important to distinguish between the “Base line” and “Operation” pilots, which are two different periods. The Base line pilots are initially three months long, while the Operation pilots last for 9 months. This is followed by a first phase with Base line pilots lasting 1.5 months and Operation pilots lasting 4.5 months, with a second phase structured in the same way. Of course this period is indicative but having an operation last for one year is important as it allows for much more data to be collected for evaluation purposes. By taking this approach, both Baseline and Operation periods can take place in similar weather, daylight and traffic flow conditions. There are some indicators that help to monitor in real time the performance of the pilot in order to identify incidences. Each city has to develop a tool to guarantee this tracking of Technical and Data Logging levels, for instance:

#### Technical
- RSU: number of active RSUs
- RSU: number and type of interactions with OBUs
- OBU: number of active OBUs
- OBU: number and type of interactions with RSUs
- OBU: time active
- OBU: kms driven by OBUs

#### Data logging
- Number of corrupt log files

During operation phase, incidences or errors such as broken devices, corrupt data, equipment malfunction etc. may occur. These errors must be identified beforehand and their probability evaluated. Methods for detecting and correcting those incidences must be taken into account as well. Each pilot site has the responsibility of carrying out this task according to their particularities. In order to improve the efficiency of the error detection process, it is important to conduct periodic reviews to detect and prevent errors. In this way, those problems, which are difficult to prevent and detect during the tests, may be solved, either they are detected in advance or after they have occurred. Even at the beta test stage of the system, it is important to engage all stakeholders in testing and reviewing the system. By demonstrating the system, not only its importance shall be explained, but also the areas of improvement shall be
4.8 Procurement models
One of the major benefits that new technologies can offer is the ability to move away from traditional procurement and ownership models. In the past, it has generally been the case that to operate a technology system, it was necessary to undertake a capital purchase of the hardware required, acquire the necessary software licensing and ensure sufficient on-going revenue (operational) funding was in place to pay for future maintenance, licensing and asset renewal. This often places a heavy burden on local authorities and can result in the need to support incompatible systems spread over various, underutilised computers and systems being operated well beyond their economic life due to their inability to fund a replacement. Where once it was necessary to buy technology as capital procurement, it is now common to see technology as a service. Many suppliers can offer systems remotely hosted in secure, highly resilient data centres that rely on the availability of cheap, reliable Internet Protocol (IP) communications links.

This allows systems to be procured flexibly using models including:

a. **Revenue only** - many systems can be procured with no capital outlay and fully financed through regular revenue payments. This allows systems to be procured based on a ‘Service Level Agreement’ (SLA) rather than a detailed technical specification and means the responsibility for ensuring sufficient hardware is provided, maintained and renewed as required and operated reliably and efficiently rests with the service provider. This model suits applications where the owner has access to revenue funding but not capital. It is common in areas such as bus real-time prediction systems where bus operators are able to contribute to the operation of the system based on their ongoing use of it rather than large up-front capital commitments.

b. **Capital/revenue split** - many public bodies find access to capital somewhat easier as a result of grant funding. This can be used to fund the ‘one-off’ set up costs of a new system and reduce the ongoing costs. The benefit of this solution, apart from the reduced revenue costs that are attractive to public bodies, is that by retaining an element of ongoing revenue commitment, systems can still be provided through an SLA, with future maintenance and upgrade costs built in.

c. **Shared services** - there is increasing pressure being placed on public bodies to merge services and work together to realise savings. The possibilities offered by IP, and the ability to host systems far away from their users make it possible for one authority to provide services for others. The move to virtualised servers, (where the needs of systems can be spread and balanced across numerous physical computers), means that it is not impractical for one organisation to provide the hardware and to offer an agreed level of service to others. In an arrangement such as this, there are benefits of scale that come from large, joint procurements, benefits to the hosting organisation in realising an income stream from the other users of the system, and a benefit to the other users in reduced operating costs. Such arrangements are becoming common in joint payroll and finance systems and are now possible for transport systems such as Urban Traffic Management Control (UTMC) and Urban Traffic Control (UTC) services.
d. **Guaranteed income** - there are some systems in transport where an income can be identified to assist in operating costs. This can apply to systems that generate revenue (website and mobile apps from which advertising revenue can be earned) and systems that have revenue *through-put* that can be utilised (car parking or smart ticketing solutions). Such systems can be procured based on an agreed level of income which can provide impetus for the supplier to seek out and develop the potential for revenue generation. Such systems usually employ a *cap and collar* arrangement in which levels of income below an agreed level require the short-fall to be shared between supplier and client and above an agreed level to result in a profit sharing mechanism being triggered.

Care must be taken when proposing capital or revenue based procurement models that an appropriate level of risk and reward is maintained. For example, a supplier expected to maintain a travel information system for five years, who is paid by a single *up-front* capital payment has little motivation to continue to invest in the system. Or a supplier expected to fund the costs of implementing a new and complex database based purely on future revenue payments is likely to build a large margin into these payments to ensure the initial outlay is repaid. As public authorities (transport authorities, ministries, cities, etc.) are important drivers for the C-ITS implementation it has to be considered that they are subject to the public procurement law - also when we it comes to the deployment of an innovative solution. So the constraints of the procurement directives have to be considered for the deployment of C-ITS. This means that for "buying" innovative solutions, like C-ITS services, public authorities need to make use of innovative or alternative approaches for procurement, like PPI (as a very general term used in this context), PCP, innovation partnership or certain open or restricted procedures.

### 4.9 Evaluation issues

Translating technical evaluation results into business results which can be understood by several and different stakeholders is a very challenging task. Within the city, the business model behind each service together with the evaluation results are important elements for making decisions on sustainability and also financing of the C-ITS services.

The evaluation methodology for evaluating the C-ITS services may be broken down into three broad work streams:

- **Generating Performance Indicators:** Assessing whether the service works means that there must be some form of metric which will change when the project moves from the baseline phase to the operational phase. The performance indicators (PI) generated must be relevant and must be able to be calculated from the data provided. Ideally they should also be transferable between the real world trials and the simulations.

- **Separating into comparable populations:** To ascertain the difference between the baseline and operational phase of the trial, it is necessary to remove as many possible sources of variation. Due to the heterogeneous nature of the pilot sites (and locations within those sites) it is necessary to disaggregate the collected data into samples which may be legitimately compared.

- **Analysing the PI change:** Once the change in PI has been assessed, it is possible to
collate the results from all of the different pilot sites to produce an overall conclusion about the effectiveness (or otherwise) of the service.

It is important to also do the evaluation of the assessment of the difference between the baseline and operational phase for a given metric. However, the changes for any given metric could be dominated by systematic variations in the population from which the metric was derived. For example, if there is an over-abundance of metrics from a road section with a speed restriction in the baseline phase, then the baseline phase would exhibit this speed restriction.

To combat this, the populations were disaggregated into multiple samples which were believed to show homogeneity between the baseline and operation phase. Examples of this split in population include:

- **Vehicle Type**: Vehicle types (buses, cars etc.) would exhibit a systematic variation in metrics ensuring that quantitative results from one vehicle type could not be aggregated with another vehicle type.
- **Pilot Site**: There are differences between pilot sites in vehicle population, driving style, road layout and multiple other factors leading to a fundamental incompatibility for numerical evaluation.
- **Trajectory**: Generally speaking, for any intersection there will be many different ways to enter and exit that intersection and it is not expected that the performance indicators for these trajectories will be directly comparable.

The vehicle type and pilot site data are directly accessible from either the collected data (pilot site) or the metadata associated with that particular vehicle (vehicle type). The trajectory identifier requires a series of post-processing steps to systematically assign IDs in a reproducible and robust fashion for both baseline and operational data.
5. Dealing with deployment challenges

It is important to develop a very detailed risk analysis taking into account all the deployment challenges (barriers) and identify actions, action holders and solutions in the early project management cycle. The barriers have been classified into five main categories: technical, legal, economic, interoperability and other. The barriers and the deployment opportunities can be considered for all C-ITS services and pilot sites.

![Barriers for all three services](image)

Figure 21. Classification of barriers

**Technical Barriers Summary table**

<table>
<thead>
<tr>
<th>Nomadic device installation – how to install nomadic devices safely in a vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interoperability issues</td>
</tr>
<tr>
<td>HMI issues</td>
</tr>
<tr>
<td>IT security</td>
</tr>
<tr>
<td>Maintenance of OBUs and RSUs</td>
</tr>
<tr>
<td>Connection and adaptation to legacy systems</td>
</tr>
<tr>
<td>Readiness of the road infrastructure for C-ITS</td>
</tr>
<tr>
<td>Road Hazard Warning (RHW) related barriers</td>
</tr>
<tr>
<td>Lack of clarity of the communication channel 3G and/or 5.9GHz</td>
</tr>
<tr>
<td>Liability</td>
</tr>
<tr>
<td>Protection from vandalism</td>
</tr>
</tbody>
</table>

**Legal and political / institutional barriers Summary table**

<table>
<thead>
<tr>
<th>Political prioritisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of knowledge on ITS and related possibilities at local level</td>
</tr>
<tr>
<td>Lack of investments</td>
</tr>
<tr>
<td>Lack of clear business model</td>
</tr>
<tr>
<td>Quality and organisation of information</td>
</tr>
<tr>
<td>Different staff members for these services / outsourcing</td>
</tr>
<tr>
<td>Lack of sufficient support from the end users / public opinion</td>
</tr>
<tr>
<td>Different departments dealing with ITS within public authorities</td>
</tr>
<tr>
<td>Legacy systems already in place</td>
</tr>
<tr>
<td>ITS has been seen as car-oriented instead of sustainability-oriented</td>
</tr>
</tbody>
</table>
Reduction of amount of traffic lights
Authority over traffic lights varies between countries
Priority at intersections opposite to level playing field

**Economic and business barriers Summary table**

- Low market penetration
- Lack of sound cost-benefit analysis
- Lack of user awareness
- Lack of stakeholder commitment
- Lack of uptake by fleet operators
- No wide range of OBU providers
- Lack of trust in the future of current solutions
- High installation costs

**Other barriers Summary table**

- Lack of awareness towards cooperative systems
- Road Safety
- Privacy issues
- Security issues
6. A transferability Guide to ITS and C-ITS

C-ITS services are not restricted to a small number of front-runner cities. All cities can benefit from experience of early adopters by means of effective knowledge sharing to facilitate decision making in initial C-ITS investment and to accelerate deployment of customised C-ITS solutions. There are number of projects which are investigating and currently twinning in cities (C-The Difference, C-MOBILE, and CAPITAL) and at national level within the C-Roads initiative. Below is a diagram explaining the transferability guide (steps include: update and implement mobility policies; assess needs and identify solutions; define replicability criteria; adaptation needs, implementation and operation guidance; make an impacts assessment; elaborate CBA and business model plans as well as raise awareness, promote and educate).

Figure 22. A transferability guide to C-ITS
7. References


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Annex 9: Data protection and privacy

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Abstract

This document presents a literature review on data protection and privacy in C-ITS, which serves as study guide for the preparation of an eponymous study module on the CAPITAL E-Learning platform.

