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

Deliverable 4.3

Feasibility study on common technical specifications for interfacing the vehicle and urban traffic management system

Deliverable number:	D4.3
Related to work package:	WP4 Strategy Coordination Support
Related to task:	T4.4 Cities requirements
Due Date:	Month 18 (October 2016)
Submission Date:	20/12/16
Lead beneficiary of WP:	Rijkswaterstaat
Version number:	1.0.0

This project has received funding from the European Union's Horizon2020 research and innovation programme under Grant Agreement No 653339.

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Dissemination Level

PU	*Public*	***X***
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Revision chart and history log

Version number	Date	Reason	Author
0.1.0	9/12/16	Initial Draft	Kaltwasser/ Cartwright
1.0.0	20/12/06	Published Version	Kaltwasser/ Cartwright

Abbreviations

Abbreviation	Explanation
ANPR	Automatic Number Plate Recognition
BTPPL	Basic Transport Package Protocol Layer
C-ITS	Cooperative Intelligent Transport Systems and Services
C-ITS-S	Central ITS Station
CAM	Cooperative Awareness Message
CEDR	Conference of European Directors of Roads
CEN	European Committee for Standardisation
CENELC	European Committee for Electrotechnical Standardisation
COBRA	Common Object Request Broker Architecture
CODECS	Cooperative ITS Deployment Coordination Support
D	Deliverable
DATEX	Data Exchange
DENM	Decentralized Environmental Notification Message
EC	European Commission
ETSI	European Telecommunications Standards Institute
HDSL	High Data Rate Digital Subscriber Line
ISO	International Organization for Standardisation
ITS	Intelligent Transport Systems
NMCS2	National Motorway Communication System (UK)
NTCIP	National Communications for ITS Protocol (US)
ODBC	Open Database Connectivity
ODG	OCIT Developer Group
OCIT	Open Communication Interface for Road Traffic Control Systems

OSI	Open Systems Interconnection
P-ITS-S	Personal ITS Station
R-ITS-S	Roadside ITS Station
RSU	Roadside Unit
SAE	Society of Automotive Engineers
SCOOT	Split Cycle Offset Optimisation Technique
SHA	Secure Hash Algorithm
SNMP	Simple Network Management Protocol
T	task
TLS	German inter-urban specification
UTMC	Urban Traffic Management System
V2I	Vehicle-to-infrastructure-communication
V-ITS-S	Vehicle ITS Station
VMS	Variable Message Sign
VPN	Virtual Private Network
WP	Work Package

List of tables and figures

Table of contents

Executive Summary

Intelligent Transport Systems (ITS) – in the sense of applying information and communication technology to optimise traffic and transport – have become a standard feature in the operation of all transport networks. This includes urban road networks, although the introduction of ITS seems to be a bit slower here than on the high-speed, inter-urban roads. Nevertheless, smart and adaptive traffic signals, park guidance and real-time information about relevant events and the current level of service of the road network and car sharing help cities to address their mobility policies.

One major challenge for cities today is to decide whether and when they want to take the next step in ITS evolution towards Cooperative ITS. The term indicates that today all elements in a modern traffic system (infrastructure components as well as vehicles and even soft mode travellers via smartphones) do have access to an abundance of digital processing power and communication means – including mobile, wireless communication – during their trip. Driven by visions of the automotive industry, a full range of technical standards has been produced in recent years by standardisation organisations like ETSI, ISO and SAE that create an ecosystem of communicative "ITS stations", which are able to share information with others inside their vicinity and hence enable distributed control strategies for their participation in the traffic and transport system.

In traditional ITS, especially infrastructure components and vehicles have mainly "observed" each other – via inductive loops, radar and infrared sensors, cameras plus image processing, etc. – rather than cooperating via machine-to-machine communication. In today's ICT terminology we would say they were not "connected". From the perspective of a city's incentive to look into C-ITS it should be mentioned here that building, maintaining and operating the sensor and actuator infrastructure for this type of systems is also creating major cost for cities, and many hope that these could be reduced significantly with the introduction of C-ITS.

But what does the deployment of C-ITS mean for this eco-system and what are the implications on potential migration paths? Is the deployment of C-ITS really feasible in this environment? These are the questions that are addressed in this document.

The conclusion drawn in this report is yes, C-ITS deployment in urban environments is feasible, but there is a strong need to make sure that the evolution from today's systems to C-ITS enabled infrastructure is done in a consistent and coherent way, addressing the need for a clear migration path from the current systems as a major prerequisite for any kind of deployment. It needs to be ensured that the different stakeholder and market actors (automotive sector, road operators, infrastructure suppliers) work together and not in parallel towards this goal.

The study finally phrases six concrete recommendations towards this goal, addressing:

- Interface interoperability
- Standards providing basic guidance
- Liaison between the C-ITS and the Urban ITS standardisation communities
- Standards tailored for use in real-world environments, including profiles and testing standards
- User guidance and support
- A dedicated group tasked to monitor progress on these issues

1. Introduction

Intelligent Transport Systems (ITS) – in the sense of applying information and communication technology to optimise traffic and transport – have become a standard feature in the operation of all transport networks. This includes urban road networks, although the introduction of ITS seems to be a bit slower here than on the high-speed, inter-urban roads. Nevertheless, smart and adaptive traffic signals, park guidance and real-time information about relevant events and the current level of service of the road network and car sharing help cities to address their mobility policies. More on the underlying considerations – and especially why city mobility policies tend to be less technology focussed than those of motorway operators – can be found in the CODECS deliverable D4.2.

One major challenge for cities today is to decide whether and when they want to take the next step in ITS evolution towards Cooperative ITS. The term indicates that today all elements in a modern traffic system (infrastructure components as well as vehicles and even soft mode travellers via smartphones) do have access to an abundance of digital processing power and communication means – including mobile, wireless communication – during their trip. Driven by visions of the automotive industry, a full range of technical standards has been produced in recent years by standardisation organisations like ETSI, ISO and SAE that create an ecosystem of communicative "ITS stations", which are able to share information with others inside their vicinity and hence enable distributed control strategies for their participation in the traffic and transport system.

