C-ITS Roadmap for European cities

CIMEC Deliverable D3.3: Final Roadmap

Mark Cartwright, Leslie Knoop

CENTAUR CONSULTING LTD

Cooperative ITS for Mobility in European Cities

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LIST OF ABBREVIATIONS

Note: Some of the abbreviations cited below have multiple meanings, even within the ITS context. The explanations below are only intended to represent the use of these terms within this Roadmap.

3G	"third generation" of mobile communications technology; uses international standards; now fairly widespread in Europe, but not universal
4G	"fourth generation" of mobile communications technology; uses international standards; beginning to be deployed in certain European cities
ALPR	Automatic Licence Plate Recognition; same as *ANPR*
ANPR	Automatic Number Plate Recognition; same as *ALPR*
AVL	Automated Vehicle Location
BS	Basic Service; used in the context of functionality such as *CAM* and *DENM* messaging
BTP	Basic Transport Protocol; an *ETSI* standard
CAI	Commonly Agreed Interface; specification developed under the InTime and CoCities projects; originally intended to be submitted for standardisation but since withdrawn
CAM	Cooperative Awareness Message; part of the *ISO* 19091 standard for C-ITS
CCTV	Closed-Circuit TeleVision
CEN	Commité Européen de Normalisation; one of Europe's core standards bodies (cf also *ETSI*, *TC278*)
C-ITS	Cooperative *ITS*; used where multiple ITS exchange data to fulfil a function, especially where the ITS belong to different stakeholders
CMC	Connected Motorcycle Consortium
CODECS	COoperative ITS DEployment Coordination Support; an EU-funded project, closely connected to CIMEC
DATEX II	Second generation of the DATEX (originally: "data exchange") specifications for sharing to traffic related information, primarily between *TMCs*; now being standardised within *CEN*
DENM	Decentralised Environmental Notification Message; part of the *ISO* 19091 standard for C-ITS
DfT	Department for Transport (within the UK)

ETSI	European Telecommunications Standards Institute; one of Europe's core standards bodies (cf also *CEN*)
G5	A *Wi-Fi*-like communications protocol, designed for short-range use involving moving vehicles; based on international standards
GLOSA	Green Light Optimum Speed Advice (or variants); generic term for a service that helps vehicle drivers maximise their change of getting through a signalised junction without stopping, by adjusting their approach speed
GN	Part of the *ETSI* standards suite for mobile communications
GPRS	General Packet Radio Service; a data communications service which is provided very widely across Europe (based on the current "second generation" mobile system GSM), but which offers relatively low data rates
GTFS	General (formerly Google) Transit Feed Service; a simple data exchange format for information about public transport services
HGV	Heavy Goods Vehicle
HMI	Human Machine Interface
HTTP	HyperText Transfer Protocol; part of the *IP* suite, and designed for transmitting web pages
ICT	Information and Communications Technology
IM	Intelligent Mobility; general term relating to highly-informed patterns of transport usage
IoT	Internet of Things; a reference to the envisaged future in which many devices exchange data automatically through *IP* networks, in a parallel way to how people use the Internet
IP	Internet Protocol; refers to the family of standards used to define the communications of the Internet (and also refers to a specific protocol within that family)
ISA	Intelligent Speed Adaptation; the external or automated control of a vehicle's speed in order to comply with relevant local restrictions, without driver involvement
ISO	International Standards Organisation; one of the global standards bodies, and the approximate equivalent to *CEN* in Europe (with which it cooperates closely)
ITS	Intelligent Transport System; loosely, any use of *ICTs* in a transport context
ITS-CMS4	The fourth Cooperative Mobility Services event, run by ETSI; held in 2015 to cross-test multiple supplier developments relevant to *C-ITS*
IVERA	An open data communication specification for traffic control apparatus and the associated central computer systems; developed in the Netherlands and freely available (cf also *OCIT*, *UTMC*)

LDM	Local Dynamic Map; a standardised way of allowing an *ITS* to store relevant local geographical information
LoRa	Low-power Radio; a specification for local radio communications geared especially to battery operated products (where low power consumption may be critical)
LTE	Long Term Evolution; a development of *3G* communications intended to fast-track some of the benefits of *4G*
M/453	Mandate 453; an instruction from the European Commission to *CEN* and *ETSI* to develop standards relevant to C-ITS (completed 2013); cf *CAM*, *DENM*, *MAP*, *SPaT* etc.
MaaS	Mobility as a Service; a new concept which intermediates between travellers and transport operators, aiming to select an optimum mix of modes on the traveller's behalf
MAP	Part of the *ETSI* specification set for C-ITS, providing an automated description of the layout of a junction and the possible paths through it; cf also *SPaT*
MDM	MobilitätsDatenMarktplatz (Mobility Data Marketplace); a national German initiative to collate available transport relevant data for shared use by others
MOVA	Microprocessor Optimised Vehicle Actuation (system); an algorithm for setting isolated traffic signals based on the arrival of vehicles along each approach
NOX	Nitrogen Oxides
NPRA	National Public Roads Administration (Norway; locally Statens vegvesen)
NTP	National Transport Plan (Norway; cf *NPRA*)
OCIT	Open Communication Interface for Road Traffic Control Systems; an open protocol published in German (cf also *OCIT-C*, *OCIT-O*, *UTMC*)
OCIT-C	The *OCIT* specification for centre-to-centre communications; cf also *DATEX II*
OCIT-O	The *OCIT* specification for centre-to-outstation communications; widely used in central Europe in particular (cf also *IVERA*)
ODG	*OCIT* Developers Group; the cross-industry forum responsible for developing and maintaining *OCIT* specifications
OEM	Original Equipment Manufacturer; in context, a company that makes and sells vehicles
PM10	Particulate Matter of diameter 10µm and smaller
PTW	Powered Two-Wheeler
R&D	Research and Development
RFI	Request for Information
R-ITS-S	Roadside *ITS* Station
RTPI	Real Time Passenger Information (system)

SIRI	Service Interface for Real-time Information; a *CEN* standard for exchanging live updates on public transport
SPaT	Signal Phase and Timing; part of the *ETSI* specification set for C-ITS, describing the current and near future settings of traffic signals; cf also *MAP*
TC278	Technical Committee 278; the TC within *CEN* responsible for *ITS* standards
TLA	Traffic Light Assistance; used of Trondheim's plans for C-ITS
TMC	Traffic Management Centre
TMS	Traffic Management System
TS	Technical Specification; a type of standard produced by organisations like *CEN*, *ISO* and *ETSI*
UC	Use Case (in this Roadmap, referring specifically to groups of applications for which cities might wish to use *C-ITS*)
UTMC	Universal Traffic Management and Control; a broad ranging framework of open specifications for city traffic management systems; developed and widely used in UK
V2I	Vehicle to Infrastructure; a *C-ITS* usage in which data is exchanged between a vehicle and a body responsible for the network (whether at roadside or remote to a central system)
V2V	Vehicle to vehicle; a *C-ITS* usage in which data is exchanged between two vehicles on the same network, normally close together
V2X	Vehicle to X; a *C-ITS* usage in which data is exchanged between a vehicle and something other than the network operator and another vehicle – for example, a pedestrian
V-ITS-S	Vehicle *ITS* Station; typically refers to a vehicle-mounted ICT which is used in a *C-ITS* context
VMP	Variable Message Panel; same as *VMS*
VMS	Variable Message Sign; same as *VMP*
VRU	Vulnerable Road User; typically user to cover cyclists and pedestrians
VRUITS	An EU-funded project investigating the potential use of *ITS* to help protect the safety of *VRUs*
WAN	Wide Area Network; a communications platform extending over long distances, typically at least 1km
WAVE	Wireless Access in Vehicular Environments; term used to refer to vehicle-based communications generally, but also specifically to a set of standards now linked to *G5*
WG	Working Group
WG17	Working Group 17: the newly formed *WG* of *CEN TC278* which is responsible for urban *ITS* standards

Wi-Fi	A radio-based technology for local area networking (typically up to around 100m), based on international standards and used extremely widely in both commercial and domestic systems
XML	eXtensible Markup Language; a standard that allows the description of data structures for exchange of *IP*-based networks, using protocols such as *HTTP*, and widely used for system-to-system communications; many *ITS* standards, including part of *DATEX II* and *SIRI*, are written using XML

1. Introduction: about the Roadmap

1.1. Project context

This document has been produced under the CIMEC project, addressing "Cooperative ITS for Medium-sized European Cities", as part of Work Package 3 (WP3).

CIMEC is a Coordination and Support Action (CSA) whose primary aims are to understand potential benefits and impacts of cooperative intelligent transport systems (C-ITS) on urban environments, since most of the work to date has been focussed heavily on the highways context. CIMEC runs from June 2015 to May 2017.

This document is the main output of CIMEC: a "Roadmap for European cities".

This document is quite extensive and detailed. Accordingly a summary is being made separately available.

1.2. Audience

This Roadmap has two key audiences.

The primary audience is "cities" (in the broad sense, including e.g. regional local road authorities), for whom the document is intended to be an educational guide on how, why and when to approach the issue of C-ITS.

The secondary audience is stakeholders whose actions provide important externalities for cities: national policymakers, funding authorities, the vehicle industry, the ICT industry, etc. For this audience, the Roadmap is intended to be an indication of where and how to focus:

- Regulatory development
- Funding interventions
- Support services
- Product development
- Marketing

While the CIMEC project is nominally focussed on "medium European cities", much of the Roadmap is expected to be equally relevant to cities which are (a) larger or smaller, or (b) outside Europe.

1.3. Nature of this Roadmap

This document is not the first Roadmap that has been collated for C-ITS. It is, however, the first – as far as the project team is aware – that has been specifically brought together from the specific perspective of local roads networks, and the public administrations (referred to for simplicity as "cities" in this document) that are responsible for them.

Previous C-ITS Roadmaps have taken quite varied approaches to defining what C-ITS is, what a "roadmap" is, and what action (if any) is expected to result. Some have focussed specifically on particular technology elements, such as roadside stations; other have focussed on system functions, such as driver alerts. Some have been predominantly geared to vehicle-to-vehicle ("V2V") operation, whereas others have been equally concerned with vehicle-to-infrastructure ("V2I") operation. Many have attempted to describe a specific timeline: by 2015 X will happen, then by 2020 Y will happen. Others, more pragmatically, have based their projections on market operations, and merely suggested an order in which specific services are likely to emerge.

This Roadmap takes a broader view. It is intended, above all, to be an overview perspective on how the city C-ITS market is expected to develop in Europe: to provide a vision that European cities can collectively recognise and support, and that other stakeholder can benefit from in their political or commercial planning.

To achieve this, the Roadmap works through the following steps:

- The opening chapters provide background on the context and current state of the art.
    - Chapter 2 recaps how complex the operation of a city is, and the practical conditions in which it operates
    - Chapter 3 describes what C-ITS is, from the perspective of a potential city user. This is not a deeply technical description!
    - Chapter 4 reviews the current state of the supplier market, specifically focussed on city C-ITS suppliers
- The middle section presents and analyses specific functionality from the perspective of what provides tangible benefit to a city.
    - Chapter 5 reviews the ways in which C-ITS could, potentially, be useful to cities, based on research conducted directly with cities and others during CIMEC and in related projects. The result is not a catalogue of what cities *want* – just of things that they are willing to listen about
    - Chapter 6 identifies the key factors that might go into evaluating a potential city C-ITS project
    - Chapter 7 builds on these, developing and assessing specific functions that are likely to form part of a city programme – subject to local relevance, budget availability, etc.
    - Complementing this, chapter 8 summarises some key lessons for how a city's selected "shortlist" of C-ITS services could be put together in a robust and practical programme
- The final section steps back to explore some additional key factors.
    - Chapter 9 explores how city C-ITS deployment will be affected by developments outside the control of cities and their supply chains, and implicitly sets a challenge to the wider set of stakeholders

In addition, Chapter 10 provides a brief summary of the Roadmap's key conclusions.

Annex A is not strictly part of the Roadmap. Instead, it presents the perspectives of the four CIMEC city partners on how they now expect to develop C-ITS locally, based on their experience and knowledge gained through the project. As such, they represent case studies that may be applicable for other cities.

1.4. How the Roadmap was built and validated

This Roadmap was built using the outputs of the first year's work of CIMEC, undertaken in WP1 (user requirements) and WP2 (market readiness), combined with additional input gained from continuing discussions with stakeholders during the second year.

A range of projects and initiatives have provided helpful input on city C-ITS. Resources consulted during the preparation of this Roadmap include:

- The C-ITS Platform, specifically the Phase 1 final report and discussions within the new Urban WG
- The Car2Car Consortium and the Amsterdam Group, through a variety of conferences, presentations and documents
- The main European Connected Corridors projects
- European R&D projects, especially CODECS but also Compass4D, CONVERGE, DriveC2X, TEAM and VRUITS
- Public documentation on the EC's planned research (especially H2020 calls) where the results may provide evidence in the near future
- Ertico reviews and activities, including the TM2.0 platform
- Where available, summaries of national C-ITS research (focusing on project partners' Member States)

This Roadmap has been validated through review in several steps. The preceding deliverable D3.2 ("Draft Roadmap"), was initially reviewed by project partners, then opened to consultation with both primary and secondary audiences through a series of workshops in February and March 2017. In addition, D3.2 was made publicly available on the CIMEC website and direct outreach made to key stakeholder groups.

As a result of review, this Roadmap has been revised in a number of fairly small, but valuable, ways, and we are grateful to all those who have contributed to its improvement.

In particular we would like to thank Silvia Murga (for Bilbao), Thorsten Miltner (for Kassel), Rob Macdonald (for Reading) and Per Einar Pedersli (for Trondheim), and their colleagues, for preparing the city statements in Annex A.

Osama al-Gazali (Albrecht Consult) and colleagues undertook the bulk of the work in WP2, which has been summarised in Chapter 4. Similarly, Hans Westerheim (SINTEF) and colleagues undertook the bulk of the work in WP1, which has been used as the basis for the use case analysis in Chapter 5.

1.5. How cities should use the Roadmap

This Roadmap is not a deeply technical document, but it is still quite long and complex. Furthermore, it is not a simple instruction handbook, but a framework from which elements will need to be extracted, analysed and adapted for local use.

It has been developed, therefore, so that city officers can use it as a reference volume. Different parts of the Roadmap will be suitable for:

- Transport teams (who are assumed to have good professional skills in managing traffic and/or public transport, and have a sound basic understanding of ITS, but not to be deeply technical
- Associated professionals, such as procurement officers or legal departments
- Senior decision makers

It is recommended that an individual should be asked, within each city, to review at least chapters 5 and 7, referring to the rest of the Roadmap to help explain the context and structures. This individual would then be best placed to suggest what C-ITS services would be most relevant to the city, and to select who else needs to be involved in developing the plan.

Once an initial concept of local developments is agreed, it may be appropriate to begin pre-commercial discussions with suppliers and potential funding authorities. Other parts of the Roadmap may then be useful in ensuring coherence and minimising programme risk.

Chapter 9 is about external factors, and may provide a useful checklist for city officers to seek specific advice on their programme.

1.6. How others should use the Roadmap

It is clear that cities are not (at least at present) the main driving force for C-ITS: many other stakeholders will be influential in how city deployment happens.

While the majority of the Roadmap is principally aimed at cities, it may provide useful background reading for national/European policymakers, standards developers, product developers, research managers and others, to assist in understanding how cities think and how they are likely to react to specific approaches.

Suppliers, in particular, will want to focus on the products that cities have expressed interest in; where the interest is still only mild, they may choose either to strengthen their offer or change their approach.

National/European policymakers and other strategic officers, similarly, may find it helpful to identify areas where cities are likely to respond well to encouragement (or pressure), and where effort is likely to be less effective. They may also find it helpful to identify functions which are of wider strategic importance but not currently on cities' immediate planning horizon, to see what mechanisms may be available to assist.

2. About cities

2.1. Introduction

Europe is a big place with a lot of cities which are different in many respects. They have different geographies, different cultures, different histories, and different governances. However, despite the many differences there are also many similarities.

This chapter provides a brief overview of the nature and operations of European cities, which provides the basis and context for all of their decision-making on C-ITS.

2.2. City governance and management structures

Each city has a wide range of tasks and responsibilities that it needs to undertake and budget for. These may include:

- Education and schools
- Social services
- Healthcare
- Public spaces (parks and gardens)
- Environment, housing and planning
- Waste and Recycling
- Leisure and Culture
- Births, deaths and marriages
- Transport: Roads, Public Transport, Car parks

Not only will the city have multiple responsibilities, but they may also be handled at a number of different levels with budget and decision making divided between them. Some cities will be essentially self-governing, although subject to national policy agendas; other are constrained within a tight and complex web of county, region and subnational bodies above, and limited by district and local activities below.

City departments tend to be siloed. They are expert within their own departments, but rarely outside of them. Despite the fact that there are often important overlaps between departments, it can be difficult to get relevant departments together and to untangle whose budget is to cover what. For instance, transport is crucial to healthcare. People have to travel to hospital appointments. What provision needs to be made for car parking and local public transport? How can technology help that? Similarly, education and transport are linked by the need to transport children to school, but the links between transport and education departments are often quite basic.

Even within a transport department, there are silos. One typical distinction is between the traffic unit and the public transport unit, which may rarely interact. Sometimes, the traffic unit is distinct from the highways unit (which deals primarily with civil engineering and roadworks), so that traffic strategies are surprised when a long-planned hole is dug. Transport planners, too, often have poor connections with operational staff.

Cities do not exist in isolation. They may border onto other conurbations under different governance and budgetary control and they may intersect with the highways network. Ensuring a seamless experience for road users across boundaries presents further complexities for the decision making process. Coordination across multiple boundaries is rarely fully effective, and inevitably coloured by questions of who is responsible for costs.

2.3. City geography, economy and demographics

When considering the best use of C-ITS for an individual city, a number of factors will need to be considered. 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 change what a city seeks from its C-ITS? Does the distribution of population within the city present special requirements?

A city which is faced with very cold weather conditions, with a lot of snow or ice, might be expected to want very different things from 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.

Perhaps surprisingly, therefore, CIMEC did not find that these geographical factors had a major impact on city's approach to C-ITS, which were much more clearly directed at delivering the city transport goals.

2.4. City transport goals and policies

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)

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 will all contribute to congestion and require management. These are the places where technology can help and is helping.

Air pollution levels are limited by EU Air Quality Directive 2008/50/EC and heavy fines can be levied for breaches. There is, therefore, a significant incentive to ensure the city manages its traffic to minimise pollutants. To a large measure, this is an extension of the need to manage congestion. Large amounts of standing traffic will increase emissions and therefore elevate pollution levels. Cities will also want to monitor city streets to ensure that they are aware of any hotspots where pollution tends to build up. Technology can help with this.

Each city has a duty to ensure **road safety**. In particular, the safety of road users is paramount while they are driving (or walking or cycling) on the city's roads, especially if they are dependent on technology that the city has implemented. Technology certainly offers opportunities to improve road user safety. All new technologies whether they are intended to improve safety or whether they aim to address another issue, must prove their safety record in real world trials. Further, any new technology needs to prove that it will not compromise road user while it seeks to solve other road issues. Any city will need to understand what risk the technology creates as well as what risks it seeks to mitigate.

Good **public transport** is, of course, important in encouraging modal shift. This gets individual drivers off the road, reducing pollution and congestion. For users, quality largely equates with timely, dependable and comfortable. By giving passengers good, reliable information and offering public transport road priority or dedicated space, a journey can be improved for passengers. Real time passenger information and bus priority are two of the ways in which technology can and has been helping to improve the quality of public transport.

There are local complexities around these main city aims. Cities with historic centres may face particular difficulties in managing road traffic. Roads in old cities tend to be narrow, may be cobbled and may have historically significant buildings close to the road. This will limit what measures can be put in place since the road cannot be widened, pollution is particularly damaging to old buildings and space will be at a premium.

2.5. City operations and budgeting

Cities have a lot on their plates. There are many aspects about running a city which take up their time, energy and budgets. While specific responsibilities may vary locally, the fact that there are many of them will not. Transport is only one in a battery of responsibilities that a city needs to juggle. Part of that juggle will include how to spend budget and in particular how to allocate budget to support policy goals which may not be set locally while still being mindful of local needs and local limits.

Every city will be constrained by budget. They will need to make choices about how best to spend their limited budget most effectively and efficiently. In terms of transport, some of this can be achieved by investment in technology. But this throws up its own challenges.

Before a city will want to invest in technology it needs to be convinced that it:

- is available and meets the specification;
- will do the job better than another (cheaper) solution;
- is well tested to achieve the outcome desired;
- is well tested to be safe in the context;
- is a price which is manageable within the budget;
- will integrate with legacy systems; and
- is future-proofed against obsolescence.

Getting the technology that's right for a city may have plenty of internal hurdles to overcome as well. Technology development is done by suppliers, but it needs to meet the needs of the city. It is easy to be enthusiastic about what is possible without sufficiently considering what is necessary, practical and cost effective. Understanding the technology is hard for people who are policy driven rather than technically minded. It is arguably even harder for those in procurement positions who are primarily driven by cost rather than policy or technology. Changes in personnel and inconsistent levels of expertise may also contribute to problems in achieving a holistic approach to transport technology acquisition. Skills shortages are widespread in some councils as budgets have led to staff cuts in order to balance budgets. This is magnified when the technology is new and limitedly trialled in the real world.

Real world procurement of systems tends to be piecemeal. Unless external funding exists for pilots cities will tend to implement small scale schemes and changes rather than introduce wholesale implementations of new technology across a whole city. So it is more likely that they will fit a few junctions with a new technology rather than all junctions and see how that goes. They will also prefer to integrate with an existing, legacy system rather than introduce a completely new system and scrap everything that has gone before. Suppliers, then, need to be mindful of the need to develop products that integrate well into existing systems, but which will upgrade easily and will allow for expansion if that is required.

3. The nature of C-ITS

3.1. Introduction

There is widespread confusion over what counts as C-ITS. What they are; their relevance to cities; the current positioning of the marketplace, and so on. Because of this, C-ITS is often viewed as a rather arbitrary technical construct, whose beneficiaries are mostly private cars on highways.

This section aims to address and calm this confusion, and thereby to enable cities to approach C-ITS as a practical opportunity. It examines and explains the main kinds of C-ITS as generally understood, in terms relevant to cities. Also included is a description of some major transport trends which will interact with, and complicate, the planning for C-ITS: autonomous vehicles, personal smart devices, and the broader "internet of things" (IoT).

Specific implementations of C-ITS (as functionality, applications or devices) are described in Sections 5 and 6 below.

3.2. C-ITS systems: V2I and V2V

The general aim of C-ITS is that, by having access to data from others, each stakeholder in the activity of transport will be able to make better decisions that they could if they just relied on their own data.

The challenge for C-ITS begins with the name. Intelligent transport systems (ITS) are technological products, and for many cities this fact is already a barrier: the policy goals of enabling the safe and efficient movement of people and goods seem a long way from software and computers. The acronym, too, sounds technical; and there can be a natural distrust on what salesmen from computing companies promise.

