E-FRAME

Extend FRAMEwork Architecture for Cooperative Systems

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D7 & D8 - Physical and Communications Viewpoints for ITS Architectures of Cooperative Systems

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TCC	Traffic Control Centre
TIC	Traffic Information Centre
OBU	On-Board Unit
CoSy TF	Cooperative Systems Task Force
TEN-T	Trans-European Transport Network
ITS	Intelligent Transport Systems
(X)FCD	(Extended) Floating Car Data
ABS	Anti-locking Breaking System
ESP (ESC)	Electronic Stability Control
VMS	Variable Message Sign
ETA	Estimated Time of Arrival
POI	Point of Interest
PS	Personal Service

Executive Summary

This document provides an introduction to creating ITS System Architectures for Cooperative Systems applications with the FRAME Architecture tools, and demonstrates this process using two examples from cooperative ITS.

An ITS Architecture is not an end in itself; it is a means to an end and can be considered to be a tool for planning, building and managing Information Systems (with a link to their organisation). In particular, it provides the basis on which the planning, including the creation of the business case, and deployment of ITS can take place. Thus an ITS Architecture provides a mechanism to understand ITS services at the “application level”, and for the principal components needed to provide them to be identified.

In this document two ITS applications are designed with the FRAME Architecture, the first of which represents the first level priority services for the European TEN-T Network of the Cooperative Systems Task Force of the EasyWay project, and the second represents an example called “Traffic Adaptive Crossing” which can be installed on any road intersection.

The Functional, Physical and Communications Viewpoints for each application are described. The Functional Viewpoint provides the basis of the Architecture, describing all the functionalities performed by the system, all the external Terminators connected with the system (e.g. as data suppliers) and all the data stores being used by the system. The Physical Viewpoint provides a view of the system that shows where the location of functionalities and data stores are defined and organised in groups, called Sub-Systems and Modules. The Communication Viewpoint describes all resulting physical dataflows in detail, including their estimated data sizes, recommended data rates and suggestions for communication standards to be used.

The selected examples show on the one side the wide applicability of the FRAME methodology at a European Level, and on the other side that the additional complexity of cooperative ITS in terms of functions, modules and data can be handled with the updated versions of the available tools.

These documented examples are fully available for the future users and can be a starting point for a related activity in the cooperative ITS domain.

1 Introduction

1.1 Scope of the deliverable

The Extended FRAME Architecture is a starting point from which specific ITS implementations can be planned. In order to visualise this potential, Deliverable D7/D8 will show how the Architecture can be used to describe Functional, Physical and Communications Viewpoints of typical Cooperative Systems.

The Functional and Physical Viewpoints show which components will be needed, the functionality that they contain, and how they are to be distributed between the sub-systems at different physical locations (e.g. roadside, in-vehicle). The Communications Viewpoint will be created from the Physical Viewpoint. It will describe, at a high or generic level, the consequential data links between the subsystems.

1.2 Overview of the document structure

This document will start with an overview of the FRAME architecture. It will give a short introduction to the FRAME Architecture and explain the concept of 'User Needs' and the Functional-, Physical-, and Communications Viewpoints.

Chapter 3.1 describes the first example – the priority services of the EasyWay Cooperative Systems task force. All steps of the Architecture creation process will be examined in this example – starting with the service description and user needs, and including all three viewpoints, functional, physical and communication.

Chapter 3.2 describes the second example – the traffic adaptive crossing. This example will be presented in analogy to the first one, described in chapter 3.1.

Chapter 4 will conclude this document explaining the feedback using the FRAME Architecture in the context of Cooperative Systems and the work to be done after the design of an ITS architecture.

2 FRAME Architecture overview

The information and examples in this document relate to Version 4.0 of the FRAME Architecture.

The contents of the FRAME Architecture are divided into two parts: User Needs and the Functional Viewpoint. In simple terms the User Needs describe what ITS can provide and the Functional Viewpoint shows how it can be done. Further, the FRAME Architecture tools provide assistance in setting up a physical viewpoint, which assigns the functions to physical entities.

More information about the methodology and an explanation of the terms used in this context can be found on the FRAME website (www.frame-online.net) or the E-FRAME deliverable D15.

2.1 User needs

User Needs provide a formalised description of the Stakeholder aspirations for the Services that are to be provided by the deployment of the Intelligent Transport Systems. For a project, what the Stakeholders themselves want should be expressed in their own words (functions, services...). Their Aspirations are “mapped” to the User Needs so that a particular ITS Architecture sub-set can be created from the Framework Architecture. The resulting ITS Architecture is then used to plan the deployment of what is needed to deliver the Services identified by the Stakeholders.

The User Needs are divided up according to the areas in which the Services operate. Hence there are User Needs for:

- Traveller Journey Assistance,
- Traffic Management,
- Public Transport Operations,
- Freight and Fleet Operations,
- Advanced Driver Assistance Systems,
- Safety and Emergency Facilities,
- Support for Law Enforcement and
- Electronic Payment.

2.2 Functional Viewpoint

In an ITS Project Architecture, the Functional Viewpoint describes the functionalities of the ITS application that satisfy the User Needs specified. It provides a description of all the links between the functions, data stores and the "outside world". These links are presented as dataflows and the Functional Viewpoint is visualised in a Data Flow Diagram.

The "outside world" is represented by the corresponding terminators, which are the source and/or destination of initial data and elaborated information.

2.2.1 Function groups and their sub-functions within FRAME

The FRAME functional architecture consists of nine functional areas, each with a unique number and a description. Each of the functional areas contains the functions for its purpose.

The Functional Architecture consists of low level functions which satisfy the user needs by processing data and elaborating information. The low level functions are grouped according an arborescent architecture in high level functions in nine functional areas, very close to transportation services: Each low level function belongs to one high level function which belongs to one Functional area. The Functional areas are:

Provide Electronic Payment Facilities

This area provides the functionality to perform the electronic payment for different services provided by the other functional areas within the architecture. It has an interface with the financial clearinghouse terminator to enable actual payment transactions to be made. Data can be transmitted from or to other Functional Areas like, for example, "Manage Traffic" (access criteria, accident warning...) or "Law Enforcement" (fraud notification or fraud detection).

Provide Safety and Emergency Facilities

This area comprises the management of what response is provided when an emergency occurs, and the notifications of stolen vehicles. This includes services like the treatment of e-call coming from a driver (terminator) or automatic e-call coming from the area Provide Advanced Driver Assistance Systems.

Manage Traffic

This area manages the traffic flows in an efficient way to use the road space and minimize the impact of vehicles on the environment. The communication possibilities include the provision of priority for emergency services. This Functional Area is very central and manages a lot of data exchange with the other Functional areas and with a lot of Terminators (Driver, Road Pavement, weather systems...)

Manage Public Transport Operations

This area is responsible for managing public transport services in an efficient way.

Provide Advanced Driver Assistance Systems

This area's functionality provides communications facilities between the vehicle's systems, other vehicle systems, the road infrastructure. and/ or other Functional Areas like, for example "Manage Traffic" or "Manage Emergencies".

Provide Traveller Journey Assistance

The main focus of this area is the planning and completing trips for travellers, and the opportunity to make requests for travel information.

Provide Support for Law Enforcement

This area is responsible for reporting violations to the law enforcement agencies, but does not include the detection of over-weight vehicles and individual vehicle pollution levels.

Manage Freight and Fleet Operations

This area provides facilities for the management of freight and fleet operations for:

- A static freight and fleet operations centre, where the route will be chosen and this may involve the use of modes other than that provided by road transport.
- The managing of the operation of a fleet of freight vehicles with scheduling and the specification of drivers' duties and vehicle maintenance.
- Providing functionality for freight and fleet management that is positioned on-board a freight vehicle for receiving instructions about route plans and schedules or other information.

Provide Support for Cooperative Systems

This area provides the functionality that is needed to support the implementation of Cooperative Systems that cannot be wholly assigned to other areas, like "Manage traffic" or "Provide Advanced Driver Assistance Systems".