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<td>ANPR</td>
<td>Automated Number Plate Recognition</td>
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<td>C-ITS</td>
<td>Cooperative Intelligent Transportation Systems</td>
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<td>CAM</td>
<td>Cooperative Awareness Message</td>
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<td>CFR</td>
<td>Charter of Fundamental Rights</td>
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<td>CM</td>
<td>Customer Medium, Client Medium</td>
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<td>CNIL</td>
<td>Commission Nationale de l’Informatique et des Libertés</td>
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<td>DENM</td>
<td>Decentralised Environmental Notification Message</td>
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<td>DPD</td>
<td>Data Protection Directive</td>
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<td>EDPS</td>
<td>European Data Protection Supervisor</td>
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<td>eID</td>
<td>Electronic Identity Document</td>
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<td>IWGDPIT</td>
<td>International Working Group on Data Protection in Telecommunications</td>
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<td>MSD</td>
<td>Minimal Set of Data</td>
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<td>PbD</td>
<td>Privacy by Design</td>
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<td>PKI</td>
<td>Public Key Infrastructure</td>
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1. Introduction

Cooperative Intelligent Transportation Systems (C-ITS) are inseparable from considerations on data protection and privacy:

“C-ITS may bring benefits for drivers by providing enhanced levels of usability and environmental awareness, and for the general public by improving road safety and protecting the safety of other drivers and pedestrians. […] But the large scale deployment of this new technology, which will entail the collection and processing of unprecedented amounts of location data of individuals in Europe, poses new challenges to the fundamental rights and to the protection of personal data and privacy both of users and of other individuals.” (WP29 2017, p. 8)

1.1 About this Document

This topic study addresses C-ITS from the angle of data protection and privacy, taking the European General Data Protection Regulation (GDPR) as main starting point. The GDPR is a new EU-wide legislation, which regulates the collection and processing of personal data. The topic study is conceptualised as a material collection, which unites relevant content on this pre-defined topic. This document is addressed predominantly at an internal audience for further usage of this content at later stages of the CAPITAL project. In this way, the material collection also serves as study guide for the development of an eponymous online training course within the project.

The remainder of the document is structured in ten chapters. The first chapter introduces core definitions, which are needed for the rest of the document. The second chapter identifies the objectives for this document. The third chapter summarises the methodology used for preparing the material collection. The fourth chapter familiarises the reader with the legal background relevant to C-ITS and Data Protection. The fifth chapter supplements this analysis with the political background. Based on these two chapters, the sixth chapter analyses three main challenges at the intersection between C-ITS and Data Protection. The seventh chapter provides readers with some tools to address these challenges. The eight chapter presents two C-ITS related case studies, which explore multiple angles presented before within one topic. The ninth chapter concludes with a discussion of the main findings of this document. The tenth chapter provides a succinct summary of the document.

1.2 Core Definitions

This sub-section introduces key definitions on data protection and privacy in the context of C-ITS. The necessity for this section follows from the legal nature of the study guide. By agreeing on definitions, which are in line with the existing legal framework in the EU, content in subsequent chapters can be better contextualised. More information on this legal framework is given in sub-section 4.2.

For the purpose of this study guide, C-ITS is defined in line with the Article 29 Data Protection Working Party (WP29), an advisory body to the European Commission on data protection issues, which is made up of national experts and the European Data Protection Supervisor (EDPS).

“C-ITS is a peer-to-peer solution for the exchange of data between vehicles and other road infrastructural facilities (traffic signs or other transmitting/receiving base stations) without the intervention of a network operator” (WP29 2017, p. 3)

Connected car data can be defined as data: “generated by a car and its occupants either when the car is moving or stationary, by itself or in communication with other vehicles or infrastructure” (Mc Kinsey 2016 in Zmud, Tooley & Miller 2016, p. 1)
Danish legal scholar Peter Blume defines **data protection** as a legal regime to protect personal data in a socially acceptable way:

“Data protection is specifically related to the legal rules that regulate to which extent and under which conditions information related to individual physical persons may be used. ... This legal regime ... should make it possible to use personal data in a manner acceptable to society.” (Blume 2010, pp. 153-154)  

No comprehensive and universally accepted definition of **privacy** has been offered. Conceptually, it has legal, psychological, social, philosophical and cultural aspects (Bloustein, 1964, p. 963). For this course, a threefold understanding of privacy will be taken, following Glancy (2012):

“These three types of privacy interests are personal autonomy, personal information, and surveillance ... The moral force of all of these privacy interests, as well as of the legal privacy rights associated with them, is based on the dignity of people expected to use [connected] vehicles.” (Glancy, 2012 p. 1187)

A **Data Subject** according to the definition provided for in the GDPR is:

“an identifiable natural person is one who can be identified, directly or indirectly, in particular by reference to an identifier such as a name, an identification number, location data, an online identifier or to one or more factors specific to the physical, physiological, genetic, mental, economic, cultural or social identity of that natural person.” (European Union 2016, Art. 4(1))

These identifiers are defined as **personal data**, the singular most important key term for data protection and privacy discussions. The relevance of personal data is further discussed in sub-sections 5.4 and 6.1.

Whereas the GDPR exclusively applies to personal data, **anonymised data** does not fall under its scope, which makes it an important concept to consider (see also sub-section 7.8):

“Anonymous data is any information from which the person to whom the data relates cannot be identified, whether by the company processing the data or by any other person ... It is an absolute threshold, and the company’s intent is not relevant. Anonymized data is no longer considered personal data and is thus outside the scope of EU data protection law.” (Burton & Hoffman 2015)

European law will legally introduce the concept of **pseudonymity** in the GDPR, serving as a tool

---

91 See also somewhat less precisely the definition by an advocacy-based NGO: “[Data Protection] is the law designed to protect your personal information, which is collected, processed and stored by “automated” means or intended to be part of a filing system.” (Privacy International no date)

92 “Personal autonomy is concerned with individual control and self-determination—people’s abilities to make independent choices about themselves ... In general, personal autonomy privacy interests focus on an individual’s ability to control such matters as who knows where she is now, where will she go next, when she will depart, how she will get there and with whom, as well as who can predict or decide where, when, and how she will travel in the future.” (Glancy 2012, p. 1188)

93 “Personal information privacy interests related to autonomous vehicles would include such matters as where, when, and how a person moves from geographical place to place, what uses are made of such personal data, why it is being collected, how it will be used, how long it will be kept, and who will and will not have access to it.” (Glancy 2012, pp. 1195-1196)

94 “Surveillance privacy interests respond to people’s aversion to being constantly watched, tracked or monitored as they travel from place to place. At the same time, surveillance privacy interests also reflect political and philosophical opposition to pervasive scrutiny of everyone who travels, particularly if that scrutiny is controlled by government.” (Glancy 2012, p. 1206)
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to relax the strict requirements for anonymization.

“Article 4(5) of the GDPR defines pseudonymization as “the processing of personal data in such a way that the data can no longer be attributed to a specific data subject without the use of additional information.” By holding the de-identified data separately from the “additional information,” the GDPR permits data handlers to use personal data more liberally without fear of infringing the rights of data subjects.” (Wes 2017)

The general definition of a controller provided in the GDPR is someone, who “alone or jointly with others, determines the purposes and means of the processing of personal data” (European Union 2016, Art. 4(7)). It is acknowledged, that the term can be further defined in more specialized European Union or Member State law.

The GDPR defines as processors those entities, that “processes personal data on behalf of the controller” (European Union 2016, Art. 4(8)). Consequently, the act of processing of data:

“means any operation or set of operations which is performed on personal data or on sets of personal data, whether or not by automated means, such as collection, recording, organisation, structuring, storage, adaptation or alteration, retrieval, consultation, use, disclosure by transmission, dissemination or otherwise making available, alignment or combination, restriction, erasure or destruction” (European Union 2016, Art. 4(2)).

Apart from anonymization, personal data can be processed, if users give consent. More information on this topic can be found in sub-section 7.1. At this stage, it suffices to define consent with the GDPR as:

“any freely given, specific, informed and unambiguous indication of the data subject’s wishes by which he or she, by a statement or by a clear affirmative action, signifies agreement to the processing of personal data relating to him or her” (European Union 2016, Art. 4(11))

2. Objectives

This chapter briefly outlines the objectives of this document. Within the online training, provided by the European CAPITAL project, one optional course will be offered on Data Protection and Privacy in C-ITS. The decision to offer this course is based on a needs assessment of the target groups for the online training, which includes non-expert public authorities and traffic operators. It is assumed that course participants will have intermediary knowledge of C-ITS.

This document aims to provide a concise overview of the material to be used in the preparation of the course. Based on an essential reading list (see chapter 11), it summarises, condenses, analyses, prioritises and clusters relevant information on the subject. Where no clear relation between data protection on the one hand and C-ITS on the other hand exists, this document aims to suggest interpretations of the current context from the perspective of C-ITS. This document aims to provide a neutral, textbook-style summary of the main content.

It is not the objective of this document to provide the precise structure of this online course. This activity will be done by the responsible project partner on basis of the material presented here, but not necessarily on basis of the presented structure. In addition, this document does not aim to provide a complete overview of the European data protection and privacy realm. Given the dynamic nature of these questions, a lack of concrete links to C-ITS and unclarities about the de facto enforcement of the GDPR, this would in fact not be possible. Instead, this document provides a concise overview of the topic and indicates further, more specialised readings, where
3. Methods

This document has been prepared in iterative desk research. Based on a number of core readings, including the GDPR (European Union 2016) and overview reports on data protection and privacy prepared for the EU or European projects (e.g.: WP29 2017, Eisses, van de Ven and Fievee 2012), the authors of this report collected written material from a wide array of sources. This includes documents from European institutions, agencies and advisory body, material prepared by interest representation groups, academic articles, reports of European projects and information material prepared by law firms and online platforms. No interviews were conducted for this study guide.

4. Legal Background

The overarching issue for this chapter is, which legal bases can be applied to connected car data (see also sub-section 6.1). If car data qualifies as personal data, the GDPR (see sub-section 4.2) and the upcoming e-Privacy regulation (see sub-section 4.4) apply. For non-personal car data, the upcoming Regulation on the Free Flow of Data will apply (see sub-section 4.5). The C-ITS Directive recognises the importance of personal data for the technology, which means that the European legal regime predominantly protects users as data subjects.

This chapter provides an overview of the legal privacy and data protection regime in Europe. The first sub-section introduces privacy as a European fundamental right. The second sub-section covers the most important legal document, the GDPR, which will come into effect on 25 March 2018. The third section connects these elements to the ITS Directive, the only legislation with direct reference to C-ITS. Two ongoing legislative initiatives are presented in sub-sections 4.4 and 4.5. The last two sub-sections present relevant jurisprudence on data protection and privacy from the angle of C-ITS.