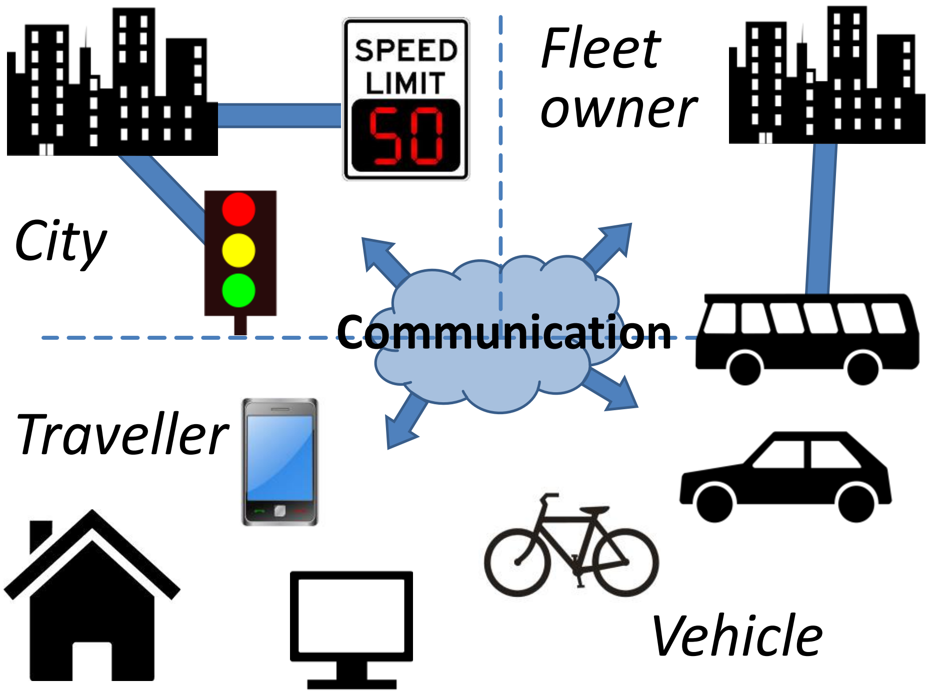
The "C" prefix complicates things. Cities can be persuaded that ITS can be useful tools – for example, to manage traffic signals or provide traveller information – but the additional feature of *cooperation* implies that the city is, at least, dependent on other people's systems. Why take this risk if you can have, and use, your own system?

In fact, the term C-ITS covers a very wide range of technical concepts, and many do *not* involve any investment by cities (although they may affect travel behaviour, and therefore require a policy response).

For instance, one class of C-ITS is the so-called V2V concept, which involve the direct communication between vehicles – usually those close together on the road. An example might be if one vehicle could send a "braking" message to the vehicle behind, which could be used to help prevent a collision – perhaps in future, by activating its own brakes much more quickly than the driver could react. V2V services will be relevant to cities for their own vehicles, of course, but for little else[1].

However, there is another class of C-ITS, termed V2I, which involves links between vehicle and "infrastructure", where the term "infrastructure" is typically interpreted as being the systems owned and operated by the manager of the road network. For instance, many V2I services envisage direct communications between vehicles and traffic signals. For these systems to work, the entity responsible for the traffic signals – almost always the city – must specify, procure, implement and operate systems which include this communication feature.

Figure 3.1 Generic concept of C-ITS: any two entities might benefit from communication



Both V2V and V2I services include a wide variety of specific functions and mechanisms, some of which are relatively well understood and some of which are still very vague. In addition, there are other C-ITS concepts – for example, a vehicle could communicate with pedestrians, perhaps to alert a blind person to an approaching vehicle. The connecting theme is the need for *communication*, and at a systems level, it is potentially possible for many different services to use the same communications link. Whether this is cost-effective, however, is a much more complex and nuanced question, and is a driving factor for much of the remainder of this Roadmap.

1 There may, however, be an easier business case to build for such vehicles: see chapters 7 and 8.

Each different C-ITS service has a different value. However, while the owner of a traditional ITS system expects to gain direct benefit, this is less obviously the case with C-ITS: both parties need the system, but one party may gain much more than the other. Indeed, this is probably the single biggest challenges for V2I systems:

- Why should a city pay to install a system, if the main beneficiaries are the drivers?
- Why should a driver pay for an in-vehicle system, if the main beneficiary is the city?

Ambitions should therefore be geared to finding solutions where there is mutual benefit: some kind of "win-win" structure (see chapter 7, "building the business case").

3.3. Describing C-ITS functions

Whether C-ITS is useful to a city[2] will obviously depend on what it does. But defining what this means can be surprisingly difficult, and lead to confusion (particularly between ITS providers and their customers).

For instance, among the different aspects of a C-ITS system are the following – all of which will be important in an actual project:

- The **communication** interface (i.e. *how* data is exchanged between city and user). The main options are communication over public mobile communications, i.e. using cellular technology, and communication using "short range" approaches like Wi-Fi at junctions (see section 3.5).
- The **messaging** interface (i.e. *what* data is exchanged between city and user).
- The **application** process (i.e. what is done with the data once it has been got).
- The **human-machine** interface (HMI). This is how information is presented to city or user personnel, and how instructions and choices are elicited from them,
- The **control** interface. Some C-ITS applications will effect a change without human intervention (e.g. by slowing a vehicle or changing signal settings).

Within the systems community, there is a lot of detailed discussion on the first two points, and in particular around the development of standard protocols. Messaging protocols are – confusingly – often referred to as "applications" or "services", in line with standard technical usage but very far from services either to the city or to the road user.

By contrast, cities will be primarily interested in the third item, i.e. what can be done with the data that has been obtained using C-ITS, and in this context will also be interested in the last two items (how humans will be engaged and how control systems will be engaged). While there has certainly

2 From here on we concentrate primarily on V2I services, i.e. where the city is directly involved in information sharing.

been some exploration of these areas, they are much less well developed than the technical aspects. From the city perspective, this knowledge gap represents a serious challenge.

In CIMEC we have adopted the following "stack" of terms to link the technology to the goal:

- A **policy goal** is a high level ambition of a city, as declared by its local politicians (in accordance with national/European regulation) and interpreted by senior decision makers. This covers the familiar issues of safety (reducing road deaths and injuries), environment (minimising emissions), economy (optimising flow of people and goods), and so on.
- An **activity area** is a strategic component of transport management in which specific measures may be used to support a policy goal. Examples include signals and signs, public transport management, travel information, freight management, dangerous goods, roadworks management, etc. Each activity area has its own existing technology tools.
- A (C-ITS) **use case** is a specific approach to supporting an activity area by a mechanism that benefits from the exchange of data between city and vehicle. The focus is on the nature of the shared information and on the benefit achieved, and not on the specific systems used to share the information.
- A **scenario**[3] is a specific structure of systems and services which enable a use case, i.e. to communicate the information envisaged in the use case (with the necessary timeliness, accuracy, reliability, security etc.).
- An **ITS station**[4] is any device or program that can act as one end of a C-ITS cooperation: it can provide or consume information, and process it appropriately.

The term **C-ITS service**[5] will also appear in some places, to mean a specific message or message set that can be exchanged by C-ITS stations. This term is usually used to denote a particular type of data exchange: those used in automated links between a vehicle-mounted system and a roadside system.

With these terms, the city will generally be responsible for the first three. Once it has determined a set of use cases to explore, it will seek solutions in the supply market for products to deliver them. It will then assess the cost and risk of the various scenarios offered by the market. Suppliers, for their part, will produce and sell C-ITS stations that they feel are good value for money for a set of scenarios.

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[3] This use of the terms "use case" and "scenario" has been developed collaboratively with the CODECS project, whose primary goals are more linked to system optimisation.

[4] This term is now established in the range of standards that govern C-ITS (see for example ISO21217:2014). There is a more technical definition but this is the essence!

[5] This use is now long established in the work of many fora (the Car to Car Communications Consortium, the Amsterdam Group, the European C-ITS Platform etc.) and projects. Despite the potential for confusion, as discussed above, it is therefore retained.

An example usage of these terms might be as follows:

- The **policy goal** is to improve the environment through reduced car usage and shift to sustainable modes; additional goals of improved accessibility and traffic flow are also relevant.
- The **activity area** is the promotion of public transport through the network by means of priority mechanisms. This may include bus lanes etc., but may also include traffic signal priority.
- The **use case** envisages a bus sending a message to the city when it is approaching a traffic signal, and the city responding (if it can) to ensure that the bus has a high chance of a green signal.
- The **scenario** may be a device on a bus sending a radio message to the traffic signal controller. A second scenario would involve the bus reporting its location to the bus management centre, which then passes a request to the urban traffic management centre that controls the signals.
- At least two **C-ITS stations** are involved: the device on the bus and the device at the signal controller. In the second scenario, two other C-ITS stations are also involved: one at the bus management centre, and one at the traffic management centre.

This example shows that there are often multiple ways of achieving the same goal, with or without C-ITS, and can even be several different C-ITS approaches.

3.4. Potential value of C-ITS

C-ITS is a technical tool; the focus of a city will be firmly on *outcomes*, i.e. how different kinds of C-ITS might result in real-world changes to traffic and travel. The value of a C-ITS project can and must be evaluated primarily with this metric.

There are several ways of addressing this. The best, where available, would be robust evidence of policy benefits which can be directly (and quantitatively) linked to specific C-ITS solutions: *lower accident rate*, *improved air quality*, etc. This information does not exist and may be very difficult to gain even in the long term, as the effect of C-ITS will be difficult to disentangle from other changes.

Only slightly easier would be to assess operational benefits: *road users are (measurably) better at avoiding potential accidents*, or *traffic through roadworks shows (measurably) higher flow*. It could also be comparative – for instance, *the overall impact on traffic and transport is neutral, but the cost of collecting traffic data is much reduced*.

Behind this are the direct improvements claimed for C-ITS, such as *road users have better information on the presence of nearby VRUs*. This kind of metric is more likely to be objectively measurable, although at present the amount of reliable data is still very limited. However, these values need to be viewed with caution, for two reasons:

- Better information does not equate to better driving: issues such as driver distraction, safety complacency or perverse behaviour (such as “road rage”) may all compromise the effect
- Even where such a claim is validated, there may be unintended consequences which are independent – for example, emissions rise, road wear increases or traffic flow breaks down

In CIMEC, Work Package 1 addressed city requirements and perspectives on C-ITS, and as a result the following *activity areas* – i.e. interventions which might benefit from C-ITS support – were identified (in no particular order):

- Multimodal traffic and transport management
- Information exchange
- Individual traffic management
- In-vehicle signalling
- Management of urban freight
- Management of electric vehicles
- Management of traffic lights
- Parking management
- Incident management
- Air pollution
- Support for vulnerable road users
- Car sharing
- Autonomous driving

As cautioned above, this is no guarantee that each of these areas will benefit. However, these are expected to be linkable to city policies in most European cities, so that a local assessment can be made. Furthermore, there are significant technical and operational issues around aspects such as privacy and cybersecurity, which need to be considered before proceeding.

The rest of this chapter continues to review the role of C-ITS as a whole in city policymaking and operations. Chapter 4 reviews these potentially-benefiting activity areas, and the specific C-ITS use cases that apply to each one, in more detail. Later chapters look at some of the implementation challenges.

3.5. Alternative architectures for C-ITS

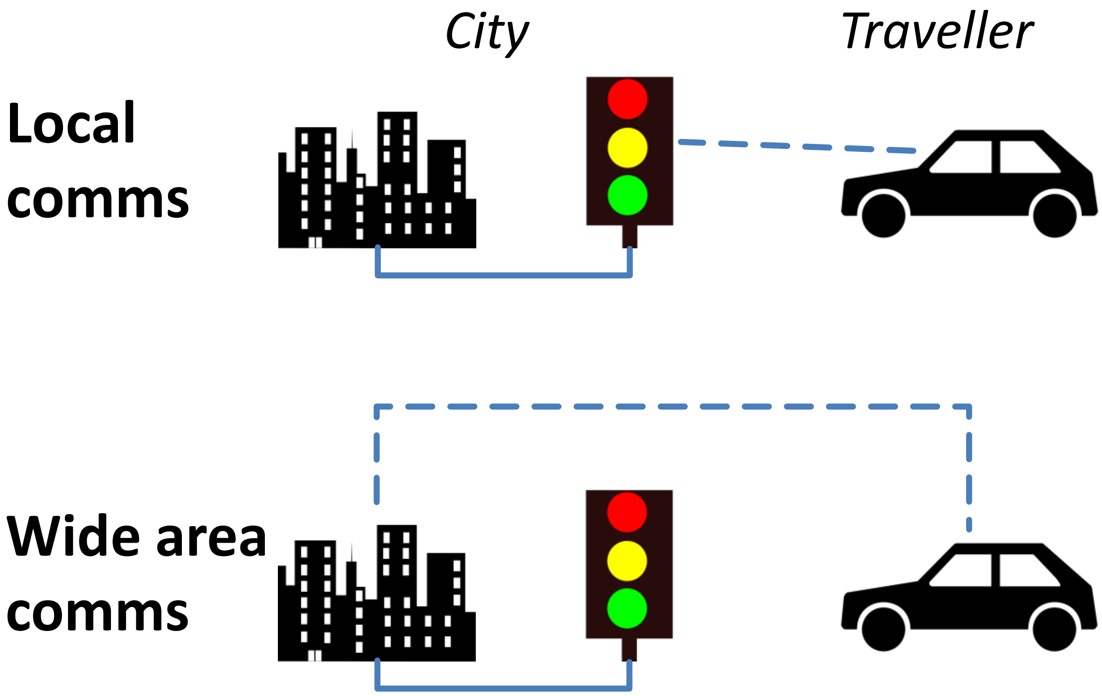
As is now clear, C-ITS can be delivered through several different fundamental architectures, which imply very different approaches to designing city projects.

Technically, the two key alternatives are:

- Approaches based on short range communications links – ETSI G5, but also Wi-Fi, Bluetooth, etc.
- Approaches based on long range communications – cellular systems, but also Tetra, DMR, etc.

Figure 3.2 shows these schematically: the cooperative link is the dotted line, which uses a suitable radio protocol (the link between city and roadside is usually wired).

Figure 3.2 Key technical architectures for C-ITS



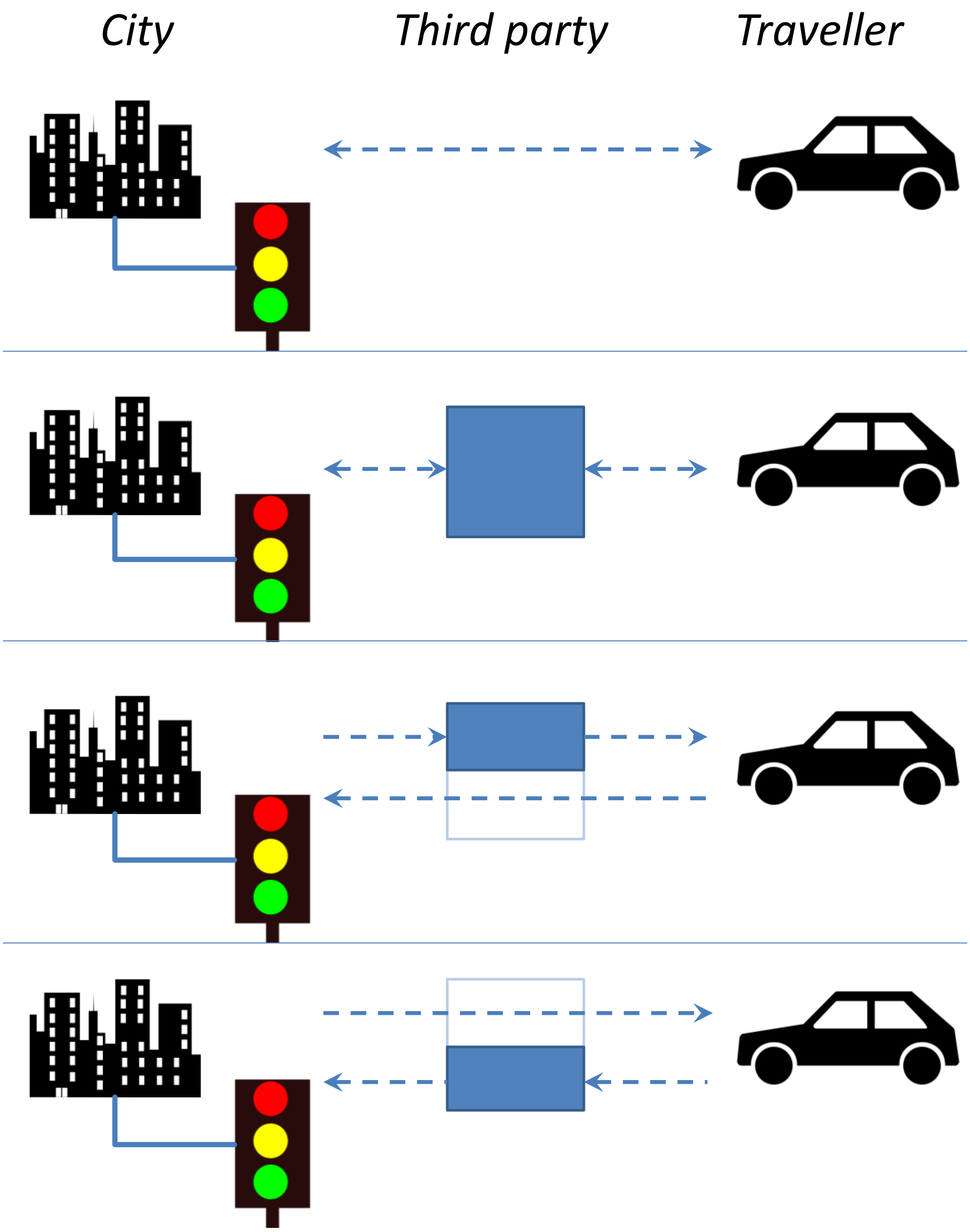
While in principle the two approaches both allow exactly the same kinds of C-ITS functionality, the technical properties of systems is likely to make one or the other more efficient for different services. For instance:

- Local communications are naturally point-based, while wide area communications cover the whole area. Local communications are therefore less well suited to network monitoring than to management of "hotspots" like junctions.
- Local communications services require new pieces of roadside equipment to be installed and maintained at all relevant sites. However, the communications services themselves are free.
- Wide area communications require very little infrastructure but impose an ongoing revenue cost. Which is more efficient depends on the number of sites equipped and the amount of data likely to be exchanged.
- Wide area communications services are, at present, much more prone to delays and interruptions. Services that require near-instantaneous response – such as collision detection and automated braking – may therefore prefer local communications[6].

[6] This is, indeed, exactly the reason that the vehicle industry is looking to these channels for many V2V applications.

In addition to this technical dichotomy, there are options based on different business architectures. This area is also (for obvious reasons) in its infancy and few clear directions can be seen; however, figure 3.3 indicates four potential solutions that have emerged during the course of CIMEC research.

Figure 3.3 Some business architectures for C-ITS



From top to bottom, these models depict the following arrangements:

- 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 etc. in a single unified approach, these may not always outweigh the benefits of mixed, but more appropriate, platforms.

3.6. Interoperability

One of the biggest technical concerns of cities, and their suppliers, is "interoperability". The issue was raised at all of the workshop sessions during February/March 2017.

In principle, what cities need in terms of systems is determined by their policy and project specifications: does it do the job, and is it cheap enough? In practice, there are significant areas of project risk which mean they put a lot of emphasis on whether it is aligned with what others are doing. No city wants to buy a "zombie" product, even if it is technically excellent.

The term "interoperability" covers a range of issues of this kind.

- Will I be able to build my system using products and devices from multiple suppliers? (I need a competitive supply market, with lower long term risks and lower prices.)
- Will I be able to link my system to all of the relevant systems that users will have on the road, whether through in-vehicle equipment, through smartphones, or through third party information services? (I need to be sure I can talk to all of them.)
- Will I be able to link my system to the systems I currently use? (I want to continue to use – and ideally to improve – my legacy ITS, from detectors to controllers, databases and algorithms.)
- Will I be able to link my system to the systems used by my neighbours? (I want services to be seamless and easy to provide both across boundaries, and across the urban/interurban interface.)

Standards are of course an important tool for facilitating interoperability (see section 4.5) but the availability of standards does not imply the interoperability of products, and vice versa. It is perfectly possibly for two systems to comply fully with the same standard and yet fail to interoperate; equally, there are many examples of non-standard systems where commercial imperatives or just good project management has led to very good interfacing.

Interoperability does not, however, "just happen". A large city, like London, Paris or Madrid, may be able to use its market position to force suppliers to undertake the necessary development, but other cities rarely have that luxury (except possibly with local SMEs). Hence, cities will often take the more passive step of investigating what everyone else is doing, and follow along. If an external interoperability framework exists, that is likely to be regarded as a significant risk reduction.

3.7. Externality: automated/autonomous vehicles

The opportunities of C-ITS represent a change for cities; but at the same time there are several other changes which involve both transport and technology, and which are widely seen as being much more significant and fundamental. City officers will need to consider C-ITS in the context of these other changes, therefore, which makes planning a lot more complex.

One such change is the emergence of autonomous vehicles. While there is a general acceptance that fully autonomous vehicles are some way off for the majority of road users, it is undeniably true that vehicles are rapidly becoming more instrumented and more automated.

The interaction between C-ITS and vehicle automation is a highly complex one. Certainly, a lot of automation uses only onboard systems (sensors, displays, and actuators); and a lot of C-ITS is geared to traditional human drivers using current-technology vehicles. But more highly-automated vehicles may also benefit from a degree of cooperation. For example, a system that auto-brakes at a red signal would find it simpler to use a C-ITS SPaT message, rather than require a camera and vision software to detect and recognise a specific kind of red light in the landscape[7].

Once highly automated vehicles are available, there remain major concerns about their potential reliance on C-ITS. In the extreme case, the user's involvement is merely to indicate a destination, and hand over control to the vehicle. With C-ITS, there are some fundamental questions on how much the city is *controlling* rather than merely *informing* the vehicle.

Probably the key driver in this will be the legal allocation of liability. If liability remains with the vehicle, then cities may be relatively sanguine about providing data, but on a "buyer beware" basis; as a result, vehicle manufacturers will not be able to rely on it, and are more likely to (continue to) focus on their own systems.

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[7] In the terms used in section 3.3, with automated vehicles there is an opportunity to use I2V control interfaces, while I2V for non-automated vehicles will necessarily have any effect only through the driver HMI (even if the information relates to a mandatory restriction like a speed limit).

Conversely, where liability passes to the road operator[8], it will be very reluctant to invest unless it has a high degree of control over the vehicles. This may mean, for instance, not allowing any road users onto the network except for those under its direct control. While this may work on highly secure or controlled zones (say, ports and airports, or pedestrianised areas), or certain highways, it will be difficult for cities to bar mixed traffic on a general basis[9].

3.8. Externality: personal smart devices

As vehicles are getting more technologically enabled, so are their users. The prevalence of personal technology such as smartphones is already having a significant impact on transport operations, and the “intelligent mobility” concept (IM) is developing rapidly.

As part of this, the link between road user and vehicle is currently under question with service concepts such as Mobility as a Service (MaaS): as well as traditional public transport, this encompasses ride sharing of private vehicles. While buses and trams will still be politically supported, cities may be ambitious to support these newer paradigms. However, with MaaS, the focus is very much on city-to-*traveller* services and not city-to-*vehicle* services.

IM began, arguably, with web-based services like journey planning, but this has more recently merged with some traditionally car-bound systems like satnavs and ride hailing. Applications that were once built into dashboards, and later converted for aftermarket equipment, are now typically delivered through apps.

This change can be expected to affect C-ITS directly. Many V2I services can be addressed through smartphones etc., rather than vehicle-mounted systems. Indeed, the boundary between the two is quite blurred for many applications: for example, identical services for (say) roadworks warning could be provided through a web page displayable both on a dashboard-positioned smartphone and on a vehicle-mounted instrument.

Because of the simplicity and relative cheapness of reusing travellers’ smartphones as an end device, cities may consider focussing on these first. However, it must be considered that not all C-ITS applications are suitable for the smartphone platform, at least with the current generation of equipment and networks.

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8 This parallels the situations in rail, where vehicle progress and even pathing is set by the track operator through the signalling system.

9 At the time of writing, legal developments were still at an early stage. The Vienna Convention, that the driver shall be in control of the vehicle at all times, has already been softened to allow driverless operation – provided a driver is present and able to override at all times; therefore, responsibility is currently still with the driver. Whether this legal position changes further in future, with higher degrees of automation, is unclear.

At the extreme end are applications that require direct, highly time-critical, and above all secure communications, especially those where there is an element of vehicle control by the infrastructure (ISA, auto-braking, etc.). To be sure, these tend not to be applications that are seen as having an early introduction.