In traditional ITS, especially infrastructure components and vehicles have mainly "observed" each other – via inductive loops, radar and infrared sensors, cameras plus image processing, etc. – rather than cooperating via machine-to-machine communication. In today's ICT terminology we would say they were not "connected". Sharing data was – except for a few cases like e.g. bus priority at signalled intersections – limited to centre side exchange of data via backbone networks (today almost exclusively via the Internet). This lack of communication between infrastructure and vehicles in the field actually very much shaped the architecture as well as the business logic of conventional ITS systems. A fair amount of functionality of such systems is actually addressing the fact that limited sensor data has to be used to approximate a comprehensive overview over the current status of infrastructure and vehicle traffic, which could indeed be omitted if these two – meanwhile both have become "intelligent" and "connected" – would start to exchange information locally. From the perspective of a city's incentive to look into C-ITS it should be mentioned here that building, maintaining and operating the sensor and actuator infrastructure for this type of systems is also creating major cost for cities, and many hope that these could be reduced significantly with the introduction of C-ITS. Vehicles do nowadays collect data during their journeys and detect relevant infrastructure information as, e.g., free parking lots. All infrastructure sensors of the cities have the disadvantage, that they provide low data quality if no one checks the correctness of the functionality of the sensors besides the commonly rare maintenance cycles. With vehicle data, the full control loop could be closed if providers and consumers were fully integrated. Such connectivity would be a prerequisite for connected, automated driving.

While this is certainly where the major potential benefit of C-ITS lies for cities – see discussion of city related use cases in deliverable D4.2 – the required integration of C-ITS components into the existing traffic management (digital) infrastructure is also the main technical challenge of deploying C-ITS in urban environments. The interface between the vehicle and roadside stations definitely has to be a true interoperability interface, with vehicles being manufactures all over the world and also sold all over the world. But what about the interfaces between this new C-ITS world and the urban traffic management system that they need to connect to if they want to provide the envisaged services? The world of urban traffic management systems does not have a strong record in European, let alone international standardisation. In fact, many interfaces in current systems are proprietary or apply de-facto or regional standards, maintained by stakeholder groups in the domain. What does the deployment of C-ITS mean for this eco-system and what are the implications on potential migration paths? Is the deployment of C-ITS really feasible in this environment? These are the questions that are addressed in this document.Closing the control loop by integrating vehicle and urban infrastructure data reduces efforts drastically.

2. Urban (C-)ITS architectures and interoperability interfaces

Taking a very unspecific and general, simplified point of view, the system architecture for urban ITS from a road operator's perspective can be depicted according to the figure below. The basic concept of the ETSI C-ITS communications architecture (ETSI EN 302 665) complements the existing architecture pattern, consisting of centre side and field components with equivalent C-ITS components (C-ITS-S and R-ITS-S), but extends it with the mobile components V-ITS-S and P-ITS-S[1]. In terms of interfaces this means that we have to consider whether and how to connect new and old components on the same layer (i.e. on centre as well as on field level), but also whether and how to connect field and centre side layer. Whilst the actual local communication between roadside and vehicle/personal ITS stations is well addressed by the whole range of C-ITS standards developed by ETSI, ISO and SAE – together forming what is widely referred to as "the ETSI G5 channel" or "the ITS G5 channel" – the standardisation needs regarding the infrastructure are currently not clear and different stakeholders and activist groups provide different concepts.

Discussions have been taking place inside the Amsterdam Group, the EC's C-ITS Platform and also inside the various pilot deployment projects, without a clear answer so far. While it is obvious that the roadside to vehicle/mobile interface must be an interoperable, standardised interface for C-ITS to work, this is not necessarily the case for interfaces inside the infrastructure. Some vendors of R-ITS-S systems and also some infrastructure operators would prefer an interoperability interface between existing field components and R-ITS-S. This would allow procuring R-ITS-S independently from traditional field devices, e.g. traffic signal controllers. Manufacturers of field devices argue that C-ITS is just a functional upgrade to their products, and the way the required communication module is connected internally is thus following their own internal system architecture.

[1] Actually, the fact that the mobile system components are addressed as intelligent, communicative elements of the system architecture – rather than subjects of observation – is the core innovation in C-ITS systems.