2.2.2 Steps to build a functional architecture

The user handbook of the FRAME Selection Tool provides a step-by-step guideline to build up one's own functional architecture, The steps are the following:

- Identify the user needs that define the services to be provided.

- Select functions from the trace table, which provide a cross reference from user needs to the functions that help to satisfy them.
- Identify their functional areas or sub-functional group.
- Confirm that the selected functions are reasonable.
- Confirm that those functions “nearby” but not selected, should be omitted.
- Select the data flows needed by the selected functions.
- Select the data stores needed by the selected data flows.
- Select the additional data flows needed by the selected data stores.
- Identify the terminators (nodes to outside world) with all these data flows.

2.3 Physical Viewpoint

The Physical Viewpoint describes where the functionalities are grouped into physical locations. If the user needs contain physical requirements, they also have to be linked to this viewpoint. The resulting physical modules and sub-systems are the basis for the procurement and development of components, while the physical data flows represent the actual, physical links (see Figure 1).

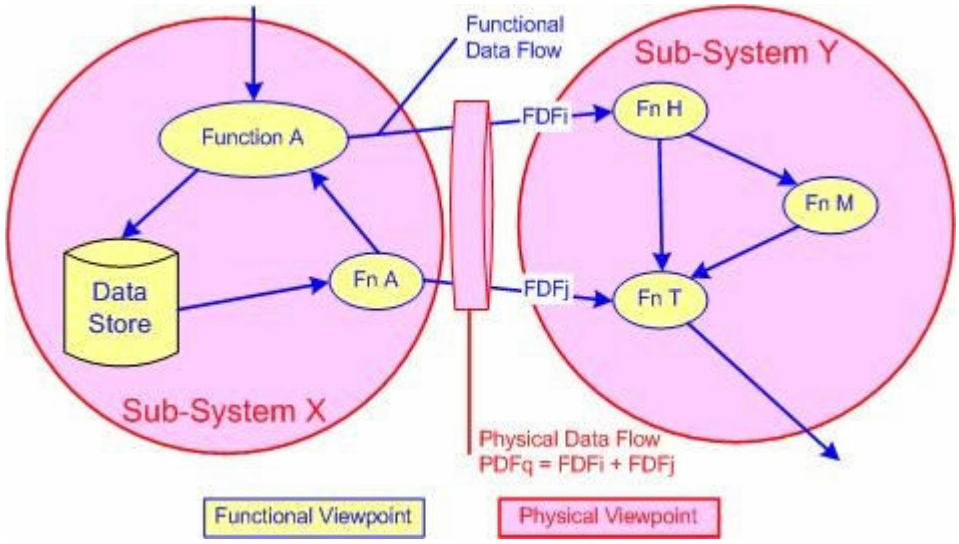

Figure 1: Relation of functional and physical viewpoints

The Physical Viewpoint, sometimes called physical architecture, is the result of grouping together the defined functions in the functional architecture from every single service into physical entities. A group of functions in a physical location is called a sub-system. Each sub-system of functions may, or may not, be divided into modules.

The following section describes the physical elements that may be used.

2.3.1 Sub-systems

Each system normally consists of two or more sub-systems, and each sub-system consists of one or more element of the functional architecture (functions, data stores) and physical data flows communicate with other sub-systems and terminators. It is important that each sub-system includes all the parts of the functional architecture that exist in the same physical location.

The KAREN project has defined the following generic locations for sub-systems:

- Central – the place that is used by parts of a system to collect and manage the storage and processing of traffic data, toll payments, freight shipping orders, and/or the generation of traffic management measures, or fleet management instructions, with or without human intervention, e.g. TCC, or TIC, or freight and fleet management centre.

- Roadside – the place that is used by parts of a system for the detection of traffic, vehicles and pedestrians, or the collection of tolls, and/or the generation of traffic management measures, and/or the provision of information and commands to drivers and/or pedestrians.

- Vehicle – a device that is capable of moving through the road network and carrying one or more people (bicycles, motorcycles, cars, public transport vehicles) and/or goods (vans and any other form of vehicle able to carry freight on roads) in which parts of system can be installed during manufacture or can be added on later.

- Personal device – a nomadic device in which part of the system can be installed so that it can be easily used (and possibly carried) by travellers as one of their personal possessions.

- Freight device – a device in which part of the system can be installed so that it is an integral part of a freight carrying unit, e. g. freight container, trailer, or vehicle body.

- Kiosk – a device usually located in a public place, into which part of the system can be installed to enable travellers to have limited and controlled access to some of its facilities.

A location may have more than one sub-system, for example more than one sub-system within the central location because of the different buildings. But a particular sub-system may not exist in two or more different locations. Sub-systems that provide the same service

in different locations (e.g. roadside and central) will be two separate sub-systems, with different identification.

2.3.2 Modules

A sub-system may consist of two or more modules and each module has the same properties as the sub-system but its own separate physical identity. The main difference between modules and sub-systems is that each module is more likely to contain functionality from a single area of the function architecture. Another reason for using modules is to create physical components that contain a grouping of functionality that is more logical from a manufacturing or physical design view point. Modules also communicate with each other using physical data flows.

2.3.3 Terminators

A terminator is an external entity representing the outside world, connected to the architecture by dataflows. Terminators are the source of the data used by the system or the destination of information generated by the system. A terminator might be an external system (e.g. weather system), a human entity (e.g. driver, traveller), a physical entity (e.g. road pavement) or an organisation (e.g. service provider).

2.3.4 Physical data flows

Physical data flows are the communication links within a system – between sub-systems, modules and to/from terminators. Each physical data flow consists of one or more functional data flows.

2.3.5 Terminator data flows

The terminator data flows are data flows which provide the communication links between sub-systems/modules and the outside world – terminators.

2.3.6 Communications Viewpoint

The communications viewpoint describes the kind of communications links needed in a system in order to support its physical data flows. It may include some requirements from the User Needs, where they relate to specific communication requirements. It consists of an analysis of the communications requirements of the reference system which is described by the physical viewpoint. Furthermore, it describes the communication technologies and standards. More information to the communications viewpoint is provided in sections 3.1.5 and 3.2.5 of this document.

3 Example Architectures for Cooperative Systems

In this chapter, two examples of Cooperative Systems will be examined regarding their architectures, i.e. functional, physical and communications viewpoints. The first example will be a system, which is defined by 7 basic services elaborated within the Easyway Cooperative Systems (CoSy) task force. The second example will be a simple traffic crossing which is controlled dynamically with the help of Cooperative System functionalities.

3.1 The 'CoSy Task Force services' example

From its inception, the Cooperative Systems Task Force planned to elaborate the Functional Architecture based on the FRAME Architecture. It also planned to define any additional elements required for the FRAME Architecture during the project and thus contribute to a new version of the FRAME Architecture which incorporates cooperative systems functionalities.

3.1.1 Definition of CoSy Task Force 1st priority services

Previous work within the Cooperative Systems Task Force (Task 2.1 Identifying 1st priority services) has identified 7 different priority services:

- S1 - Hazardous location notification
- S2 - Traffic jam ahead warning
- S3 - Road works warning
- S4 - Decentralised floating car data
- S5 - Traffic information and recommended itinerary
- S6 - In-vehicle signage (including speed management)
- S7 - Automatic access control / parking management (including Intelligent Truck Parking)

To describe and define the services, a template was created which included the following items for each service:

- Service area (e.g. safety related)
- Service name
- General functions (describing what the service is doing)
- Data sources
- Road type applied (e.g. motorways)
- User group

- Objective
- Message content
- Condition for starting the service
- Condition for terminating the service
- Break down

Figure 2 shows an extract of this template. A full list of the service description is provided in Appendix A, and a description of the process how the new services were identified can be found in the document “Proposal for first priority EasyWay cooperative services”. A description like this, or something similar is recommended to be prepared by every party that aims to implement an ITS service. This helps during the next step of selecting the user needs.