In addition to this technical point, the smartphone culture raises three more societal questions:

- How does IM change the actual pattern of transport use, and the policy opportunities for intervention?
- How do user expectations regarding personal technologies affect which interventions are likely to gain traction?
- How can we ensure that the use of smartphone based services does not compromise road safety?

On the first point, as cities move to consider mobility rather than transport, the smartphone provides a much more natural way to engage with the person rather than the vehicle. For private cars at least, cities are more likely to be looking at technologies that constrain their use, such as tolling, rather than enabling it. But it is difficult to see that OEMs, or indeed car users, will have any commercial interest in providing systems that make their use less convenient. This could seriously limit the business case for deploying car-based C-ITS.

The second point is more difficult to assess. While it is undoubtedly true that people are becoming very comfortable with their mobile devices, and that this offers a good way to connect with them, they are also (if they are vehicle drivers) generally comfortable with their in-vehicle instrumentation. In this case, there are two conflicting arguments: one that says drivers should not be encouraged to use their smartphones; and one that says, if they are going to do this anyway, let us ensure they are using driving-relevant apps designed for minimal distraction, etc.

Regarding the third point, there are both established standards and establish laws for the ergonomics of technologies for drivers' use. However, these are currently aimed at systems which are either clearly part of the vehicle operation (like indicators) or incidental but inbuilt (such as radios), or are fully external (like using a telephone or television). The concept of a general-purpose device which runs an application specifically geared to driving is not fully addressed in these, despite the fact that services like satnav apps are already widely used.

3.9. Externality: smart cities

One of the main features that distinguishes cities from highways authorities is that cities have a much greater range of interests and responsibilities, typically including education, social care, health, policing, environment and leisure, and commercial development. Within the overall city agenda, transport is just one small (if important) element.

With this perspective, senior city decision makers will be thinking about the next steps, not for transport particularly, for the city as a whole. At a political level, concepts of "liveable cities", "sustainable cities" and (increasingly) "smart cities" will drive their strategic planning.

The smart city concept has a technology link, of course, and has been given a technical underpinning by the concept of the "Internet of Things" (IoT). The principle here is straightforward – instrument many elements of a city, then enable them to communicate with each other and with systems of others.

However, the use of the IoT in practice is still at a very early stage. The issue can be seen as paralleling C-ITS but on a much larger scale. In effect, city planners are saying, for all of these millions of devices: OK, now we can talk, but what shall we talk *about*? It's the difference between having a PC plus an internet connection, and creating online shopping, social media, streaming video, and all of the other web services that make the connection meaningful.

This externality is both a challenge and an opportunity for C-ITS. A challenge, because C-ITS need to find their place within this much larger picture, and are potentially constrained by the priorities and plans of the city to be "smart". But an opportunity, because the transport-limited context of C-ITS could enable a coherent set of "smart city" services to be delivered relatively soon, and practicably.

In particular, C-ITS could be an excellent testbed for cities to explore the balance between the major architectural questions raised elsewhere in the chapter: the need for public-space systems, support for personal smart devices, operational models involving open data and third-party service providers, etc.

3.10. Newer transport modes

Technology innovations are not the only challenge to city policymakers. Purely within the transport sphere, there are numerous developments to the "traditional" mix of vehicles and services that cities are familiar with. Cities will in future have to take these options into account; indeed, they may have an important role in encouraging (or discouraging) specific innovations. And in many cases there may be an impact on the approach adopted to C-ITS.

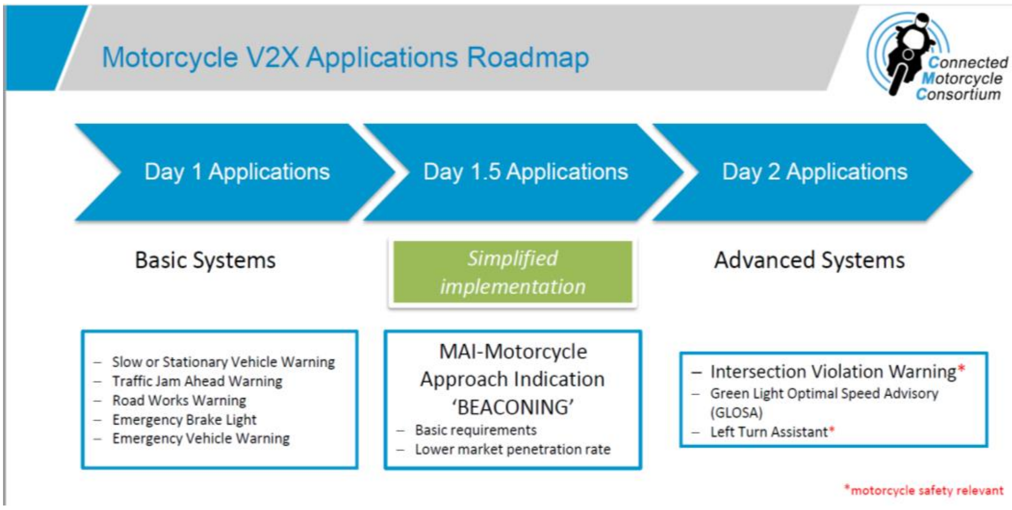
Section 3.6 above looks at the specific, and radical, issue of evolving vehicle automation *per se*. But the different vehicles have very different implications for policy. Cities may be particularly interested in (for example) automated buses, taxis, or urban freight vehicles, rather than general traffic. More importantly for the near term, non-automated vehicles are being used in different ways. Section 3.8, for instance, discusses MaaS. There are also many other extant schemes in what has become known as the "sharing economy", from bicycle hire to community mini-buses and car-clubs – and of course "ride-matching" services like Uber and Lyft. With suitable engineering, C-ITS services can be tailored and offered specifically to individual user groups of this kind.

In some cases, work is underway within industry to identify the specific opportunities and challenges. For example, the Connected Motorcycle Consortium[10] (CMC) highlights the need for

10 See http://www.cmc-info.net/.

improving safety at intersections specifically for powered two-wheelers (PTWs), but points out that they have very different requirements for location accuracy, lane designation, user interface, etc. from car drivers. A city that is actively encouraging PTWs (for example, because of the lower emission and space requirements, relative to cars) will need to ensure that it is attentive to these specialist needs.

Figure 3.4 PTW industry ambitions for C-ITS (taken from CMC)



4. The supply market

4.1. Introduction

A city C-ITS project means, in the end, that the city will identify, procure, deploy and operate some products capable of delivering C-ITS services. However, the previous sections have highlighted a number of challenges relating to the supply market:

- Cities do not know what products are available.
- Cities do not know which products will work with each other, or with the systems that will be acquired by road users.
- Cities do not know the cost of acquiring or operating products.
- Cities do not believe that the mature is mature, and would like to know how it will evolve over time.

This chapter addresses these issues by describing the current state of play of the supply market[11], under the following headings:

- Market sectors and structure (section 4.2).
- Key suppliers leading C-ITS (section 4.3).
- Product offerings (section 4.4).
- Standards and their take-up (section 4.5).

4.2. Market sectors and structure

The C-ITS market is a sub-set of the overall ITS market. It is not new, but is still not widely deployed in either the urban or the inter-urban environments.

Urban C-ITS is in an early stage of large-scale deployment and cannot – at the time of writing this report – deliver reliable, mature cooperative components/products/solutions for normal large scale operation. This is linked mainly to the deployment challenges – identified by the suppliers themselves – the majority of which are economic and political.

One important economic challenge is that there is currently no concrete business case to justify, by means of expected benefits, a city to buy C-ITS. As a Catch-22 problem, this constrains the amount of effort that suppliers can reasonably put into C-ITS product development.

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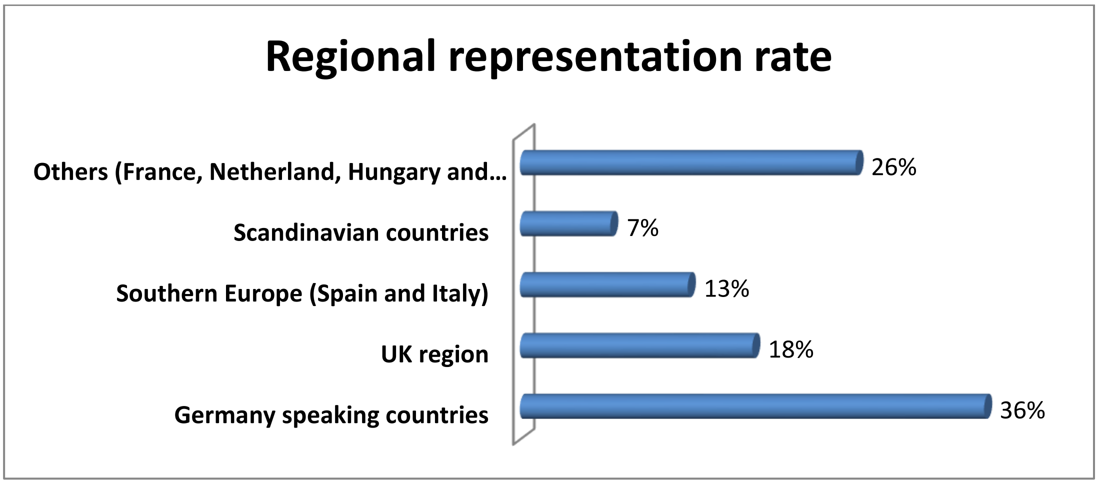
11 The content of this chapter was developed during Work Package 2 of CIMEC, which conducted a market survey and collated the results with information from other contacts and sources. Full details are contained in CIMEC Deliverables D2.3 and 2.4. We are grateful to all those who provided information during this process.

The ITS supply market is not uniform across Europe – most suppliers have a local national or regional focus – and this is reflected too for C-ITS. Some evidence of the geographical distribution of suppliers appeared in the CIMEC information gathering process. Figure 4.1 (below) counts respondents by country/region, and indicates that more than third of responses are suppliers from the central European region (German-speaking countries), followed by the UK region, and then by Southern Europe (Spain and Italy)[12].

Figure 4.1 Geographical distribution of suppliers responding to the CIMEC survey (2016)



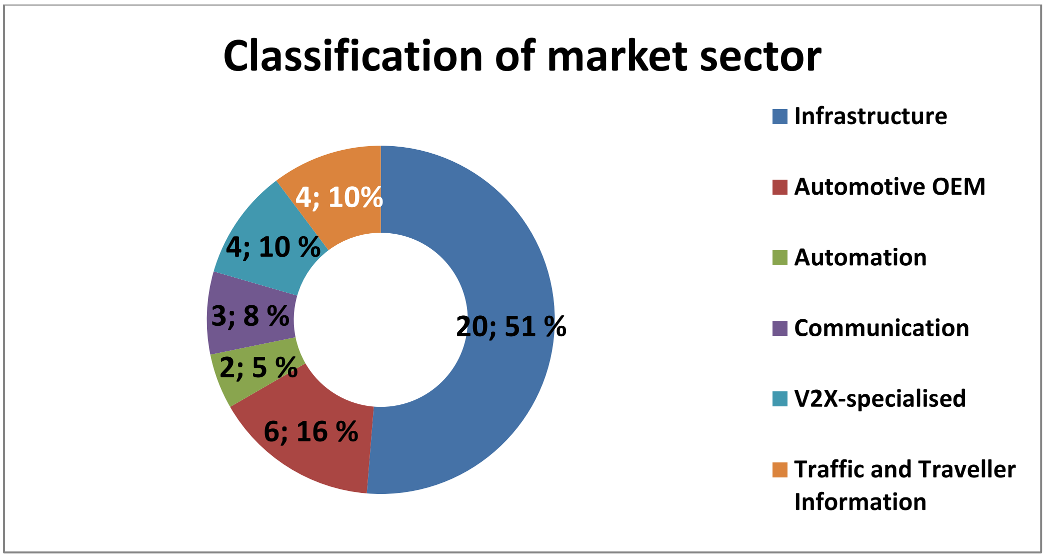
These suppliers represent a variety of different market sectors: they provide different types of solution and have a different focus/market segment interest. Six general groups can be distinguished, as follows:

- Infrastructure-based suppliers, who provide conventional ITS solutions such as traffic light controllers, ANPR, etc. to public road authorities.
- Automotive Original Equipment Manufacturers (OEM), who sell cars that become safer, more efficient and connected for added-value non-safety services (i.e. by equipping them with cooperative technologies).
- Automation suppliers, who provide transport solutions such as parking solutions for installation within (and integration with) autonomous or automated vehicles.
- Communication-based suppliers, who provide communication modules with software or hardware to public road authorities and/or the automotive industry, etc.
- V2X-specialists, who focus mainly on cooperative solutions, components and products, and sell them to public road authorities and the automotive industry, etc.
- Providers of traffic and traveller information services, who work on acquiring data and providing data-based services, or who manufacture navigation systems, or both.

12 The usual caveats to survey results apply, but at least this may show the regions in which suppliers are keen to be offering C-ITS in an open market.

In the CIMEC survey, most of the responses (51%) came from the infrastructure industry, with a participation rate of 51%. This is perhaps not surprising given the nature of the CIMEC project, but it is encouraging that the survey results are indeed likely to be relevant to cities and their immediate suppliers[13].

Figure 4.2 Sector focus of suppliers responding to the CIMEC survey (2016)



The survey also found some interesting results on the size of the responding supplier companies[14] (see Figure 4.3, overleaf). Almost half of the respondents were "small" and over 40% were "big" or "very big", with very few of intermediate size.

The impression is of a very divided market. The substantial presence of large companies suggests that the existing ITS-market still retains a strong interest in delivering the next, cooperative, steps. But the substantial number of smaller companies – more niche, perhaps built around specific innovations – suggests a dynamic market.

The market dynamics is not clear. Key suppliers certainly dominate the development and deployment of current ITS. But for C-ITS in future, they may be expected to enter into partnerships with innovative small companies, act as integrators or lead suppliers, or acquire smaller businesses, in a complex process.

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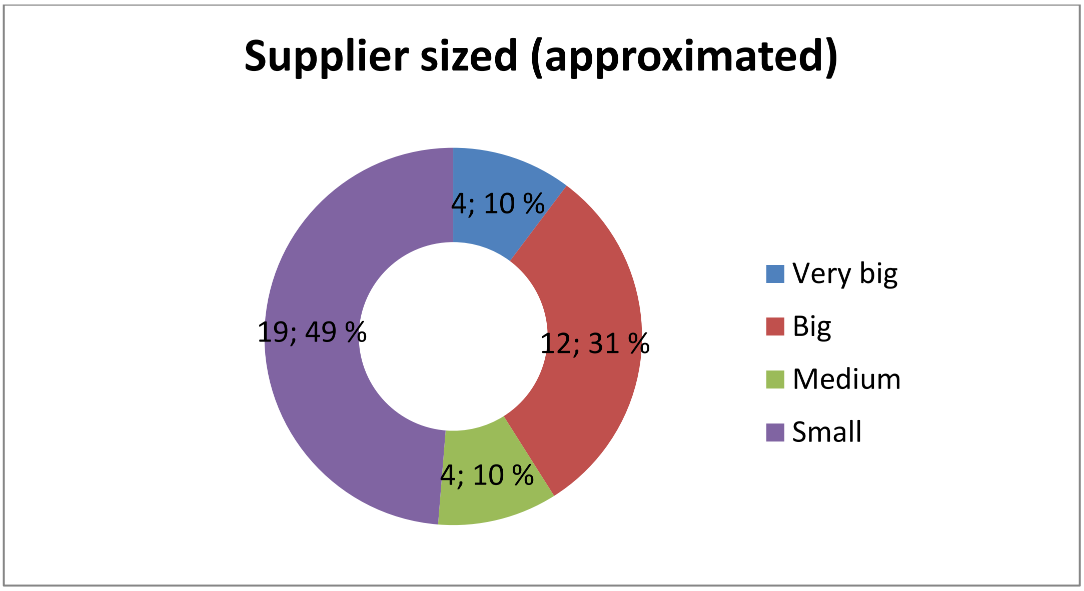
13 A more negative interpretation is that the connections between city-focussed (i.e. infrastructure-based) suppliers, and vehicle- or road-user-focussed suppliers, are still rather weak. This certainly aligns with informal discussions during the project.

14 This was estimated using public information on the number of employees, sales, number of departments with the company, etc.

Figure 4.3 Size of supplier companies responding to the CIMEC survey (2016)



4.3. Key suppliers leading C-ITS

Regardless of the type of supplier, most of them see C-ITS as a technological potential, on the one hand to improve their existing ITS-services (added-value services), and on the other, to enable new services such as intersection safety warning systems against vulnerable road users (VRU). In addition, suppliers regard C-ITS as a connectivity-enabler for automated connected driving.

However, that doesn't mean all ITS suppliers are investing heavily in C-ITS development. Perhaps they don't want to risk their existing, successful ITS business, and/or they are not confident enough in the market to take control, but many suppliers seem to be waiting for a much smaller number of "key suppliers" to act.

With regard to C-ITS development, we can distinguish between four main groups.

- Small active suppliers without direct market power.
- Passive mainstream ITS suppliers.
- Suppliers of components.
- "Key suppliers": the limited number of larger suppliers with a substantial C-ITS investment programme.

The first group are **small active suppliers** who principally work for key suppliers, the first category, and adjust their goals and ambitions accordingly since their business relies heavily on the strategic decision of the other suppliers. They have specific ambitions such as:

- Worldwide V2X equipment supplier with concrete numbers.
- Hybrid-secure application platform for V2X.
- Independent recognized tester and certifier.

The second group are **passive suppliers**: the mainstream ITS suppliers, who are interested in C-ITS, but are waiting for a key player to deploy such a solution before entering this market. This category is risk-averse to the new technology and would join in the game when there is an established market and thus proof of business.

The third group are **component suppliers**. These suppliers are more technologically oriented: they provide specific technologies that are needed by other suppliers, e.g. positioning technologies or RSU chip sets. Like the first group, they rely on larger integration companies to deliver services to cities. However, they differ in that they concentrate on technical innovation rather than on applications for traffic and transport management.

The fourth group we have called **key suppliers**: these form the main engine of industrial C-ITS development. Two clear sub-groups exist: automotive-based suppliers and infrastructure-based suppliers.

Each has a clear vision and plan of action and are very active in the current large scale deployment of C-ITS in the inter-urban environment. Nevertheless, their number is currently quite small.

Key suppliers have developed their own cooperative product(s), component(s) and system(s) and they are now in the trials phase. One example is the statement by one key supplier who plans to deliver / sell cooperative-based equipment and associated functionalities “by the end of 2016”. Assuming that this ambition is fulfilled, it is expected that the solution provided – at least in its first market versions – will face technical challenges for its integration with existing urban ITS.

4.4. Product offerings

The CIMEC supplier survey explored the capabilities and ambitions of individual suppliers for delivering C-ITS solutions. Table 6.1 below summarises the current offers of responding suppliers[15]. The product description is in the supplier’s own words.

It is acknowledged that the limited space of a questionnaire, and limited respondent time, have resulted in responses that are not always very clear. For example:

- “Warning to drivers and intelligent junctions”: what is meant by intelligent junction?
- “Supporting C-ITS via infrastructure (ITS G5-based technology) and supporting systems that support connected & autonomous systems”: what are supporting systems?
- “Partly GLOSA, crowd sourcing and many others”: what others, and what is the balance between these activities?

[15] We did try to follow through where possible, but unsurprisingly suppliers do not want to reveal commercially confidential information.

- “R-ITS-S R&D development platform for R-ITS-S or V-ITS-S”: obviously refers to development work rather than to commercially available products.

Overall, the responses confirm that the development of C-ITS within the industry is still at an early stage. Mature and effective solutions/products/components are therefore likely to take some time to emerge.

Note to Table 4.1: products from “key suppliers” (as defined above) are *in italics*.

Table 4.1 Product offerings identified by industry in the CIMEC survey (2016)

No. of suppliers	Supplier description of offer	Complete systems	In-field / In-vehicle	Communi-cation	Software / application	Mobility services
1	Software services to find, book and pay for parking spaces in cities via smartphone app. and in-vehicle software in cooperation with an automotive company					☑
1	Solutions for intersection in-vehicle signage for traffic lights and fleet management				☑	
1	*Warning to drivers and intelligent junction*	☑	☑	☑	☑	☑
1	*Supporting C-ITS via infrastructure (ITS G5-based technology) and supporting systems that support connected & autonomous systems*	☑	☑	☑	☑	☑
1	*Platform [the supplier did not reveal any information, but its sister company stated that they made their platform C-ITS enabled]*	☑	☑	☑	☑	☑
1	- R-ITS-S - R&D development platform for R-ITS-S or V-ITS-S - V2X diagnostics tablet to capture, log, replay or analyse V2X live on site, complete - Software stack conforms to ETSI Plug test ITS-CMS4 2015 with CAM BS, DEN BS, SPAT/MAP, LDM, BTP and GN		☑	☑		
1	Partly GLOSA, crowd sourcing and many others	☑	☑	☑	☑	☑
1	*Complete system (sensors, V2X-enabler, application and services, maturity and readiness are questionable*	☑	☑	☑	☑	☑
1	*V2X-enabler soft- and hardware and possible applications*	☑	☑	☑	☑	☑
1	Our wireless sensing systems are used to provide real time information about outdoor parking availability and traffic	☑	☑	☑	☑	☑
1	Provide service such as prioritisation of public transport at intersections using radio modems for wireless data communication			☑		
1	*Management module for cooperative systems and communication unit (R-ITS-S)*		☑	☑		
1	Cloud-based, distributed communication modem with application capabilities			☑		

No. of suppliers	Supplier description of offer	Complete systems	In-field / In-vehicle	Communi-cation	Software / application	Mobility services
1	Products deliver scalable communication software for telecommunications, transportation and the automotive market, ready-to-use software solution supports US and European standards, solution is hardware agnostic			☑	☑	
1	Software and methodologies for (cyber-) security and safety of connected automated driving				☑	
1	Automated road transport system incl. communication with traffic light, only if necessary	☑	☑	☑	☑	☑
1	Implementation of ITS-G5 using software toolkits other suppliers. Only in pilot-phase					
1	Test-field for in-vehicle signage					
1	Provides conformance testing					
1	Location-based services and data content, maps and traffic			☑		
2	No solutions					
3	No solutions yet					

4.5. Standards and their take-up

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[16]. Interoperability standards specifically aim at enabling competitive markets and procurement processes, preventing vendor lock-in problems that can lead to excess cost and risk for cities.

With the rapidly growing digitisation of all aspects of traffic and transport management, ITS standards play an increasingly important role in facilitating interoperability, compatibility, portability to new devices, components, systems and services. This is likely to be even more important with C-ITS, because of the need for reliable open connections between cities and vehicles.

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16 See for example the White Paper *Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system*, European Commission, 2011.

Lack of standards is seen by both suppliers and cities as an important technical barrier/challenge to urban C-ITS deployment. Key suppliers (including suppliers of infrastructure-based products) are generally very active in standard development – while at the same time pursuing their own proprietary technical developments. At a regional, national and European level, suppliers are involved in:

- The CEN Working Group on urban ITS (TC278/WG17), launched in 2016.
- The C-ITS Platform Working Group on "C- ITS, public transport and automation in urban areas", also launched in 2016.
- The CEN/ISO "Release 1" list of C-ITS standards, issued in 2013.
- The joint CEN/ETSI work under European Commission Mandate M/453 (Final Report issued in 2013).
- European C-ITS projects and support actions such as CVIS (2006-2010), Compass4D (2012-2015), TEAM (2012-2016) and CODECS (2015-2018).
- Industry-led C-ITS related standardisation efforts of regional/national standardisation associations.

The impact of these standards activities on actual products is not yet clear: with the product market still in an early phase, much of the development focus appears to be on technical feasibility work rather than full-scale development of, and compliance with, standardised architectures. With the possible exception of ETSI ITS G5 – the specialist short-range communication channel designed for roadside-to-vehicle use – suppliers have therefore been principally re-using existing mainstream standards, from:

- The traffic sector (e.g. DATEX II) and transport sector (e.g. SIRI), defined and fairly mature within CEN.
- The radio communications industry: 3G, LTE, Wi-Fi, Bluetooth, etc.
- The data communications industry: the IP suite, HTTP, XML, etc.
- Local standards architectures, such as UTMC, ODG (OCIT-O V3.0) and IVERA.