4.1 Charter of Fundamental Rights

The European Charter of Fundamental Rights (CFR) protects privacy as a fundamental individual right. It is binding across Europe. The CFR is put into practice by the GDPR (see section 4.2):

“Everyone has the right to the protection of personal data concerning him or her. Such data must be processed fairly for specified purposes and on the basis of the consent of the person concerned or some other legitimate basis laid down by law. Everyone has the right of access to data which has been collected concerning him or her, and the right to have it rectified.” (European Union 2012, Art. 8)

The take-home message on the CFR is that privacy is a highly protected individual right.

4.2 General Data Protection Regulation

Until March 2018, the European Data Protection regime is guided by the Data Protection Directive (DPD) of 1995. The DPD makes the processing of personal data dependent on consent of the data subject. In line with the legal regime of the European Union, member states were required to translate the directive into national law (Eisses, van de Ven and Fievee 2012, p. 21), which created multiple differences in national implementation (Korff 2002).

This is the situation, which the GDPR seeks to address. Passed in 2016, full implementation of
the GDPR will start on 25 March 2018, which has ramifications for data protection and privacy in the realm of C-ITS. A complete overview of the changes from DPD to GDPR can be found in Chaturvedi (2017). The majority of definitions, as given above, does not change from DPD to GDPR (Gabel & Hickman 2016a), but the scope of the GDPR nonetheless makes it a crucial document:

“It is difficult to overstate the importance of the GDPR. First, it is very wide-ranging, and will impact almost every organisation that is based in the EU, as well as every organisation that does business in the EU, even if based abroad. Second, the GDPR is extremely serious. For too long, EU legislators and [Data Protection Authorities] have felt that organisations do not take their data protection responsibilities seriously enough, and so the GDPR dramatically increases the maximum penalties for non-compliance to the greater of €20 million, or four percent of worldwide turnover … Third, the GDPR raises the bar for compliance significantly. It requires greater openness and transparency: it imposes tighter limits on the use of personal data; and it gives individuals more powerful rights to enforce against organisations. Satisfying these requirements will prove to be a serious challenge for many organisations.” (White&Case 2016)

The GDPR sets out six principles of data protection. Although these are not revolutionary vis-à-vis the DPD, they nonetheless provide a unified outlook on the European data protection regime:

- Lawfulness, fairness and transparency
- Purpose limitation
- Data minimisation
- Accuracy
- Storage limitation
- Integrity and confidentiality

Two principles are especially relevant for C-ITS. The first one is transparency, as this principle expects users to be aware of the nature and purpose of data collection. It is not clear, to what extent this principle is met at the moment. The second relevant principle is data minimization, as C-ITS is connected to big data collection, where the usefulness is often established after the collection of data, which contravenes the obligations of the GDPR:

“Organisations collect personal data and then later decide the purposes for which they wish to use those data. The Directive does not permit this approach, and the GDPR tightens the restrictions further, stating that organisations should not collect data that are not necessary for a specified purpose that has been notified to data subjects. Organisations must ensure that, in relation to all processing activities by default, they process only the minimum amount of personal data necessary to achieve their lawful processing purposes.” (Gabel & Hickman 2016b)

Processing of personal data needs to be lawful, which requires consent by users, or a necessity based on legal obligations or vital interests (European Union 2016, Art 6). More information on

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95 GDPR Article 5(1): "Personal data shall be: (a) processed lawfully, fairly and in a transparent manner in relation to the data subject ('lawfulness, fairness and transparency'); (b) collected for specified, explicit and legitimate purposes and not further processed in a manner that is incompatible with those purposes; … ('purpose limitation'); (c) adequate, relevant and limited to what is necessary in relation to the purposes for which they are processed ('data minimisation'); (d) accurate and, where necessary, kept up to date; every reasonable step must be taken to ensure that personal data that are inaccurate, having regard to the purposes for which they are processed, are erased or rectified without delay ('accuracy'); (e) kept in a form which permits identification of data subjects for no longer than is necessary for the purposes for which the personal data are processed … ('storage limitation'); (f) processed in a manner that ensures appropriate security of the personal data, including protection against unauthorised or unlawful processing and against accidental loss, destruction or damage, using appropriate technical or organisational measures ('integrity and confidentiality')." (European Union 2016)
the lawfulness of processing is included below in Section 6.2.

The concept of consent by users or customers (analysed further in sub-section 7.1) receives a central standing in the GDPR. Users need to be asked for their consent in an accessible, legible and distinguishable form. They need to provide a written declaration. It must be possible to easily withdraw consent at any time. It is not the responsibility of the data subject, but of the controller to ensure that valid consent has been given.

In addition, the GDPR devotes an entire section of the rights of the data subject. These include the right for information provision (Arts. 13-14), the right of access (Art. 15), the right to rectification (Art. 16), the right to erasure, commonly known as the ‘right to be forgotten’ (Art. 17), the right to restrict processing, the right to data portability (Art. 20) and the right to object to data processing (Art. 21). For more information on this, refer to Gabel & Hickman (2016c).

Despite the GDPR’s intention to harmonise data protection law across the EU, there are some aspects, which remain in the hands of the member states. These include for instance the processing of ID numbers (European Union, 2016, Art. 87) or of personal data from official documents (European Union, 2016, Art. 86), which could be relevant for the processing of data from drivers’ licenses. More information on this area can be found in Gabel & Hickman (2016f).

The GDPR prescribes a number of steps for all European actors that collect and process data. While the scope of this deliverable does not allow exploring these, it is nonetheless worth mentioning that companies and authorities need to designate a Data Protection Officer, conduct Impact Assessments and establish Codes of Conduct in line with the GDPR (Gabel & Hickman 2016d). Lack of compliance can be enforced by national Data Protection Authorities with “new maximum fines of the greater of €20 million or four percent of an undertaking’s worldwide turnover. This is arguably the most significant single change set out in the GDPR” (Gabel & Hickman 2016e).

The take-home message on the GDPR is that the EU is giving itself an all-encompassing, strong framework for the protection of personal data with definitions and processes that are relevant throughout this topic study.

4.3 ITS Directive

In 2010, the European Commission adopted Directive 2010/40/EU to provide a legal framework for deployment and coordination of intelligent transportation across Europe. One article of the directive refers to privacy and data protection. Member States are responsible for the lawful processing of data in C-ITS (see also sub-section 6.2) and the necessary protection of data. The use of anonymization is encouraged.

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96 GDPR, Art. 7: “(1) Where processing is based on consent, the controller shall be able to demonstrate that the data subject has consented to processing of his or her personal data. (2) If the data subject's consent is given in the context of a written declaration which also concerns other matters, the request for consent shall be presented in a manner which is clearly distinguishable from the other matters, in an intelligible and easily accessible form, using clear and plain language. Any part of such a declaration which constitutes an infringement of this Regulation shall not be binding. (3) The data subject shall have the right to withdraw his or her consent at any time. The withdrawal of consent shall not affect the lawfulness of processing based on consent before its withdrawal. Prior to giving consent, the data subject shall be informed thereof. It shall be as easy to withdraw as to give consent.” (European Union 2016)

97 ITS Directive, Art. 10: “(1) Member States shall ensure that the processing of personal data in the context of the operation of ITS applications and services is carried out in accordance with Union rules protecting fundamental rights and freedoms of individuals... (2) In particular, Member States shall ensure that personal data are protected against misuse, including unlawful access, alteration or loss. (3) Without prejudice to paragraph 1, in order to ensure privacy, the use of anonymous data shall be encouraged, where appropriate, for the performance of the ITS applications and services ... (4) … States shall also ensure that the provisions on consent to the processing of such personal data are respected.” (European Union 2010)
The directive refers directly to the CFR as legal basis for privacy as a fundamental right. Accordingly, the directive makes additional remarks on data minimization and purpose limitation, as C-ITS refers to personal data:

“It is explicitly recognised in the preamble of the directive that the deployment and use of ITS applications and services will entail the processing of personal data. Such processing should be carried out in accordance with Union law. In particular it is stated that the principles of purpose limitation and data minimisation should be applied to ITS applications.” (Eisses, van de Ven and Fievee 2012, p. 22)

Overall, the directive signals the consistency of the European position on the issue of data protection and privacy. However, by tasking Member States to ensure data protection in C-ITS, the harmonising effect of the GDPR might be reduced.

The take-home message of the ITS Directive is that data protection in C-ITS is a crucial topic, which nonetheless remains in the hands of Member States.

4.4 Proposal for e-Privacy Regulation

The GDPR will be supplemented by a new regulation on e-Privacy. This document is currently undergoing the last legislative phases in a trilogue across the European Institutions and will add strength to the GDPR in terms of data protection (i-Scoop 2017). The regulation is also relevant in the area of connected transportation:

“Under the proposed Regulation, which would be directly applicable in each EU member state, manufacturers and retail distributors of vehicles would have to ensure that the systems in vehicles being “placed on the market” are configured in a way that prevents third parties from processing data generated by those vehicles, unless they have the user’s consent to enable third party access to that data. This requirement can be read as building upon the privacy-by-design and privacy-by-default requirements of the GDPR. The e-Privacy provisions could effectively prohibit the sale of connected cars in the EU which do not meet this requirement.” (Appt 2017)

The take-home message for the e-Privacy Regulation is that vehicle manufacturers will have to ensure ex ante compliance of connected cars with the GDPR.

4.5 Proposal for Regulation on Free Flow of Data

In September 2017, the European Commission proposed a new regulation on the free flow of non-personal data. Whereas the GDPR covers only personal data, this new regulation aims for “the free movement of data other than personal data within the Union by laying down rules relating to data localisation requirements, the availability of data to competent authorities and data porting for professional users” (European Commission 2017, Art. 1). This means that the flow of anonymised personal data or the flow of non-personal technical data will fall under this regulation.

National authorities, which want to work with C-ITS related non-personal data are also addressed by the proposal:

“This Regulation shall not affect the powers of competent authorities to request and receive access to data for the performance of their official duties in accordance with Union or national law. Access to data by competent authorities may not be refused on the basis that the data is stored or otherwise processed in another Member State.” (European Commission 2017, Art. 5(1))

The proposal is currently undergoing the political process, so that no definitive remarks on its
content and effect can be made at the point of writing.

The take-home message on the regulation as of now is that non-personal car data of technical nature could be freely shared across C-ITS actors.

4.6 Relevant European Case Law

There has not been a data protection and privacy case with specific focus on C-ITS in front of the European Courts. One Dutch case referring to the roles of public authorities in data protection carries relevance for the topic of this study guide. Naturally, this case takes the 1995 DPD as legal basis.