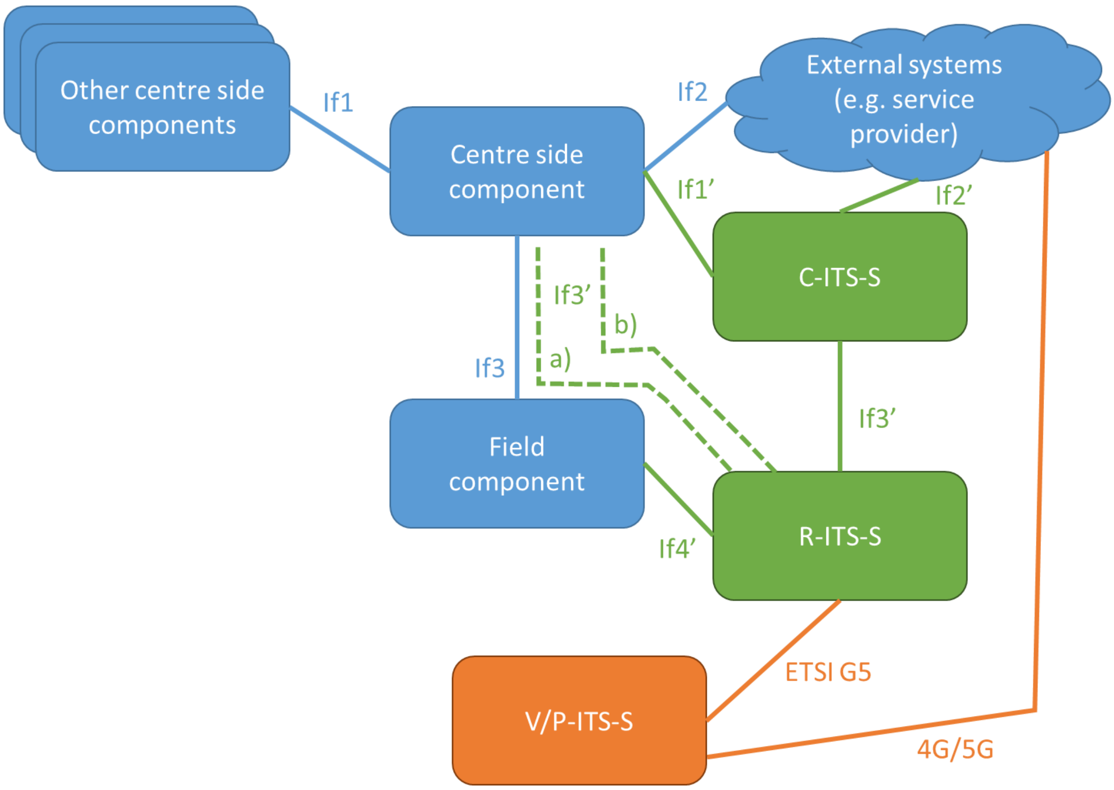

Figure 1 - C-ITS components in existing system architectures

A similar challenge is on the centre-to-roadside interface design. Today's systems operate either regional and/or industry standards on the interface connecting the centre and the roadside, e.g. UTMC, OCIT or IVERA in the urban domain or TLS and NMCS2 for inter-urban systems, or they use proprietary interfaces. Also the American NTCIP standard is used in a few places in Europe. Attempts made for formal standardisation on a European level (CEN) have in the past failed to succeed. It must be noted that interoperability is not yet required here for system operation, but it has a strong impact on market conditions and procurement processes and its influence on costs and budgets leads in many cases to drastic aging of the infrastructure components.

The same more or less holds for interfaces connecting centre side components internally. The only remarkable difference applies to interfaces connecting centres to other stakeholders' systems, where the CEN/TS 16157 family of standards ("DATEX II") is well established in the inter-urban domain and seems to attract a growing user community also in the urban sector. The following section will provide a more detailed view on these interfaces and highlight current, relevant developments.

2.1. Interoperability Interfaces

As already briefly mentioned in the previous section, it is not obvious in all cases to determine which interface must or should be interoperability interfaces and which may be based on proprietary specifications. Note that 'proprietary' does not necessarily mean at the discretion of the manufacturer or supplier. In some cases, the interface specification is effectively provided by the user of the interface as part of the procurement documentation. Nevertheless, local authorities typically do not use such procurement processes due to a lack of technical capacity.

"Interoperability" here means that the requirements for product delivery or system design specify this particular interface to be designed in a way that allows the system to be easily connected to other, non-specified and not pre-known systems. This interface characteristic is typically achieved by requiring the interface to comply with open standards, which then can be the basis for compliance assessment and component testing. The assessment, whether an interface needs to be an interoperability interface or not varies with the requirements allocated to the interface and of course also with the stakeholder viewpoint taken for the assessment. An initial assessment of the status of interoperability required by the different interfaces depicted in Figure 1and the issues currently discussed can be found in the following table.

If	Component 1	Component 2	Proposed interoperability	Contentious?	Remark
If1	Centre	Centre	Currently de-facto or regional standards, or proprietary	No	UTMC OCIT-I/C proprietary
If1'	Centre	C-ITS-S	Unclear		Requirements to be discussed in AG, corridors, C-Roads…
If2	Centre	Service Provider	Interoperable	No	CEN/TS16157 (DATEX II)
If2'	C-ITS-S	Service Provider	Interoperable	Unclear	No specification yet; Some operators prefer the path via If1'-If2
If3	Centre	Roadside	Unclear	Yes. Currently de-facto or regional standards, but work item proposed for CEN/TC278 WG17	It has to be decided whether current interfaces are expected to migrate to a EU standard.
If3'	C-ITS-S	R-ITS-S	Unclear		Requirements to be discussed in AG, corridors, C-Roads…
If3'a	Centre	R-ITS-S			Logical flow to be implemented via If4' and If3
If3'b	Centre	R-ITS-S			Logical flow to be implemented using If3' specification
If4'	Roadside	R-ITS-S	Interoperable	Yes.	Suppliers seem to prefer integration of R-ITS-S into Roadside components via proprietary interfaces

If	Component 1	Component 2	Proposed interoperability	Contentious?	Remark
ETSI G5	R-ITS-S	V-ITS-S P-ITS-S	Interoperable	No.	ETSI ITS G5 initially, but other stakeholders (Telcos) promote other solutions, e.g. 4G/5G
4G/5G	Centre	Vehicles	Interoperable	productive	All connected technology today in vehicles via service provider's backbone for in vehicles services

Table 1 - Interface overview and initial interoperability assessment

As this initial overview already shows, many questions regarding the needs for interoperability on the various interfaces are currently discussed contentiously and need final resolution before any large scale deployment can be sensibly expected. The lack of standards here can become one of the major technical obstacles regarding C-ITS deployment in urban environments. Users will largely be reluctant to implement C-ITS functionality at the price of vendor lock-in due to lacking interoperability between components. The next sections try to highlight the state of the art and the current status of this discussion in more detail.

2.2. Centre-to-centre interfaces

A "traffic centre" in the broadest sense describes a central collection of functional units ("centre side components") operated by one single organisation (the 'operator'). Nevertheless, these centres are also connected with other "centres" or systems operated by other market actors, e.g. operators of adjacent networks, operators of other modes of transport or private and public providers of mobility services (ref. If2 in Figure 1). These interfaces to other systems are denoted in this report as "centre-to-centre" interface, although especially private sector service providers would not necessarily denote their systems as "centres". From the standardisation point of view, these interfaces are clearly interoperability interfaces, since the rapidly increasing level of backbone connectivity requires almost plug-and-play like, low threshold connection complexity.

Many traffic centres traditionally support multiple standards on this interface, e.g. ALERT-C (ISO/IS 14819) for digital transmission via the Traffic Message Channel of the Radio Data System or TPEG (ISO/TS 21219) for modern digital bearers. Nevertheless, CEN/TS 16157 (DATEX II) seems to become the dominant standard on this level, fuelled by recommendations for the use of DATEX II in this scenario in recent EU Delegated Regulations (885, 886, 962) and starting initially in the inter-urban domain, but recently gaining ground also for use by local authorities. The spread of DATEX II is supported by the fact that the Delegated Regulations require the European Member States to establish national "single points of access", which often are used by local authorities as well to publish their data content, especially for use by private sector service providers.

The rise of DATEX II is not unchallenged, especially for use in urban environments. Many intra-centre interface standards (see next section) have traditionally been promoted also for centre-to-centre data exchange, in particular for connection between traffic management centres, where the systems on both sides may support common regional or industry standards, e.g. UTMC or OCIT-C. The gear towards DATEX II is seen as a 'foreign' standard being forced into places where good solutions already exist. This is complemented by the perception of DATEX II as a complex, 'heavy' standard that is not easy to implement. On the other hand, the push towards the use of DATEX II – in particular the DATEX II data model – does offer an opportunity for harmonisation of the regional standards that have so far developed in isolation. Ten years ago, UTMC, OTS2, OCIT-C and others were disparate standards in use in Europe with similar functionality but incompatible data models. Meanwhile, OTS2 has already adopted the DATEX II data model, UTMC has made an announcement to evolve towards DATEX II based data models for centre-to-centre exchange and while OCIT-C still maintains and promotes its own data model, the first OCIT-C-to-DATEX II converters are about to find their way into mainstream products on the German market.