ID	Service Area	Name of Service	General functions	data sources	Road type applied	User		Providing Information/Instruction			Break-Down
						User group	Objective	Message content	Condition for starting the service	Condition for terminating the service	
S3	Safety-Related	Road works warning	The service road works warning will inform the driver of ongoing road works and associated obstruction of road traffic in the vicinity through I2V communication. The purpose is to inform the driver in advance to increase his/her awareness and to inform of the potential dangerous conditions at road works. The service will inform about distance to road work, speed limits, etc.	DIRECT DATA SOURCES: * TCC Decision Support System * Road Operator INDIRECT DATA SOURCES: 1) short-term / long-term scheduled roadworks: - road maintenance plan - scheduled events (daily, weekly, monthly) - road maintenance centre phone call 2) roadwork monitoring: roadside traffic sensors and detection technologies CCTV (closed-circuit television) -> video stream -> automated image processing analysis 3) roadwork trailers, winter maintenance or heavy load vehicles - provide regularly updated position - trajectory - size and vehicle type	Motorways (including tunnels and bridges)	Drivers on motorways	To make drivers aware of the situation and prevent following accidents and congestion caused by bottleneck road	1) Service identifier (N) 2) detailed cause of trigger (O) 3) Current time (N) 4) Location, direction, length and lane of the road sections affected (N) 5) Recommendations/instructions [link to VSL, Lane management services] (O) 6) time when roadwork installation starts (O) 7) time until roadwork scene cleared (O) 8) recommended diversion route (O) 9) message time-to-live (N)	The warning strategy starts according to the roadwork trip start or notification from the maintenance centre.	* Call / Message from Roadwork Trailer or Maintenence Centre that roadworks are finished. * Roadwork scene clearing validated by operator via CCTV * Service timeout for planned roadworks for TISP (e.g. 1 month)	Step 1: Information about roadworks is given by plan, roadwork trailer or maintenance centre. Step 2: Generate warnings according to planned warning strategy. Step 3: Transmit the warning/information to the affected drivers on the specific road segments via a language independent format. At mean time, providing the information to TISP for warning other road users (e.g. through web information for pre-trip planning). Step 4: Display message at the OBU according to priority and requirements Step 5: Retransmit message according to requirements to ensure that new vehicles also get the information Step 6a: Monitor roadwork on a regular basis or continously Step 6b: Update message content when new information is available (e.g. update roadwork position regularly) Step 7: Stop service if terminating condition is valid
						Other traffic information providers	To warn other road users of the roadwork specific interface	1) Service identifier (N) 2) detailed cause of trigger (O) 3) Current time (N) 4) Location, direction, length and lane of the road sections affected (N) 5) Recommendations/instructions [link to VSL, Lane management services] (O) 6) time until roadwork scene cleared (O) 7) recommended diversion route (O) 8) message time-to-live (N)			
								(N)ecessary (O)ptional			

Figure 2: Description of Priority Services

The example architecture developed here covers all of those services described above except for S4 – Decentralised floating car data. At the point in time when this document was created, this service was not fully described and agreed.

3.1.2 Defined User Needs

The list of the European User Needs in the FRAME Architecture is divided into 10 areas:

1. General
2. Infrastructure Planning and Maintenance
3. Law Enforcement
4. Financial Transactions
5. Emergency Services
6. Travel Information and Guidance
7. Traffic, Incidents and Demand Management
8. Intelligent Vehicle Systems
9. Freight and Fleet Management
10. Public Transport Management

For a detailed description of the areas please visit: http://www.frame-online.net. Table 1 shows the User needs for the 1st priority services and to which priority service area they correspond.

Table 1: User Needs for 1st priority services

		Hazardous location notification	Traffic jam ahead warning	Road works warning	Decentralised floating car data	Traffic information and recom	In-vehicle signage	Automatic access control / parking
UN-ID	**Description**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**
1.10.6	Systems developed from the Framework Architecture shall be able to check input data for reasonableness before it is used by a later part of the system.				x			
2.1.0.1	The system shall be able to exchange traffic and travel information between adjacent TICs to enhance local information.					x		
2.1.0.2	The system shall be able to provide facilities to enable co-operation and decision making between all relevant authorities (e.g. Ministries, local authorities, police forces etc.) to define optimum traffic management strategies.	x	x	x		x		
2.1.0.3	The system shall be able to exchange traffic and travel information between adjacent TCC's to improve strategic planning.	x	x	x		x		
2.1.2.1	The system shall be able to model the road network for strategic planning calculations, e.g. to make best use of the existing road infrastructure.					x		
2.1.1.3	The system shall be able to collect traffic data for road network use analysis and prediction calculations.					x		
6.1.0.1	The system shall provide emergency or urgent information to all road users free of charge.	x	x	x		x		

		Hazardous location notification	Traffic jam ahead warning	Road works warning	Decentralised floating car data	Traffic information and recom	In-vehicle signage	Automatic access control / parking
UN-ID	**Description**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**
6.1.0.4	The system shall be able to provide information on alternative routes where they are quicker cheaper shorter scenic etc.					x		
6.1.2.3	The system shall be able to provide information to all drivers including route restrictions, travel times, etc.	x	x	x		x		
6.1.2.7	The system shall provide information using graphical representation or text. Graphical form shall include the use of maps as well as text.	x	x	x		x	x	x
6.1.2.8	The system shall provide information in the native language at the output location, and/or from a user selected choice of other appropriate foreign languages.	x	x	x		x	x	x
6.1.2.10	The system shall be able to provide access information for those travellers with special needs (e.g. physical access, lifts, escalators, parking & toilets, nappy changing rooms, access for (guide) dogs, etc.) at relevant areas, e.g. transit areas.							x
6.1.2.11	The system shall be able to provide information about "Points of Interest" e.g. location, opening times, price of service, nearest transport service points.							x
6.1.2.12	The system shall be able to receive information about a point of interest from the providers/owners/managers of that "Point of Interest".							x
6.2.0.1	The system shall provide emergency, or urgent, information to all users free of charge.	x	x	x		x	x	x
6.2.0.4	The system shall provide traffic information to the traveller during his/her trip in a timely manner, and include travel conditions, accidents, special events, car park status, etc.	x	x	x		x	x	x
6.2.0.7	The system shall be able to know where it is in the transport network and hence provide the position of vehicle or person carrying it.	x	x	x	x	x	x	x
6.2.2.1	The system shall be able to inform travellers on the current average travel time between fixed points.					x		
6.2.2.4	The system shall provide road and traffic safety advice based on current weather and traffic conditions.	x	x					
6.2.2.5	The system shall be able to provide information to all drivers including route restrictions, travel times, etc.	x	x	x		x		
6.2.2.10	The system shall be able to collect data from a variety of different sources, e.g. road/traffic management, police, weather services, floating car etc.	x	x	x		x		
6.2.2.11	The system shall be able to provide operators with an overall view of all active events in an area.					x		
6.2.3.1	The system within the vehicle, or in the centre, shall support various types of presentation to the user.	x	x	x		x	x	x
6.2.3.2	The system shall normally provide messages from a finite set of well defined messages.	x	x	x		x	x	x
6.2.3.3	The system shall provide information in the native language at the output location, and/or from a user selected choice of other appropriate foreign languages, when applicable.	x	x	x		x	x	x
6.2.3.4	The system shall provide information using "open" standard communication protocols.	x	x	x		x	x	x
6.2.3.8	The system shall be able to provide road and traffic information using road-side equipment, e.g. VMS.	x	x	x				
6.4.0.1	The system shall provide travellers with recommended routes to specified destinations.					x		x