The question before the court referred to the right of access of data subjects:

“Mr. R requested to be informed of all instances where data relating to him were transferred in the preceding two years, and of the content and recipients. Dutch law on local authority personal records limited the communication of data to one year prior to the relevant request.” (Laudati 2016, p. 10)

The court determined regarding the right to access that this time frame might be too short:

“Right of access is necessary to enable the data subject to exercise his other rights (rectification, blocking, erasure, and notify recipients of same; object to processing or request damages) … It is for the Member States to fix a time limit for storage of information on the recipients and the content of the data disclosed, and to provide access to that information which constitutes a fair balance between the interest of the data subject in exercising his rights and the burden on the controller to store that information. In the present case, limiting storage of information on recipients and content to one year, while the basic data is stored much longer, does not constitute a fair balance.” (Laudati 2016, pp. 10-11)

A second case zoomed in on the qualification of data, where the Court argued in October 2016 that personal data depends on whether any individual can lawfully obtain the necessary information to re-identify a person:

“Information not directly identifying a person, will be deemed personal data in the hands of any party (but only in relation to that specific party) that can lawfully obtain sufficient additional data to link the information to a person and therewith identify that person. The Court further states, that for a qualification of data as personal it is not required “that all the information enabling the identification of the data subject must be in the hands of one person”. For data to be treated as personal data it is sufficient that the controller can or may employ legal means reasonably available to obtain corresponding additional knowledge from a third person through which the identification of the respective person is possible.” (Storing 2017, p. 9)

In addition to this, the Data Protection Officer of the European Anti-Fraud Office OLAF prepared an overview of definitions and interpretations of key terms in the DPD based on previous judgement (Laudati 2016).

The take-home message on European Case Law is that jurisprudence of C-ITS is not yet sufficiently developed.

4.7 Relevant National Judgements and Opinions

An overview study prepared by a Dutch consultancy for the European Commission in 2012 lists some national cases, which are directly relevant for data protection in C-ITS:
Their first summary refers to a French complaint in the realm of e-Ticketing for public transportation (CNIL, 2009)

“In the Keolis Case, several users submitted a complaint to the French data protection authority CNIL concerning the anonymous transport ticket named “Korrigo” in the city of Rennes. The complaints related to the following issues:

- The anonymous ticket was far more expensive than the comparable personalised ticket (between 2.5 and 4 times)
- For the anonymous medium, only single ride tickets were offered (no season tickets / subscriptions)
- Little information on the possibility to use an anonymous ticket was provided.

The CNIL ordered that these issues were to be solved as well as other breaches of the French “Informatique et Liberté” Law (duration of the data storage, lack of information concerning users’ rights, and lack of global policy concerning security and confidentiality). The case may serve as an example and confirmation of the principle that privacy is a fundamental right of natural persons. As far as reasonably possible, anonymous use of a service shall not be positioned as premium service at higher costs or made unattractive to the customer by reduced functionality or availability” (Eisses, van de Ven and Fievee 2012, p. 28)

Their second summary refers to prosecutorial use of Automatic Number Plate Recognition (ANPR) cameras in the Netherlands:

“In this case, data collected with ANPR cameras were used as supportive evidence in a severe criminal case, showing the likely location / time / route of the suspect around the time the crime was committed. The data collected should however have been deleted from the ANPR system as there was a ‘no hit’ situation at the time of collection (no match with a black/grey list of vehicle registration marks), as defined by the purpose and the usage protocol of the equipment … This case is an example of ‘function creep’, personal data are processed beyond the agreed terms and beyond their legitimate purpose.” (Eisses, van de Ven and Fievee 2012, p. 28)

The take-home message of national jurisprudence is that anonymous techniques should not be less functional than personal ones and that an extension of data processing requires extended consent.

5. Political Background

The European legal background on data protection and privacy is general in nature. The interpretation of these legal principles from the perspective of C-ITS is driven by discussions and statements from the European institutions and interest representatives. A selection of this political background is presented in this chapter. In conclusion, this section shows that the interpretation of the legal regime places the user into the centre of data protection and privacy considerations.

The first sub-section recounts general OECD principles for data protection. The second sub-section identifies the position of the European Commission taken in its C-ITS strategy. The third section summarises the professional view of data protection authorities on connected cars. The fourth sub-section recounts user demands on data protection and privacy. The fifth sub-section contrasts this with select positions of industry representatives. No information regarding the position of implementing public authorities or traffic operators has been recorded.

5.1 OECD Data Protection Principles

Already in 1980, the Organisation for Economic Cooperation and Development (OECD)
developed seven guidelines for data protection and privacy principles (OECD 1980). These virtually universally accepted principles were foundational for the development of legal and political tools for data protection in Europe:

"Notice: subjects whose data is being collected should be given notice of such collection. 
Purpose: data collected should be used only for stated purpose(s) and for no other purposes. 
Consent: personal data should not be disclosed or shared with third parties without consent from its subject(s). 
Security: once collected, personal data should be kept safe and secure from potential abuse, theft, or loss. 
Disclosure: subjects whose personal data is being collected should be informed as to the party or parties collecting such data. 
Access: subjects should be granted access to their personal data and allowed to correct any inaccuracies. 
Accountability: subjects should be able to hold personal data collectors accountable for adhering to all seven of these principles." (Eisses, van de Ven and Fievee 2012, pp. 20-21)

The take-home message from the OECD principles is that the is an established canon of data protection guidelines.

5.2 C-ITS Strategy

In November 2016, the European Commission published its C-ITS Strategy, which sets the priorities for deployment until 2019. One chapter focuses on privacy and data protection safeguards:

"The protection of personal data and privacy is a determining factor for the successful deployment of cooperative, connected and automated vehicles. Users must have the assurance that personal data are not a commodity, and know they can effectively control how and for what purposes their data are being used. Data broadcast by C-ITS from vehicles will, in principle, qualify as personal data as it will relate to an identified or identifiable natural person. The implementation of C-ITS therefore requires compliance with the applicable data protection legal framework. These rules lay down that processing of such data is only lawful if it is based on one of the grounds listed therein, such as the consent of users. Data protection by design and by default principles and data protection impact assessments are of central importance in the basic C-ITS system layout and engineering, especially in the context of the applied communication security scheme. The responses to the public consultation indicate that when these conditions are met the willingness of end-users to give consent to broadcast data is not a barrier, in particular when the data is to be used to enhance road safety or improve traffic management." (European Commission, 2016 p. 8)

The take-home message from the C-ITS Strategy is that the European Commission favours a Privacy by Design (see sub-section 7.2) approach, as they take car data to be personal data.

5.3 International Conference of Data Protection and Privacy Commissioners

In September 2017, the International Conference of Data Protection and Privacy Commissioners (ICDPPC), a global forum for public authorities, released a Resolution on Data Protection in Automated and Connected Vehicles, in which the body strongly urges all involved stakeholders to:

"1. give data subjects information as to what data is collected and processed in the deployment of connected vehicles, for what purposes and by whom, 
2. utilize anonymization measures to minimize the amount of personal data, or to use
pseudonymization when not feasible,
3. keep personal data no longer than necessary in relation to the legitimate purpose for which they are processed, for further compatible purposes, or in accordance with law or with consent, and to delete them after this period,
4. provide technical means to erase personal data when a vehicle is sold or returned to its owner,
5. provide granular and easy to use privacy controls for vehicle users enabling them to, where appropriate, grant or withhold access to different data categories in vehicles,
6. provide technical means for vehicle users to restrict the collection of data,
7. provide secure data storage devices that put vehicle users in full control regarding the access to the data collected by their vehicles,” (ICDPPC 2017, Arts.1-7)

The take-home message from the ICDPPC is that the OECS principles have already been translated to the field of C-ITS and connected cars.

5.4 User Perspectives
In 2016, the Federation Internationale de l’Automobile commissioned the largest public survey on user attitudes towards data protection in connected driving in Europe.

“The study shows a clear disconnect between the data tracked and what citizens are willing to accept. Europeans overwhelmingly want to control their data and decide with which service provider to share it. … 91% wanted the possibility to switch off connectivity. A further 83% wanted to decide when and for how long consent to access car data should last. In the case of sharing data during a breakdown, 92% felt that they should get to choose who repairs the car. Respondents felt comfortable sharing their breakdown data with local garages, insurance providers, automobile manufacturers and Automobile Clubs. With connected cars, drivers are most concerned about the disclosure of private information (88%), commercial use of personal data (86%), vehicle hacking (85%) and vehicle tracking (70%), all of which is possible with today’s connected vehicles. 95% of people surveyed believed that there was a need for specific legislation to protect their rights concerning vehicle and driver data.” (FIA Region I 2016, p. 1)

Based on the 12.000 responses collected for the study from regular drivers in 12 European countries, an overview of how comfortable users feel to share specific data emerges (FIA Region I 2016, p. 11)
These figures refute a claim made earlier by a global consultancy\(^98\) about whether data protection and privacy can be roadblocks in the deployment of the connected car:

“Against many expectations, personal data privacy does not seem to be a major roadblock to customer acceptance. Already today, a large majority of consumers very consciously share their personal data with their smartphone software manufacturer; only a quarter of customers categorically refuse to let OEMs use their driving data.” (McKinsey 2015, p. 6).

The take-home message from the user perspective is that all car data is seen as personal data.

### 5.5 Industry Declarations

In November 2014, the German Association of Car Manufacturers, VDA, released its Data Protection Principles for Connected Cars, which articulates some principles for the VDA and its members. One principle relates to transparency:

“The data of in-vehicle systems generated in the vehicle are primarily technical data showing the status of the system and environment in order to be able to trigger appropriate vehicle functions. The data are partly transient and are partly stored as a snapshot of a particular moment in time, e.g. for reporting a fault or for displaying operating values. They are stored in aggregated form, e.g. as fault codes, to assist with servicing and diagnosis … The customer can obtain information about the diagnostic data through the service organisation. The members of the VDA enable customers to inform themselves about categories of processed vehicle data and their purpose. This is done, for example, through online services or online portals or user manuals, but also through displays in the vehicle itself so that the customer can gain an overview of the active functions of the connected vehicle.” (VDA 2014, p. 2)

Another principle relates to self-determination of users and makes explicit reference to C-ITS traffic systems. The VDA wants to deploy a range of tools to ensure users’ self-determination:

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\(^{98}\) Based on a survey of around 3000 respondents in Germany, US and China (McKinsey 2015, p. 19).
"The members of the VDA are striving to enable customers to determine themselves the processing and use of personal data through various options. The members of the VDA will enable these options through contractual provisions, consents or technical features in the framework of optional features and choices that are given, through which the customer can activate or deactivate services, unless the processing is regulated by law. If the customer can enter, manage and use data himself, for example in the case of infotainment systems, he must also be able to delete them. Through corresponding features, which are also supposed to include a delete function, the members of the VDA enable customers to have self-determination ... The VDA member companies want to enable vehicles to communicate with intelligent traffic systems. As far as possible, these data are to be used anonymously. If this is not possible, or is only possible via a pseudonym, the members will provide the customer with decision options either through use of the service or through technical features or through consents or contractual provisions, which the customer can reverse at any time." (VDA 2014, p. 3)

In 2014, an alliance of US-American car manufacturers agreed on a set of binding industry standards:

“Transparency: Participating Members commit to providing Owners and Registered Users with ready access to clear, meaningful notices about the Participating Member’s collection, use, and sharing of Covered Information.

Choice: Participating Members commit to offering Owners and Registered Users with certain choices regarding the collection, use, and sharing of Covered Information.