The recent launch of the Urban ITS standardisation working group (WG17) in CEN's Technical Committee 278 may further support this development, since some standardisation projects proposed by the upfront project team PT1701 as recommendations for WG17's work program contain the ambition to migrate regional standardisation to a European level.

One challenge of this standardisation move is the fact that the DATEX II data model has traditionally been developed based on requirements from the inter-urban domain. While the overall modelling methodology and toolkit may fit perfectly also for use in the urban domain, the existing information models may not always reflect the urban requirements well, and also may important information models be missing at all. The current DATEX II model does e.g. not contain any significant modelling of traffic signals. In terms of existing information models not fitting the urban requirements, the most prominent candidate is certainly the location referencing sub-model which contains a lot of referencing systems that work very well on motorways (ALERT-C code tables, kilometering schemes…), but do not fit at all into the urban environment. A slowly but steadily growing community of urban DATEX II users has just begun to solve these problems by providing urban data models, profiles and extensions, and the DATEX II organisation – currently established under the umbrella of CEDR's chapter N7 (ITS) in the Technical Domain Network Management and co-funded by the European Commission as a Program Support Action for the Connecting Europe Facility until 2020 – has also started to address the urban user domain in their annual work program.

An interesting observation in the light of the deployment of C-ITS systems is the challenge of "hybrid communication", i.e. the desire of road operators that offer C-ITS services from their roadside infrastructure via ETSI G5 to provide the same information content to service providers via backbone access. Looking at Figure 1 there are two possible ways of doing this, either via the established If2 or via a dedicated If2', which would then provide the new C-ITS generated content directly from the C-ITS-S to the backbone. Preferences differ here significantly. Some operators run dedicated information platforms and want to integrate the new content in this platform, leading to a preference for If2. Others would like to keep all C-ITS related service bundled and hence prefer the If2' solution. In any case, the 'hybrid communication' concept has stimulated a whole wave of C-ITS related DATEX II models or DATEX II profiles with C-ITS extensions, which now will have to be channelled into the mainstream standardisation flow. The DATEX II organisation is addressing this task with a dedicated Activity that is currently analysing requirements from use of DATEX II in C-ITS pilot implementations.

2.3. Intra-centre interfaces (including legacy to C-ITS-S)

Interfaces being used by one operator internally to connect centre side components to each other have different requirements than centre-to-centre interfaces. The driver for interoperability here is not the connectivity with other systems, but the market perspective of procuring new – and maintaining existing – centre-side components. If the connectivity between two such components is realised by a proprietary interface, replacing a component may become difficult and/or expensive and the operator may sooner or later be locked into systems from one particular vendor or from a group of vendors that support the proprietary interface technology.

On the other hand, the data structures exchanged between centre-side components may be much deeper and more complex and of stronger relevance for the business processes of the operator, compared to the centre-to-centre case. While the information exchanged with external parties is mostly on the level of traffic information (traffic parameters, traffic events, etc.), the information exchanged between centre side components is typically mission critical for the business processes of the operator and often reflects technical details of the internal systems' design. Typical message content here includes configuration information for roadside devices or direct command information for roadside devices to implement operator actions. So while the information exchanged centre-to-centre is typically broad but flat – qualifying well for the heavy European consensus process in European Standards Developing Organisations – the interfaces inside a centre are rather tight but deep, which would call for a swift and lightweight consensus process, e.g. in an industry led open standardisation organisation. It will be interesting to see whether this will build up tension to decouple the standardisation of intra-centre and centre-to-centre interfaces in the future, which traditionally have often been using the same interface specification.

As in the centre-to-centre case, the C-ITS development has raised a question whether If1' in Figure 1would simply be using an update of If1 or whether this is a completely different interface, dedicated to the C-ITS part of the overall system. Current pilot deployments use all sorts of possible combinations. Where the development is driven by suppliers of existing ITS systems, the C-ITS functionality needed for IF1' is preferably embedded in the next generation of the If1 interface, e.g. the OCIT Developers Group is working on a OCIT-C version 2 which will natively support C-ITS functions for use in future urban traffic management. In other scenarios, different combinations are preferred, e.g. in the Austrian C-ITS corridor specifications[2], this interface uses the OCIT-C v1.1 transport protocol, but integrates a DATEX II based information model. In essence, a lot of the data structures on this interface are actually implied by the radio messages that in the end are to be exchanged with the vehicles on the ETSI G5 channel, i.e. they are common anyway and derived from the ASN.1 modules taken from the ETSI or ISO messaging standards and data dictionaries used on the ETSI G5 channel.

2.4. Interface from centre to roadside (including C-ITS-S to R-ITS-S)

Maybe the most important interface for setting up an urban traffic management architecture is the interface between centre and roadside. Interoperability is essential here since the constant maintenance and evolution of the roadside infrastructure is an important business process of road operators / local authorities and interoperability is crucial here to enable a mixed vendor environment and a vivid market.

The standards in use in Europe on this interface have so far been developed as regional standards with the supplier industry taking the lead in technical specification and the users (i.e. the road operators) – providing requirements. The regional nature of this standardisation construct reflects – and to certain extend creates – the corresponding market structure. Regional markets reflect the different legal framework conditions, different engineering cultures and also of course the language barriers in Europe. The OCIT set of standards (OCIT-Outstations for centre to roadside) – although today also being used outside the German language area – has originally been developed in the German speaking part of Europe (the so called DACH area). UTMC has been developed in the UK market. Other interface specifications for centre-to-roadside have been developed as national initiatives. The aspect of engineering cultures is also important to consider here. Urban traffic management systems in the UK traditionally focus a lot of business logic in the centre, whereas urban traffic management in the DACH area has developed bottom-up with a lot of business logic being locally placed in the roadside controllers. It is obvious that the design of a centre-to-roadside interface will look differently in these two scenarios.