		Hazardous location notification	Traffic jam ahead warning	Road works warning	Decentralised floating car data	Traffic information and recom	In-vehicle signage	Automatic access control / parking
UN-ID	**Description**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**
6.4.0.2	The system shall not base its decisions on a restricted sub-set of the road network e.g. motorways only.					x		
6.4.0.3	The system shall know where it is within the road network.	x	x	x		x	x	x
6.4.0.4	The system shall be able to modify its navigation instructions if an incorrect turn is made.	x	x	x		x		x
6.4.0.5	The system shall be able to provide a driver with a suitable alternative route, when the original planned route becomes unavailable.					x		
6.4.1.1	The system shall be able to provide guidance to Car Parks (with parking spaces).							x
6.4.1.2	The system shall be able to use real-time information to compute the recommended route.					x		
6.4.1.3	The system shall be able to compute the total predicted journey time over the route selected.					x		
6.4.1.5	The system shall be able to provide guidance to "Points of Interest".							x
6.4.1.6	The system shall provide information which is consistent with any other information being presented about the road.	x	x	x		x	x	
7.1.0.3	The system shall not do anything to reduce road safety.	x	x	x		x	x	x
7.1.0.5	The system shall manage road traffic in such a way that congestion (travel time) may be reduced.					x		
7.1.0.7	The system shall be able to exchange information between TICs and TCCs, including across national boundaries.	x	x	x				
7.1.1.1	The system shall be able to monitor sections of the road network to provide the current traffic conditions (e.g. flows, occupancies, speed and travel times etc.) as real time data.	x	x			x		
7.1.1.5	The system shall be able to monitor the entire road network (network state surveillance tool).					x		
7.1.1.6	The system shall be able to monitor and record weather conditions (wind, fog, rain level, ice, etc.).	x						
7.1.1.8	The system shall be able to measure the range of visibility and detect reductions caused by adverse weather and pollution conditions (but not darkness).	x						
7.1.11.1	The system shall be able to monitor the current usage of the parking facilities.							x
7.1.11.2	The system shall be able to forecast the need for parking slots.							x
7.1.11.3	The system shall be able to identify those vehicles, or their drivers, which violate the parking regulations, e.g. fail to pay, stay too long, etc.							x
7.1.11.4	The system shall be able to collect and store data from all car parks to provide a historical record.							x
7.1.2.1	The system shall be able to use consistent historical data to complement real-time data, when necessary.					x		
7.1.2.2	The system shall be able to predict short, medium, and long-term traffic conditions.	x	x	x		x		
7.1.2.3	The system shall be able to use historical data to complement predicted data, when necessary.	x	x			x		
7.1.2.4	The system shall be able to analyse road and traffic data to predict possible critical situations.		x					
7.1.2.5	The system shall be able to predict weather conditions, in particular the formation of fog and/or ice.	x						

		Hazardous location notification	Traffic jam ahead warning	Road works warning	Decentralised floating car data	Traffic information and recom	In-vehicle signage	Automatic access control / parking
UN-ID	**Description**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**
7.1.2.7	The system shall be able to provide historical and predicted data.	x	x			x		
7.1.3.1	The system shall enable a TCC operator to control, possibly remotely, infrastructure elements (e.g. traffic lights, VMS).	x	x	x				
7.1.3.3	The system shall be able to provide a graphical representation of the road network (including equipment, incidents, traffic condition etc....) to TCC operators.	x	x	x		x		x
7.1.3.4	The system shall be able to activate control devices (e.g. traffic lights, VMS), either individually or in groups.	x	x	x				
7.1.3.6	The system shall be able to implement planned control strategies for planned events (e.g. sport, cultural, etc.).					x		
7.1.3.7	The system shall be able to support a database of all known (future) events.					x		
7.1.4.4	The system shall be able to provide advice to drivers as they approach car parks (on-street and off-street, as well as motorway service area parking).							x
7.1.5.7	The system shall be able to recommend re-routing strategies to reduce congestion.					x		
7.1.7.1	The system shall be able to show the maximum authorised speed of vehicles on selected carriageways to be shown to drivers.						x	
7.1.7.2	The system shall be able to set variable speed limits on parts of the road network.						x	
7.1.7.3	The system shall be able to calculate recommended speed limits for given traffic and weather conditions, and road network characteristics.						x	
7.1.7.4	The system shall transmit recommended speed limits to equipped vehicles.						x	
7.1.7.5	The system shall be able to support a database of all speed limits on the road network.					x	x	
7.1.7.6	The system shall be able to support an in-vehicle database of road network data (e.g. speed limits, road hazards, junctions etc.).						x	
7.2.0.1	The system shall detect and respond to various incidents on the road network.	x	x	x		x	x	x
7.2.0.2	The system shall not do anything to reduce road safety.	x	x	x		x	x	x
7.2.0.3	The system shall not do anything that might aggravate, or cause, an incident.	x	x	x		x	x	x
7.2.0.6	The system shall minimise the time between the occurrence of an incident and its detection.	x	x					
7.2.0.7	The system shall be able to validate that an incident has occurred in order to minimise false alarms.	x	x					
7.2.2.1	The system shall be able to collect and store data on each incident, e.g. location, type, severity, number & type of vehicles involved, the emergency/rescue vehicles needed etc.		x					
7.2.2.2	The system shall be able to identify and classify all incidents on the road network.	x	x					
7.2.2.3	The system shall be able to provide information on each incident to TICs for onward transmission to travellers.	x	x					
7.2.3.1	The system shall be able to produce incident data statistics, e.g. frequencies of occurrence, by time, type and location	x	x					
7.2.4.1	The system shall be able to minimise the consequences of an incident on the road network for those travellers who are not involved.	x	x	x		x	x	
7.2.5.1	The system shall be able to detect "non-vehicle" incidents before they can escalate into traffic accidents, e.g. bad weather conditions, objects on the road, ghost drivers, etc.	x						

		Hazardous location notification	Traffic jam ahead warning	Road works warning	Decentralised floating car data	Traffic information and recom	In-vehicle signage	Automatic access control / parking
UN-ID	**Description**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**
7.2.5.2	The system shall be able to provide local warnings on dangerous sections of the road network.	x						
7.3.0.1	The system shall provide information that will influence travellers' decisions regarding their destinations, time, mode of travel, route etc.					x		
7.3.3.1	The system shall be able to implement parking strategies in specific areas, including P+R strategies.							x
7.4.1.1	The system shall be able to maintain a database of the road network.	x	x	x		x	x	x
7.4.1.4	The system shall be able to obtain information (values and status) from the host vehicle's systems (e.g. ABS, ESP, Longitudinal and Lateral Acceleration, Speed, Wipers) without affecting the safe functioning of those systems, i.e. .extended floating car data.				x			
7.4.1.6	The system shall be able to determine the visibility in the vicinity of the host vehicle, and classify the cause of the reduction, e.g. fog, rain, darkness.	x						
7.4.1.12	The system shall enable a road-side device to send weather and environmental conditions to the TCC.	x						
7.4.1.13	The system shall be able to fuse the XFCD data from a number of vehicles with the host vehicle data to create a more accurate view of the road and traffic conditions in that area.				x			
7.4.1.17	The system shall be able to communicate with another vehicle either directly or via a road-side device. (Communications).				x			
7.4.1.27	The system shall enable the TCC to determine whether an incident has occurred.		x					
7.4.1.28	The system shall enable a road-side unit to determine whether an incident has occurred.		x					
7.4.1.31	The system shall be able to warn drivers in a timely manner of moving incidents (e.g. road/winter maintenance vehicles long/wide loads) via an in-vehicle display.						x	
7.4.1.33	The system shall be able to locate the tail end of a traffic queue and estimate its speed of propagation.		x					
7.4.1.35	The system shall be able to warn drivers in a timely manner of incidents ahead (e.g. road works, accident, traffic queue) via an in-vehicle display. Where available and relevant this information shall include lane(s)/road section(s) affected and expected delay.		x	x				
7.4.1.36	The system shall be able to warn the driver in a timely manner, via an in-vehicle display, of adverse road surfaces and weather conditions along the planned route.	x						
7.4.1.37 7.4.1.38	The system shall be able to warn drivers, via an in-vehicle device, of adverse driving conditions ahead (e.g. slippery road, low visibility, queuing traffic) and advise on the appropriate action (e.g. speed). The system shall be able to warn drivers, via a road-side device, of adverse driving conditions ahead (e.g. slippery road, low visibility, queuing traffic) and advise on the appropriate action (e.g. speed).	x					x	
7.4.1.39	The system shall be able to warn the driver, via an in-vehicle device, that the host vehicle is about to enter a curve that has been classified as a black spot for that category of vehicle, and recommend a suitable speed and trajectory.	x						
7.4.1.44	The system shall be able to send information about incidents ahead in the next section from a road-side device to drivers via an in-vehicle device.						x	