A separate CIMEC report has advised on the specific developments required within standards[17]. The recommendations cover the need to identify and address:

- Standards already in use in urban ITS that need to be adapted for C-ITS use.
- C-ITS standards that might limit the functionality in urban use cases.
- Standards that have an impact on urban operators' business processes.
- Standards supporting procurement.
- New standards requirements specifically focussed on the urban C-ITS context; in particular, a control interface standard to link roadside devices (such as signal controllers) to in-station systems.
- Mechanisms for certification of product compliance.
- A common security mechanism (including a trust authority).

These issues appear likely to be addressed in ongoing/planned policy and standardisation projects.

17 CIMEC Deliverable D2.5, "C-ITS standardization requirements for the urban environment".

5. Why implement C-ITS?

5.1. Introduction

Numerous research and development projects have addressed the technical issues of C-ITS, and have shown that the technology can be made to work. However, the contribution from these technical solutions to the planning of urban transport policies, and the implementation of these policies, is much less well understood.

To address this gap, this section collates information on city-relevant C-ITS “use cases”, which have been identified through consultations with city authorities and stakeholders across Europe[18]. It reflects the understanding of C-ITS as the cities see it, including how C-ITS can be an enabling technology, but also where the potential of C-ITS is not fully recognised or described.

In this section, each use case is described in terms of:

- The information that has to be *collected from* the vehicle/road user in order to fulfil the use case.
- The information that has to be *provided to* the vehicle/road user to fulfil the use case.
- The cities’ perspective on potential and requirements related to use of C-ITS in the use case.

This section focusses solely on benefits in principle. It does not consider the likely extent of benefits achievable, the challenges in delivering the services, or the potential for unintended consequences.

5.2. Policy goals, activity areas and use cases

In WP1 of CIMEC, a range of relevant activity areas were identified by the cities, and subsequently grouped in the following main categories, which are used as the basis for the structure of this chapter[19]:

- Information exchange
- Individual traffic management
- In-vehicle signalling
- Management of urban freight
- Management of electric vehicles

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18 The content of this section builds on CIMEC deliverable D1.1, *City status and requirements for C-ITS deployment*. Some adjustments have been made to include external sources of information, and to enhance the clarity of presentation.

19 One additional category from WP1, “Multimodal traffic and transport management”, has been dropped from this list, as it provides only a very general and high level description of the role of city transport services. All of the remaining categories contribute, in some way, to this goal.

- Management of traffic lights
- Parking management
- Incident management
- Air pollution
- Support for vulnerable road users
- Car sharing
- Autonomous driving

Each is relevant to one or more of the key city policy goals: to improve **traffic efficiency**, to improve **traffic safety**, to improve the **environment**[20], or to improve **accessibility**.

These categories overlap to some extent. In particular, the two first categories are quite general: while many ITS interventions can be associated with these areas, they do not suggest a specific goal or function for C-ITS applications. Subsequent categories, which are more specific, support these more general activity areas, and each other.

> *It must be emphasised that these are just potential areas for city activity, not firm recommendations. Individual cities will still need to consider whether these services are of local benefit, and (if so) how they are best delivered. For example, many cities may regard "individual traffic management" as not a city function, preferring simply to make available relevant information (say, on access restrictions or road closures) to external information service providers.*
>
> *Later sections of this Roadmap present approaches to developing a streamlined development plan which is relevant to local needs.*

This process resulted in the following Use-cases, each encompassing one or several of the activity areas identified by the cities[21]:

- UC1: Individual routing of vehicles
- UC2: In-vehicle signs
- UC3: In-vehicle signal information
- UC4: Management of loading and unloading areas for freight vehicles

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20 This policy goal was captured in WP1 as "enhancing modal shift by "Push" measures", "enhancing modal shift by "Pull" measures", and "developing clean and silent transport systems". It is simplified here for convenience.

21 Implementing some of these use cases will require a change of legislation. This is an externality which is beyond the control of cities, and a survey of legal issues in Member States is outside the scope of CIMEC. Later sections of this Roadmap suggest how this should be approached by cities.

- UC5: Access control for heavy goods vehicles with dangerous goods
- UC6: Regulation of access to free lanes for electrical vehicles
- UC7: Green lights for police and emergency vehicles
- UC8: Traffic light management
- UC9: Green lights for public transport vehicles
- UC10: Green lights for cyclists
- UC11: Parking management
- UC12: Inform about incidents in the road network and access control to these areas
- UC13: Inform about emergencies in the road network and access control to these areas
- UC14: Dynamic access control for air quality management
- UC15: Speed enforcement around schools
- UC16: C-ITS services for vulnerable road users
- UC17: Pedestrians crossing in front of bus/tram
- UC18: Bike lane change and unusual crossing

The work of CIMEC has been informed by that of other work, including within the European C-ITS Platform, the Amsterdam Group, and many historical C-ITS-related projects from the past decade or two. Generally, the opportunities identified for C-ITS in these contexts have been captured within the work of CIMEC WP1.

However, there are some additional C-ITS use cases relevant for cities which have been identified by the current generation of projects, and in particular the CODECS project[22] and the VRUITS project[23]. The CODECS use cases within the areas of Vulnerable road users and Public transport are presented in sections 5.12 and 5.15 respectively.

22 See www.codecs-project.eu. The CODECS Roadmap, containing the description of use cases established during that project, is not yet published, but see CODECS Deliverable 3.1, *Workshop perspectives in functional roadmapping: summary*.

23 See www.vruits.eu. VRUITS Deliverables 2.1, *Technology potential of ITS addressing the needs of vulnerable road users*, and 4.1, *Usability assessment of selected applications*, are especially relevant.

Each use case is presented in a table form as follows:

Table 5.1 Use case template

USE CASE NAME	XXXXX
Activity areas	The kinds of C-ITS service that this use case might make sure of
Information collected from the vehicle	The kinds of information that relevant road user may need to provide to the city in order to enable the service. Generally, the more information that is provided, the better or more accurate the service can be. However, partial information (say, including vehicle location but no destination) may still allow a useful service, and may in fact be simpler and cheaper to implement.
Information provided to the vehicle	The kinds of information that the city might construct, based on the information receiver from the road user, to present back. The nature of this information will depend partly on what can be practically and accurately extracted from the city's core systems. Cities are usually not going to be able to control how the information is used in the receiving system. There is therefore a dependency on the supplier of road user equipment to make the presentation safe, effective and actionable by the road user.
City perspective on use of C-ITS	The kinds of policy impact that the city might hope to support by means of the services specified in the use case.

5.3. Information exchange

Information exchange is a requirement for (and inherent in the definition of) C-ITS, rather than a C-ITS service in itself, and does not directly address a transport policy goal. However, while no specific C-ITS use cases are identified in this section, discussions with cities did illustrate some of the challenges and issues the cities may look for C-ITS applications as tools to reduce or solve:

- Use of smart phones for information exchange
- Intelligent data platform
- Big data management to identify transport on demand
- Congestion information exchange for traffic diversion
- Data exchange for all road users
- Multi modal traffic information
- Strengthen the traffic information of public transport
- Real time information about diversions and any kind of incidences
- Timely public transport information
- Predicting resident time of public transport at the stop station
- Data exchange between different traffic management operators
- Provide extensive data for road operator
- Vehicle-infrastructure communication
- Exchanging strategies between urban environment + inter-urban environment
- Standardised geo-information

This list, then, provides a mix of technical opportunities, policy goals and system fundamentals, which will colour the progress of a city's C-ITS thinking. These issues are considered in more detail in the sections of this Roadmap dealing with technical planning (see in particular sections 6 and 8).

5.4. Individual vehicle management

This category of (potential) city activity addresses the policy goal "improving transport efficiency".

Discussions with cities identified seven separate activity areas within this category. Three additional activity areas did not emerge with cities but have been added during project discussions, and taking into account external inputs.

Table 5.2 Individual routing of vehicles

USE CASE NAME	UC1: INDIVIDUAL ROUTING OF VEHICLES
Activity areas	Individual routing of vehicles Cooperative routing Navi Intelligent routing Hazardous warning of tunnels Routing information for through traffic Routing through the city Scenario-based traffic management Strategic routing Congestion, events and incident on-board information for diversion advice
Information collected from the vehicle	Location, speed, direction, type, destination
Information provided to the vehicle	Route, driving advice
City perspective on use of C-ITS	The cities may benefit from being able to separate different types of vehicles in the traffic, and by being able to give priorities and restrictions based on the vehicle characteristics, the time of day, the type of passenger or goods on-board and based on the transportation task being performed by the vehicle. Implementing this use case will require that the traffic management functions of the city will be changed so that they are able to manage information about individual vehicles. The C-ITS perspective will include implementation of systems supporting communication with individual vehicles.

5.5. In-vehicle signs and signals

This category of activity areas addresses the policy goal “improving transport efficiency”.

Table 5.3 In-vehicle signs

USE CASE NAME	UC2: IN-VEHICLE SIGNS
Activity areas	Virtual signage Switching states of dynamic road signs to individual transport
Information collected from the vehicle	Location, speed, direction, vehicle characteristics, destination
Information provided to the vehicle	Status of traffic signals
City perspective on use of C-ITS	Implementing this use case may make it easier to dynamically change the road regulation.

Table 5.4 In-vehicle signal information

USE CASE NAME	UC3: IN-VEHICLE SIGNAL INFORMATION
Activity areas	Green Light Optimum Speed Advisory (GLOSA) Time to green/time to red
Information collected from the vehicle	Location, speed, direction, vehicle characteristics, destination
Information provided to the vehicle	Status of traffic signals
City perspective on use of C-ITS	Implementing this use case may make junction behaviour smoother, reducing accidents and emissions.

Many interactions between city and road user currently rely on signs and signals, and C-ITS services would naturally attempt to work with this. For example, UC11 includes the option of in-vehicle displays of car park occupancy and directions.

Specialist variants on GLOSA may be implemented specifically for freight vehicles (aligned with UCs and policies in section 0) or for VRUs (aligned with those in section 5.12).

5.6. Management of urban freight

This category of activity areas addresses the policy goals "improving transport efficiency", "improving traffic safety" and "improving the environment". Two C-ITS use cases have been identified within this category of activity areas, encompassing three activity areas described by cities.

Table 5.5 Management of loading and unloading areas for freight vehicles

USE CASE NAME	UC4: MANAGEMENT OF LOADING AND UNLOADING AREAS FOR FREIGHT VEHICLES
Activity areas	Management of loading and unloading areas for freight vehicles Loading and unloading slots management at real time
Information collected from the vehicle	Location, speed, direction, wanted areas to use
Information provided to the vehicle	Free loading/unloading area close by
City perspective on use of C-ITS	By implementing this use case the city could reduce the mileage for freight vehicles in the city looking for a free area to use for loading and/or unloading, thus contributing to improved air quality, traffic efficiency and reduced traffic nuisance (such as prohibited parking or loading).

Table 5.6 Access control for heavy goods vehicles with dangerous goods

USE CASE NAME	UC5: ACCESS CONTROL FOR HEAVY GOODS VEHICLES WITH DANGEROUS GOODS
Activity area	Management of HGVs with dangerous goods, particularly to high vulnerability parts of the network like bridges and tunnels
Information collected from the vehicle	Location, speed, direction, vehicle characteristics, type of goods, destination
Information provided to the vehicle	Drive/stop in front of tunnel
City perspective on use of C-ITS	Implementing this use case may increase road safety and reduce congestion, as the traffic management function will be able to stop certain goods from being brought into sensitive parts of the network under given circumstances. Implementing this use case will require that the traffic management functions will be changed to be able to identify and manage individual vehicles in the traffic.

In addition, a number of activity areas were mentioned by cities, but were not described in a sufficiently detailed form to enable the identification of a C-ITS use case. However, they indicate contexts where related functionality might be applicable:

- Urban freight management in city centre
- Optimisation of HGV flow
- Routing of HGVs
- Include commercial vehicles in the bus priority system

5.7. Management of electric vehicles

This category of activity areas addresses the policy goal (or benefit area) “improving the environment”. Although it is quite specific, the current focus on electro-mobility makes this a topical use case.

Table 5.7 Regulation of access to free lanes for electrical vehicles

USE CASE NAME	UC6: REGULATION OF ACCESS TO FREE LANES FOR ELECTRICAL VEHICLES
Activity area	Regulation of access to free lanes for electrical vehicles
Information collected from the vehicle	Location, speed, direction, destination, vehicle characteristics
Information provided to the vehicle	Advice on use of lanes
City perspective on use of C-ITS	By dynamically changing which vehicles being allowed to use “free” lanes the city can ensure that these lanes are reserved for e.g. public transport in rush hours and that these lanes can be utilised for other types of vehicles outside the rush hours. The type of vehicle can in principle be other than electric vehicles.

5.8. Management of traffic lights

This category of activity areas addresses the policy goals “improving transport efficiency”, “improving traffic safety” and “improving the environment”. The four C-ITS use cases identified within this category encompass a wide range of activity areas described by the cities.

Table 5.8 Green lights for police and emergency vehicles

USE CASE NAME	UC7: GREEN LIGHTS FOR POLICE AND EMERGENCY VEHICLES
Activity areas	Green lights for police and emergency vehicles Responsiveness of traffic lights to emergency vehicles Traffic signal priority for fire services
Information collected from the vehicle	Location, speed, direction, destination, route, vehicle characteristics
Information provided to the vehicle	Green lights ahead ok/not ok
City perspective on use of C-ITS	Implementing this use case may increase the safety in the traffic during emergency driving.

Table 5.9 Traffic light management

USE CASE NAME	UC8: TRAFFIC LIGHT MANAGEMENT
Activity areas	Optimisation of traffic lights Virtual green wave
Information collected from the vehicle	Location, speed, direction, destination, vehicle characteristics
Information provided to the vehicle	(None, but may be combined with other signal based C-ITS services.)
City perspective on use of C-ITS	Implementing this use case may increase the efficiency of the traffic, giving fewer stops and starts during driving, and hence, also reducing the use of fuel for (heavier) vehicles and reducing air quality and noise problems.

Table 5.10 **Green lights for public transport vehicles**

USE CASE NAME	UC9: GREEN LIGHTS FOR PUBLIC TRANSPORT VEHICLES
Activity areas	More effective traffic lights assistance for public transport vehicles Public transport preferences at intersections Public transport systems co-operation with the centralised traffic light system
Information collected from the vehicle	Location, speed, direction, destination, route, stopping points and times, vehicle characteristics
Information provided to the vehicle	Green lights ahead ok/not ok, likely waiting time at signal
City perspective on use of C-ITS	Implementing this use case may increase the efficiency and punctuality for public transport, and may also provide more green time for general traffic.

Table 5.11 **Green lights for cyclists**

USE CASE NAME	UC10: GREEN LIGHTS FOR CYCLISTS
Activity area	Priority for cyclists
Information collected from the cyclist	Position, speed
Information provided to the cyclist	Green lights ahead
City perspective on use of C-ITS	Implementing this use case may make it more attractive to travel in the city by bike, and contribute to reduction in pollution and noise

Unsurprisingly, since traffic signals are already core to city ITS, this is the category that has yielded the largest number of separate use cases.

5.9. Parking management

This category of activity areas addresses the policy goals “improving transport efficiency” and “improving the environment”. The C-ITS use case identified within this category encompasses all of the activity areas described by the cities.

Table 5.12 **Parking management**

USE CASE NAME	UC11: PARKING MANAGEMENT
Activity areas	Inner-city parking management Access control for residential parking in low emission zones Parking management
Information collected from the vehicle	Location, speed, destination, vehicle characteristics, expected parking time,
Information provided to the vehicle	Parking permissions and limitations, parking space availability
City perspective on use of C-ITS	Implementing this use case may reduce the mileage and number of vehicles running in the city looking for a vacant parking space, and provide a tool to manage access to specific parking areas. It may allow for a better utilisation of the parking spaces in the city, and the payment for using the parking spaces can be dynamically, based on time of day, vehicle characteristics etc.

The following activity areas have not been described by the cities in a manner required for identification of a C-ITS use case, but indicate applications with similar or additional functionality:

- Exchange car parking data and allow for customer focussed car parking provision
- Parking guidance system
- Direction sign information of parking lots

5.10. Incident management

This category of activity areas addresses the policy goals “improving transport efficiency” and “improving traffic safety”. The two C-ITS use cases identified within this category encompass all activity areas described by the cities.

Table 5.13 Inform about incidents in the road network and access control to these areas

USE CASE NAME	UC12: INFORM ABOUT INCIDENTS IN THE ROAD NETWORK AND ACCESS CONTROL TO THESE AREAS
Activity areas	Incident management Incident management and information provision
Information collected from the vehicle	Location, speed, direction, destination, vehicle characteristics
Information provided to the vehicle	Location of the incident, nature of incident, expected traffic impact (e.g. expected delay), possible re-routing alternatives
City perspective on use of C-ITS	Implementing this use case may increase the efficiency and safety in the traffic during incidents in the roads.

Table 5.14 Inform about emergencies in the road network and access control to these areas

USE CASE NAME	UC13: INFORM ABOUT EMERGENCIES IN THE ROAD NETWORK AND ACCESS CONTROL TO THESE AREAS
Activity area	Emergency warnings
Information collected from the vehicle	Location, direction
Information provided to the vehicle	Location of emergency, nature of emergency, expected traffic impact (e.g. expected delay), possible re-routing alternatives
City perspective on use of C-ITS	By implementing this use case the city could improve the reassurance of the city traffic in case of emergencies. It could also support the efficiency of the city traffic during an emergency situation as vehicles close by could be redirected during the situation.

5.11. Air pollution

This category of activity areas addresses the policy goal “improving the environment”.

Table 5.15 Dynamic access control for air quality management

USE CASE NAME	UC14: DYNAMIC ACCESS CONTROL FOR AIR QUALITY MANAGEMENT
Activity area	Poor air quality on single days
Information collected from the vehicle	Location, destination, vehicle characteristics
Information provided to the vehicle	Level of pollutants (e.g. NOX) in sections ahead Possible movement restrictions on the vehicle, imposed as a management measure
City perspective on use of C-ITS	Implementing this use case allows the city to reduce the traffic on given days. This can be done by denying certain types of vehicles access to (parts of) the city, or by closing parts of the city completely for traffic. By doing so, the city can actively work to reduce further emission.

One additional activity area was described by the cities – namely “pay as you pollute”. While this has not been described in a sufficiently detailed manner for the identification of a C-ITS use case, it does indicate another area where C-ITS applications may be relevant.

5.12. Support for vulnerable road users

This category of activity areas addresses the policy goals “improving the environment”, “improving traffic safety” and “improving accessibility”. The two CIMEC C-ITS use cases identified within this category of activity areas, encompass two of the thirteen activity areas described by the cities within this category.

Table 5.16 Speed enforcement around schools

USE CASE NAME	UC15: SPEED ENFORCEMENT AROUND SCHOOLS
Information collected from the vehicle	Location, speed, destination
Information provided to the vehicle	Speed limit starts + Speed limit ends
City perspective on use of C-ITS	By implementing this use case the city may increase the safety for the school children. This could indirectly support walking or bicycling of the children when they travel to and from the school.

Table 5.17 C-ITS services for vulnerable road users

USE CASE NAME	UC16: C-ITS SERVICES FOR VULNERABLE ROAD USERS
Information collected from the person	Location, speed, destination
Information provided to the person	Status for traffic lights
City perspective on use of C-ITS	By implementing this use case the city may make it more attractive to walk/cycle in the city.

Several additional activity areas were described by cities; although there were not in sufficient detail to describe a C-ITS use case, they indicate area where C-ITS may have a role:

- School travelling management
- Availability of requesting green traffic light by young students
- Enabling technologies for blind people (including acoustics)
- Detection of pedestrians and cyclists
- Warning of pedestrians between vehicles

In addition, using the results of the CODECS and the VRUITS projects, the following additional C-ITS use cases arise.

Table 5.18 Pedestrians crossing in front of bus/tram

USE CASE NAME	UC17: PEDESTRIANS CROSSING IN FRONT OF BUS/TRAM
Information collected from the vehicle	Vehicle approaching bus stop/tram stop
Information provided to the vehicle	Pedestrians are leaving bus and may cross the road There are pedestrians in front of the bus/tram
City perspective on use of C-ITS	By implementing such a use case the safety for public transport passengers can be improved, however, the bus/tram companies need to be active in making this happen.

Table 5.19 Bike lane change and unusual crossing

USE CASE NAME	UC18: BIKE LANE CHANGE AND UNUSUAL CROSSING
Information collected from the bike	Speed, position, direction
Information provided to the bike	Car approaching
City perspective on use of C-ITS	This use case can be seen the opposite way, that the vehicles are communicating their speed, position and direction and the message and that the cars are informed about an approaching bike. By implementing this use case the safety of cyclists may be improved.

Additional activity areas identified by CODECS and VRUITS include the following:

- **Bus situation awareness of passengers with special needs** (CODECS): The description in CODECS documents suggests that this application is based on a one-way information provision (i.e. broadcast) from the vehicle, or possibly from the bus company, rather than cooperative; accordingly, there is no clear C-ITS role for cities.
- **Virtual pedestrian road crossing** (CODECS): Similarly, this appears to be a broadcast service from pedestrians.
- **Bicycle priority** (CODECS): Depending on implementation, this application may be included in Use Case 3 and/or Use Case 10.
- **Bicycle sharing** (CODECS): This appears to be cooperative between bicycle users, or managers of a cycle sharing scheme. The description is not sufficiently clear to enable the definition of a use case for cities.
- **VRUITS applications** (VRUITS): The majority of VRUITS applications are based on detection of VRUs in various situations or parts of the transport system, by different types of ITS technology. In most cases,

like many of the CODECS applications identified above, these are based on one-way (broadcast) messages from the VRU that are received and acted on by other road users.

While no specific CIMEC Use Case is identified for these applications, there are a number of "grey areas" where CIMEC and/or VRUITS applications imply the need to extend Use case 15:

- Pedestrian crossing the road at mid-block, potentially occluded by parked car.
- Vehicle on a crossroad, pedal cyclist crossing the road from the right or from the left.
- Powered two-wheeler management at junctions.

5.13. Car sharing

This category of activity areas addresses the policy goals "improving transport efficiency" and "improving the environment".

Cities certainly see car pooling and car sharing as a welcome area of user activity, as it removes traffic from the roads, and some have initiatives to encourage and facilitate such services. However, the role of C-ITS in supporting these services is not very clear, and in particular it is not clearly explained how city investment in C-ITS would help.

5.14. Autonomous driving

This category of activity areas addresses the policy goals "improving transport efficiency" and "improving traffic safety". Cities recognise the opportunity – and the challenges – to "support autonomous driving", and in particular expect this to have a significant impact on their ITS (both traditional and cooperative).

However, cities see automated and autonomous driving as an area where responsibility for innovation lies between the vehicle industry and the regulators, and where the city activity is consequently likely to respond rather than to lead. So, while the city responsibility in an automated environment may be substantial, this is unlikely to be an area where cities can take much control.

Later sections of this Roadmap suggest how cities may include this factor in their strategic planning.

5.15. Public transport

As all the activity areas identified in CIMEC WP1 involving specific applications for public transport include traffic lights management, public transport application was not identified as a separate category in the CIMEC D1.1; instead, public transport priority was included as UC8 in the category "Management of traffic lights" (see section 5.8).

Additional activity areas identified by the CODECS project, where C-ITS might be relevant, include the following:

- Bus/tram, stopping, starting, turning
- Tram interlock control
- Localisation
- Stop request
- Fleet management
- Vehicle management at garage
- Urban rail

None of these has been identified as a separate city-relevant use case in this document, primarily because there is no clear role for the city: any C-ITS application in these areas is seen as a matter for vehicle users, fleet/service managers, and/or third party information providers.