Respect for Context: Participating Members commit to using and sharing Covered Information in ways that are consistent with the context in which the Covered Information was collected, taking account of the likely impact on Owners and Registered Users.

Data Minimization, De-Identification & Retention: Participating Members commit to collecting Covered Information only as needed for legitimate business purposes. Participating Members commit to retaining Covered Information no longer than they determine necessary for legitimate business purposes.

Data Security: Participating Members commit to implementing reasonable measures to protect Covered Information against loss and unauthorized access or use.

Integrity & Access: Participating Members commit to implementing reasonable measures to maintain the accuracy of Covered Information and commit to giving Owners and Registered Users reasonable means to review and correct Personal Subscription Information.

Accountability: Participating Members commit to taking reasonable steps to ensure that they and other entities that receive Covered Information adhere to the Principles." (AutoAlliance in Fockler 2016)

The take-home message from the industry declarations is that not all car data is personal data, but that there are non-personal technical data points that can be processed without regard to the GDPR.

6. Main Challenges

The previous chapters on the legal background and the political background show that there are several central questions to data protection and privacy regarding to C-ITS. These questions arise because of different interpretations of the relevant legal basis, because of the responsibilities of specific actors or because of legal unclarities.

This chapter summarises three of these main challenges. The first sub-section looks at the question of data classification. It is important to identify the type of data collection, as the relevant legal basis depends on this (see sub-sections 4.2 and 4.5). The second sub-section explores the
importance of processing personal data. This is relevant for public authorities, which will be in the position to process C-ITS-relevant data. The third sub-section briefly looks at the question of data ownership, where in the absence of relevant legislation, divergent positions have been communicated.

6.1 Types of Data
C-ITS-equipped vehicles produce a wide-ranging number of data points. Zmud, Tooley and Miller (2016, pp. 7-9) provide a non-exhaustive list of data collected by a connected car, which serves as an overview for a discussion on types of data and their relevance to data protection and privacy:

<table>
<thead>
<tr>
<th>Car-Related Data</th>
<th>Infrastructure Data</th>
<th>Performance Data</th>
<th>Car Occupant Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car length,</td>
<td>Roadway friction</td>
<td>Traffic speed</td>
<td>Trip origin</td>
</tr>
<tr>
<td>Car width</td>
<td>Road geometry</td>
<td>Travel times</td>
<td>Trip destination</td>
</tr>
<tr>
<td>Car bumper height</td>
<td>Road markings</td>
<td>Travel volume</td>
<td>Trip timing</td>
</tr>
<tr>
<td>Time stamp</td>
<td>Surface temperature</td>
<td>Occupancy</td>
<td>Traveller address,</td>
</tr>
<tr>
<td>Speed and heading</td>
<td>Subsurface temperature</td>
<td>Traffic density</td>
<td>Traveller trip records</td>
</tr>
<tr>
<td>Car acceleration</td>
<td>Moisture</td>
<td>Origin data</td>
<td>Traveller profile data</td>
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<tr>
<td>Turn signal status</td>
<td>Icing</td>
<td>Destination data</td>
<td>Toll payment,</td>
</tr>
<tr>
<td>Brake status</td>
<td>Treatment status</td>
<td>Incident status</td>
<td>Parking reservations</td>
</tr>
<tr>
<td>Stability control status</td>
<td>Air temperature</td>
<td>Video images</td>
<td>Parking fees</td>
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<tr>
<td>Driving wheel angle</td>
<td>Wind speed</td>
<td></td>
<td>Ridesharing options</td>
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<tr>
<td>Car steering</td>
<td>Precipitation</td>
<td></td>
<td>Traveller Occupancy</td>
</tr>
<tr>
<td>Tire pressure</td>
<td>Visibility</td>
<td></td>
<td>Distance travelled</td>
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<tr>
<td>Traction control state</td>
<td>Traffic signal equipment</td>
<td></td>
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<tr>
<td>Wiper status and run rate</td>
<td>Signal phase and timing</td>
<td></td>
<td></td>
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<tr>
<td>Exterior lights</td>
<td>Intersection geometry</td>
<td></td>
<td></td>
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<tr>
<td>Vehicle position</td>
<td>Dynamic message signs</td>
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<td></td>
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<tr>
<td>Obstacle direction</td>
<td>Speed limit signs</td>
<td></td>
<td></td>
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<tr>
<td>Obstacle distance</td>
<td>Dynamic lane signs</td>
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<td></td>
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<tr>
<td>Road friction</td>
<td>Parking facility locations</td>
<td></td>
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<tr>
<td>Fuel consumption</td>
<td>Parking spaces available</td>
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<tr>
<td>Emissions data</td>
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<td>Electronic stability</td>
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<td>control</td>
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</tbody>
</table>

The classification of the type of data between personal and non-personal data is crucial to define what legal framework should be applied. Not all the data produced by the connected vehicle are equal, needing to identify to what sectors the data belongs to and what concerns are built in this classification between personal and non-personal data. Data generated by a connected car that is exclusively technical, for instance, will follow a different legal regime (see Chapter 4).

The open question related to these data points is how to group them into different types of data. The VDA provides an overview of data collection on a connected car, which makes a distinction between technical data with low data protection relevance and personal data, which has high data protection relevance (VDA 2014, p. 5)
This distinction is rejected in a legal memorandum prepared for the My Car My Data Campaign (see sub-section 5.4), which unequivocally classifies all car data as personal data. More precisely, it does not accept the distinction made by the VDA that technical data cannot be personal data:

“Data in connected vehicles qualifies as personal data to any party that may reference that data with reasonable means to a specific individual. For such a qualification it is neither relevant whether data compromises technical data, nor whether data is vehicle generated or provided by the customer." (Storing 2017, p. 2)

“In particular, VDA, ACEA and SMMT so far prominently defended a position according to which data may be generally separated in different categories resulting in an “either / or” distinction between non-personal and personal data. With the exception of data for services requiring user or vehicle identification, data is considered to be merely of technical nature with allegedly no relevance to data privacy law. … The opinion of the European Commission, the German government, the German data protection supervisory authorities and the vast majority of legal scholars differs from the estimations of the European automotive industry associations described above. According to this view, data in connected vehicles, irrespective of its content, does qualify as personal data if it can be linked to one or more individual data subjects such as customers. Any indirect reference to a customer is sufficient for the data to qualify as personal data. Information is indirectly linked if data references foremost to material things but secondarily allows drawing conclusions concerning an individual’s personal circumstances. In other words, although technical data references primary to the vehicle as a material thing, it makes it possible for certain parties to infer facts regarding personal circumstances of the customer (Storing 2017, pp. 4-5)

The memorandum reiterates the point with the qualification that data controlling can prevent reidentification of the data, thus no longer rendering it personal data. The position of data controller is connected to the strict responsibilities of ensuring data protection as defined in the GDPR:

“As a result, data does not automatically lose relevance in terms of privacy just because it is being qualified as technical data. In contrast, data might even primarily contain technical information but can at the same time qualify as personal data” (Storing 2017, p. 7)

“Data coming from connected vehicles is not automatically deemed personal data for everyone. Instead, it needs to be assessed whether or not a specific company actually controlling the data is in a position to identify a person behind that data. Naturally, a vast variety of constellations is conceivable.” (Storing 2017, p. 9)

“Thus, any entity actually accessing or processing data qualifies as a controller irrespective of the underlying legal basis for such data access or processing … As a result, qualification as a controller is a mere legal reflex to an existing factual constellation: The moment, any entity irrespective of whether it is an OEM or a third party service provider accesses or processes data
on its own behalf it is deemed a controller and thus has to comply with the obligations and restrictions of European data privacy law. In other words: The controller as the addressee of data privacy law. Consequently, qualification as controller does neither grant unlimited, exclusive data access nor data ownership or a similar claim to data or even the right to process data at one's own discretion. On the contrary, it sets strict boundaries for such endeavours.” (Storing 2017, p. 11)

6.2 Processing of Data

Public authorities and traffic operators might be tasked with processing connected car data for C-ITS services. There might also be other third parties, such as vehicle manufacturers, which can take the role of processor as defined in the GDPR (see sub-section 1.2). Therefore, it is relevant to understand the importance of data processing in C-ITS and related controversies, which predominantly focus on the role of user consent (see sub-section 7.1).

There are two central bodies for interpreting the existing legal framework on data protection and privacy from the perspective of C-ITS. These are the C-ITS Platform and WP29, two advisory bodies to the European Commission. Whereas the former focuses on the C-ITS aspect, the latter focuses on data protection issues. In 2017, these two bodies provided diverging interpretations on the processing of data in C-ITS solutions.

On a wider level, the two parties agreed that:

“broadcast messages exchanged by the vehicles are personal data [because] the messages contain authorisation certificates, issued by the PKI, univocally associated to the sender; [and] the messages contain heading, timestamp, location data and the dimensions of the vehicle” (WP29 2017, p. 4)

The first disagreement regards the legal basis for processing of data. The C-ITS Platform sees CAM and DENM messages as pseudonymized data:

“The document qualifies the mechanism in place to exchange CAM and DENM messages with their digital certificates as a processing of pseudonymized data, arguing that additional information (the association between the certificate holder and the data of the vehicle) is kept separate from the data utilizer (this information is held by the certification authorities). Thus according to art. 4(5) of GDPR additional information would be needed in order to identify data subjects. This is why the document claims that art. 11 of the GDPR (processing which does not require identification) would have to apply.” (WP29 2017, p. 4)

In turn, the WP29 argues that pseudonymized data can be re-identified and therefore needs to be classified as personal data:

“Article 11 states that there are processing operations for which the identification of a data subject is not necessary, or no longer necessary, and the controller shall not be obliged to identify the data subject for the sole purpose of complying with the GDPR. This article should be interpreted as a way to enforce ‘genuine’ data minimization, without however hindering the exercise of data subjects’ rights. Exercise of these rights must be made possible with the help of ‘additional information’ provided by the data subject. By invoking art. 11 of the GDPR without specifying what additional data are necessary to enable identification of the data subjects, the exercise of data subjects’ rights (access, rectification, portability, etc.) is de facto prevented ... The Working Party rejects any interpretation of Article 11 aiming at reducing the responsibility of the controller(s) for compliance with data protection obligations.” (WP29 2017, pp. 6-7)

Additional disagreement centres on the lawfulness of data processing. There are six possible avenues for this envisioned in the GDPR:
“Lawfulness for the processing of personal data involved in the functioning of C-ITS must be sought in art. 6(1) of GDPR. Processing shall be lawful only if and to the extent that at least one of the following cases applies: (a) the data subject has given consent to the processing of his or her personal data for one or more specific purposes; (b) processing is necessary for the performance of a contract to which the data subject is party; (c) processing is necessary for compliance with a legal obligation to which the controller is subject; (d) processing is necessary in order to protect the vital interests of the data subject or of another natural person; (e) processing is necessary for the performance of a task carried out in the public interest or in the exercise of official authority vested in the controller; (f) processing is necessary for the purposes of the legitimate interests pursued by the controller or by a third party, except where such interests are overridden by the interests or fundamental rights and freedoms of the data subject.” (WP29 2017, p. 9, emphasis added)

The C-ITS Platform suggests public interest, performance of a contract, consent and legitimate interest as possible legal bases for processing personal C-ITS data (WP29 2017, p. 5).