		Hazardous location notification	Traffic jam ahead warning	Road works warning	Decentralised floating car data	Traffic information and recom	In-vehicle signage	Automatic access control / parking
UN-ID	**Description**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**
7.4.1.46	The system shall be able to estimate the condition of the road surface in the vicinity of the host vehicle and send warnings to a road-side deveice.				x			
7.4.1.47	The system shall be able to send information about incidents on the road network ahead from the TCC to drivers via an in-vehicle device.						x	
7.4.1.48	The system shall provide "copies" of the traffic signs that are relevant to the current section of the road (e.g. speed limit, road hazards, junctions) to the driver at all times via an in-vehicle display.	x	x	x			x	
7.4.2.2	The system shall be able to warn drivers in a timely manner of self-reporting ghost drivers via an in-vehicle display.						x	
7.4.3.9	The system shall provide "copies" of the traffic signs that are relevant to the current section of the road (e.g. speed limit road hazards junctions) to the driver at all times via an in-vehicle display.						x	
7.4.4.1	The system shall be able to recommend a safe speed limit according to the prevailing traffic, weather and road conditions based on the current legal speed limit.						x	
7.4.4.2	The system shall be able to warn drivers, via an in-vehicle display, of different legal speed limits as a result of particular weather conditions via an in-vehicle display.						x	
7.4.4.3	The system shall provide legal speed limits continuously to the driver, via an in-vehicle display, according to the type of the host vehicle and the lane in which it is travelling (Intelligent Speed Adaptation – ISA). A suitable message should be provided if the service provision cannot be guaranteed.						x	
7.4.4.5	The system shall enable the driver of the host vehicle, via an in-vehicle device, to receive safety-related information (e.g. legal speed limit, recommended speed limit) from other vehicles in the vicinity.						x	
7.4.4.6	The system shall enable the driver of the host vehicle, via an in-vehicle device, to receive safety-related information (e.g. legal speed limit, recommended speed limit) from a road-side device.							
7.4.4.7	The system shall enable the driver of the host vehicle, via an in-vehicle device, to receive safety-related information (e.g. legal speed limit, recommended speed limit) from the TCC.							
7.4.4.9	The system shall enable a road-side device to display safety-related information (e.g. legal speed limit, recommended speed limit) to drivers via a road-side device).						x	
7.4.4.10	The system shall enable the TCC to display safety-related information (e.g. legal speed limit, recommended speed limit) to drivers via a road-side device).							
7.4.4.16	The system shall inform the driver, via an in-vehicle display, that there is a modification to the speed limit ahead, and the reason for it.						x	
7.4.4.17	The system shall provide "copies" of the traffic signs that are relevant to the current section of the road (e.g. speed limit, road hazards, junctions) to the driver at all times via an in-vehicle display.	x	x	x			x	
7.5.1.3	The system shall be able to monitor the current inter-urban traffic and weather/environmental conditions, identify incidents, assess their impact, make short term predictions, and select and initiate an appropriate mitigation strategy.		x					
7.5.1.8	The system shall enable the TCC to inform drivers, via an in-vehicle device, about (foreseen and unexpected) incidents on the driver's planned route.					x		

		Hazardous location notification	Traffic jam ahead warning	Road works warning	Decentralised floating car data	Traffic information and recom	In-vehicle signage	Automatic access control / parking
UN-ID	**Description**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**
7.5.1.13	The system shall be able to determine the characteristics of the host vehicle (e.g. Type, (Total) weight, Width, Length (including trailer)).							x
7.5.1.15	The system shall be able to provide the driver via an in-vehicle device with a route to a selected destination that takes account of the vehicle type, the state of the traffic on the road network and any incidents/congestion (route options may be offered and one selected by the driver).					x		
7.5.1.16	The system shall be able to calculate an optimal speed for each type of vehicle through designated sections of the road network and provide that information to drivers via an in-vehicle device.						x	
7.5.1.17	The system shall be able to compute an alternative local route for vehicles approaching a location to be avoided (e.g. one where there is a traffic incident or congestion above a given severity), and does not create congestion downstream. The alternative route computed may depend upon the vehicle type, and may need to be changed as the incident or congestion to be avoided evolves over time.					x		
7.5.1.18	The system shall be able to inform the driver via an in-vehicle device that an incident has been detected ahead on the selected route and provide a revised route.					x		
7.5.1.19	The system shall be able to present an alternative route that avoids an incident or congestion to the driver via an in-vehicle device, and to update that route if necessary.					x		
7.5.1.20	The system shall enable the TCC to instruct drivers, via an in-vehicle device, of an alternative route that should be followed (to avoid an incident).					x		
7.5.1.23	The system shall inform the driver via an in-vehicle device that the vehicle has departed from the selected route and a revised route has been requested.					x		
7.6.2.2	The system shall enable the driver of the host vehicle to provide the destination and personal settings for the journey (e.g. desired route, way points, special needs).					x		x
7.6.2.6	The system shall enable the traveller to request and receive (anticipated) weather/environmental conditions on, or before, a planned trip.	x						
7.6.2.7	The system shall be able to calculate the expected time of arrival at a destination or way point based on the driver's profile and the anticipated traffic conditions.					x		
7.6.2.8	The system shall be able to provide the driver, via an in-vehicle device, with a personalised route.					x		
7.6.2.9	The system shall be able to provide the driver, via an in-vehicle device, with an estimated time of arrival which is updated at regular intervals.					x		
7.6.2.10	The system shall enable the driver to (request and) receive, via an in-vehicle device, personalised on-trip information about incidents that may affect the planned journey.					x		
7.6.2.11	The system shall enable a traveller to request and receive, via an in-vehicle device, personalised on-trip alternative journey plans (to avoid an incident) and to accept/reject the proposal(s).					x		
7.6.2.12	The system shall be able to provide the driver, via an in-vehicle device, with suggested alternative routes.					x		
7.6.4.1	The system shall be able to exchange relevant information between adjacent TCCs and TICs to ensure the continuity of services for travellers.	x	x	x				

		Hazardous location notification	Traffic jam ahead warning	Road works warning	Decentralised floating car data	Traffic information and recom	In-vehicle signage	Automatic access control / parking
UN-ID	**Description**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**
8.2.5.2	The system shall be able to receive mandatory speed limits from outside the vehicle (and store them within the vehicle).						x	
8.2.5.4	The system shall be able to display continuously to the driver the current mandatory speed limit.						x	
8.5.0.1	The system shall minimise the risk of an accident due to the impaired alertness of the driver.	x	x	x		x	x	x
8.5.3.4	The system shall be able to collect information about the vehicle and its environment for other organisations to use i.e. probe or floating car data.				x			
8.5.5.1	The system shall provide “copies” of the traffic signs that are relevant to the current section of the road (e.g. speed limit, road hazards, junctions) to the driver at all times.	x	x	x			x	
8.5.5.2	The system shall be able to send to following vehicles “copies” of the traffic signs, or information about the local traffic (e.g. sudden congestion), that it may be of useful to receive in advance.						x	
9.5.7.4	The system shall enable the freight vehicle driver, to request a reservation for a rest area parking place. The request will include the planned route, estimated time, required duration, potential flexibility, possible hazardous goods and vehicle type.							x
9.5.7.5	The system shall enable a rest area parking reservation to be made based on the request that has been received, or to state that one is not available and/or propose and alternative booking, and to send the details to the freight vehicle driver and the fleet operator.							x
9.5.7.6	The system shall enable the driver to accept or reject alternative proposals for a rest area parking place.							x
9.5.7.7	The system shall be able to receive an ETA from a vehicle that is approaching a rest area based on current traffic conditions, and to receive confirmation to the driver that the reserved parking place is still available together with information about the other services that are available.							x
9.5.7.8	The system shall enable the driver to determine the ETA to the booked rest area parking place, based on current traffic information, and to confirm/modify/cancel details of the booking.							x
9.5.7.9	The system shall be able to identify the vehicle that arrives at a rest area, and to inform the driver which parking slot to use and how to get there.							x
9.5.7.10	The system shall be able to receive a message that a vehicle is leaving the rest area.							x