These well justified differences have in the past led to objections against any attempt for European standardisation on this interface. C-ITS is now challenging the technical potential of the base technologies used for the established specifications and standards, and it seems as if the new requirements create a 'new spirit' situation anyway. Is this the time now to also merge the regional standards? Of course any new generation of such a standard will have to respect the huge amount of infrastructure in place and will have to address the migration path question very carefully. Nevertheless, the innovation pressure and the very mature – but also maybe saturated – interface standards for centre-to-roadside

[2] Available via the ECo-AT project website at http://eco-at.info/Specification_request.html

may probably provide a window of opportunity here to go for a European standardisation. In order to assess this situation a bit more in depth, the following sections will analyse this important interface a bit more in detail and highlight, how C-ITS requirements have an impact on the evolution of these standards.

With the current backbone technology of the connected vehicles, some roadside equipment could actually become obsolete due to the interconnection of the centres. Still remaining is the problem of positioning of the information. Different maps, map matching algorithms and positioning in vehicle and for the infrastructure providers result in serious mismatches of vehicle information. Even if the positioning issue will be solved in autonomous vehicles with technology like dGPS, the positioning of the infrastructure components was never planned to be sufficiently precise to allow for traffic control based on positioning information. In the past there had not been enough use cases to exchange information between vehicles and urban traffic management directly. With C-ITS both sides will have to change.

2.4.1. OCIT

2.4.1.1. OCIT-Outstations – state-of-the-art

The ODG[3] working group has been developing interfaces for road traffic systems under the OCIT brand since 1988. Until now, OCIT interfaces between traffic control centres and traffic signal controllers (OCIT Outstations for traffic light controllers) as well as for centre-side system networking (OCIT-Center to Center, formerly OCIT-Instations) are established on the market. OCIT interfaces have initially been developed for the German-speaking market. Due to the increasing spread of OCIT interfaces in non-German speaking markets, the OCIT-C standards are also provided in English language nowadays.

OCIT Outstations provides profiles for permanent and dial-up switched lines that allow the use of all current transmission media including Internet-based connections. Profile 3 is hence not limited to any physical transmission media. This enabled over the last years an increasing use of a wide spectrum of standard-communication techniques such as fibre-optics, HDSL based fixed network connections, UMTS cellular connections, etc.

The application protocol BTPPL[4] of OCIT Outstations is allocated above the level of the TCP/IP layer in the ISO OSI reference model. OCIT Outstations is an object-oriented communication protocol that can address remote objects in field devices via defined method calls. It supports authentication independently of IP and supports access security with a 160 Bit SHA-1 Algorithm. Currently, data transferred via BTPPL is not encrypted. Therefore, some users use VPN-techniques for connections over the Internet.

OCIT Outstations has multi-client- but not multi-master capabilities.

Due to the use of TCP/IP, OCIT Outstations has no real-time properties and therefore events and commands are always provided with a time stamp. The synchronization of cycle time counters is carried out based on local procedures in the field devices.

BTPPL works with Request-Respond messages, requestor is almost always the centre side. OCIT Outstations can be used very differently by different control centres and for this reason, field devices must always support all objects/methods in order to ensure interoperability between control centre and field devices.

In OCIT Outstations, the properties of objects/methods are specified in a machine-readable format in so-called TYPE-files (XML-file). These allow, amongst other things, central processing of manufacturer-specific message objects.

The data model (object model) of OCIT Outstations covers the following function blocks

Control

All common control switching requests are supported, project specified requests can also be implemented, for example via freely definable modifications. It is possible to address up to 4 related nodes as well as up to 4 sub-nodes.

Status information

Status information belonging to current control switching requests, information about field devices, software status etc.

Archives / Lists

OCIT-Outstations provides a configurable tool for generation and collection of data (process-/traffic data and messages) of field devices. This allows configuring, how objects are queried and when their data is stored in an archive. Archives can be persistent, date read will not be deleted and remain

[3] OCIT Developer Group, made up of 4 traffic signal system suppliers

[4] Basic Transport Package Protocol Layer

available to other systems. Archives can provide input of data according to configurable rules (EVENT) to the control centre. Process data has a time stamp with a resolution of 1/100 seconds.

All common types of process data are supported (public transport prioritisation messages according to the R09.16 standard, signal states, classified detector-raw data and their configurable aggregation, free definable user parameters etc.)

Configuration data

OCIT-Outstations supports the so-called user configuration of a subset of the configuration data set defined in OCIT-C, e.g. signal programs including on/off programs, different types of timing parameters, etc. Traffic adaptive signal programs are not standardised, but can be provided in binary containers. The configuration of the manufacturer data set is not possible with OCIT Outstations. Proprietary manufacturer tools are required for this purpose. The configured data, including version numbers, checksums and build numbers can be retrieved from the field device.

Other

In addition to the above mentioned, other functions of OCIT Outstations are provided, so for example, for configuration of message filters or queries which instances of objects are present in the field device.

The current status of OCIT Outstations does not cover all user requirements, e.g. required are:

- a practical certification procedure,
- improved test procedures for ongoing operation,
- behavioural descriptions for important functionalities
- improved functionalities for the practical support of configuration processes.

It will be difficult to solve the tasks arising from the different traffic adaptive signal control procedures in use. Users have been demanding a suitable Standardisation here already for a long time.

The described deficits on one hand as well as the lack of any legal obligation for the use of standards has led to the fact that OCIT Outstations is currently estimated only to cover 30% of interfaces operated between control centres and traffic signal controllers.

2.4.1.2. C-ITS extensions of OCIT-Outstations

The rapid development towards cooperative systems has prompted ODG 2014 to start development of C-ITS extensions for OCIT interfaces.

For OCIT Outstations, two draft documents have been available since April 2015, which specify C-ITS extensions for traffic signal controllers. Furthermore, one document was developed for the field device type „Roadside Unit“ RSU, which specifies C-ITS communication detached from a traffic signal controller. The present documents, which have not yet been fully specified, cover the following new functionalities:

- Transmission of the topology information for a junction to the control unit and monitoring topology information stored there respectively
- Measurement query for the representation of a vehicle within the intersection area (travel distance and the travel time of the vehicle)
- Query for aggregated lane specific and connection specific values
- Query for CAM messages with rescue-, emergency- or safety-car containers
- Query for DENM messages (construction zones, accidents, critical road sections)
- Sending public transport request telegrams from the control centre to the field device

- Query the current signal status of the traffic signal controllers and the time until next status exchange
- Query of predicted duration for the current status of a signal group, or transmission from the control centre to the field device, respectively
- Query of predicted residual signal time for one or more signal groups, or transmission from the control centre to the field device, respectively

ODG has not published any announcement so far when the documents will be finally released. ODG is currently requesting users is to carry out pilot projects to prove practical usability for roll-out of "Day 1 Use Cases".