5.16. Non-traffic uses of C-ITS

In section 3.9, it was noted that C-ITS are emerging in a world where there is an increasing focus on integrating city systems that have historically been separate – the “smart cities” concept. This is an extremely broad area and one that is very fertile for new ideas. The opportunity for a city, therefore, is to use the data obtained from C-ITS to improve other services.

CIMEC has not undertake a full review of potential smart-cities use cases – for example, those that integrate transport with healthcare, social case, policing or schools. However during discussions with stakeholders, a number of plausible uses have emerged, in particular related to ways of improving non-traffic elements of a city’s transport system.

For example, the following ideas have been put forward:

- Vehicles could provide information to the city about problems with road surfaces: potholes, blind spots etc. This information would build a database that could assist in planning highways repairs or improvements, ultimately benefiting the safety and efficiency of the network as a whole.
- Similarly, vehicles could provide information about ice patches that could assist in planning efficient gritting, which would both improve safety and make the gritting much more cost-effective.
- Vehicles could be used to trigger street lighting or illuminated information signs during the night. This could potentially save a considerable amount of energy and light pollution.

These ideas are not really C-ITS use cases *per se*, but rather indicate opportunities for cities to make use of the data that C-ITS provide them with.

5.17. Summary of city C-ITS use cases

Table 18 below lists the use cases identified in this section: applications where cities have indicated that they see a potential need for their participation in a C-ITS system.

Table 5.20 Summary of city C-ITS use cases

USE CASE	RELEVANT ACTIVITY AREAS
UC1: Individual routing of vehicles	Individual routing of vehicles Cooperative routing Navi Intelligent routing Hazardous warning of tunnels Routing information for through traffic Routing through the city Scenario-based traffic management Strategic routing Congestion, events and incident on-board information for diversion advice
UC2: In-vehicle signs	Virtual signage Switching states of dynamic road signs to individual transport
UC3: In-vehicle signal information	Green Light Optimum Speed Advisory (GLOSA) Time to green/time to red
UC4: Management of loading and unloading areas for freight vehicles	Management of loading and unloading areas for freight vehicles Loading and unloading slots management at real time
UC5: Access control for heavy goods vehicles with dangerous goods	Management of HGVs with dangerous goods, particularly to high vulnerability parts of the network like bridges and tunnels
UC6: Regulation of access to free lanes for electrical vehicles	Regulation of access to free lanes for electrical vehicles
UC7: Green lights for police and emergency vehicles	Green lights for police and emergency vehicles Responsiveness of traffic lights to emergency vehicles Traffic signal priority for fire services
UC8: Traffic light management	Optimisation of traffic lights Virtual green wave
UC9: Green lights for public transport vehicles	More effective traffic lights assistance for public transport vehicles Public transport preferences at intersections Public transport systems co-operation with the centralised traffic light system
UC10: Green lights for cyclists	Green waves for cyclists
UC11: Parking management	Inner-city parking management Access control for residential parking in low emission zones Parking management
UC12: Inform about incidents in the road network and access control to these areas	Incident management Incident management and information provision
UC13: Inform about emergencies in the road network and access control to these areas	Emergency warnings
UC14: Dynamic access control for air quality management	Poor air quality (NOX) on single days

USE CASE	RELEVANT ACTIVITY AREAS
UC15: Speed enforcement around schools	
UC16: C-ITS services for vulnerable road users	
UC17: Pedestrians crossing in front of bus/tram	
UC18: Bike lane change and unusual crossing	

6. Categorising C-ITS

6.1. Introduction

Sections 3 and 4 have examined the relevance of C-ITS to cities, and presented the hypothesised benefits for them in terms of delivering policy. This section looks at some of the high-level factors involved in determining whether a C-ITS project is realistic.

The aim of this section is to identify factors which a city could use to address:

- *whether to pursue* a particular C-ITS solution (functionality)
- *how to implement* a particular solution (design and procurement)

These factors are not particular to C-ITS, but are presented here in structured form so that the "fit" with different C-ITS options can be assessed.

The primary decision is often categorised as "benefit-to-cost": in this chapter, benefits are discussed in section 6.2 and (monetary) costs in section 6.3. However, "costs" are not simply about money: other concerns that cities might need to resolve, before and during a C-ITS project, include:

- Do such products actually exist? (market maturity, section 6.4)
- Even if it works technically, will it fail because of the actions of others? (dependencies, section 6.5)
- What new problems might this create? (liability and risks, section 6.6)
- Are privacy concerns a barrier? (personal data, section 6.7)

6.2. Size and nature of benefit

This primary factor in selecting a potential C-ITS project is, of course, the benefit that will arise from its delivery. The key factors include considerations of:

- Who receives the benefit (e.g. all vehicles, buses only, specific vehicles, cyclists only)
- How widespread the benefit is (e.g. just at a single junction vs city-wide)
- How the benefit is valued (e.g. in monetary terms, in time saved, in accident reduction, or just in political kudos)
- How robust the benefit estimate is likely to be (e.g. how much relevant, quantified evidence exists)

Of these the first – who benefits – is most closely connected to city policy (as described in section 3.4). Implicit in this is the question about whether the benefit should be seen as primarily for the individual, or collectively for the city; and how much public responsibility exists for those individuals. So, a system that improves general traffic flow is by definition a collective benefit, although the majority of benefit recipients are likely to be car drivers. By contrast, a scheme that provides audible warnings to blind people at crossings has a much more limited set of beneficiaries, but is providing a service that they could not easily provide for themselves and so may be seen as a public function.

The second point – location of the benefit – is more complex than it appears. Transport networks are highly connected and an intervention at one point (say, a crossing of major roads, or a central circulation ring) could have an effect on a sizeable faction of a city. Moreover, transport challenges are often localised, particularly at junctions. Most cities will have a "hot list" of problematic trouble spots (or zones) for accidents, emissions, congestion etc., and will want to address any C-ITS benefits to these first.

The third point again is strongly policy linked. While investing in C-ITS for purely monetary reasons (for instance, to save on loop maintenance) is certainly possible, most deployment arguments focus on more direct benefits. Clearly, any prevailing policy on project appraisal – for instance, a "monetary value" on road deaths or injuries – needs to be considered in this process. However, there may be political reasons to refine or even override this: for example, money spent on safety measures near a school may be regarded as better use of public funding than on an industrial estate, even if the accident statistics indicate otherwise.

Whatever the benefits argument may be, it is common to model these in advance to present a *quantitative value* for the project. The methods used will vary but may include a whole-life model, with stated input assumptions about impact on speeds, emissions, braking behaviour or wait times, and model outputs on the total (lives saved, environmental impact etc.) for the project. The political decision is then whether a total benefit of X is worth a total cost of Y.

The techniques for such modelling can be complex but are generally well understood. The problem in applying them almost always comes in the input assumptions: will people actually behave in the way you have modelled?

The last point is crucial. Evidence of benefit that is based on very small trials, involving a handful of vehicles, a highly-optimised test environment, specially trained or briefed drivers, overt monitoring of behaviour, or monitoring only over a short period, may be quite a poor predictor of the benefits achievable in a more realistic, mainstream scenario. Unfortunately, at present, the evidence of C-ITS benefits is very limited to small scale trials, not robust over the long term. This situation will inevitably improve as time passes, although for some applications it may be many years before a genuine objective case can be put forward. (See also section 5.4 below, on market maturity.)

6.3. Cost of implementation/operation

In most ICT projects, while the benefits can be hard to quantify, the costs are generally a lot easier. Again, there are robust established methods, such as discounted cash flow, to estimate whole-life costs.

For a city C-ITS project in particular, the main cost elements are as follows – a mixture of goods and services and staff:

- Cost of acquiring (or upgrading) roadside devices: hardware, software and radio communications.
- Cost of installing and commissioning roadside devices.

- Cost of acquiring (or upgrading) central systems, including the additional cost of integration of roadside devices.
- (Additional) cost of the city's communication network between centre and roadside; also possibly additional costs of electricity supply.
- Cost of acquiring and/or training staff to use the system.
- Cost of maintenance, repair, upgrade and replacement of system elements.
- Any direct contribution to the cost of in-vehicle systems – in the case of city vehicles, the whole cost.
- Cost of marketing to prospective road users.
- Cost of technical support to actual road users.
- Potential costs associated with consequences such as complaints and claims.

Savings to current operations (which can be modelled as "negative costs") potentially include reduced costs of deployment, replacement, or upkeep of existing systems.

Two important financial considerations are as follows:

- "Cost of current systems" includes, potentially, not only the current cost of operating and maintaining them, but also the cost and risk of continuing to operate them for a number of years into the future. Typically, these will increase as systems become obsolete. If a replacement is needed anyway, the marginal cost premium of a C-ITS-enabled replacement is likely to be less problematic.
- As suppliers learn more about C-ITS and can amortise development costs more readily, the marginal cost of C-ITS capability is likely to reduce over time. In some cases suppliers may choose either to provide C-ITS capability either as a zero-cost extra, or to supply only C-ITS enabled equipment[24].

Because C-ITS is still an emerging technology, and because of the complicating factors in understanding future transport, cost models for city C-ITS projects will be difficult to get exactly right, at least for the next few years. However, there are some general observations that can be made.

- Small projects will be less expensive and less risky than large projects! If a city is interested in a particular C-ITS functionality, because there are no mature implementations, a pilot is definitely a good idea.
- The more complex and innovative the roadside station is, the more expensive it will be for suppliers to develop and validate, and for cities to acquire, install and maintain. Because of this, cities may prefer to begin working with C-ITS that require minimal change to roadside infrastructure (in particular, those using wide-area communications – see section 3.5).
- Personnel costs can be harder to justify than capital costs of equipment. This will be lowest for services that require little operator involvement, and little engagement with road users (e.g. floating vehicle data, fed automatically into a traffic management system).

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[24] However, having C-ITS enabled equipment is very different from having a functional C-ITS system. Most computers and phones ship with advanced facilities that are never used, because the user doesn't have the software, hardware, understanding, or just time to exploit them.

- The consequential costs of complaints and claims is hard to know in advance: it should be rare, but could be very high – especially if the system is proved to have contributed to a serious accident. While safety-related C-ITS services offer some of the best potential value, they also carry the highest risk. Services that are "informative" or "advisory" to road users will create less risk.

6.4. Market maturity and future-proofness

Many city ITS are supplied by mature markets. However, the market for C-ITS, generally, is not mature. Before moving to actual system procurement, a city will need to be confident of finding suppliers who will be able to meet its technical requirements. This is not simple for at least three reasons:

- The city may not know what the market has to offer.
- Suppliers may themselves be unclear about what they are able to offer, particular for products which are at an early stage of development. In particular, a keen salesman may promise that his company has viable C-ITS solutions before they are fully ready.
- The availability of compliant products may depend critically on very small changes in the specification. One line of requirement can make the difference between a supplier responding: "yes, we have a reliable product off the shelf", "we aim to launch that within a couple of months", "this is in our strategy but would be a new product", and "that's impossible".

Actually, cities will typically (for the reasons identified in chapter 3) not have technical requirements, but business requirements which could be met in a number of ways. Part of the city's role, therefore, is to try to design its project in such a way as to make best use of today's products, while maintaining its flexibility for the future.

Approaches to address these knowledge gaps include[25]:

- Talking informally to existing suppliers.
- Talking to other cities.
- Participating in industry events: workshops, conferences etc.
- Undertaking (or commissioning) market research.
- Running a pre-competitive Request for Information, using an indicative specification.

The outcome of this information gathering process will vary, and there is no clear "right answer". Some cities may have a general long term strategy, in which early projects – where the products are relatively mature – are presented in the context of a much broader, but less specific, future. Others

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25 Much of this is necessarily local action. However, there are opportunities to support cities in addressing these issues, through networking fora (like Polis, OCA, UTMC, IVERA), through national/regional implementation programmes, or through observatories at national, European or even global level.

may prefer to stick with specific projects until they are more comfortable building a holistic programme.

Long term strategies will need to consider things like:

- Technical and operational frameworks, and the use of appropriate standards
- Functional coherence between the various system elements over time
- Upgrade, extension and replacement cycles, particularly if products improve (or costs come down) over time
- Fit to the wider future context within the city (e.g. the issues raised in sections 3.6-3.9).

Short term approaches can be more *ad hoc*. They involve less commitment, but there is the risk that the resulting "standalone" systems will make a subsequent project harder to deliver.

Finally, early C-ITS projects may become a hostage to fortune: once a few sites are equipped and some services provided, these might rapidly lead the public to expect them everywhere (and to work perfectly and continuously). The city could then feel politically obliged to commit large scale resources permanently, even if the original intention was merely to run a limited trial. Careful control is therefore essential for public communication regarding pilot projects.

6.5. Dependencies on third parties

One of the key challenges of C-ITS is that it requires road users to be suitably equipped with matching technologies, and to ensure that they are used. However, the level of dependency, and the hurdle to a road user becoming connected, varies greatly between different solution concepts.

The three key factors are:

- Which users need to be equipped.
- How specialized and costly the user devices and/or applications are.
- What level of system management is expected of the road user.

These factors will affect the rate of take-up, and the effectiveness in practice, of the road user end of the C-ITS system.

Systems that focus on professional drivers, who are likely to have been trained and may have employment incentives to use the system, will probably be taken up more fully and more effectively than systems that focus on general road users (car drivers, cyclists and motorcyclists, pedestrians etc.).

Complex, expensive systems are also – for obvious financial reasons – likely to be more suitable for high-value and commercial vehicles (like freight or public transport) than for consumer use.

In addition to the road users themselves, there may be a range of other third parties that affect the delivery of C-ITS benefits. These include:

- The suppliers of city products, as discussed in sections 3.5 and 6.4.
- The suppliers of road user products (vehicles and in-vehicle equipment). If the market for such products is open and dynamic, the city may have little control over what is used and how.
- Business partners in the delivery of C-ITS services and their benefits. For example, a taxi company may have different requirements from the city for a C-ITS system. Negotiating a suitable compromise may not always be simple.
- Public service partners. For example, the police may prefer to use C-ITS in ways that is detrimental to transport policy (by increasing queues in the event of an incident, for example).

These issues are not showstoppers, but they do represent factors that need thought before C-ITS deployment, and may need ongoing management during the operation of the C-ITS.

6.6. Liability exposure and risk

A key worry of cities is that, because of the potential for much more direct links with vehicles and their control, C-ITS will impose significant risk on them. This is in addition to the usual risks associated with any technical project.

Among the key risks are the following:

- Breach of privacy.
- Accident liability.
- Political risk (e.g. through poor public reception).
- Supply failure.
- Imposition of excessive costs or other burdens on road users.
- Operational inadequacy (e.g. through shortage of skilled staff).

The issue of privacy is a huge issue, with large variations around Europe on what is and is not acceptable; section 6.7 addresses this separately. Supply failure, cost burden and poor delivery are all typical risks of a systems project and cities will have mechanisms to manage those. The other two risk areas – accident liability and political risk – need further comment.

The risk of accident liability applies particularly to C-ITS applications which are explicitly aimed at safety improvement, through the prevention or mitigation of road accidents. There is an obvious risk if the system fails and an accident occurs[26].

But there are risks even when the system is working: if an accident occurs and at least one of those involved was using (perhaps even relying on) C-ITS. In this case, the city's involvement may impose a

[26] This is currently the case with, for example, failed traffic signals. However these are mature systems, and operate with a combination of highly robust internal engineering (to prevent all-green stages) and legal clarity (on the duty of drivers to watch the road). C-ITS lacks this.

level of legal liability. Therefore, by deploying some kinds of C-ITS service – for example, if the city tells drivers/vehicles a wrong "safe route" or "safe speed" – it may risk large fines, court costs etc.

There is considerable policy-level discussion around the liability for autonomous and automated vehicles, and with some recent fatalities now linked to advanced vehicle instrumentation – notably Tesla's Autopilot – case law is likely to emerge in the near future. However, the more general problem of C-ITS has not had so much consideration.

This concern is one of the biggest reasons for cities to be cautious about safety-linked C-ITS applications in particular.

There is a broader concern too. Even if a C-ITS system is proven to reduce the total number of accidents, it may be politically and publicly unacceptable for the city to be seen as *causing* an accident. And political risk covers many other areas:

- If the system is seen to be a waste of money.
- If the system is seen to be the wrong kind of system for the city.
- If the system is seen to be intrusive.
- If the system is seen to be a vanity project.

The political risk for C-ITS is much higher than for most other ITS. Systems like traffic signals are "internal" projects and do not directly impinge on road users. C-ITS, of its nature, does – and this is another reason for cities preferring to work with known, limited fleets like buses, rather than with road users generally.

Conversely, of course, a C-ITS project may be seen (and justified) as essentially a political project:

- If it shows the city is technologically advanced and forward-thinking ("smart").
- If it attracts high-profile visitors or inward investment.
- If the intervention is deliberate and targeted at, say, emissions management or disabled travellers.

6.7. Use of personal data

Many C-ITS implementations require information to be passed from the vehicle to other parties. Insofar as this could be regarded as personal data, there is a significant potential issue of data protection. In some parts of Europe this is a very problematic, not just legally but also culturally.

When private data is handled, as well as ensuring the basic legality and the public/political acceptability, there is also a need to ensure that the appropriate data protection mechanisms are in place. This may include systems issues (such as encryption), process issues (such as destruction of data after a specified time) and personnel issues (i.e. vetting and training).

For the purposes of planning a C-ITS strategy, it may be useful to categorise cooperative functionality into the following classes of personal data usage[27]:

- Class 1: **none**. In this class, the vehicle provides no information to the city and the cooperative element lies only in its acquisition and usage of city data that it receives. An example would be if a signal controller broadcasts SPaT messages, and the vehicle unit picks this up and uses onboard intelligence (and its geolocation) to calculate and present a GLOSA message to the driver.
- Class 2: **neutral**. In this class, the vehicle sends a completely anonymous message to the city, whose content may be something like “there is a vehicle at location X, travelling in direction Y”. Because of the message anonymity, this data is not strictly “personal” – although technical arguments may make this class still problematic (for example, the city still receives an identifier such as an IP address).
- Class 3: **basic**. In this class, the vehicle passes some basic information, such as its current location, but accompanied with an identifier. This enables the city to track its movement, which can be helpful for journey time monitoring but starts to be seen as intrusive in some cultures. It is likely to be easier to accept this kind of service for specific classes of vehicles, such as licensed taxis or public transport.
- Class 4: **contextual**. In this class, the vehicle passes information not just about itself but about its environment too. This may include information about other road users nearby, or about the state of the road, or about the weather. This class is technically a lot more complex than class 3, although the level of “personal” concern may not be much different, and drivers may be even be happier to allow their vehicle to be located if it is used to uplink temperature or rain data.
- Class 5: **detailed**. In this class, detailed information about the operation of the vehicle is provided: speed, occupancy, emissions etc. While this data, collectively, may be very valuable – either as “big data” for transport management, for behavioural research, or for enforcement – it obviously carries the highest personalisation value.

Where privacy is a big issue, Class 1 services are likely to be deployed earliest by cities. However, the benefit for the city is more indirect for these services, as they require road users to behave in the assumed, predicted, beneficial way (e.g. to brake more steadily). As soon as Class 2 or higher class services are available, the city has access to a data source that it can use to intervene actively, e.g. to change signal timings or road speed limits.

Third party service providers may find it easier to deliver higher class services. In particular companies with whom the road user already has a relationship – their vehicle vendor, or their mobile phone company – may provide Class 4 or even Class 5 services (such as maintenance alerts), with the explicit and willing agreement of the road user.

This distinction may make it helpful to consider carefully the potential benefits of third party services working with the city (as described in section 3.5, Figure 3.3).

27 The relevant European law on data protection focusses specifically on identifiability of data subjects, and this is the basis for this classification. It is also intended that this is concordant with asset valuation and risk assessment under an ISO27000-based system security policy.

7. Elements of the city business case

7.1. Introduction

It has been noted already that cities will implement C-ITS only where they see a reasonable case for benefit to local transport, in the context of established policy and limited budgets. This is challenging as many urban C-ITS services are still in their infancy, and robust long term evidence is not yet available. Inevitably, costs and risks will reduce over time as more real-world evidence accrues.

This chapter therefore looks at how a city might create a realistic strategy for rolling out C-ITS within its own systems. This includes a consideration of which services are likely to be most relevant, how they can be packaged together, how to engage with others, and what will trigger a decision to procure (if and when the time comes).

The guidance presented here is taken from three sources:

- The evidence from earlier phases of the CIMEC project, as represented in chapters 2-6.
- The views expressed by CIMEC city partners and the City Pool.
- The progress and (where available) results from other C-ITS projects and initiatives, especially those which have attempted to develop or collate evidence.

This guidance does not address issues of political engagement, for instance whether the city could or should seek to influence their member state government, OEMs, regulators, or the supply industry. These processes will doubtless be important, but will depend closely on the specific local circumstances and people involved.

The positions presented in this chapter are presented in simple declarative terms. This is simply to avoid every sentence being heavily caveated and cumbersome: it should not be taken to imply formal advice, and for individual cities, there may be good local reasons to indicate a different course of action.

7.2. Overview of available evidence

The quality of evidence available for different C-ITS services is very variable. Table 7.1 below outlines the current state of the art, specifically as regards European urban deployment, using the following key:

- **** means robust and quantified evidence of benefit, proven in a variety of different contexts
- *** means demonstrated in the open market, but with limited evidence (i.e. short term or few sites)
- ** means demonstrated in R&D projects, with quantified evidence of benefit, but with little or no evidence from open market deployments
- * means robust evidence of technical feasibility demonstrated through R&D projects, but with little attempt to measure benefits
- - means subject only to desk studies or initial concept demonstration (e.g. lab demonstration only)

Table 7.1 is deliberately technology-neutral. It is intended to guide cities (and others) on which services are the most practical to explore in the short and medium term. The decision as to which solution is used – including, where appropriate, the choice to use a non-C-ITS solution – will be made on other grounds.

The table reflects only interventions which actively involve a city in deploying solutions. Where benefits exist elsewhere, this is noted in the comments.

Table 7.1 Evidence of benefit from city C-ITS use cases[28]

USE CASE	EVIDENCE	COMMENTS
UC1: Individual routing of vehicles	***	Widely provided through third-party services (e.g. satnav services). Some cities may prefer to support these with an open data feed for the road network (structure, congestion status, works etc.).
UC2: In-vehicle signs	*	Reasonably widely trialled but there seems to be little quantitative evidence of benefit
UC3: In-vehicle signal information	**	Good evidence of benefit in limited trials
UC4: Management of loading and unloading areas for freight vehicles	*	Freight vehicles are generally managed by the fleet operator, rather than through direct city intervention. As with UC1, some cities will anticipate delivering services like these indirectly, through open data feeds and/or through centre-to-centre links with distributors.
UC5: Access control for heavy goods vehicles with dangerous goods	-	Freight vehicles are generally managed by the fleet operator (see UC4)
UC6: Regulation of access to free lanes for electrical vehicles	-	
UC7: Green lights for police and emergency vehicles	*	Reasonably widely trialled but there seems to be little quantitative evidence of benefit
UC8: Traffic light management	**	Existing deployments of floating vehicle data mainly use "passive" or indirect cooperation, e.g. by detecting Bluetooth signals
UC9: Green lights for public transport vehicles	****	Widely provided, though an established marketplace and a great variety of solution architectures

28 This assessment, and those in the remainder of this chapter, are provided by the CIMEC project team at the beginning of 2017: they should be taken as indicative only, rather than definitive. We would expect the evaluations to change over time, as more practical experience is gained, more products are offered, and more detailed analysis is conducted.