WP29 agrees with the platform’s arguments on contract performance and legitimate interest (WP29 2017, p. 11). It does not take position on public interest, but suggests that compliance with a legal obligation is an important aspect that the C-ITS platform did not consider enough, especially given the possibility of delegated acts under the C-ITS Directive (WP29 2017, p. 9). However, “such a legal obligation should not allow for blanket collection and processing of personal data” (WP29 2017, p. 9).

The most contentious element appears to focus on the question of consent. For the C-ITS Platform, consent does not constitute a possible legal basis for processing, as the controller is not the sufficiently defined:

“With regard to the legal ground of consent, the C-ITS Working Group elaborates on the technical constraints posed by the broadcasting nature of the communications. In the C-ITS context, the actors that fulfil the role of data controllers might not have a direct one-to-one relation with the data subject. The data subject is not and cannot be aware of all recipients of his messages, given the way the standard is conceived” (WP29 2017, p. 5)

WP29 does not dispute the critical features regarding consent, but maintains that the existence of a controller is a necessary pre-condition for processing:

“In particular, since C-ITS is based on continuous broadcast, there is no point of discontinuity in the transmission to signal intention or wishes on the user’s side. Also, broadcasting is an entirely forward-going communication scheme, with no retro-action, and this makes it impossible to set a mutual recognition mechanism between the data subject (sender) and controller (recipient). This lack of mutual recognition by itself should not exclude the use of consent, but makes it more difficult to only process data for specific and well-defined purposes by known data controllers, On the other hand, the assertion made in the document that consent cannot be considered as a viable legal basis because the controller has not been defined at this stage to a level that would enable the data subject to be aware of its identity is misleading: the existence of well-defined controller(s) is a precondition for the processing itself, and no legal basis under art. 6(1) of GDPR would justify vagueness in its identification.” (WP29 2017, pp. 10-11)

That said, WP29 is adamant about the delicate nature of consent in C-ITS and about the limits of consent as an appropriate legal basis for processing:

“all elements of valid consent have to be met, as outlined in art. 7 of the GDPR and recital 42. Data controllers need to pay careful attention to the modalities of obtaining specific, free and
informed consent from different participants, such as car owners or car users. Such consent must be provided separately, for specific purposes, may not be bundled with the contract to buy or lease a new car and the consent must be as easily withdrawn as it is given. Additionally, consent is not an adequate legal ground when it comes to employees, given that the employer-employee relationship is characterized by legal subordination, and employees are not free to deny consent.” (WP29 2017, p. 10)

6.3 Data Ownership

The third controversy central controversy relates to data ownership. The unresolved nature of data ownership is related to the many involved actors and their diverging interests (Zmud, Tooley & Miller 2016, p. 1):

“Data ownership is complicated and nuanced. OEMs acknowledge that the owner or lessee of the car is the owner of the connected car data; however, they can access and control the data through user agreements. Data aggregators consider themselves to be the owners of the information that they sell, which is derived from the data. Owner–operators consider themselves to be the owners of the data collected by their sensors.” (Zmud, Tooley & Miller 2016, p. 4)

A study commissioned by the European Commission found that ownership of data from Event Data Recorders (EDR), non-mandatory ‘black boxes’ for cars, mostly falls with the vehicle owner:

“The ownership of EDR data is not well defined in each of the European countries considered and there are a number of parties (e.g. vehicle owner, vehicle driver, vehicle manufacturer etc.) who could claim to be the owner. Legal advice was not conclusive on this point, but the most consistent opinion was that whoever owns the vehicle in which the EDR device is installed, also owns the EDR device and, by extension, any EDR data recorded on it. … Currently, the issue of ownership is likely to have to be determined on a case-by-case basis, depending on the facts in any given situation, but was considered most likely to be the owner of the vehicle (EDR) in most European countries. This is in line with the position taken in the US, where the vehicle owner is defined as the owner of the EDR data.” (Hynd & McCarthy 2014 p. 51)

This approach becomes problematic, once a car owner is not automatically a car user:

“If manufacturers are not able to achieve the contractual ownership of certain data carriers, the rightful ownership of the vehicle as a data carrier would entitle the owner to prevent third party access to vehicle data and to demand access to technically locked data memories in the vehicle. Because of this, external access is usually subject to a contract or declaration of consent. Clarity is required around the data that may be generated, stored, and used and where required consents secured from owners, drivers and even passengers. This is even more complicated where the vehicle is shared amongst various users or when it is sold. Users of connected data may need to set up procedures to establish contact and obtain consent to the use of the new owner/users’ data.” (Appt 2017)

A large-scale survey of car users in Europe established that 90% of respondents want connected car data to be owned by the users (FIA Region I, 2016, p. 1).

7. Concepts and Tools

Some tools and concepts exist to address the challenges described in the last chapter. This chapter introduces a selection of those, albeit not necessarily in relation to C-ITS. The tools are also not equally well-suited to respect privacy and ensure data protection for connected cars and their users. Instead, this chapter provides a comprehensive overview of possible design choices.
for C-ITS applications and services, which need to be analysed in light of the legal and political background identified above. The chapter’s content ranges from important concepts to structural design choices and specific design choices, concluding with technical notes on data protection and privacy.

7.1 Informed Consent

The most direct way to allow for the usage of personal data in C-ITS applications is by user consent. Once consent has been given, the data can be lawfully processed (see sub-sections 4.2 and 6.2). In the words of a WP29 opinion on the DPD:

“If it is correctly used, consent is a tool giving the data subject control over the processing of his data. If incorrectly used, the data subject’s control becomes illusory and consent constitutes an inappropriate basis for processing.” (WP29 2011, p. 2)

Recital 32 of the GDPR adds information, on how to ensure that consent is informed, which amounts to a restrictive understanding of the concept:

“Consent should be given by a clear affirmative act establishing a freely given, specific, informed and unambiguous indication of the data subject’s agreement to the processing of personal data relating to him or her, such as by a written statement, including by electronic means, or an oral statement. This could include ticking a box when visiting an internet website, choosing technical settings for information society services or another statement or conduct which clearly indicates in this context the data subject’s acceptance of the proposed processing of his or her personal data. Silence, pre-ticked boxes or inactivity should not therefore constitute consent. Consent should cover all processing activities carried out for the same purpose or purposes. When the processing has multiple purposes, consent should be given for all of them. If the data subject’s consent is to be given following a request by electronic means, the request must be clear, concise and not unnecessarily disruptive to the use of the service for which it is provided.” (European Union 2016)

Moreover, consent is required for different processing steps, although this aspect is limited:

“To meet the specificity requirement under Article 7, a request for consent to data processing must be “clearly distinguishable” from any other matters in a written document, and it must be provided “in an intelligible and easily accessible form, using clear and plain language.” However, the law exempts controllers from obtaining consent for subsequent processing operations if the operations are “compatible.”” (Maldoff 2016)

7.2 Privacy by Design

The most important macro-structural design choice relates to the concept of Privacy by Design (PbD), which is also instilled in the GDPR. PbD was developed in Canada in the late 1990s and became a popular frame of reference. Taking IT systems, business practices and physical design into consideration, PbD is based on seven core principles, which aim to make privacy an integral part of any given system from the first development onwards:

“1. Proactive and Preventative: [...] PbD anticipates and prevents privacy invasive events before they happen…
2. Privacy as the Default Setting: We can all be certain of one thing — the default rules! PbD seeks to deliver the maximum degree of privacy by ensuring that personal data are automatically protected in any given IT system …
3. Privacy Embedded into Design: PbD is embedded into the design and architecture of IT systems and business practices. It is not bolted on as an add-on, after the fact. The result is that
privacy becomes an essential component of the core functionality being delivered...

4. **Positive-Sum**, not Zero-Sum: PbD seeks to accommodate all legitimate interests and objectives in a positive-sum “win-win” manner … PbD avoids the pretense of false dichotomies, such as privacy vs. security, demonstrating that it is possible to have both.

5. **Full Lifecycle Protection**: … Strong security measures are essential to privacy, from start to finish. This ensures that all data are securely retained, and then securely destroyed at the end of the process, in a timely fashion...

6. **Visibility and Transparency**: PbD seeks to assure […] that all component parts and operations remain visible and transparent, to users and providers alike…

7. **Keep it User-Centric**: Above all, PbD requires architects and operators to keep the interests of the individual uppermost by offering such measures as strong privacy defaults, appropriate notice, and empowering user-friendly options.” (Cavoukian 2011, p. 2)

### 7.3 All-or-Nothing Approach

One possible micro-structural design choice is all-or-nothing. The all-or-nothing approach means, that users of a service need to opt in to **all elements of data collection and storage**, without options to tailor the service to their needs. One example for this, albeit not related to C-ITS, is the Belgian eID:

“The Belgian eID card traditionally belongs to the first generation of eIDs and has implemented an “all or nothing” model. This means that the citizen, when he/she wishes to use his/her eID card, has to disclose all the personal data that are stored in his card and does not have the opportunity to choose which types of personal data he/she would like to disclose … [T]he National Register Number is not technologically protected against access and even provided by default with any use of the eID card, due to the “all or nothing” model. … [I]t is thus an example of an identification solution where the existing strict privacy protection rules have not been reflected in design choices, thus facilitating the needless disclosure of personal data.” (Kosta, Dumortier & Graux 2012, pp. 15-16)

### 7.4 Notice-and-Choice Model

A second micro-structural design choice relates to the way that information about data collection is presented. Notice-and-Choice is the most commonly used model for acquiring user consent for processing data. It consists in a notice, for example in form of a cookie banner on a website, which is the main element of expressing consent. According to the United States Department of Commerce:

“From the consumer perspective, the current system of notice-and-choice does not appear to provide adequately transparent descriptions of personal data use, which may leave consumers with doubts (or even misunderstandings) about how companies handle personal data and inhibit their exercise of informed choices.” (Internet Policy Taskforce 2010, p. 22)

### 7.5 Rules-and-Tools Model

An alternative to the notice-and-choice model is the rules-and-tools approach, which can be succinctly described as follows:

“Rules would be, for example, government regulations that limit how personal information can be used. Tools would be digital reminders, such as an on-screen alert that enhance a user’s perception that an action he is taking has privacy implications. Such reminders are known as “nudges”, since they gently push the user to notice a situation and react. For example, a user putting her birth date on a social networking site hoping for birthday greetings would receive a nudge on her screen before she confirms the action which points out that this information can also be used for targeted marketing and identity theft.” (PRECIOSA 2011, p. 27)
Along the same lines, WP29 suggests to leave it to users:

“to select whether they want to participate in the [C-ITS] system, and if so, select the tracking options (timing, speed, locations [and frequency]) that best fit their preferences” (WP29 2017, p. 10)