3.1.3 Functional Viewpoint

For the creation of the functional viewpoint it is important to identify the services to be provided first and to clarify the main functionality that provides them. The FRAME Architecture provides a large number of functions and sub-functions, but if the required specific function is not defined in the overall framework, a new one can be defined. However, in general, one should try to combine different functions in order to reach the overall functionality.

Depending on the selected user needs in the FRAME Tools, the functions needed to realise these user needs are specified, please see table 2 below for an example of the selected functions.

Table 2: Functions selected for the EasyWay 1st priority services

Number	Name
3.1.1.10	Collect Urban Traffic Data
3.1.1.7	Urban Traffic Data Management
3.1.2.10	Collect Inter-urban Traffic Data
3.1.2.5.16	Implement Inter-urban Traffic Commands
3.1.2.7	Provide Inter-urban Traffic Data Management
3.1.2.8	Collect Inter-urban Data from Vehicles
3.1.4.1	Monitor numbers of vehicles in Car Parks
3.1.4.2	Detect the occupancy of Car Park spaces
3.1.4.3	Calculate Occupancy for individual Car Park Spaces
3.1.4.4	Calculate Car Park Occupancy and Status
3.1.4.5	Output Car Park Messages
3.1.4.7	Provide Operator interface for Car Park Management
3.1.5.1	Monitor Service Area Vehicle Occupation
3.1.5.2	Calculate Service Area Occupancy and Status
3.1.5.4	Provide Operator interface to manage Service Areas
3.1.5.6	Mange Service Area Rest Zone Bookings
3.1.5.7	Detect Vehicle Approaching Rest Zone
3.1.6.2	Process Road Traffic Data
3.1.6.3	Create Traffic Predictions with Simulation Methods
3.1.6.4	Manage Traffic Prediction Data Store
3.1.6.5	Provide Traffic Predictions Operator Interface
3.1.6.6	Process Traffic Prediction Results
3.1.7.1	Assess Tunnel Status and Take Action

Number	Name
3.1.7.3	Provide Tunnel Operator Interface
3.1.8.1	Assess Bridge Status and Take Action
3.1.8.3	Provide Bridge Operator Interface
3.2.10	Manage Store of Incident Data
3.2.11	Provide Operator Interface for Incident Management
3.2.12	Detect Incidents from Data
3.2.13	Classify and Identify Incidents
3.2.14	Send Incident Details to Vehicles
3.2.6	Assess Incidents and Devise Responses
3.2.8	Send Incident Details to Others
3.2.9	Send Incident Details to Information Providers
3.4.1	Monitor Weather Conditions
3.4.11	Analyse Environmental Data and Implement Actions
3.4.7	Provide Environment Management Operator Interface
3.4.8	Manage Environmental Conditions Data Store
3.5.8	Provide Maintenance Data Store Management
5.12.5	Provide Vehicle ID
5.12.7	Communicate with In-vehicle Systems
5.12.8	Manage Vehicle Communication to Driver
5.12.9	Output Commands and Dynamic Warnings
5.13.10	Display Current Road Information to Driver
5.13.6	Determine Vehicle Position
5.13.7	Prepare Extended Floating Car Data
5.13.9	Determine Applicable Road Information
5.14.1	Provide Driver Interface for Trip Planning
5.14.2	Create and Revise Vehicle Trip Plan
5.14.4	Implement Vehicle Trip Plan and Track Vehicle

Number	Name
5.14.5	Provide Driver Trip Guidance Interface
5.14.6	Monitor Vehicle Trip Plan Implementation
5.14.7	Manage Store of Vehicle Trip Plans
5.14.8	Mange Freight Vehicle Rest Zone Use
6.3.10	Implement Trip Plan and Track Traveller
6.3.11	Monitor Trip Plan Implementation for Traveller
6.3.12	Manage Revised Trip Plan Creation for Traveller
6.3.13	Provide Traveller Trip Interface
6.5.3.8	Collect Data About Road Traffic
6.5.3.9	Plan Trip Details

3.1.4 Physical Viewpoint

System Context (Figure 3)

20 terminators provide the links to the outside world. While most of them are data suppliers, there are also terminators such as the Bridge Operator and the Tunnel Operator which receive instructions upon request from the CoSy TF Centre.

Sub-systems of the created system

The system contains four sub-systems – central, roadside, vehicle and portable device. The sub-systems are further divided into modules to gain flexibility in component procurement and integration.

Central Sub-system – CoSy TF Center

The central sub-system has a vital role in this concept. Today's high capacity backbone communication networks allow a highly centralised system design, which has a lot of beneficial aspects:

- Decrease costs of roadside and on-board equipment

  Such a system requires high data processing and storage capacities at the central location, but lowers the requirements and therefore the costs of other, non-central equipment. This is crucial for end-user acceptance of the on-board unit, as they need to accept the costs.