USE CASE	EVIDENCE	COMMENTS
UC10: Green lights for cyclists	*	The relatively few cycle priority systems are based on passive cycle detection and are not cooperative. Cycle priority is widely provided through infrastructure means (e.g. cycle lanes with independent signalling)
UC11: Parking management	***	Depends on having good monitoring systems for parking bays. In a parking garage, bay monitoring is easier and guidance can be provided non-cooperatively through zonal occupancy displays. Some cities may prefer to support this service with an open data feed (availability of parking bays).
UC12: Inform about incidents in the road network and access control to these areas	*	Information is widely provided non-cooperatively through broadcast channels (e.g. radio broadcasts). Access control is not very well tested
UC13: Inform about emergencies in the road network and access control to these areas	*	As UC12
UC14: Dynamic access control for air quality management	*	Air quality management has been trialled through non-cooperative ITS, such as traffic signal settings and information warnings, with mixed effect. C-ITS based access control is much less well understood
UC15: Speed enforcement around schools	-	
UC16: C-ITS services for vulnerable road users	*	A wide variety of concepts exist in this UC, few of which have been defined and trialled in specific services
UC17: Pedestrians crossing in front of bus/tram	-	Could be regarded as a specific example of UC16
UC18: Bike lane change and unusual crossing	*	Could be regarded as a specific example of UC16

7.3. Political feasibility

For a project to be considered by a city, it needs first to be acknowledged by the political leaders as relevant. In extreme cases, strong political backing may be all that is required (e.g. because the city is keen to obtain status as a beacon or leader in a particular area).

In most cases, where there are no overriding political considerations, a city's decision to invest in C-ITS will be based on a balance of technical and commercial considerations, justifications of value, and estimates of risk. However, even then, the level of evidence expected will depend on politics: how open the current politicians are to technology, whether improving transport is high on the city's agenda, and so on.

In a few cases, political considerations may be so strong that only very limited evidence is needed. Examples might include:

- If delivering C-ITS is part of a major long term commitment (e.g. for structural funds or for enhanced city status)

- If there is a competition that the city is politically keen to win (e.g. to be the nation's leading "smart city")

Circumstances of this kind are often opportunistic, and cannot be relied upon.

Paradoxically, while political drive may be a good way of getting a project approved, they may not be good for the long term benefits of the system. For example, if the focus is on an early launch, the city may not commit sufficient resources to operation, maintenance and upgrade.

7.4. Technical feasibility

Once the necessary political approval is obtained, the city will seek to plan for:

- What systems might be required
- How they would integrate with (or replace) existing systems
- What level of operational support they would require (e.g. in terms of personnel)
- What external links and partnerships might be required
- Etc.

Chapters 3-4 review the C-ITS technical options generally, but not all will work for specific C-ITS services. Table 7.2 below summarises the main options, and challenges, for the different use cases, with respect to four specific issues:

- Suitability of short range communications, including ETSI ITS G5 (i.e. through roadside units)
- Suitability of long range communications, such as 3G/4G mobile services
- Ease of integration into existing traffic management systems (e.g. how much work will be needed to develop interfaces and new algorithms, etc.)
- Ease of integration into road user systems (e.g. how much the service depends on investment and rollout by OEMs, and on drivers using the tools effectively)

The scale is as follows for the two "suitability" criteria:

- ** means that this communications channel is likely to be technically effective for the service
- * means that this channel could work for some aspects of the service, but would not deliver full functionality (generally because they lack the range or are too slow)
- - means that this channel would not be suitable for the service

The scale is as follows for the two "ease of integration" criteria[29]:

[29] These criteria will be very dependent on what systems the city already has, and what it could expect from its road users. The assessment of these criteria should therefore be regarded as indicative for the general European city context.

- *** means that the service could run well independently of existing systems, or with only very straightforward links
- ** means that the service would need to be integrated, but the tools to achieve this (features, products or standards) already exist or would be relatively simple to develop
- * means that significant work on new features, products or standards is likely to be needed to achieve integration (including HMI for in-vehicle systems)
- - means that this integration would not be realistically achievable in the foreseeable future

So in either case, more stars is "good".

Table 7.2 Technical options for city C-ITS use cases

USE CASE	SHORT RANGE SUITABILITY	LONG RANGE SUITABILITY	EXISTING TM INTEGRATION	EXISTING USER INTEGRATION
UC1: Individual routing of vehicles	*	**	**	***
UC2: In-vehicle signs	**	**	**	**
UC3: In-vehicle signal information	**	*	**	*
UC4: Management of loading and unloading areas for freight vehicles	**	**	*	**
UC5: Access control for heavy goods vehicles with dangerous goods	**	**	**	**
UC6: Regulation of access to free lanes for electrical vehicles	*	**	-	*
UC7: Green lights for police and emergency vehicles	**	**	**	**
UC8: Traffic light management	**	**	**	**
UC9: Green lights for public transport vehicles	**	**	**	**
UC10: Green lights for cyclists	**	**	**	**
UC11: Parking management	**	**	***	***
UC12: Inform about incidents in the road network and access control to these areas[30]	*	**	**/-	**/*
UC13: Inform about emergencies in the road network and access control to these areas[30]	*	**	**/-	**/*
UC14: Dynamic access control for air quality management	**	**	*	*
UC15: Speed enforcement around schools	**	-	**	*
UC16: C-ITS services for vulnerable road users	**	*	*	*
UC17: Pedestrians crossing in front of bus/tram	**	*	***	*
UC18: Bike lane change and unusual crossing	**	*	*	*

30 For the integration scores, the first mark is for information, and the second for access control.

In summary, technical issues are not fundamental, although some services would be more challenging to deliver than others. In particular:

- Both short and long range communications are able to fulfil a majority of the use cases (albeit with different strengths and weaknesses)
- Regulatory and enforcement services are going to be quite hard to deliver, while non-time-critical information services should be quite easy
- The integration challenge is largely dependent on the maturity of existing applications (so, signal priority and parking management are well established, whereas GLOSA or VRU services are more novel)

7.5. Commercial feasibility

A city will also need to have a reasonably stable indication of the commercial implications of a C-ITS project. Once a business model has been determined (see section 3.5 and Figure 3.3), the city will know what actual products and services it needs to acquire, and it can start to plan for:

- Suitable procurement approaches – buy, lease, contract, etc.
- Approaches to phased procurement
- The cost of acquisition and future development
- The cost of management, maintenance and support
- Potential implications of procurement delays
- Contract management and monitoring activities

In taking these decisions a city will doubtless take advantage of available information on what approaches are likely to be most beneficial for it, including:

- Other cities which have deployed already
- Supplier materials and representations
- Impartial market studies
- Commissioned research
- Open Requests for Information (RFIs) issued to the market
- Piloting

Commercial challenges are indirectly linked to the specific use cases that the city wishes to support, but more directly to the system/service elements that it decides to procure. As is clear from chapter 4, the supply market is not currently sufficiently coherent to offer a full range of "off the shelf" C-ITS products; but on the basis of the information that has been provided, Table 7.3 below outlines the principal potential elements.

For the "feasibility" score, the following key is used:

- ** means low commercial risk: products exist, the city is unlikely to be exposed to significant problems

- * means medium commercial risk: product development, acquisition and maintenance provide challenges to the supply market, contracting is not fully proven, but the city has good control over contract enforcement
- - means high commercial risk: product development and validation provide major challenges, the city has only limited contractual control, and/or action but third parties could render the product useless

The cost of implementation, clearly, will depend greatly on the scale of the city and of the deployment project. The cost assessment, therefore, is only semi-quantitative as the following key is used:

- ** means the cost of a useful system may be kept very modest
- * means the cost of a useful system will be significant, either because it depends on a large scale deployment or because the individual cost element is likely to be pricey
- - means the cost of a useful system will be very high

Table 7.3 Commercial risk to the city of C-ITS cost elements

COST ELEMENT	FEASIBILITY	COST	COMMENTS
Short range communications facilities and associated networking	*	*	
Long range communications facilities and associated networking	**	**	Subject to usage charges: cost assessment could be lower if large amounts of data are used
Functional roadside units	*	*	Risk on applications development and test Feasibility could be – for functions that depend heavily on driver response
In vehicle units: city-acquired	**	*	Likely to be relevant for limited fleets with a strong link to the city, e.g. buses or gritters
In vehicle units: third party	-	**	The cost to city is zero or minimal Feasibility is scored low because of lack of control the city has. Could be higher if there are good risk mitigations (e.g. commercial agreements with freight companies, accepted product standards)
Central systems: cooperative services	*	*	
Central systems: adaptation of/ integration with traffic management	*	*	Feasibility could be lower for some services which require a high level of adaptation
Staffing	*	*	Obtaining, training and retaining unfamiliar skills will be a challenge
Open data arrangements: data publication	**	**	
Open data arrangements: data acquisition	*	*	Risks associated with using external data need to be mitigated by "failsafe" provisions in the system

7.6. Utility – to road users

Benefits of C-ITS are generally of two kinds: benefits to individual road users, in the course of their transport activities, and wider benefits (to road users and others) through collective action by the city. Benefits to road users have generally been more widely studied, although in some cases they may have relatively little resonance for the city as a whole.

Potential benefits of C-ITS services to individual road users include:

- Saving travel time
- Saving fuel
- Improving the likelihood of accidents
- Improving the comfort of travelling through better information

Where C-ITS is coupled with vehicle automation, there is also the possibility of improving the driving experience through removing some of the needs for driver activity[31]. However, these are predominantly benefits of the automated vehicle rather than the C-ITS.

For a city, the individual benefit of "saving travel time" translates into "reduced congestion", as vehicles will be on the road for less time; and "saving fuel" translates into "improved air quality", as fewer pollutants are emitted. However these connections are not simple: individual benefits do not always add up to collective benefits.

- Many cities do not want to make car travel more attractive, compared to public transport or active modes
- If travel time and fuel (and emissions) are reduced for one path through a signalled intersection, they are likely to be increased through the opposing path

Cities are therefore likely to focus primarily on services to "high value" road users:

- Buses/trams carry many people, so travel time savings are multiplied relative to single-occupancy vehicles
- Buses and trucks emit much more pollution than cars and motorcycles, so smoothing their passage through the network is likely to generate disproportionate environmental improvements

Services to general traffic will be more conservative, and will be those that tend to reinforce existing traffic management – such as incident warnings, which dissuade drivers from entering an area and may help to reduce congestion around a problem spot.

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31 Examples include automated stopping at junctions, automated choice of which exit to take from a junction, and automated compliance with local speed limits. All of these involve both vehicle automation and a supporting C-ITS service.

Some services are beneficial to road users and relatively neutral to the city, for example vehicle activation of isolated signals during quiet periods. In these cases, implementation is likely to be highly dependent on cost and (potentially) political priority.

7.7. Utility – to city managers

Section 7.6 discusses C-ITS services which have a direct (positive) benefit for individual road users, and which may under some circumstance also have a collective benefit to the city. However there are also some C-ITS solutions which offer benefit to the city generally, but only indirectly to individual travellers (e.g. through improved traffic flow) – and indeed some road users may be directly disadvantaged.

Services of this kind were discussed in section 3.4 and resulted in the schedule of CIMEC Use Cases described in chapter 4. Benefits may, in fact, be broader than merely traffic, and could include:

- Solutions which improve air quality or other environmental features (e.g. noise) in residential areas
- Solutions which support other city services (e.g. waste collection, social care) through prioritisation
- Solutions which support city maintenance activities (e.g. roadworks)

Each city will have its own priority list for C-ITS services, based on the local economy, demographics, environmental challenges etc. At a European level, Table 7.4 below summarises the likely priority level, i.e. which services cities see as delivering the most important benefits in the near term[32]. The scale is indicative only, and is as follows:

- *** means high priority: widespread interest in exploring and potentially delivering these services
- ** means medium priority: interest from some cities in these services
- * means low priority: while cities perceive a potential value, few are focussing on these services in the first instance

As previously noted, there is a significant element of policy pragmatism in the support for public transport and VRUs, and the avoidance of use cases for regulation/enforcement.

32 This list draws specifically on discussions within the European C-ITS Platform's urban working group, although it should be noted that the approach to categorising specific C-ITS services was somewhat different there.

Table 7.4 Overview of city benefits arising from C-ITS use cases

USE CASE	PRIORITY	COMMENTS
UC1: Individual routing of vehicles	**	Varying views: some cities regard it as high priority, others regard this as a matter for fleet managers or commercial services
UC2: In-vehicle signs	**	
UC3: In-vehicle signal information	***	GLOSA/time to green is the second most popular use case, especially for freight vehicles (it is recognised that it depends critical on in-vehicle systems and driver response)
UC4: Management of loading and unloading areas for freight vehicles	*	
UC5: Access control for heavy goods vehicles with dangerous goods	**	Considered important but predominantly of interest to very specific points on the network (tunnels, bridges)
UC6: Regulation of access to free lanes for electrical vehicles	*	
UC7: Green lights for police and emergency vehicles	**	Popular (but it is noted that emergency vehicles can go through red lights anyway)
UC8: Traffic light management	**	Fairly popular, although cities have doubts whether sufficient high-quality floating vehicle data will be available
UC9: Green lights for public transport vehicles	***	The most popular single use case
UC10: Green lights for cyclists	**	Popular but there is no clear understanding of the best system approach
UC11: Parking management	**	Fairly popular for on-street parking
UC12: Inform about incidents in the road network and access control to these areas	**	Road works warnings are fairly popular, although it is recognised that this will be much less easy to benefit from in cities than on the highway
UC13: Inform about emergencies in the road network and access control to these areas	*	
UC14: Dynamic access control for air quality management	*	
UC15: Speed enforcement around schools	*	
UC16: C-ITS services for vulnerable road users (including UC17 and UC18)	**	Generally popular for policy reasons, although cities have no clear idea about what specific C-ITS services might be deployed or what systems could be used

7.8. Social/legal issues

Social and legal issues (including for security and liability) are expected to be important in many cities' business cases, as they impose external risks which cannot simply be mitigated by good project decisions. However, it is beyond the scope of CIMEC to undertake a full analysis of the social and legal issues associated with C-ITS: many of them vary around Europe, and in any case they appear to be quite fluid at present.

The principal exception is on privacy and data protection, where the systems issues, at least, can be relatively well understood. Section 6.7 categorised C-ITS in the following classes[33]:

- Class 1: **none**: no information
- Class 2: **neutral**: a completely anonymous message
- Class 3: **basic**: some basic information, such as current location, accompanied with an identifier
- Class 4: **contextual**: information both about itself and about its environment (other road users, the state of the road, the weather etc.)
- Class 5: **detailed**: detailed information about the operation of the vehicle: speed, occupancy, emissions etc.

There is no clear relationship between the services we have discussed and the privacy classes: many can operate at various levels. However there are minimum levels, depending on the nature of the service: Table 7.5 identifies the principal privacy class options for each use case, although in many cases there may be "work-arounds" that reduce the privacy problem.

Table 7.5 Privacy issues within C-ITS use cases

USE CASE	MIN CLASS	COMMENTS
UC1: Individual routing of vehicles	5	Needs indication of destination, associated with a specific vehicle.
UC2: In-vehicle signs	1	
UC3: In-vehicle signal information	1	Some implementations envisage a trigger message from the vehicle (class 2/3)
UC4: Management of loading and unloading areas for freight vehicles	4	
UC5: Access control for heavy goods vehicles with dangerous goods	5	
UC6: Regulation of access to free lanes for electrical vehicles	5	
UC7: Green lights for police and emergency vehicles	2/3	Would at least need to identify itself as an emergency vehicle
UC8: Traffic light management	2	
UC9: Green lights for public transport vehicles	2/3	Would at least need to identify itself as a public transport vehicle
UC10: Green lights for cyclists	2/3	Would at least need to identify itself as a cycle Options for non-C-ITS implementation may be easier
UC11: Parking management	3/5	Need to have at least vehicle type

33 This does not include any data obtained by the city by non-C-ITS means, such as number plate recognition or CCTV cameras. A city data protection plan would of course need to cover this data too.

USE CASE	MIN CLASS	COMMENTS
UC12: Inform about incidents in the road network and access control to these areas	1/5	1 for information, at least 3 but probably 5 for access control
UC13: Inform about emergencies in the road network and access control to these areas	1/5	1 for information, at least 3 but probably 5 for access control
UC14: Dynamic access control for air quality management	3/5	At least 3 but probably 5 for access control
UC15: Speed enforcement around schools	3/5	At least 3 but probably 5 for enforcement
UC16: C-ITS services for vulnerable road users (including UC17 and UC18)	4/5	Depends on the specific service, but almost certainly at least 4

8. Implementing city C-ITS infrastructure

8.1. Introduction

The previous chapters of this Roadmap have presented a lot of material on the relevance of C-ITS to cities, and the issues involved in using it. This chapter brings this all together, to collate headline guidance to cities on whether, when and how to become involved in C-ITS projects.

This is certainly not a “handbook” for city C-ITS planning and implementation. Cities will have their established working practices, and are comfortable and familiar undertaking these activities in more traditional ITS areas (say, for traffic signal control or bus information systems). They also have established links with suppliers, political contexts in their member states, etc. All of these will significantly colour the strategy, and dominate the procedures adopted for implementation.

8.2. Setting a strategy

The strategy is a concise description of why the city is expecting to invest: what it is aiming to achieve, with what mechanisms, and perhaps by when.

C-ITS is just a tool, and this strategy will be developed as part of a cascade from:

- A top-level city strategy that speaks about economy, environment, employment, health etc., and with reference to visions such as sustainability and inclusion
- Perhaps, a city business strategy that sets a framework for its governance, links with the private sector, approach to intellectual property, etc.
- A transport strategy that outlines ambitions for public transport ridership and network development, active modes, emissions reduction etc., to support the city strategy
- An ITS strategy that talks about how the city expects to collect data, process it, and use it for the benefit of the people through technology systems

Some of the main “futures” elements will be the opportunities for reaching people through developing personal technologies, the potential for vehicle automation, and the need to integrate services “smartly”. It will be very local which of these will drive the local approach to C-ITS.

Political strategy could be set by:

- The desire to be seen as progressive, and a “beacon” for new technology
- The desire to maximise the city profile, and associated opportunities, in a particular transport area – say, freight (if there is a local port) or cycling (in a university city without too many hills)
- The simple desire to capture the funding and support available through a national or European programme

8.3. Project ownership

The function of C-ITS is to engage with road users in a very different way from traditional systems. It is both more direct and more personal, and potentially a lot broader in scope. As such, it is important to decide on what basis the city wishes to adopt C-ITS: whether purely as a focussed project opportunity – say, to improve pedestrian safety near schools – or as a wide-ranging "smart cities" platform (as discussed in section 3.9).

Many cities operate their transport services in different "silos" of focus expertise, which have responsibility for identifying and meeting the challenges within their specific area: highway surface, signage, parking, public transport, etc. Each of these silos can consider the C-ITS services relevant to its own focus area.

By contrast, a multi-purpose C-ITS solution may be more efficient (for instance by providing a common platform for multiple services). A project of this kind also needs an organisational "home", whether and existing functional team or a newly creating specialist unit. However C-ITS should not become its own silo – it needs to work closely with all of the functional units to determine and deliver a system which works for all of them.

Achieving this is quite challenging, especially for budgeting, prioritising and decision making. Senior leadership and control will be essential, but technical expertise needs to be fully respected too[34].

8.4. Skills

The role of cities in using transport technology has undergone major changes in recent years, and this has had significant impact on the skills that city staff need to have.

In the early days – when ITS meant mainly traffic signals – most cities had people who were skilled in planning junction strategies and timing plans etc. More recently, with much more complex functions available (and less money), technical design has been largely left to suppliers. This has led to a widespread use of "output specifications" in procurement, which is contractually efficient but opens the risk of proprietary systems and supplier lock-in. Standards like DATEX and OCIT, and integration initiatives like UTMC, have helped to mitigate these problems, but in general cities are still very dependent on their key suppliers for system design.

With cooperative systems, the challenges are increased yet further: partly because C-ITS products are still at an early stage of development, partly because the options are so varied and complex,

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34 One stakeholder observed that "the keyword is ownership to the challenges on one side and ownership to the solutions on the other".

partly because of the direct link with road users, and partly just because of the nature of modern ICTs.

For all of these reasons, cities need to take much more direct control of the system design with C-ITS than with (for example) traditional traffic management systems[35]. This places a considerable responsibility on the city to ensure that it has the necessary technical skills available: system integration, technical standards, product evaluation, data management, performance management, system security, user interface design, etc.

8.5. Designing a communication architecture

Most European cities have some ITS, and most of those will have a clear idea about how the different ITS systems join together. Many systems will be isolated (for example, traffic signals at remote junctions), while some will necessarily be connected (for example, variable message signs).

This background will help determine the optimal architecture for the city, in terms of:

- What communications channels it uses (local or wide area) to get information from road users and provide information back to them
- What data it seeks to gather into roadside units (if any) or central systems, and where those central systems are deployed
- Which third parties it can usefully use as part of its overall system – perhaps central systems managed by neighbouring cities or commercial bus companies, perhaps long-term partnerships with communications companies

At present it seems that two primary technical architectures exist (as described in section Figure 3.2): one based on local communications focussed on junctions (and other specific network points), geared specifically to direct communication with in-vehicle units, and a second focussed on wide area communications through mobile channels, less reliable or instantaneous but capable of reaching a much wider population through both in-vehicle systems and personal devices. In practice it may be more appropriate to use both mechanisms, either to increase resilience/reliability, or because specific services require particular communications characteristics.

While the chosen architecture should not determine which services are to be offered in isolation, it is an important part of the planning process. A service which does not naturally fit within a practical city C-ITS architecture may be too risky, expensive or hard to sustain.

For example, a city's main policy focus may suggest that reducing child accidents is the most important C-ITS service. However, perhaps these accidents mostly take place scattered around

35 This comment applies primarily to systems acquired and operated by the city itself. Third party and commercial services will have very different considerations.

residential areas, where implementing roadside stations and local communications is unrealistic; detection of dangerous behaviour is problematic; and it is unclear how drivers could be warned in time to have an effect. In that case, the service may be postponed (and instead an education programme put in place), and the C-ITS strategy refocused onto ambulance priority at signals near ambulance stations.

8.6. Planning a programme

There are few specific rules that can be given about how to design a medium-term plan for C-ITS infrastructure: any plan will depend on the selection of services (perhaps based on the Use Cases on chapter 4) and the response of the local supply market (cf chapters 6 and 4) in terms of product readiness, price and delivery.

There are, however, some general guidelines, which are not specific to C-ITS but apply to any complex programme. These include:

- Think about phased implementations: don't try to do everything at once
- First focus on relatively simple, low risk projects, even if they are relatively low priority. Apart from anything else, this will build valuable experience in working with the C-ITS architecture
- Don't over-promise to the users of the system, or to local politicians
- Be aware that you may have to change course part way through the programme, and try not to build any key component that is unchangeable
- Don't leave the programme half finished, especially if the majority of benefits accrue only in the later stages
- Make sure the budget profile is realistic. If you are at risk of political fluctuations over the 10-15 year timescale, try to get multi-party backing

8.7. Coordinating the stakeholders

Cities are used to public consultation at a high level, and in many cases to working with strategic partners (such as the police or major local employers) on a day-to-day basis. However, C-ITS services may require a significantly greater level of coordination with users and potential users.

Table 8.1 summarises the primary users as the stakeholders with whom coordination will almost certainly be necessary, to ensure the service is specified, acquired, and implemented in a practical way, and is used as intended. In addition to these, coordination will be required with many other stakeholders at a more strategic level, including potentially:

- National governments
- Local politicians
- City senior managers
- Various regulators (if different)
- Funding authorities (if different – e.g. research agencies)
- Other specialist units within the city, e.g. air quality officers

- OEMs for affected vehicles
- Electricity and communications services suppliers
- Emergency services
- Affected public services, e.g. schools or hospitals
- Local business communities
- Etc.

Of course, any staff involved in traffic management will also need to be regarded as stakeholders, especially if they have operational, enforcement or public-facing roles that are connected with the use of the C-ITS.