No information is currently available about the shape and timing for the corresponding C-ITS extensions for OCIT-C.

2.4.2. UTMC

2.4.2.1. Organisation

In the early 1990s, the UK Department for Transport (DfT) initiated the UTMC research project in order to address the challenges of an increasingly diverse ITS marketplace. This led directly to a six-year DfT-funded R&D programme to trial deployment of such integrated systems, with the supporting research on standards and good practice captured in an open information framework.

Since 2004 UTMC has provided the de facto framework for the traffic management systems marketplace across the UK. Through UTMC, the competitive supply marketplace and the interoperability of systems in the UK has been significantly boosted.

The UTMC initiative is currently managed directly by its user community, the UTMC Development Group (UDG)[5]. Commercial work for the UDG is managed through a not-for-profit company, UMTC Ltd. DfT continues to participate and to be actively interested in UTMC developments.

2.4.2.2. General architecture

At the core of the UTMC initiative is the UTMC Technical Specification. This is a substantial, complex and evolving library of documentation, but its underlying philosophy is simple: use mainstream technology, set standards where useful, be created and maintained by consensus, and be open and readily available. The UTMC architecture includes a framework of five generic "nodes".

The two core nodes are referred to as "Node B" - functional elements (i.e. computing systems and software services) in a traffic management centre/traffic information centre - and "Node C" - functional elements on the roadside. Between them, these nodes supply UTMC systems with their intelligence. The eyes and hands of a UTMC system are provided by controlled elements at the roadside ("Node D").

Nodes B, C and D cover the ITS facilities that a city will have at its disposal. The current UTMC technical specification addresses principally these three elements, and the specific means for them to interact. Base data and contextual data specifications cover Transport Links/Transport Routes, Accidents/Events/Incidents, Car Parks and Roadworks. For device management, there are defined data specifications for both Detectors (including loops, ANPR, CCTV, Air Quality/Weather etc) and information/control systems (Access Control, Traffic Signals and VMS).

[5] UDG is a membership organisation: its elected Management Group contains both local authorities and supplier representatives.

For data management and analysis purposes, UTMC also includes framework data objects to cover profiles and predictions.

These elements of architecture were originally developed during the mid-late 1990s, drawing input from a range of external initiatives around the world.

In principle, UTMC is neutral to communications technology: each city is free to choose which communications service most cost-effectively enables each connecting data stream to be provided. In practice, UTMC systems are built to a fairly common networking approach, which includes:

Existing (legacy) communications where it is difficult or expensive to replace – often between Nodes C and D

IP communications from centre to roadside (between Nodes B and C), currently predominantly using SNMP[6]

LAN communications between centre applications (Node B to Node B), using Ethernet, IP and standard LAN data technologies including ODBC, CORBA and XML

UTMC remains open to external good practice and seeks to draw wherever possible on established standards. However, for these core components, it has discovered only a few relevant external activities that is can absorb easily (such as jpeg/mpeg for imagery and video). For example, OCIT is not readily compatible with UK traffic control systems such as SCOOT.

2.4.2.3. External connectivity of UTMC

Outside the city control, UTMC envisages two further nodes: Node A represents other centres with which the city needs to interact (other cities, highways, police, public transport companies etc), while Node E represents mobile road users.

Unlike for the internal architecture, these elements are well supported by external initiatives. Specifically, UTMC has always referenced DATEX (now DATEX II) for the Node B – Node A link, which covers all centre-to-centre exchange traffic data. The continuing development and rationalisation of DATEX continues to strengthen this connection.

For consistency, there is an ongoing programme to align “intra-UTMC” specifications with DATEX II. In particular, extensive reworking of the UTMC VMS specification has been undertaken, so that it now includes a centre-to-roadside protocol based closely on the DATEX specification, which is now codified in CEN/TS 16157-4:2014. Similar work is underway with respect to traffic signal control.

The other external link, with Node E, is what we now recognise as being the C-ITS interface. The technical situation of this is, clearly, at a much earlier and less-well-developed stage than for Node A links, and even the requirements are much less well understood. UTMC is therefore following European C-ITS initiatives with keen interest.

The UTMC philosophy and architecture allows for three possible C-ITS models, depending on whether the mobile unit connects directly to the roadside (Node C or D, perhaps with a local communications channel such as ITS G5, WiFi or Bluetooth) or to the centre (Node B, probably through a commercial mobile channel). The choice of architecture is expected to be made – as for the rest of UTMC – by considerations of cost effectiveness.

2.4.2.4. Shortfalls of UTMC

As with OCIT, there are a number of areas in which UTMC is silent: it does not specify system functionality, it does not specify performance/quality levels, it is reliant on supplier self-certification, etc. Some of these are deliberate choices: for example, the development of functionality is seen as a key area for supplier innovation and UTMC does not want to constrain this. Some is a result of user priori-

[6]This is aligned with, for example, the US NTCIP architecture

tisation: community effort is naturally deployed where the interests are strongest. And some is a simple matter of economics: product certification is time consuming and expensive to do, and no-one is willing to pay for it[7].

2.4.3. Other European standards

National standards have been developed in the transport technology market also in several other EU countries (IVERA, DIASER, VnetS…). In Spain, the American NTCIP standard has been used by some operators. In essence, this development has been and is driven by the manufacturers and their respective market interests.

While these existing standards are largely identical to OCIT's / UTMC's application level functionality, most of them are not based on modern ICT base technology. This circumstance, among other things makes integration of C-ITS extensions more difficult and is hampering the EU-wide market opening since the national markets of transport technology are simply too small to bear with the significant development costs for several national standards.

The following proposals are recurrently discussed to mitigate the described problems:

- Development of EU communication protocols (Instations and Outstations) according to the ICT state of the art
- Standardisation of traffic adaptive control algorithms
- Introduction of certification processes

2.5. Interface between roadside components. In particular legacy controllers to R-ITS-S

Another interface that traditionally is not standardised in Europe is the local interface between different roadside components. Even before C-ITS systems emerged on the horizon, the roadside sub-systems already contained multiple components. Nevertheless, these have traditionally been seen as different configuration options from one supplier. There are exceptions, but these are rare and typically handled via supplier cooperation. As an example in the DACH region, algorithms for traffic adaptive signal control algorithms can be procured independently from the signal controller, but the integration of the algorithm in the controller is based on bilateral cooperation between the suppliers and not on the use of interoperability standards. It should be noted here that this is very different for example in the United States, where a common traffic signal controller reference model exists and components can be procured independently from each other and integrated by the operator.