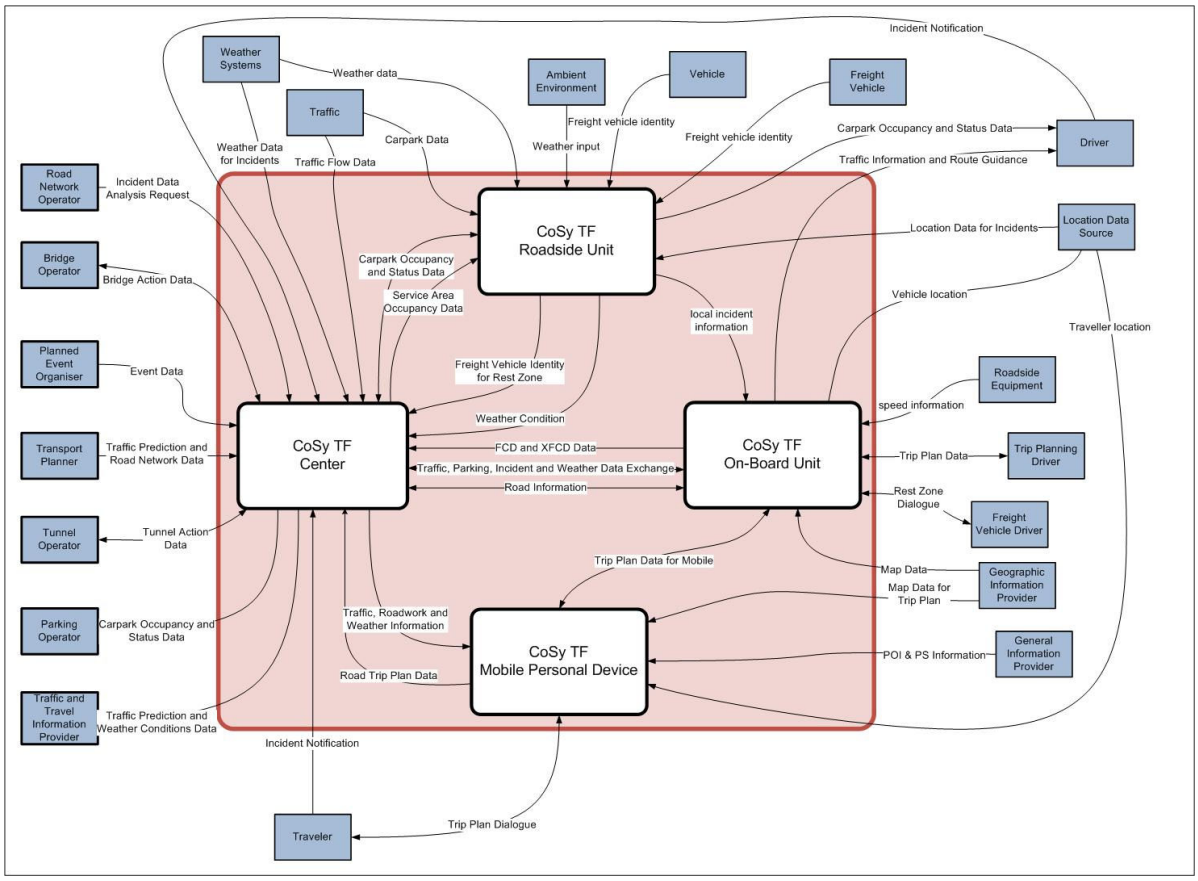

Figure 3: System Context Diagram CoSy TF

- Central data fusion

  The roadside sensor data will be fused with extended floating car data, resulting in more comprehensive information of the current road network status. Furthermore, it enables effective interfaces and information exchange with external information service providers. The more different data sources are gathered at a single location the more possibilities for sophisticated data fusion algorithms arise.

- Central data maintenance

  In this concept, the road operator is responsible for data maintenance since it is also the entity that is legally responsible for traffic information. This ensures that the entity responsible for data maintenance has experience and an established organisational means for responsible data maintenance. The centralised data maintenance and fusion approach also enables easier system upgrades as most of the system's "intelligence" is focused on a single location compared to an upgrade of all on-board units. All data stores are located in the CoSy TF Centre. Four of them store traffic data and are therefore located in the module "Provide Traffic

Management" while one of them stores incident data and is located in the module "Provide Incident Management".

- Single source of data

  The architecture ensures that there is only a single data collection source of a specific type within the system. This when combined with the benefits mentioned earlier ensures compliance of all information which can still be provided in a customised format via different output streams. The avoidance of duplication of data stores saves system costs.

The following table shows the modules which are included in the central sub-system:

Table 3: CoSy TF Central sub-system modules

CoSy TF Center	Center	3.1.5.1	Monitor Service Area Vehicle Occupation	Car Park and Rest Zone information
CoSy TF Center	Center	3.4.11	Analyse Environmental Data and Implement Actions	Provide Environmental Conditions Assessment
CoSy TF Center	Center	3.4.7	Provide Environment Management Operator Interface	Provide Environmental Conditions Assessment
CoSy TF Center	Center	3.4.8	Manage Environmental Conditions Data Store	Provide Environmental Conditions Assessment
CoSy TF Center	Center	3.2.10	Manage Store of Incident Data	Provide Incident Management
CoSy TF Center	Center	3.2.11	Provide Operator Interface for Incident Management	Provide Incident Management
CoSy TF Center	Center	3.2.12	Detect Incidents from Data	Provide Incident Management
CoSy TF Center	Center	3.2.13	Classify and Identify Incidents	Provide Incident Management
CoSy TF Center	Center	3.2.6	Assess Incidents and Devise Responses	Provide Incident Management
CoSy TF Center	Center	3.2.8	Send Incident Details to Others	Provide Incident Management
CoSy TF Center	Center	3.2.9	Send Incident Details to Information Providers	Provide Incident Management
CoSy TF Center	Center	3.1.4.4	Calculate Car Park Occupancy and Status	Provide Parking Management
CoSy TF Center	Center	3.1.4.7	Provide Operator interface for Car Park Management	Provide Parking Management
CoSy TF Center	Center	3.1.5.2	Calculate Service Area Occupancy and Status	Provide Parking Management
CoSy TF Center	Center	3.1.5.4	Provide Operator interface to manage Service Areas	Provide Parking Management
CoSy TF Center	Center	3.1.5.6	Mange Service Area Rest Zone Bookings	Provide Parking Management
CoSy TF Center	Center	3.5.8	Provide Maintenance Data Store Management	Provide Safety Support for Maintenance Management
CoSy TF Center	Center	3.1.1.10	Collect Urban Traffic Data	Provide Traffic Management
CoSy TF Center	Center	3.1.1.7	Urban Traffic Data Management	Provide Traffic Management
CoSy TF Center	Center	3.1.2.10	Collect Inter-urban Traffic Data	Provide Traffic Management
CoSy TF Center	Center	3.1.2.5.16	Implement Inter-urban Traffic Commands	Provide Traffic Management
CoSy TF Center	Center	3.1.2.7	Provide Inter-urban Traffic Data Management	Provide Traffic Management
CoSy TF Center	Center	3.1.2.8	Collect Inter-urban Data from Vehicles	Provide Traffic Management
CoSy TF Center	Center	3.1.6.2	Process Road Traffic Data	Provide Traffic Management
CoSy TF Center	Center	3.1.6.3	Create Traffic Predictions with Simulation Methods	Provide Traffic Management
CoSy TF Center	Center	3.1.6.4	Manage Traffic Prediction Data Store	Provide Traffic Management
CoSy TF Center	Center	3.1.6.5	Provide Traffic Predictions Operator Interface	Provide Traffic Management
CoSy TF Center	Center	3.1.6.6	Process Traffic Prediction Results	Provide Traffic Management
CoSy TF Center	Center	3.1.7.1	Assess Tunnel Status and Take Action	Provide Traffic Management
CoSy TF Center	Center	3.1.7.3	Provide Tunnel Operator Interface	Provide Traffic Management
CoSy TF Center	Center	3.1.8.1	Assess Bridge Status and Take Action	Provide Traffic Management
CoSy TF Center	Center	3.1.8.3	Provide Bridge Operator Interface	Provide Traffic Management
CoSy TF Center	Center	6.5.3.8	Collect Data About Road Traffic	Provide Traffic Management

On-board Unit – CoSy TF On-Board Unit

In the in-vehicle sub-system the messages from the infrastructure are decoded and processed. This includes the management of the HMI display of messages to the driver, preparing and transmitting floating car data, trip plan management and the determination of vehicle position as well as the provision of the vehicle ID.

The following table shows the modules which are included in the on-board unit sub-system:

Table 4: CoSy TF On-board unit sub-system modules

CoSy TF On-Board Unit	Vehicle	5.12.7	Communicate with In-vehicle Systems	Provide On-board Communication Interfaces
CoSy TF On-Board Unit	Vehicle	5.12.8	Manage Vehicle Communication to Driver	Provide On-board Communication Interfaces
CoSy TF On-Board Unit	Vehicle	5.12.9	Output Commands and Dynamic Warnings	Provide On-board Communication Interfaces
CoSy TF On-Board Unit	Vehicle	5.13.10	Display Current Road Information to Driver	Provide On-board Communication Interfaces
CoSy TF On-Board Unit	Vehicle	5.13.7	Prepare Extended Floating Car Data	Provide speed information and FCD
CoSy TF On-Board Unit	Vehicle	5.13.9	Determine Applicable Road Information	Provide supported Navigation
CoSy TF On-Board Unit	Vehicle	5.14.1	Provide Driver Interface for Trip Planning	Provide supported Navigation
CoSy TF On-Board Unit	Vehicle	5.14.2	Create and Revise Vehicle Trip Plan	Provide supported Navigation
CoSy TF On-Board Unit	Vehicle	5.14.4	Implement Vehicle Trip Plan and Track Vehicle	Provide supported Navigation
CoSy TF On-Board Unit	Vehicle	5.14.5	Provide Driver Trip Guidance Interface	Provide supported Navigation
CoSy TF On-Board Unit	Vehicle	5.14.6	Monitor Vehicle Trip Plan Implementation	Provide supported Navigation
CoSy TF On-Board Unit	Vehicle	5.14.7	Manage Store of Vehicle Trip Plans	Provide supported Navigation
CoSy TF On-Board Unit	Vehicle	5.14.8	Mange Freight Vehicle Rest Zone Use	Provide supported Navigation
CoSy TF On-Board Unit	Vehicle	5.12.5	Provide Vehicle ID	Provide Vehicle Position
CoSy TF On-Board Unit	Vehicle	5.13.6	Determine Vehicle Position	Provide Vehicle Position

Roadside Unit – CoSy TF Roadside Unit

This sub-system contains all the elements of the system which are located at the roadside. Unlike the other sub-systems it is likely that the various modules it contains will not be integrated but located at physically separate locations.