Table 8.1 Principal user groups for different C-ITS use cases

USE CASE	PRINCIPAL USER GROUPS
UC1: Individual routing of vehicles	Owners/managers of affected vehicle fleets Driver of those vehicles
UC2: In-vehicle signs	All drivers of (equipped) vehicles
UC3: In-vehicle signal information	All drivers of (equipped) vehicles
UC4: Management of loading and unloading areas for freight vehicles	Owners/managers of affected vehicle fleets Driver of those vehicles
UC5: Access control for heavy goods vehicles with dangerous goods	Owners/managers of affected vehicle fleets Driver of those vehicles
UC6: Regulation of access to free lanes for electrical vehicles	All drivers of (equipped) vehicles
UC7: Green lights for police and emergency vehicles	Owners/managers of affected vehicle fleets Driver of those vehicles
UC8: Traffic light management	(None)
UC9: Green lights for public transport vehicles	Owners/managers of affected vehicle fleets Driver of those vehicles
UC10: Green lights for cyclists	All (equipped) cyclists Potentially other road users (depending on implementation)
UC11: Parking management	All drivers of (equipped) vehicles
UC12: Inform about incidents in the road network and access control to these areas	All drivers of (equipped) vehicles
UC13: Inform about emergencies in the road network and access control to these areas	All drivers of (equipped) vehicles
UC14: Dynamic access control for air quality management	All drivers of (equipped) vehicles
UC15: Speed enforcement around schools	All drivers of (equipped) vehicles
UC16: C-ITS services for vulnerable road users (including UC17 and UC18)	Depends on the specific service, but almost certainly at least 4

8.8. Procurement and implementation

The issues involved in procuring C-ITS infrastructure revolve around:

- Determining the appropriate commercial model
- Developing the specification requirements and evaluation criteria
- Managing any supplier competition, including responding to questions

These are not specific to C-ITS, but because of the unfamiliar challenges on technical design, business operation and so on – both within the city and within the supplier community – it may be challenging to ensure that the risks are kept under control during the process.

The challenges continue after procurement and during the implementation phase. New ITS services are very often subject to unforeseen technical hitches, even where there is an off-the-shelf solution that "merely" needs to be connected in to existing facilities. For C-ITS, where solutions will be at least very new and possible still being developed post-procurement, the challenges are redoubled. Moreover, although the city may be able to afford some teething problems in integration with its own internal systems, integration with equipped road users (depending on the service) may need to be instantaneous, fully reliable and free of interruptions.

This risk merely serves to highlight the need to adopt a cautious deployment programme, as discussed in section 8.6 above.

8.9. Operations and maintenance

Once an ITS service is implemented, it needs to be maintained and (in some cases) actively operated, either by the city itself or by a third party. This applies, in particular, to any new C-ITS facility.

The different services have different requirements for factors like acceptable time to repair, expected upgrade schedule, need for pro-active maintenance (to ensure adequate uptime) etc. All of these factors need to be taken into account during procurement, in order to ensure that the system as delivered can be maintained in an effective state.

In particular, it is a sad truth that – at any given time – many individual ITS devices belonging to European cities are non-functional, and awaiting repair. For budgetary reasons, this repair can often be postponed for a long time. Where there is a fallback position this may not be too much of a problem: for example, an adaptive signal controller can drop back to fixed time operation if a detector loop fails. For some C-ITS solutions, this level of loss and fallback may not be acceptable.

Again, this is a risk that highlights the need for a cautious deployment programme.

9. The wider context

9.1. Introduction

This final chapter of the Roadmap is slightly different, in that it does not directly address cities or their supply chain. Instead, this chapter picks up the issues that have arisen where city actions are constrained or limited by factors outside their control, and suggests potential actions that would help to ease these.

The audience, therefore, is primarily policymakers at national and European levels, but also the automotive industry and its telematics supply chain. Existing collaborative arrangements (such as the C-ITS Platform) are welcomed, of course, and may provide a valuable basis for developing some of these additional actions.

9.2. Legal developments

European cities do not exist in a political vacuum: they are subject to a wide range of legal obligations of two kinds:

- Duties that they need to fulfil
- Constraints and limitations that they must observe

At present, there are some general duties related to ITS that apply – directly or indirectly[36] – to all European cities. However there are no current duties that compel them to implement C-ITS.

Conversely, there is a wide range of regulation under which any ITS implementation is obliged to follow some demanding provisions in design, operation and procedure. Some of these are referred to in this Roadmap. Of these, some are broadly supportive of deployment (for instance, standards that reduce implementation risk) and some necessarily impose additional costs, risks and restrictions (such as the requirement for data protection).

It is widely recognised that C-ITS is still an innovating area and not to be excessively constrained by regulation. However, this does mean that cities are unsure about what their obligations might be in the future, and this makes them cautious about investment.

Policymakers need to ensure that the legal environment is sufficiently clear, and sufficiently supportive, regarding both duties and constraints, in order to encourage appropriate, coherent C-ITS deployment.

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36 Indirect application includes obligations on Member States under the ITS Directive and some other European provisions.

Specifically there is a need for clarity on:

- Whether cities are (directly or indirectly) obliged in law to implement specific C-ITS services, and if so when
- What the specifications of the relevant services are
- What support arrangements will be in place to ensure that this is achieved coherently
- The long term stability (at least 10 years) for these arrangements

9.3. Private sector developments

Cities cannot control the readiness of the market for C-ITS services, as described in sections 6.4 and 6.5. Whether they can plan practically a deployment will therefore depend on what progress is made in other sectors, particularly in the vehicle telematics industry, but also (as described in sections 3.6-3.9) in areas like vehicle autonomy and smart personal devices.

At present there is little coherence among these industries. While European OEMs are now generally committing to have some form of C-ITS readiness in vehicles "from 2019", this is quite independent from development in (for example) the bus AVL market or the market for nav-aid apps. Some industries are wholly nascent – for example "telematics" for cyclists.

The pace of cities' C-ITS implementation will be strongly coupled to these other developments. Policymakers, in their promotion of a connected future, therefore need also to also consider these other areas when setting their expectations and designing interventions.

9.4. Developing the evidence base

A city's decision and planning to invest in C-ITS (as described in section 7) is likely to depend on the available evidence, in order to demonstrate that the planned investment is sustainable and cost-effective. Such evidence is limited at present, and it is easy for cities to dismiss the most C-ITS concepts as unjustifiable: having no proven benefit and being excessively risky.

It is beyond the ability of all but the largest cities to undertake speculative investment in C-ITS research on their own. The options are too many and too technical, and they do not have sufficient personnel capacity to plan and manage them.

Central authorities therefore have (and are beginning to discharge) a critical role in gaining the necessary evidence. The EC, through Horizon 2020 in particular, is supporting R&D projects which are intended to capture evidence from city-scale deployments of C-ITS services. This has to be a continuing process, and there will be a need for the foreseeable future to sustain, interpret and disseminate this evidence to cities[37].

Elements of this Roadmap may be useful as a basis document, which can be evolved over time to provide up-to-date guidance on selecting and implementing city C-ITS services.

9.5. Funding support

Some of the key risks that cities see with C-ITS are commercial ones: cities continue to feel their budgets are very tight, and see an inexorable rise in social costs with an ageing population, high unemployment, etc.

Some of these risks are cost-related. Perhaps the prices of C-ITS will come down dramatically in a few years, or systems improve to give much better benefit for the same cost. Perhaps at least the supply market will be more mature, and products more stable, so that prices are better known and cost risks reduced.

Other risks relate to the source of funding: not so much for the capital cost of equipment, but for the revenue costs of maintenance, operational services and staffing. If cities believe that central funds might be made available for city C-ITS deployment, then they will be alert to those opportunities.

The provision of central funding support is a well-established approach to move innovations towards maturity. There are many options, from co-funding to targeted grants, competitions and challenges, that are already widely used at both European and national levels, and some of these mechanisms are already beginning to be used for C-ITS.

Cities may calculate that if their Member State government wants C-ITS enough, they will eventually pay for cities to implement. And if they do not, perhaps it was never worth doing anyway.

It is a political decision, though one that needs technical awareness, to determine the timing, mechanisms and scale of central support funding. If there is too little while the market is still immature, cities may not move and supplier innovation (in the absence of a market) may wither. However, there is also a risk that cities might wait for central funding before beginning to invest, even after suitable and well-justified products are available.

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37 As evidence develops the appropriate mechanism may of course change: possibly a future role for the C-ITS Platform.

9.6. Implementation support

As well as the simple availability of cash, a second major concern is that cities do not have a clear technical view of what actual systems need to be put in place to deliver C-ITS effectively. While consultants can assist in this, they will also be on a learning curve as city C-ITS begin to be deployed.

In similar contexts, it has proven helpful to have a level of coordination to develop and promote good practice approaches: standard models for design, operation and integration[38]. This may be delivered through a "centre of excellence", a stakeholder network/forum, or a resource library – or a combination of the three.

This implementation support would best be organised to work with and through the established networks around Europe, including those that are predominantly city-focussed and those that are more technical. The C-ITS Platform urban WG may, in future, provide (at least) a valuable meeting space for these stakeholder groups.

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38 It also helps the supply market, if they no longer have to build many slightly-different types of system.

10. Conclusions

10.1. Summary of "state of the art"

The market for C-ITS is still rapidly developing, especially those elements that relate to cities. While there has been some useful technical research and urban demonstrators are beginning now to yield some practical results, Europe is still a long way from a stable product supply market.

Developments to date have been more focussed on technical feasibility (including the development of standards) than on in-service benefits and cost-effective product engineering. There is little consensus on appropriate business models. Moreover, a range of externalities, including vehicle automation, the advent of smart personal devices, and the "smart cities" agenda, are making cities' approach to C-ITS more confusing and complicated.

A large variety of technology options have been put forward for C-ITS, and many of them depend critically on action by cities. In most case a hypothesised benefit has been proposed – but not validated in general traffic trials. The research agenda is now moving to fulfil this evidence gap, but it will be some years before a clear set of results is available.

Compounding these challenges, there is a difference of goals between the various stakeholder groups. OEMs primarily serve their customers, which is to say vehicle drivers – and much of the OEM's thinking on C-ITS is geared to car drivers specifically, since that represents the largest market. Cities, by contrast have no real incentive to make life easy for general car drivers, and would prefer to encourage modal shift, car sharing, freight optimisation, active modes and alternative fuels.

Until quite recently, OEMs were pressing ahead with C-ITS using ETSI ITS G5 short range communication, with deployment expected "from 2019". By contrast, many cities are currently more focussed on services like bus priority and traveller information, using smartphone delivery, cellular networks, and third party services using open data.

There is currently no agreed narrative that joins these two perspectives through C-ITS. However, in the past year or so there has been a marked increase in cities wanting to know more about G5 technologies, and a lot more cellular development within the OEMs. This more practical approach is very welcome.

10.2. Summary of recommended city actions

Cities will doubtless continue to explore the full range of ITS for their policy goals, and where this offers C-ITS as a practical and cost-effective solution (as for example with bus priority) they will naturally consider it.

As soon as this becomes a feasible option, it is recommended that cities begin to frame a strategic position. Many C-ITS approaches become optimised through the use of shared technology platforms:

communications channels, roadside units, central databases, open data feeds and so on. Moreover, a shared approach to business model will also assist in the programming, negotiation and support of both short term and any longer term C-ITS services.

Useful starting points in this Roadmap may be:

- Chapter 5, as an overview of what C-ITS services other cities have suggested as being of potential interest
- Chapter 7, as a quick-reference evaluation of the (current) practicality of different C-ITS services
- Chapters 6 and 8, among others, as a checklist on factors to include in the programme

10.3. Summary of recommended actions by others

10.3.1. Evidence base

It is already clear that one of the major barriers to city C-ITS is the lack of robust evidence that there is a tangible benefit for them, and unlike many highways authorities, few cities have the resources to undertake the relevant research and pilots. There is therefore a need for an evidence base to be collated.

Europe benefits from a range of projects – historical, current and upcoming – that should provide valuable evidence. These results need to be collated and made available in a manner which does not depend on piecemeal publication by projects, and is sustainable over the long term.

10.3.2. Coordination and communication

The city C-ITS market is still in its early stages and there is much to be gained from ensuring a continued level of dialogue among stakeholders. It is recommended that the valuable communication enabled by bodies such as the C-ITS Platform at European level, and connected activities at national/regional levels, should be sustained and strengthened.

These activities should develop towards services that allow for cities, and their advisers and supply chains, to contact a central focus for support in identifying current good practice and available knowledge resources – including the evidence base referred to.

Annex A: Case studies from partner cities

A.1. Introduction

To assist cities (and other stakeholders) in understanding how to proceed with C-ITS, the city partners within the CIMEC project have each considered the Roadmap in detail, and used the knowledge gained to outline their own strategic approach to C-ITS.

This Annex, therefore, consists of a set of case studies from four rather different European cities. In order to be as authentic as possible, these drafted were by the cities alone: no other project partner was involved in the preparation of these statements, and only minimal editorial adjustment (for example, on subheadings) has been applied.

Please note that the content of this Annex is indicative only, and not a commitment on behalf of the cities.

A.2. Bilbao

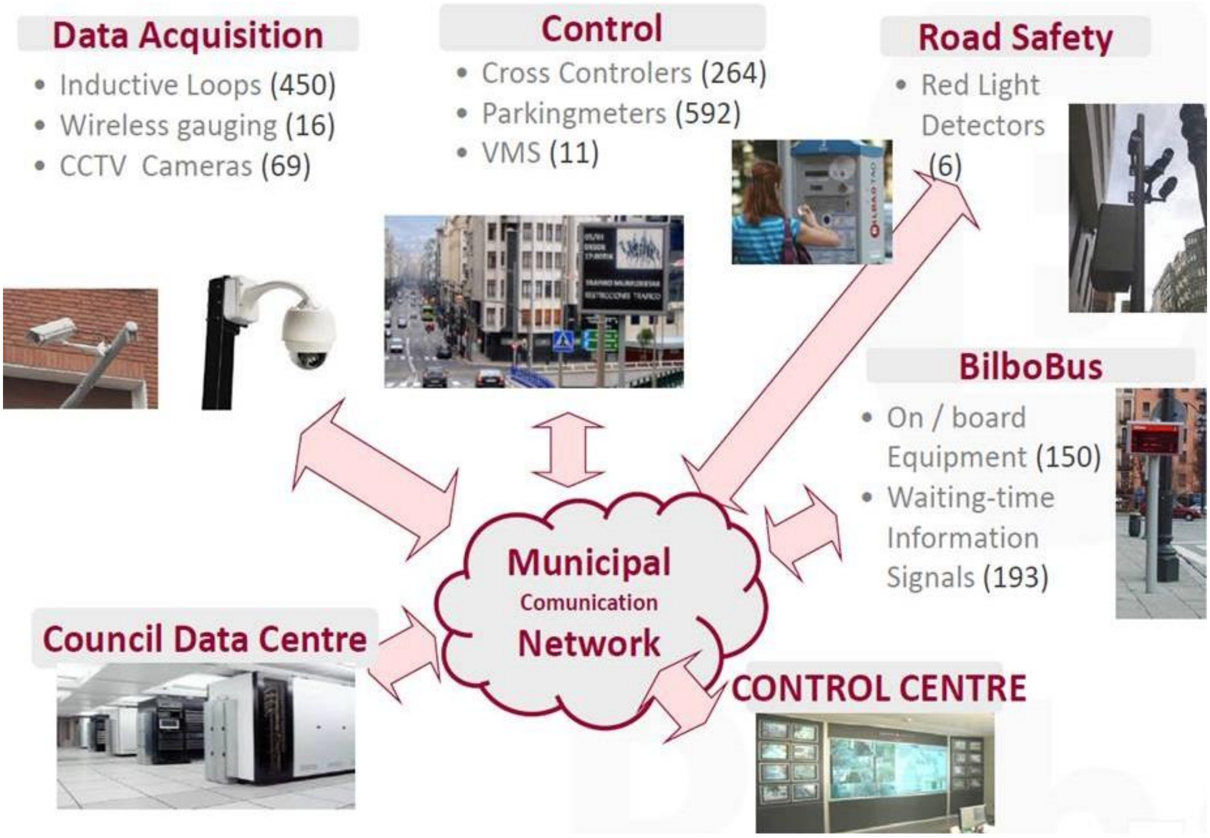
A.2.1. Current situation and current projects

Bilbao´s existing ITS and C-ITS services are the following:

The Transport Management and Information System in Bilbao allows the city to monitor and control the traffic situation. Sensors, CCTV cameras and other systems deployed in the city are connected to the Traffic Control Centre and centralizes the following systems:

- CCTV Camera system which allows monitoring of traffic conditions in real time
- Red light crossing detection system for fining.
- Vehicle classification system for categorizing the traffic information.
- Traffic lights regulation system. The centralization of traffic light system enables real-time monitoring and performance of the Traffic Control Centre on the elements of regulation.
- VMP information system to provide real-time information: traffic status on major roads, rotation parking availability and street conditions or incidents.
- Access control to pedestrian areas - Bilbao has some pedestrian areas in which specific vehicles are allowed during loading and unloading time-frames or for authorized vehicles.
- Bilbobus exploitation system support- through continuous, real time and automatic localization of bus network for its regulatory and operational control.

Figure A.1 ITS infrastructure in Bilbao



The aforementioned information is displayed in different ways: municipal website, Variable Message Panels (VMP), distributed in the bus shelters, parking access, etc.

Within Co-Cities European project, Bilbao deployed the Commonly Agreed Interface (CAI). Through this platform, Bilbao publishes static and dynamic information about traffic conditions, public transport network (Bilbobus) and rotation parking location and availability in an open and standard way.

Furthermore a bus priority system in the main corridors of public bus is deployed.

Regarding the ongoing projects and services, with the aim of improving the urban freight distribution, Bilbao is currently working on the provision of information about the availability of delivery parking slots and the integration into the open data system.

It is a C-Freight pilot zone in city centre, monitored with different technologies: Human inspections, CCTV Snapshots, Wireless Magnetic Loops, and ALPR. The data from different sources is managed in the ecotraffic platform and it is provided in open data. Through an app the user can check the availability of the delivery slots monitored on this project and adapt the route according to the real situation. Once the driver is in the slot, can get the necessary ticket and time to do the corresponding delivery service.

A.2.2. C-ITS for On Street Parking management and control system

The aim of this new management system is to improve the service of On Street Parking increasing the security, infractions and the provision of real time information to end users (disabled, delivery, special vehicles…). From January 2017 on onwards about 10 electrical vehicles with plate recognition cameras (ALPR) are circulating around the city. While the control vehicles can verify at real time if the parked vehicles are fulfilling the on street parking regulation, at the same time those vehicles can obtain real time information about parking availability. It is expected to publish the information of the parking availability in the open data platform, with the aim of developing an official app to provide parking availability information.

According to Bilbao´s ITS and C-ITS running services and the planned ones, the most interesting use cases are the following:

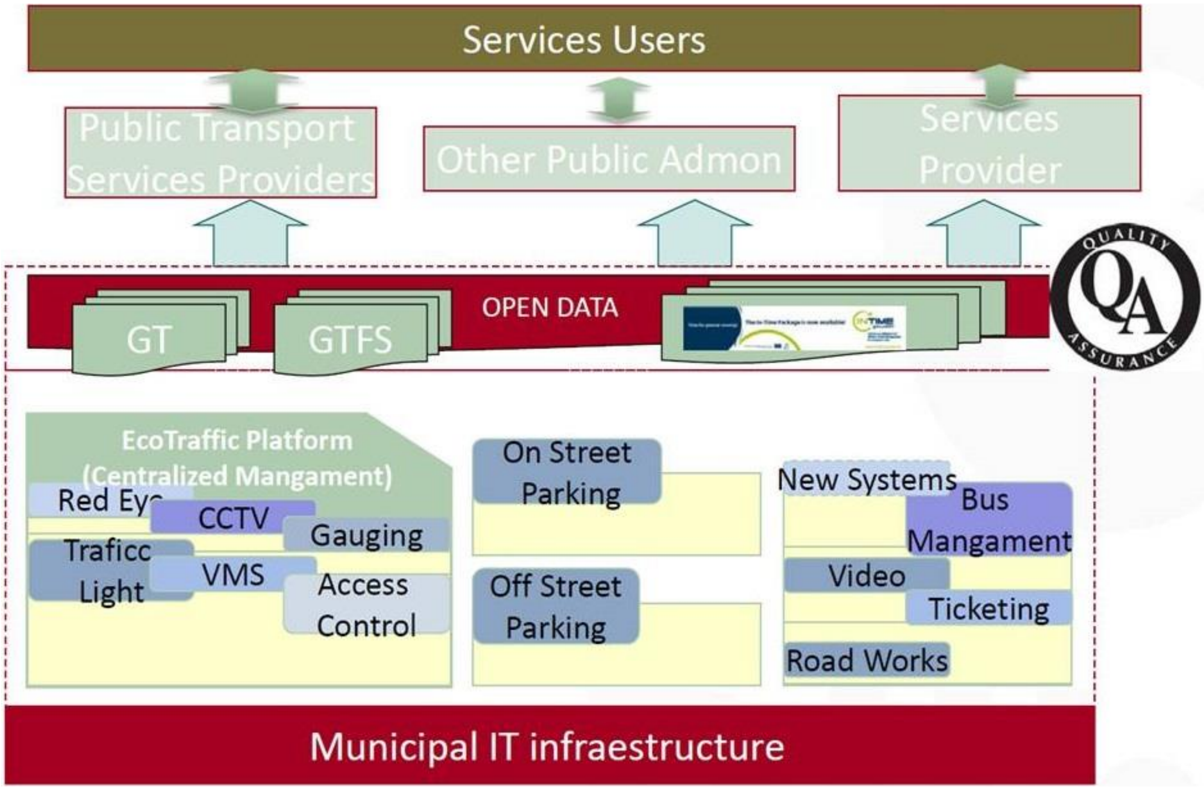
- UC4: Management of loading and unloading areas for freight vehicle
- UC9: Green lights for public transport vehicles
- UC16: C-ITS services for vulnerable road users

The general approach for undertaking this kind of projects and services is to test it first in a pilot before making any kind of investment, and in general different kind of parties will be involved depending on the project. It might be necessary to involve other administration such as surrounding cities/towns or regional administrations. It might be also necessary to have the support of a specialized consultancy to plan and develop the different features and finally, and official tender process will be launched in order to officially contract the supplier/s and executors companies.

A.2.3. Communications architecture

Talking about the architecture, the communication approach will depend on each of the specific services. It can be stated that in general the communication architecture will be hybrid, using both cellular communication and from the roadside devices. Wi-Fi, optical fibre and GPRS/3G will be some of the protocols will be used.

Figure A.2 Data flow in Bilbao



A.3. Kassel

A.3.1. Current situation and current projects

Kassel is a medium-sized city with 200.000 inhabitants in the city itself and around 1.000.000 inhabitations in the region of Nordhessen (Northern Hessen). It is the administrative, economically, educational and cultural center of the northern part of the state of Hessen.