### 7.6 Data Minimisation

A very different approach to data protection and privacy is to minimize the amount of data collected and stored, which might be in conflict with the aims pursued and opportunities offered by C-ITS:

“This is the principle that data processing should be kept to a minimum and that data should not be held for longer than necessary. … The principle of data minimization creates a tension with the trend towards big data and the connected car, which tends to involve collecting as much data as possible about consumers. It is critical to ask the question as to whether and how data should be collected in the first place – stakeholders should ask whether data can be held locally or needs to be transmitted back to the car manufacturer or other third parties. There is also a requirement under the EU GDPR that companies will think in advance about the potential opportunities to use data collected by cars.” (Parker, Shandro & Cullen 2017, p. 10)

### 7.7 Certificates and Broadcasting

Most critical data protection elements are related to the GDPR. As the GDPR only applies to personal data, WP29 suggests two technical solutions to minimize the risk of re-identification, which is needed to ensure that personal data is adequately anonymized for further processing:

“Firstly, the issuing policy of PKI certificates can be improved. As long as a certificate is valid, a vehicle can be identified and tracked, and short range tracking is an important C-ITS design component. The short range tracking allows for a tight causal connection between road conditions and the vehicles driving in that area, and is therefore considered necessary to enable the system and make applications work. In order to prevent long term tracking, which is not essential for road safety, authorization tickets are changed over time…”

Secondly, the frequency of broadcasting of CAM messages needs to be adjusted. According to the proposed frequency settings of CAM messages, it would be possible to track vehicles in the range of a few meters. ... Mobility data are inherently and strongly correlated, and very repetitive for most drivers, and the exercise of reconciling apparently disjointed segments in an end-to-end path should not be considered unreasonable for an attacker with the means and the motivation.” (WP29 2017, p. 7)

### 7.8 Encryption and Anonymisation

Lastly, there are information security techniques to anonymise personal data. For most traffic applications, it has been argued that anonymous data is sufficiently detailed:

“One strategy for avoiding problems associated with personal information is to rely on anonymous information instead […which] should be sufficient for such uses as transportation planning, traffic management and the like. The challenge will be to maintain the anonymity of this information, which often gains value when linked to an identifiable person. Unfortunately, there is no permanent, solid divide separating anonymous data from personal information.” (Glancy 2012, p. 1200)

WP29 prepared an overview of several anonymization techniques:
“Noise addition: This means that an imprecision is added to the original data. For example, a doctor may measure your weight correctly, but after noise addition it shows a weight bandwidth of +/- 10lb.

Substitution: Information values of the original data are replaced with other parameters. For example, instead of indicating a patient’s height with 5’7″, this value is substituted by the word “blue.” If a patient’s height is 5’8″, it is registered as “yellow.” Substitution is often combined with noise addition.

Aggregation: In order not to be singled out, an individual is grouped with several other individuals that share some or all personal data, i.e. their place of residence and age. For example, a data set does not capture the inhabitants of San Francisco with certain characteristics, but the inhabitants of Northern California.

K-anonymity: is a form of aggregation. The process impedes re-identification by removing some information but letting the data be intact for future use. If the scrubbed data set is released and the information for each person contained in the release cannot be distinguished from at least k-1 individuals, it is considered k-anonymous. One method of k-anonymity is data suppression. You can suppress data by replacing a value with a place holder. For example, instead of “age 29,” the value is “X.” Another method is by generalizing the data. Instead of “age 29,” the input is “between 25 and 35.”

L-diversity: is an extension of k-anonymity … L-diversity protects anonymity by giving every attribute at least l different values.” (Burton & Hoffman 2015)

Individual anonymization techniques are not flawless. The Article 29 Working Party evaluated the techniques listed about based on their effectiveness and suggest combining them in order to ensure anonymization of the data (WP29 2014, p. 24):

<table>
<thead>
<tr>
<th>Technique</th>
<th>Is singling-out still a risk?</th>
<th>Is linkability still a risk?</th>
<th>Is inference still a risk?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noise Addition</td>
<td>Yes</td>
<td>May not</td>
<td>May not</td>
</tr>
<tr>
<td>Substitution</td>
<td>Yes</td>
<td>Yes</td>
<td>May not</td>
</tr>
<tr>
<td>K-Anonymity</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>L-Diversity</td>
<td>No</td>
<td>Yes</td>
<td>May not</td>
</tr>
</tbody>
</table>

8. Case Studies

There are no case studies available on data protection for C-ITS applications or services managed by public authorities in European cities. Therefore, this chapter presents material for two case studies, which serve as proxy situations for some of the implementation issues related to C-ITS. In the context of the training courses, participants will be asked to analyze these case studies from the perspective of the background, the challenges and the tools presented above. The aim of these case studies is to develop implementation-oriented thinking with awareness of data protection issues at hand.

The first sub-section presents a case study on e-tickets in public transportation. It focuses on the relevance of anonymization techniques and the responsibilities of transport authorities in...
collecting and storing data. The second sub-section presents a case study on the eCall, which is a mandatory European safety element in new cars. This case study explores the trade-off between safety and data protection, as well as design choices in line with the existing legal framework.

8.1 E-Ticketing in Public Transport
The wider context for e-ticketing in public transport systems can be described as follows:

“In the past decades electronic fare collection has been introduced on a large scale in public transport systems across Europe ... There are large differences between schemes. A common characteristic is that a so-called Customer Medium [CM] (often a chipcard) is used to carry transport credits and/or travel rights in electronic form.” (Eisses, van de Ven and Fievee 2012, p. 71)

There is no specific legal basis for this service, but it can be assumed to fall under the GDPR, where personal data is collected. The legal basis for processing is consent by the data subject for using the data in accordance with Art 6(1)(a) GDPR (Eisses, van de Ven and Fievee 2012, p. 72).

With regards to the applied architecture and types of data collected:

“eTicketing schemes rely on smart cards carried by the end-users. Service usage is determined by detection of passages of turnstiles or user registration at booths. Transactions and credits can be stored on the smartcard alone, but many schemes collect and store usage data from turnstiles and booth in a central system to monitor usage and detect fraud. The personal data involved in e-ticketing are generally of type (connected samples of position and time, allowing reconstruction of trips/routes). Depending on the scale of the e-ticketing the data may be of complete traces of a natural person. Often, a number of recent transactions is also kept on the CM.” (Eisses, van de Ven and Fievee 2012, pp. 72-73)

A study prepared for the European Network and Information Security Agency (ENISA) outlines some of the issues with e-ticketing:

“The online purchasing of tickets in the transportation sector poses challenges in the way how (and whether) the principle of minimal disclosure is respected in this field ... Users tend to reveal a large number of personal information and leave traces of their location at various time points for the sake of “convenience”. … [T]he unique number that is stored on the card allows for the tracking of the location of the user and, when combined with the identification data of the user that may be revealed when the electronic ticket card has been purchased via a credit or debit card, it offers a rich amount of personal information that can be used for user tracking and user profiling.” (Kosta, Dumortier & Graux 2012, p. 28)

A report, commissioned by the European Commission, summarized a number of recommendations given by the French data protection authority, (CNI, 2011), by the International Working Group for Data Protection in Telecommunication” (IWGDPT 2007) and by a EU-funded project on fare management (IFM 2010):

- “The cardholder/service user should be adequately informed on e.g. the purposes of the processing, the identity of the controller, the data categories processed, other parties with access to personal data, the right to use an anonymous ticket, and how the rights to inspect data, have errors corrected and have old data erased can be exercised.
- Anonymous tickets/CM should be available at the same rates and under
the same conditions as personalised tickets...

- For a personalised CM, the cardholder should have the right to refuse that his picture is stored in digital form...
- All personal details that may be processed are specified. Other personal details should not be processed. Data processing shall be anonymised, except when a need exists in the area of investigation or mitigation of fraud...
- Public transport companies can only collect the date, the time of use and data which are necessary to calculate the price of the ticket. Data revealing the place where the ticket has been validated (the station of validation) should not be processed as it is not necessary for the calculation of the price...
- All data can be stored for the full duration of the contractual relationship and, upon the end of it, for two years for commercial and statistical purposes. However data revealing information about the movements of the users shall be anonymised...
- Marketing: the consent of the user for the use of personal data for marketing purposes shall be distinct from the acceptance of the general contractual obligations...
- Public transport companies shall enable passengers to view their transaction data and/or journey data via the internet... The passenger shall be enabled to inspect what personal data are stored by the public transport company. He shall be entitled to request to improve, add, remove or protect data that are factually incorrect, incomplete or irrelevant." (Eisses, van de Ven and Fievee 2012, pp. 74-78)

Accordingly, “an important element of the discussions around e-ticketing is always the option to travel anonymously” (Eisses, van de Ven and Fievee 2012, p. 73). However, a case study of the Italian city of Cesena reveals that anonymous e-tickets cannot guarantee anonymity. This means that the data does fall under the scope of the GDPR:

“[In this paper we focus on anonymous, disposable 10-ride electronic tickets for public transportation. Such tickets can be generally bought anonymously through resellers or automated machines and, while they are identified through a unique ID, they do not carry any information on the owner’s identity. Thus, these tickets are perceived as the most privacy-friendly by the users while, at the same time, retaining some of the advantages of personal travel passes … In this paper we present the case study of a real, citywide public transport network in Italy. By analyzing and decoding the tickets issued by the company, we infer the information collected during their use. We use this knowledge to show that even anonymized and numerically limited travel histories are indeed enough to profile users with a great depth of detail … Simple anonymization of the travel histories of public transportation users is not sufficient to protect their privacy, and therefore suggests caution in the disclosure or trade of such data without the informed consent of the users themselves.” (Avoine et al. 2014, p. 2)

The authors of the case study describe three possible ways of collecting and processing the data linked to e-tickets, two of which are presented below (Avoine et al. 2014, p. 8).
The first system is the most commonly used one, and also the one most prone to data protection and privacy violations. About the second system, which requires a hardware update to install a jitter to introduce randomness, the authors write:

“We propose a more advanced and privacy friendly approach in the second system model. Here the same data are transmitted to the same remote storage, but in four different atoms. Each atom contains only the minimal data set required to compute a single aggregate. Delivering these atoms individually and at different times and encrypting the ticket-id (for aggregate S3) actively breaks the link between the identifier and other information and therefore enhances privacy. We note that, as aggregate S3 is intended to monitor daily patterns, the encrypted ticket identifier has to stay the same only for the duration of the day.” (Avoine et al. pp. 7-8).