Again, the challenge of integrating C-ITS functionality in the field devices now re-raises the discussion of this approach. The existing field devices have to be connected to C-ITS roadside stations (R-ITS-S). For some scenarios it might be possible to avoid the local connection by connecting both field components to their respective centre side component. But in other scenarios and other use cases, the local connection is mandatory (If4' in Figure 1). One typical scenario is the provision of V2I services via field devices in situations where the centre-to-field connection is implemented via cellular networks and not always available. Examples are the stand-alone mode for roadworks warning using safety trailers or traffic signal controllers that are connected to the centre via cellular communication and do not maintain constant connection to the centre. In such situations, the content for V2I messages sent by R-ITS-S has to come from the traffic management field device via a local connection.

The preferred architecture for this local connection is currently widely discussed and very different proposals compete with each other. As already stated earlier, suppliers of established traffic manage-

[7] This is even true of safety critical systems such as traffic signals. A separate UK initiative, TOPAS (http://www.topasgroup.org.uk/) provides a compliance register for key products, but is not involved in certification.

ment systems simply integrate the R-ITS-S as an optional feature into their products. The connection between the 'traditional' and the 'cooperative' components is internal and remains at the discretion of the manufacturer. Others demand for an interoperability interface here, arguing that the R-ITS-S is an innovative, high potential component of future C-ITS enabled mobility and that there should be a flourishing market for innovation of such systems that should not be forced into the constrained, conservative market of traffic management field devices. This is also stimulated by the discussion about the system architecture of roadside systems. Some promote the EN 320 665 architecture as a general proposal for all roadside systems in the future, where the actual application (e.g. the traffic signal control algorithm) would just be one application amongst others. Others see this only as the internal architecture of one new dedicated roadside component (the R-ITS-S), which is then connected to other – existing or to be developed – roadside components.

3. Interfaces and standardisation

This report is titled *"Feasibility study on common technical specifications for interfacing the vehicle and urban traffic management system"*. As we have seen in the analysis presented in the previous sections, the main specific technical challenge for integrating C-ITS in the urban environment – besides the common C-ITS deployment challenges present in all environments like security, data privacy, etc. – is the integration of C-ITS components in the urban traffic management system. The main issues to address are the interfaces used to connect the new components with the legacy system, which have to be interoperable to open up a potential migration path. Interoperability of interfaces requires consensus about the use of common specifications, and such consensus is normally laid down in standards.

3.1. Urban ITS standardisation so far

As pointed out already in the overview of urban traffic management system architectures in the previous sections, standardisation of interfaces being internal to the system landscape of the operator in Europe has so far been predominantly organised on regional level, i.e. there has never been a successful large scale, "top-down" standardisation initiative for these internal interfaces on European scale that would – for example – compare to the NTCIP approach in the United States. Some attempts have been made inside the scope of CEN TC278, but all failed to deliver European standards being actually used in the field.

The reality on the markets have actually created a different structure, where local communities have developed around regional markets that found a way to self-organise a structure to create and maintain requires standards (ODG and OCA in the German speaking DACH area, UDG and UTMC in UK, IVERA in the Netherlands, etc.). The standardisation processes here are typically tailored, swift and slender, compared to 'heavy' processes in the officially accredited European Standardisation Organisations CEN, ETSI and CENELC. Nevertheless, they also reflect a more limited scope of consensus. Even these standards are sometimes perceived as a burden rather than a benefit and suppliers offer even leaner options based on their own proprietary interfaces. The risk of vendor lock-in on one hand and the benefit of tailored, proprietary on the other have to be understood as the two sides of one coin.

This is obviously different where it comes to external interfaces, i.e. interfaces that connect system components under control of the operator to third party systems. Interoperability and the use of standards is mandatory here. This external connectivity has started quite a while ago on with backbone interfaces connecting traffic centres to other stakeholder systems (e.g. service providers) via the Internet. CEN/TS 16157 (DATEX II) has been established as a standard here and gradually finds its way into urban traffic centres, although the previous section already indicated that different communities follow that path on different levels of enthusiasm. In a similar way we see now the emergence of the ITS G5 channel – expected to be rolled-out in European vehicles from 2019 on – as an interoperability interface to connect infrastructure to vehicles on a large scale, covered by a full set of international standards and profiles from ETSI, ISO and SAE.

The opportunities of C-ITS have stimulated considerations which steps in standardisation of interface for urban traffic management would be beneficial for the near future, based on two main observations:

a) Many specifications in use in the urban domain are very mature and their ICT technology base or their basic paradigms are probably outdated. Loosing track if ICT mainstream developments and maintaining outdated ICT specifications lead into a dead end, since the small ITS market is not able to carry technology maintenance and since ITS system are no silos but integrated into the whole ICT environment of the road operator organisation.

b) C-ITS promises benefits, but also provides challenges with entirely new data quantity structures and timing requirements. If C-ITS is to be incorporated into the next generation of traffic management systems, the next generation of interfaces of such systems must be able to cope with these requirements.

Many expect that this will eventually lead to a re-assessment of the situation and eventually European standards will be developed for urban traffic management that allow for migration from current status and also enable C-ITS functionality.

3.2. Current Plans

On 12 February 2016, the European Commission published the Commission Implementing Decision C(2016) 808 regarding a standardisation request to the European standardisation organisations as regards Intelligent Transport Systems (ITS) in urban areas in support of Directive 2010/40/EU, which is better known as Mandate M/546. The proposals found in the annex for an extensive work programme on urban ITS had been fuelled by the deliverables of a dedicated pre-study on this topic carried out by a dedicated project team (PT1701). This teams had been tasked to look into “Standards and actions necessary to enable urban infrastructure coordination to support Urban ITS”, and to identify resources required to develop them.

The work of PT1701 was of course based on the EC's ITS Action Plan (2008) and the subsequent ITS Directive 2010/40/EU, but further also on the work proposed by the Urban-ITS Expert Group that had addressed gaps in standardisation in the domains of:

- multimodal travel information (e.g. data formats for new mobility services)
- urban logistics (info & reservation of loading bays, intelligent parking) and
- traffic management,

showing a renewed focus on the urban dimension in EU transport policy.