Figure A.3 Traffic information display and parking guidance system Kassel

Kassel runs a parking guidance system since 2008 and operates 2 traffic information displays (cf. Figure A.3). In 2011 the city parliament decided to implement a traffic and mobility management system for Kassel. The plan was – and still is – to optimize traffic with the aims of

- reducing the traffic impact on people and environment
- increasing traffic safety
- reducing travel times and costs
- improving the traffic infrastructure efficiency
- avoiding building new traffic infrastructure

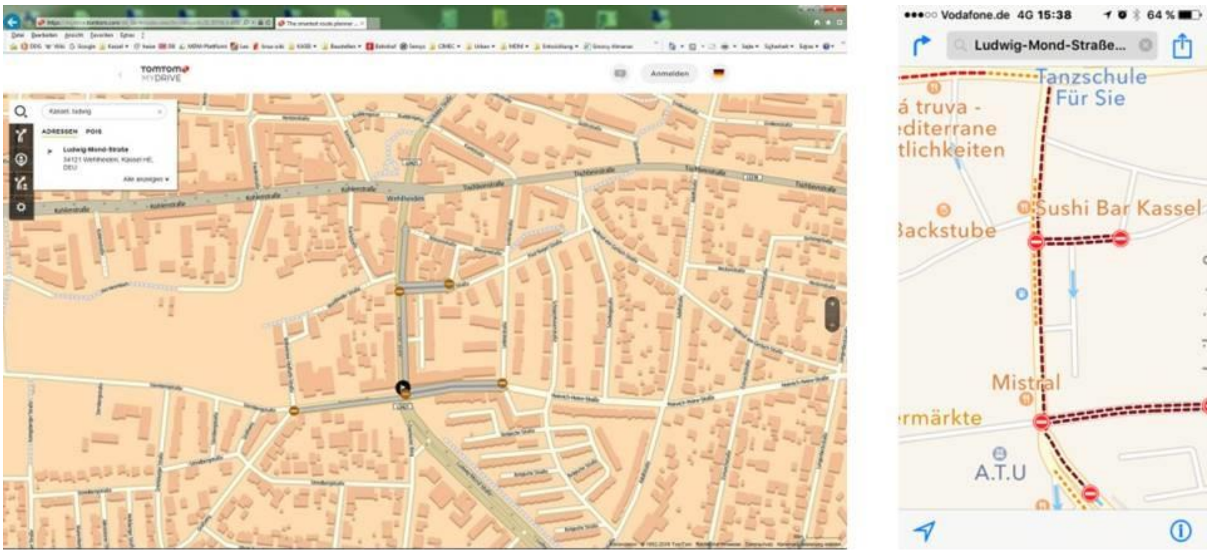
To reach these goals the city of Kassel's department of transportation works on better information and utilities for road users. That means to help them to make their proper decisions by choosing the transport mode, the travel route and the travel point of time. The benefit for Kassel's road users and inhabitants is a smoother traffic with less negative impacts.

A.3.2. Project UR:BAN

Due to the fact that new utilities are not developed or not ready to buy at the market, a participation in research projects is fruitful. Kassel's Department of Transportation was project partner in the project UR:BAN (urban area: user friendly assistance and traffic network management) funded by the German federal ministry of economic affairs and energy. During this project (2012-2015) a traffic management system (TMS) was installed to support some of the project use cases. Therefore a connection to the national single point of access (the German mobility data marketplace "MobilitätsDatenMarktplatz (MDM)") was implemented.

The TMS allows to georeference traffic incidents. Using the interface to the MDM and another one to the state agency for traffic information in the state of Hessen ("Landesmeldestelle") it is possible to exchange traffic information, like road works. Navigation system providers like TomTom use the data from the MDM to take the information into account for their routing services and inform the road users (cf. Figure A.4). This is an example for CIMEC UC 12.

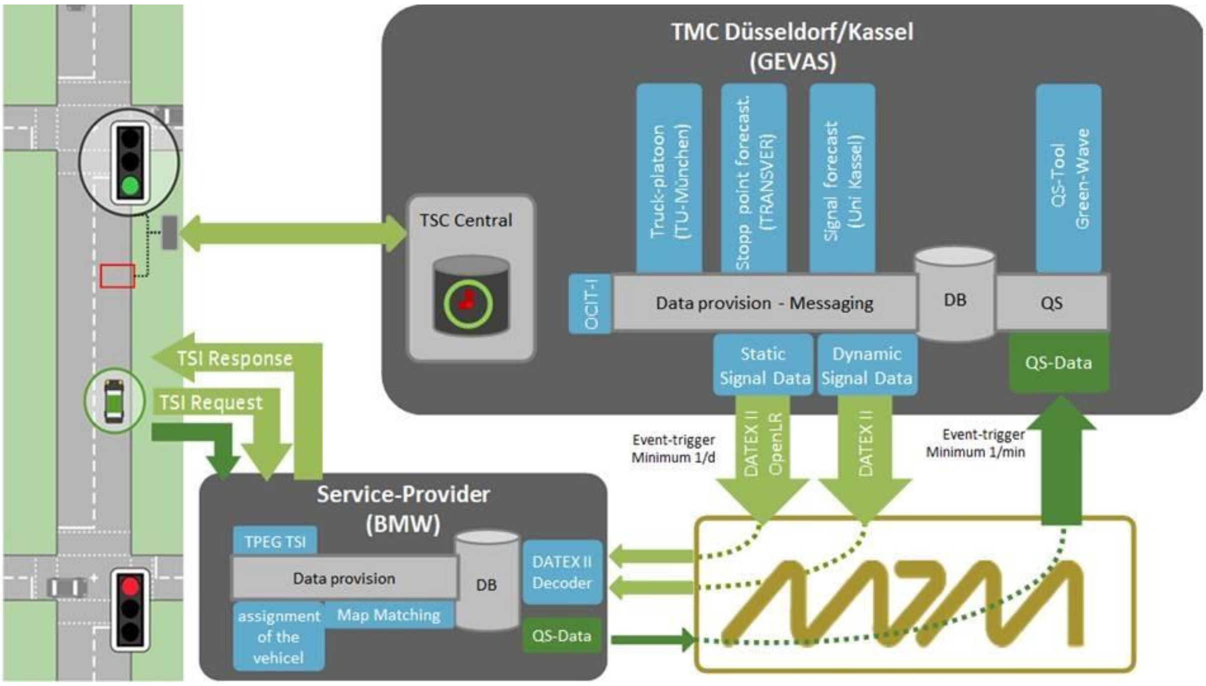
Figure A.4 Traffic information on TomTom website and iPhone app, provided by the city of Kassel via MDM



The MDM interface is also used to provide information about the vacancy of parking slots in garages connected to Kassel's parking guidance system. Several service providers use this information to inform road users via smartphone apps or web sites. This is an example for CIMEC UC 11.

One use case according to CIMEC UC 3 was tested in the UR:BAN project. The idea was to use historical data of traffic controller process data to calculate a prognosis whether the signal at the traffic light ahead will be red or green. The road user should get this information via a smartphone app to adapt its speed. The goal is to pass the next traffic light without stopping. The service is implemented in the TMC Kassel and today expanded to the most traffic lights in the city. The service is called Green Light Optimized Speed Advisory (GLOSA) (cf. Figure A.5). A study of the University of Munich demonstrated that this service can minimize negative impacts like PM10 or NOx. Kassel's Department of Transportation plans to provide this service to the public.

Figure A.5 Data flow for the GLOSA-service via TMC, MDM and service provider, according to the UR:BAN project

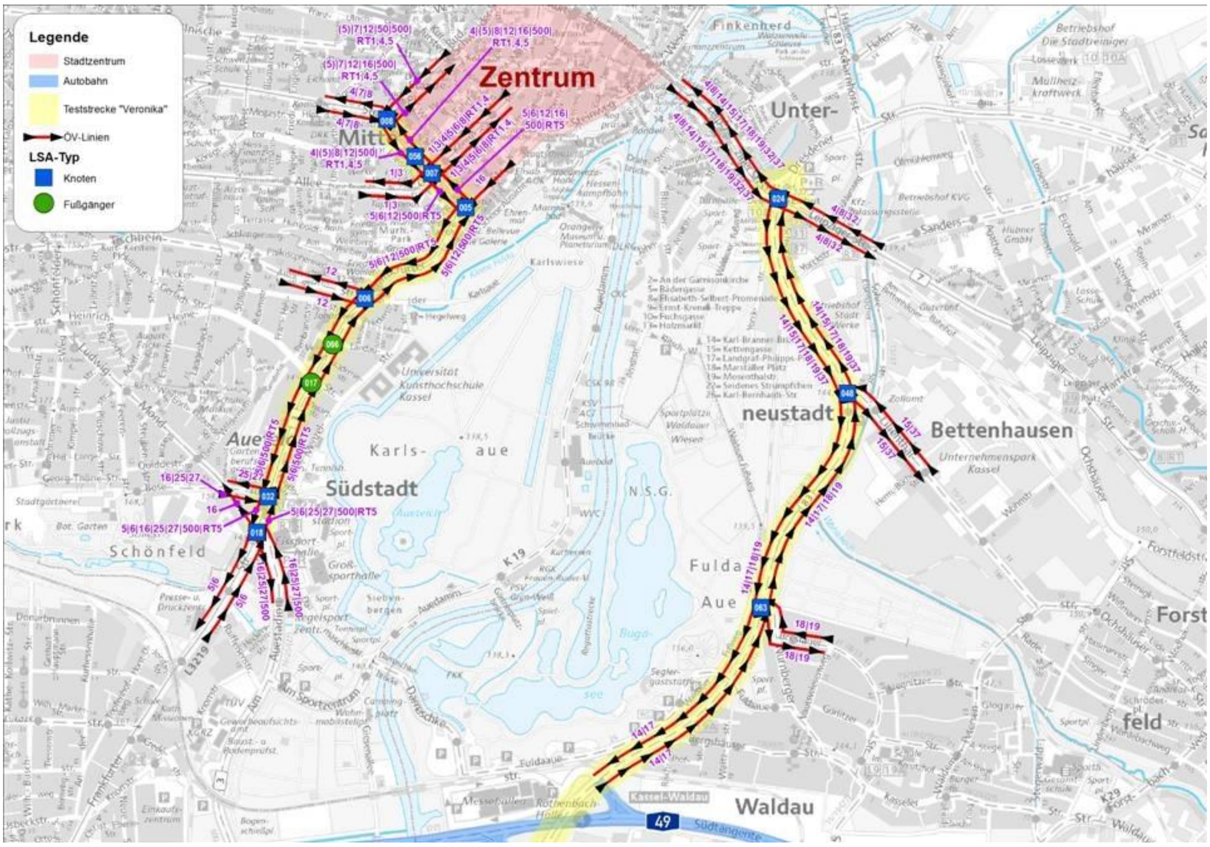


Due to the fact that it is not easy to find actions to reduce air pollution, the use case GLOSA is a part of the clean air plan for the Kassel region.

A.3.3. Project VERONIKA

In 2017 the new project VERONIKA started with participation of Kassel’s Department of Transportation. The aim of this project is to test the ETSI ITS G5-Standard for public transport priority (cf. CIMEC UC 9). The project is funded by the German federal ministry of transportation and digital infrastructure. So far Kassel’s public transport priority system, which was installed in 2002-2013 bases on beacons and a data set transmitted on a special analogue radio frequency. The ETSI ITS G5-Standard is bases on digital short range communication. This standard will be used in the test field of the project VERONIKA (cf. Figure A.6). Supplementary the technology will be tested for emergency vehicles requesting for green lights (cf. CIMEC UC 7).

Figure A.6 Test field Kassel in the project VERONIKA



A.3.4. Communications architecture

Kassel's Department of Transportation invests in communication infrastructure (like broadband communication) and quality management to provide high quality services. In addition proper work flows have to be coordinated and installed. This is the basis for good quality services. Only if the services, like GLOSA or traffic information, have got a high quality level road users will accept and use the services. This is the requirement to realize effects in the road network and the environment. And that is one reason to invest in C-ITS.

In connection with C-ITS-applications standardized protocols and interfaces are very important from the point of view of Kassel's Department of Transportation. The connections and data protocols between for example TMC and traffic controllers or TMC and service providers should be standardized. In mid-Europe (Germany, Austria and Switzerland) the OCIT-Standard is quite widespread. New releases of these standards like OCIT-O V3 or OCIT-C V2.0 are announced. They will help to implement new C-ITS-services in cities. The staff of Kassel's Department of Transportation brings in its ideas in different standardization groups. This is important to reach a widespread implementation of C-ITS solutions.

A.4. Reading

A.4.1. Overview

Reading Borough Council sees a range of approaches to C-ITS depending on the different types of use cases. Using knowledge gained from CIMEC, Reading was recently successful in securing £250k of DfT funding for a C-ITS based project. Primarily this focuses on updating the urban traffic management and control systems using Bluetooth journey time data, as a proxy for connected vehicle data, and existing state of the art VMS as a proxy for in-vehicle information which will enable Reading to prepare for in car C-ITS. Reading is also focusing on connected roadworks and connected cycles. In the longer term, Reading's strategy is to wait and see what comes forward from industry, what can be done with vehicle data and whether new C-ITS products and services represent better value for money. We have set out this longer term strategy below.

Figure A.7 Current parking information signage in Reading

A.4.2. Use Cases

In the first instant Reading's main interest is around C-ITS for public transport [UC9], Buses are already connected vehicles through the Real Time Passenger Information (RTPI) system and there is some scope to improve bus journey times through certain junctions through using this system and through better integration with the urban traffic management and control system. For emergency vehicles, Reading has already explored a number of solutions for the police, ambulance and fire, however the outcome was that the emergency services were happy with just using blue lights and sirens and hence nothing was implemented and hence UC7 is not a priority.

C-ITS for vulnerable users is seen as an early priority [UC10], increasing is a key policy goal in Reading and a part of the C-ITS funding will support connected technologies for cycling which will enable tracking and provide data on cycle pinch points where vehicles get close to cycles.

Parking Management [UC11] and Management of loading and unloading areas for freight vehicles [UC4] are both areas where Reading has interest in utilising C-ITS solutions as they come forward. Reading has recently installed over 80 on street parking studs in disabled bays to provide disabled parking services and would like to roll these out to freight in the next instance. Hence, the future of migration to C-ITS alternatives will be a logical step as services come forward.

Reading currently operate a Bluetooth based journey time monitoring system and C-ITS could be a relatively early application as a replacement to this when it comes to the end of its live. 20% penetration of C-ITS in vehicles, sufficient for journey times, is likely to be in the early 2020's but factors such as access to the data and cost of roadside units will be key factors.

In the longer term we can see the potential for C-ITS to replace loop detectors at traffic signals and roadside VMS and this is therefore not a priority. In addition, providing in-vehicle traffic signal green time information is not a priority. A lot of the traffic signals in Reading operate under MOVA control which is not currently compatible with this type of approach.

A.4.3. Communications architecture

Reading currently has a mix of wired (copper and fibre) and wireless (3/4G mobile and radio links) connecting its ITS equipment and buses. Where development is coming forward, Reading is taking the opportunity to extend its fibre links for the high band width applications. In addition Reading has secured smart city funding and is looking at a low cost IoT platform such as LoRA WAN or Sigfox. The disabled bay parking studs in Reading are already connected by Nwave, a Low Powered WAVE communications network with all studs connected to a single base station with a second station for resilience only. LP Wan is a way that Reading see connecting cycles and start / end roadworks markers in the first instance, although G5 C-ITS base stations will be reviewed in the coming years as the technology comes forward.

A.4.4. Third party involvement

Reading would expect to involve a wide range of types of third parties. Reading would expect that a number of C-ITS technologies will come forward as part of UTMC offerings from major traffic management companies. However, Reading also see that by investing in an IoT platform and encouraging innovation, we will see solutions coming forward from small innovative companies and that these will complement the main offerings. Connected cycle technology could be an example of the types of small innovative solutions. With more connected devices, big data, data management and AI become increasingly important and Reading will be investing in some 3rd party specialist data analysts. C-ITS discussion is at an early stage with suppliers.

A.4.5. Timetable

We have a 12 month timetable for the C-ITS project, which is more an enabling project for G5 C-ITS and will support the start of an IoT based C-ITS in the short term. This investment may trigger industry to continue to develop applications across a wide range of smart city areas over the next 2 years or so. Reading has £1.7m of Smart city funding to help encourage this. G5 based C-ITS projects will be considered as the technology comes forward and as G5 is rolled out in vehicles and products. G5 C-ITS will probably not be relevant to roll out until the early 2020’s for some applications and towards the end of the decade for other applications depending on how many after sales G5 units are developed and sold in vehicles and the data ownership issues associated with this.

A.5. Trondheim

A.5.1. Current situation and current projects

The city of Trondheim are in a process of both testing and implementing C-ITS technology. There are of course many reasons for doing this, but the driving force is an agreement between the national authorities and the municipality that the public transport shall be the main transport system and all future growth of transport needs of the public shall be done by public transport. If one succeeds, this will benefit all the citizens by improved transport efficiency, traffic safety and better environment. Together with the urban transport projects the NPRA have proposed some C-ITS projects that will both contribute in non urban and urban networks.

Table A.1. Use cases addressed by Trondheim

USE CASE	PROJECT DESCRIPTION AND STATUS
In-vehicle signs	Proposed project: Give information about road conditions and traffic advise before entering driving demanding roads in the mountains. Individual based information due to weight in motion results and measurement of the vehicle.
Control the access of heavy goods vehicles with dangerous goods to tunnels	Pilot proposal: Autonomous transport of walking/biking in tunnels closed for this transport.
Traffic Light management	In operation, one with time information and one with predicted speed advise.
Parking management	Two systems are in operation. - A videobased system combined with a mobile app. This is a booking system for parking slots. - IoT system with sensors. Today this inform users if there are available parking slot, but more intelligent information back to users is possible to build in.

USE CASE	PROJECT DESCRIPTION AND STATUS
Inform about incidents in the road network and control access to these areas	VMS in operation and pilot plans for more intelligent data collection.
Inform about emergencies in the road network and control access to these areas	Pilot: Online feeding of emergency information to Navi-systems, by using datex2 node.
Control access to given roads for not emission-free cars on days with poor air quality	Pilot: Geofencing system for hybrid vehicles to change driving system (electrical/fossil)

Figure A.8 Traffic light assistance in Trondheim

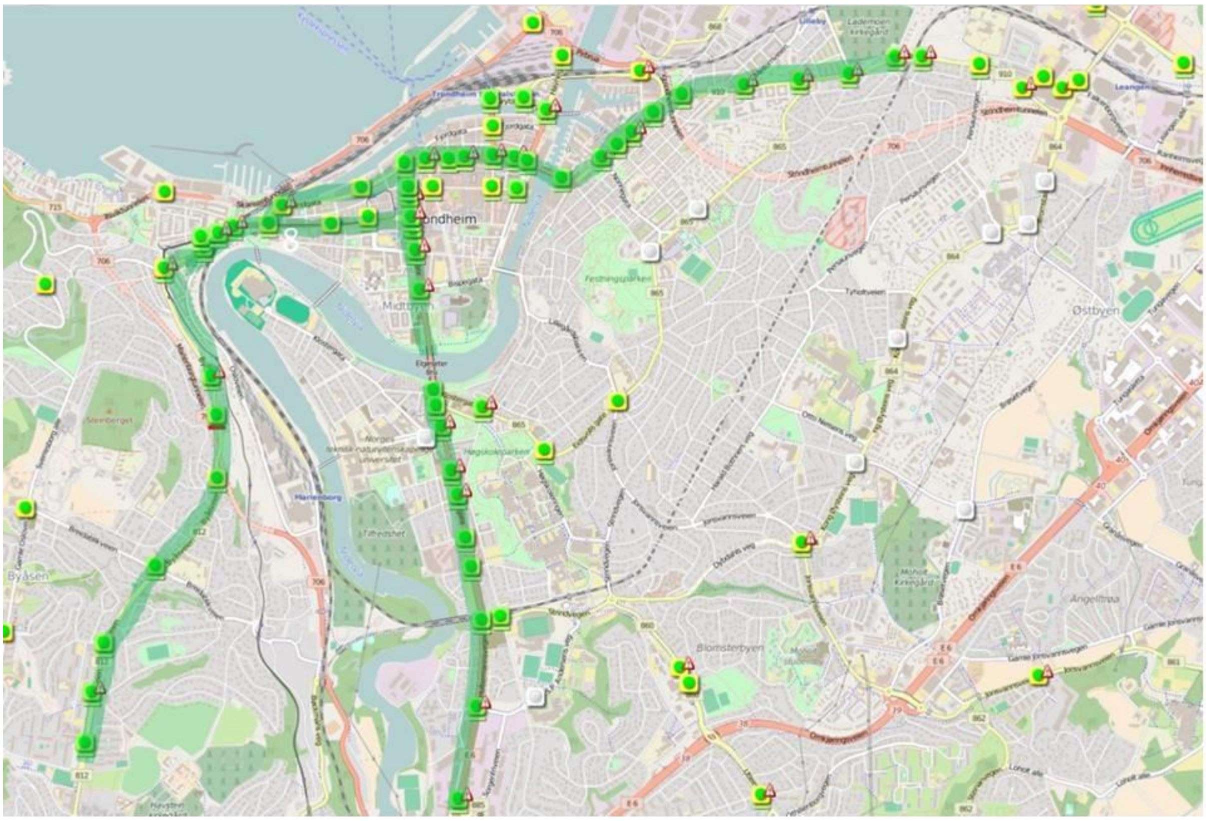
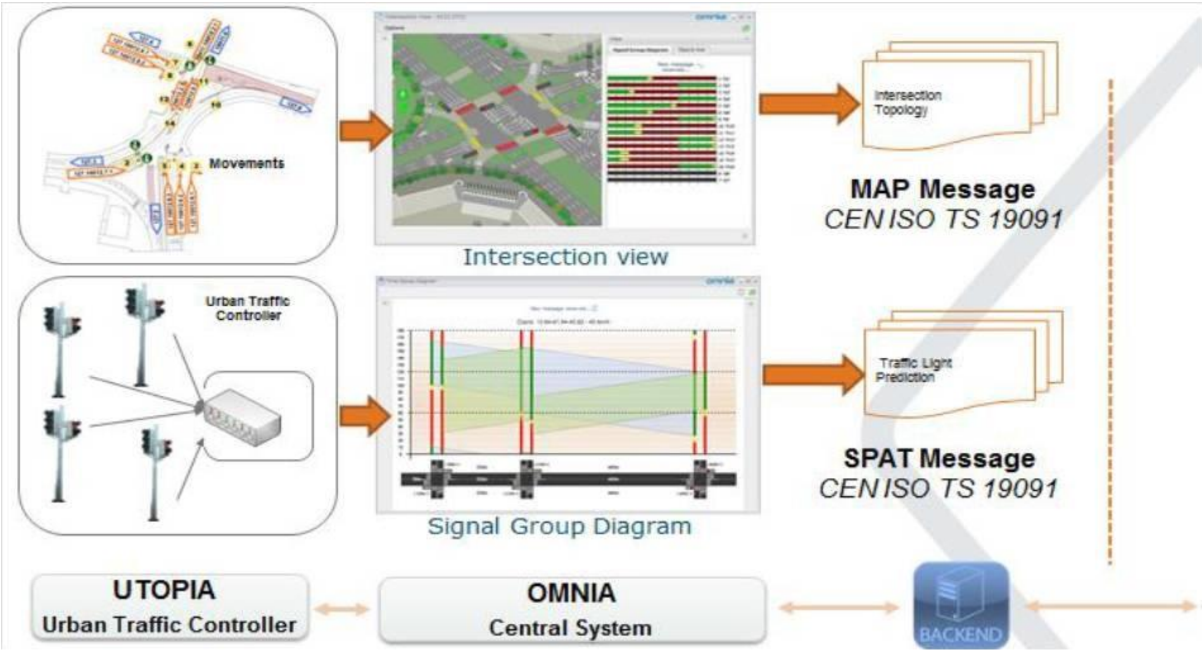


Figure A.9 Use of standards in Trondheim's TLA



A.5.2. Future projects

Other oncoming C-ITS pilots include:

- Inform about need of road maintenance based on self detecting friction from vehicle.
- Autonomous driving, pilots in operation in several cities.
- Maas, connect private transport to public transport and more efficient use of taxi

The pilots are a part of the NTP (National Transport Plan). The project plans will be set this summer and shall be implemented and evaluated within the next 3-4 years.

NPRA will be the project facilitator for the non urban pilots but for the city of Trondheim projects and pilots both the municipality and county organisation will be the main facilitators. There have been established a common arena for all stakeholders within the smart city concept. This will ensure better communication and cooperation, and testing and future implementation will hopefully be a success. The projects will also involve the local university and the resource institutes and of course local ITS suppliers. Trondheim is a front runner in ITS suppliers and standardisation work and this gives a great contribution to the projects and the systems sustainability.

A.5.3. Communications architecture

There will be used different communication architecture. Some of them will use the 5G technology and some system will use the international standards for C-ITS communication, by develop and test ITS-stations.