Based on this overview of the case study, the concepts and tools developed in Chapter 7 are relevant in multiple ways:

- When buying an anonymised monthly ticket at a vending machine, users of public transport are normally not well informed about the Terms and Conditions of their purchase. Accordingly, informed consent may not be present. The vending machines, as well as parallel interfaces online or in face-to-face shops, should provide an easily accessible overview of the collected and transmitted data in public transportation. There should not be pre-ticked boxes or an automatic assumption of consent.
- If users disagree with the transmission of specific data points, for instance their home address, they should be able to de-select data collection and processing for this category. Such decisions should not reduce the scope or the price of the ticket (see also the Keolis case in sub-section 4.7). This approach would help to overcome the all-or-nothing nature of public transportation tickets.
- Public transportation providers should consider to minimise data collection. For instance, they could decide that photos, addresses or ID numbers of the user are not necessary to guarantee the functioning of their services. Moreover, the recording of end stations, as common for instance in the Netherlands, could be removed without negative implications on the billing processes. Payment information, such as credit card details, should be stored separately and not be used for the processing of traffic data.
- Following the suggestions of Avoine et al., public transportation providers could use encryption and anonymization tools in a PbD approach, which can help to avoid tracking or profiling of individual users. This would for instance include separate storage of the timestamp, the first stop and the ticket ID through instalment of a jitter.

8.2 eCall Systems in Private Cars
The eCall system, mandatory since 2015, triggers automatic data transmission in case of an
"When a vehicle gets involved in a serious crash, the eCall system will trigger a voice call to a so-called Public Safety Answering Point [PSAP] and automatically send basic data on the accident … The [Minimum Set of Data] (MSD) contains the time of the incident, the position and driving direction of the vehicle, the identity of the vehicle (Vehicle Identification Number: VIN), some qualification of the severity of the incident, the service provider and optionally the type of fuel". (Eisses, van de Ven and Fievee, 2012 pp. 58-59)

It is assumed that the eCall will fall under the DGDPR and the ePrivacy Regulation once they enter into force. As the service is mandatory, the legal basis for processing is compliance with European or national legislation, i.e.: Art. 6(1)(c) (cf: Eisses, van de Ven and Fievee, 2012 p. 50, p. 59).

The initiative is dependent on the involvement of multiple actors and the transmission, processing and storage of personal data:

“For an eCall to take place, it requires the involvement of a number of actors, from the implementation of the eCall platform in the vehicle up to the handling of an actual eCall, namely: (i) vehicle manufacturers who provide the eCall in-vehicle platform, (ii) mobile network operators who ensure the conveyance of data and communications from the in-vehicle platform to the recipient of an eCall, (iii) the PSAP which is the recipient of the eCall and of the eCall data, and (iv) the emergency services which will be providing the required emergency assistance to … The PSAP will temporarily store eCall data in its back office system for reference purposes and as input to incident analyses.” (Eisses, van de Ven and Fievee 2012, pp. 59-60)

The European Data Protection Supervisor (EDPS) issued detailed comments on data protection issues related to the eCall initiative (EDPS, 2011), which are summarised below:

“In basic eCall, the [EDPS] regards the PSAP as data controller … Specific modalities, involving one or more actors in the chain, shall be elaborated to ensure that the individual is adequately informed on the processing and the exercise of their rights concerning personal data processing. Permanent tracking of the vehicle is not needed for the purpose and shall be avoided. The data are only to be exchanged in case of an emergency. Only a strict minimum of data shall be processed by the mobile network operator and sent to the PSAP as part of delivering the basic eCall service” (Eisses, van de Ven and Fievee 2011, p. 61)

Prior to the adoption of the eCall Regulation, the European Parliament (EP) commissioned a study on data protection aspects in the proposal. The authors found that the eCall entails the processing of personal data and consequently recommended that data minimization and adequate procedures need to be enshrined in the proposal:

“The functioning of the mandatory (even “dormant”) in-vehicle eCall system may entail the processing of personal data. The scope of the MSD would need to be expressly enshrined in law. In defining the scope of the MSD, the principles of proportionality and minimisation should be observed, pursuant to which only data which is necessary to achieve the intended purpose, i.e. the proper handling of emergency calls, should be processed. The Proposal must be further clarified to ensure that the prohibition of constant tracking does not affect proper operation of the eCall system, since tracking is used to determine the direction of driving. In particular, the possibility of storing several (e.g. three) last locations of the vehicle should be sufficient.” (Konarski, Karwala & Schulte-Nolke 2014, p. 9)

In February 2017, a data policy analyst for a Brussels-based Think Tank published an op-ed in Euractiv regarding the eCall systems. His position is that the EU’s focus on privacy results in a
negative trade-off regarding safety of drivers:

“Due to unwarranted concerns about privacy, policymakers restricted the data vehicles will share with emergency services even though additional information could further improve safety without impacting privacy … If the emergency services had access to more real-time crash data, they could much better prepare to deal with the injuries and hazards they are likely to face at the scene. … When the EU conducted a feasibility study of automatic crash notification in 2009, it included a much wider range of data, such as acceleration, rotation, which seat-belts are in use, and what the driver did with the car’s controls before the crash. This data, had it been allowed in the final legislation, would have given first responders a better indication of the injuries they might have to deal with. Unfortunately, policymakers caved in to the demands of privacy groups.” (Wallace 2017).

Based on this overview of the case study, the concepts and tools developed in Chapter 7 are relevant in multiple ways:

- With eCall functionalities being mandatory in European cars, an all-or-nothing approach is likely to happen. Nonetheless, car owners need to explicitly give informed consent to the data being stored upon the purchase of their cars. Car dealers cannot assume that silence by the users constitutes consent. The amount and type of data stored needs to be specified.
- Data minimisation is relevant for deciding, which timeframe is applied to data transmission through the eCall, and which data points are sent. This touches on the debate, how many seconds and/or previous locations are being stored and whether information on speeding, driver occupation and number of passengers is relevant for the emergency services and insurance companies.
- Users should be given the choice to send more data if they want to in a rules-and-tools approach. Decision to stay with the legal minimum, however, should not restrict the functionality of the eCall.

9. Discussion and Conclusion

This chapter briefly discusses the process of preparing this study guide and the next steps for setting up the study module. This discussion concludes that the material for the study is easily available, of sufficient quality and ready to be processed for the course.

First, information on this topic is easily available. The high political profile of data protection in general and the GDPR in specific has resulted in multiple extensive treatises on the legal framework. The majority of relevant readings is publicly available. This applies to all documents from the European institutions, agencies and advisory bodies, as well as to the publications of interest groups, European projects and consultancies. Availability is in principle more restricted for academic sources, but most core readings are available publicly online as well.

Second, the collection of information for this topic study was successful. All core sub-topics could be addressed with information from high-quality sources. The slightly dated work of Eisses, van de Ven and Fievee (2012) has provided a comprehensive overview of topics relevant for inclusion into this document. Moreover, the work of WP29 (2017) has provided durable links between data protection, privacy and C-ITS to be pursued further for this document.

However, a number of limitations apply to this material collection. On the one hand, the majority of available readings on data protection for the connected car originates from the United States, where both the concrete legislative framework and the theoretical thinking are more advanced than in Europe. As the legal regime is, however, drastically different across the Atlantic, not all of
the available literature could be taken into account. On the other hand, there are no concrete case studies available on C-ITS and data protection in Europe. The authors have reached out informally to individuals involved with the most advanced C-ITS sites in Europe, but none of them possess data protection factsheets or layouts, which could be used for this course.

For the preparation of the course, the material presented here can be readily used, but needs to be rearranged. Whereas this topic study provides a neutral, textbook-styled summary of relevant material, the course would have to start from problems, issues or conflicts (e.g.: types of data – see sections 5.4, 5.5 and 6.1), then identify the relevant legal framework (e.g.: The GDPR – see section 4.2) and conclude with an inventory of tools to comply with this framework.

One guiding principle for this preparation could be a perspective of ‘next steps’ for data protection and privacy in C-ITS. This could be operationalised in three distinct ways.

- The first next step would be **legal**. It remains to be seen how the GDPR is implemented in general and how its implementation will look in the realm of C-ITS. Additionally, the regulations on e-Privacy and Free Flow of Data, once adopted, will provide more depth to the legal development. Given the importance placed on C-ITS across Europe, it would also be interesting to think about specific legislation on C-ITS, which would address for instance the role of processors and controllers in automatic V2V communication.

- The second next step would be **political**. Irrespective of the legal framework, a fundamental decision on data ownership and consent for processing will be crucial. Given the lack of awareness by end users in this regard, such decision is likely to be of top-down nature. If car data is understood to be personal data and consent as currently exercised evaluated to be invalid, then political initiatives are needed to maintain the momentum for C-ITS deployment.

- The third next would be **practical**. Notwithstanding the issues and debates described in this topic study, there are a number of actions that interested public authorities and traffic operators can undertake. This includes for instance a a priori focus on PbD design in urban C-ITS solutions. Moreover, public authorities can practise data minimisation or implement a rules-and-tools approach. In the absence of clear legal guidelines and facing unresolved political debates, this practical approach might be the most appropriate for C-ITS deployment.

### 10. Summary

This topic study presents an overview of key material for understanding data protection and privacy from the perspective of C-ITS and for the implementation of C-ITS. WP29 provides a concise discussion of privacy risks associated with C-ITS, which summarises the points touched upon in this study guide.

First, C-ITS necessarily involves the extensive broadcasting of location and mobility data. Users appear to not yet be prepared to share these data points, as they are aware of the possible privacy implications.

“First of all, C-ITS by concept will make exposable what we were not used to disclose: where we drive and the way we drive. By means of the transmitting and receiving capabilities of the vehicles, these intimate pieces of information will be publically broadcasted to any nearby vehicle.” (WP29 2017, p. 8)

Second, users need to be aware of the types of data collected, the recipients, how these are processed and for which purpose. This awareness is needed to establish user consent, which is a tricky question for C-ITS in general.
Lack of transparency is another major privacy risk. Through their vehicles, users will become continuous broadcasters. They must be fully aware of the scope of the processing, of the other peers with whom they exchange data in the C-ITS environment (other vehicles, car manufacturers, roads managers, other public or private parties) and how they process these data.” (WP29 2017, p. 8)

Because of the structural set-up of C-ITS, the protection of personal data becomes even more important. This protection is guided by the GDPR, which applies to C-ITS insofar as personal data is collected. Control of personal data can be ensured through a number of tools for informed consent.

The choice of broadcast among peers to distribute messages, instead of one to one communications, poses another challenge: messages can be received by an unrestricted number of entities, whose intentions and technological capacity are not, and cannot be known to the sender. This causes an informational asymmetry between the senders and the other peers (receivers) of the C-ITS. This asymmetry needs to be rebalanced with a higher level of control on the personal data.” (WP29 2017, p. 8)

Last, the amount of data collected in C-ITS is ripe for business exploitation. This opens questions on the free flow of non-personal data (either technical, or anonymised) and the question of data access and data ownership. This area is not yet sufficiently legislated to make a definitive judgement of what will happen.

Kinematic and location data will be highly valuable to a number of interested parties with diverse intentions and purposes, ranging from advertisers to car manufacturers and insurance companies. Unrestricted and indiscriminate access to data shared within C-ITS may allow for the unfair accumulation of individual movement profiles.” (WP29 2017, p. 8)
11. References


Parker, N, Shandro, A, Cullen, E 2017, Autonomous and Connected Vehicles: Navigating the