Meanwhile, CEN had launched a dedicated working group for "Urban ITS" inside TC278 (CEN TC278 WG17), which had its Kick-Off meeting in autumn 2016.

Quite a few work items proposed by the pre-study for considerations address interoperability interfaces discussed - directly or indirectly – in the previous sections of this report. In its section addressing traffic management, the mandate explicitly says: *"Compatible data formats, open and documented interfaces and protocols for transmission of relevant data, independently of their source (e.g. sensors, floating car data, traffic control centres), and their integration in current and future traffic information systems and traffic management operations, for various road networks including urban-interurban links, shall be ensured (i.e. worked out where necessary). "*.

Although this definition is obviously not going technically deep enough to identify which of the interfaces in Figure 1 is directly addressed by these standards – i.e. only the external ones or also the internal interfaces? – it clearly shows the impetus to address the standardisation of interoperability interfaces in urban ITS systems now on a European scale.

It should be noted that the initiative leading to Mandate M/546 and the launch of CEN TC278 WG17 is addressing urban ITS in general and not C-ITS in particular. To this end, this initiative is complementary to the general standardisation work on C-ITS covered by mandate M/453 and addressed partially in ETSI TC ITS and partially in CEN TC278 WG18 (which is identical to IS TC204 WG18). It is currently not clear, which of these initiatives will be addressing the standardisation challenges described in the previous sections, in particular the issue of migration path / connecting to legacy systems. It could be argued that the legacy interface would belong into WG17 rather than WG16, and some of the detailed work item proposals elaborated by PT1701 in their final report actually would allow to host these issues, but final confirmation will have to wait until respective work item proposals for either of the CEN Working Groups have been adopted.

Suppliers of urban traffic management systems are currently busy to work on making their products "C-ITS enabled". This includes work inside the domain standardisation groups on new versions of their interface standard that are expected to support C-ITS functionality. The OCIT Developers Group ODG for example has announced that a new version of their outstation interface OCIT-O v3.0 can be ready for field tests in April 2017, similar announcements have been made by the IVERA group in the Netherlands. But beyond the continuation of standardisation in regional clusters, many suppliers have also noted the EC standardisation mandate and showed interest in participating in corresponding work items in WG17. So it may indeed be the time now to work on the next generation of urban ITS interoperability standards, with C-ITS enabled functionality, based on an up-to-date ICT basis and system architecture and for the first time on a pan-European scale.

4. Feasibility of C-ITS deployment

Is C-ITS deployment in urban environments feasible? The answer to the main question addressed by this report will be a "Yes, but…".

Integrating C-ITS into urban traffic management systems (and hence connecting the urban traffic management infrastructure with the vehicle) is technically feasible by updating some of the interfaces in the architecture presented in section 2 of this report to incorporate the functionalities and data definitions required to establish an end-to-end link from the traffic management centre, vie the ITS infrastructure to the vehicle. But of course this must be an update of existing interfaces in order to open up a migration path from the current legacy system to a future system that includes C-ITS enabled components.

Some suppliers and also some industry standardisation groups have already announced upgrades of their products, specifications, standards to be "C-ITS enabled" in the near future, but it is yet to be seen how much C-ITS will actually be possible via this path. Proponents of C-ITS promote their "ITS station architecture" as a blueprint for all systems involved in C-ITS, be it for vehicle, nomadic device, infrastructure or centre. This approach would be looking for integration of the existing business logic into the ITS station concept as a migration concept, and that would certainly be much more revolution than evolution, compared to the approaches taken by the current ITS infrastructure suppliers.

IT has to be admitted that most current interface technologies used in the current legacy systems are at a rather late stage of their life cycle. It is not only the potentially exploding amount of data becoming available via C-ITS that suggests to re-think basic architecture assumptions and ICT base technology choices, that often date back into the last century. It is also the fact that ICT is a fast moving business compared to traffic and transport and that this domain is too small to afford maintaining technologies that are abandoned by the ICT mainstream. At the end of the day this means: if the ICT mainstream moves, ITS has to follow suit. We will see how new emerging technologies will influence this discussion, especially new technologies coming from the Big Data community certainly address scenarios that are rather similar to processing vehicle data from all moving vehicles in a road network.

So the answer is Yes, but there is a strong need to make sure that the evolution from today's systems to C-ITS enabled infrastructure is done in a consistent and coherent way, addressing the need for a clear migration path from the current systems as a major prerequisite for any kind of deployment. It needs to be ensured that the different stakeholder and market actors (automotive sector, road operators, infrastructure suppliers) work together and not in parallel towards this goal. The successful first infrastructure oriented ETSI Plugtest in Livorno in November 2016 is an example, how this cooperation can work. The EC with its various activities in the domain of C-ITS as well as the domain of Urban ITS needs to ensure that the policies developed and the steering signals given in both strands are coherent and foster this cooperation.

5. Recommendations

Based on the feasibility analysis in the previous section, the following concrete recommendations can be derived:

1. Interoperability of all relevant interfaces in the urban ITS system architecture by pursuing relevant standardisation work must be ensured. The ITS market is small and market players have no strong background in EU level standardisation. Extra support from the EC may help to avoid fragmented solutions and interoperability gaps.
2. Basic and commonly shared and accepted standards need to be provided upfront that allow all stakeholders to understand the subsequent technical detail work and ensure that stakeholder communication and consensus can be facilitated.
3. A constant and constructive liaison must be established between the urban ITS community (active in standardisation in the scope of Mandate M/546) and the C-ITS community (M/453 and successor activities). In particular, close cooperation of CEN TC278 WG16 and WG17 must be fostered.
4. Standardisation work must be geared towards interoperability. In particular, base standards must be accompanied by application profiles and testing standards that allow users to procure systems and deploy services that are truly interoperable.
5. Beyond the mere specification & validation work and the consensus finding that takes place or at least can take place inside the standardisation working groups, user guidance and support must be ensured that makes the complex technical standards accessible to users. Experience with emerging ITS standards in the past (e.g. DATEX II) has shown that this important aspect is usually under estimated. Inaccessible standards – even if technically sound and useful – will not make impact on the market.
6. Since all previous recommendations are process-oriented, it is recommended to establish a group – or task a suitable existing group – to monitor these aspects on a regular basis and react in case that developments don't show the expected progress.