The roadside sub-system is responsible for establishing the bi-directional communication between vehicle and infrastructure. This also includes basic local processing such as the grouping or verification of extended floating car data packets. Furthermore, local data fusion is processed in case there are real-time restrictions. In addition to traffic flow monitoring, weather and environmental conditions are also monitored at critical points to enhance the information provided to the central system by an external service provider. This is needed to address local weather system dynamics and data which is only relevant for the road operator and therefore not provided by external parties.

The following table shows the modules which are included in the road-side unit sub-system:

Table 5: CoSy TF Road-side unit sub-system modules

CoSy TF Roadside Unit	Roadside	3.1.4.1	Monitor numbers of vehicles in Car Parks	Car Park and Rest Zone information
CoSy TF Roadside Unit	Roadside	3.1.4.2	Detect the occupancy of Car Park spaces	Car Park and Rest Zone information
CoSy TF Roadside Unit	Roadside	3.1.4.5	Output Car Park Messages	Car Park and Rest Zone information
CoSy TF Roadside Unit	Roadside	3.1.5.7	Detect Vehicle Approaching Rest Zone	Car Park and Rest Zone information
CoSy TF Roadside Unit	Roadside	3.4.1	Monitor Weather Conditions	Monitor Environment
CoSy TF Roadside Unit	Roadside	3.1.4.3	Calculate Occupancy for individual Car Park Spaces	Provide Parking Management
CoSy TF Roadside Unit	Roadside	3.2.14	Send Incident Details to Vehicles	Provide Roadside Communication

Mobile Personal Device – CoSy TF Mobile Personal Device

The scope of this sub-system is to support a Traveller on trip by creating, managing and monitoring the trip plan. Additional features depend on user preferences and on the mobile device itself. Functions shown below are the minimum functions a Mobile Personal Device has to have to be used within the CoSy TF System. In the future it may be possible to think about the integration of those features into an On-Board Unit as well, so that as soon as the Mobile Personal Device is used in the car all communication is done via the On-Board Unit.

The following table shows the modules which are included in the mobile personal device sub-system – since all functions located in the Mobile Personal Device correspond merely to one functional area, only one module exists.

Table 6: CoSy TF Mobile device sub-system modules

CoSy TF Mobile Personal Device	Personal Device	6.3.10	Implement Trip Plan and Track Traveller	Provide Trip Planning Personal Device
CoSy TF Mobile Personal Device	Personal Device	6.3.11	Monitor Trip Plan Implementation for Traveller	Provide Trip Planning Personal Device
CoSy TF Mobile Personal Device	Personal Device	6.3.12	Manage Revised Trip Plan Creation for Traveller	Provide Trip Planning Personal Device
CoSy TF Mobile Personal Device	Personal Device	6.3.13	Provide Traveller Trip Interface	Provide Trip Planning Personal Device
CoSy TF Mobile Personal Device	Personal Device	6.5.3.9	Plan Trip Details	Provide Trip Planning Personal Device

3.1.5 Communications Viewpoint

To reduce complexity physical dataflows are organised into groups of similar requirements. The two main groups represent internal or external dataflows from / to terminators.

Internal Dataflows:

Remark: The indicated sizes of dataflows are rough estimations and only give indications for communication requirements.

Group 1: Dataflows between CoSy TF Centre and CoSy TF Roadside Unit

#	Name	approximate size	Interval	remarks
1	Carpark Occupancy and Status Data	< 1 kB	10 sec	
2	Service Area Occupancy and Status Data	< 1 kB	10 sec	
3	Freight Vehicle Identity for Rest Zone	< 1 kB	on request	
4	Weather Condition	30 kB	10 sec	

Message sizes do not exceed 33kB, therefore can be easily transmitted via wireless communication, e.g. GSM/GPRS or WLAN are possibilities.

Group 2: Dataflows between CoSy TF Roadside Unit and CoSy TF On-Board Unit

#	Name	approximate size	Interval	remarks
1	local incident information	< 1 kB	event-driven	time-critical, and reliable transmission

Message size is very small, any reliable wireless communication can be used, or mechanisms to enhance reliability.

Group 3: Dataflows between CoSy TF On-Board Unit and CoSy TF Mobile Personal Device

#	Name	approximate size	Interval	remarks
1	Trip Plan Data for Mobile	< 500 kB	on request	

For this link wireless communication is recommended to provide interoperability, even a Bluetooth communication link is possible.

Group 4: Dataflows between CoSy TF Mobile Personal Device and CoSy TF Centre

#	Name	approximate size	Interval	remarks
1	Traffic, Roadwork and Weather Information	2 kB	30 sec	
2	Road Trip Plan Data	< 500 kB	on request	

As the Mobile Personal Device is mobile a communication link with a high coverage area like GSM/GPRS or UMTS is recommended.

Group 5: Dataflows between CoSy TF Centre and CoSy TF On-Board Unit

#	Name	approximate size	Interval	remarks
1	FCD and XFCD Data	< 1 kB	30 sec	
2	Traffic, Parking, Incident and Weather Data Exchange	2 kB	10 sec	
3	Road Information	< 1 kB	10 sec	

The same requirements as above apply, the On-Board Unit is mobile around the road network, and therefore a communication link with a high coverage area is recommended.

External Dataflows:

Group 1: Dataflows between Terminators and CoSy TF Centre

#	Name	approximate size	Interval	remarks
1	Event Data	500 kB	30 min	
2	Traffic Prediction and Road Network Data	< 1 kB	60 sec	
3	Carpark Occupancy and Status Data	< 1 kB	10 sec	
4	Traffic Prediction and Weather Conditions Data	< 1 kB	60 sec	
5	Weather Data for Incidents	< 1 kB	Event-driven	
6	Traffic Flow Data	< 1 kB	5 sec	
7	Incident Notification (from Traveller)	< 10 kB	Event-driven	Time-critical
8	Incident Notification (from Driver)	< 10 kB	Event-driven	Time-critical
9	Incident Data Analysis request	< 1 kB	Event-driven	
10	Tunnel Action Data	< 1 kB	Event-driven	
11	Bridge Action Data	< 1 kB	Event-driven	

As each dataflow is sent from a different terminator, any wired or wireless communication link is possible.

Group 2: Dataflows between Terminators and CoSy TF Roadside Unit

#	Name	approximate size	Interval	remarks
1	Weather input	< 1 kB	30 sec	
2	Weather data	< 1 kB	30 sec	
3	Carpark data	< 1 kB	10 sec	
4	Location data for Incidents	< 1 kB	Event-driven	
5	Carpark Occupancy and Status Data	< 1 kB	10 sec	
6	Freight Vehicle Identity (from Freight Vehicle)	< 1 kB	Event-driven	
7	Freight Vehicle Identity (from Vehicle)	< 1 kB	Event-driven	

All messages are small, some of the terminators are mobile and for them a wireless communication is unavoidable, terminators like ambient environment may be linked through a wired connection.

Group 3: Dataflows between Terminators and CoSy TF On-Board Unit

#	Name	approximate size	Interval	remarks
1	Speed Information	< 1 kB	10 sec	
2	Map Data	1 MB	Event-driven	
3	Vehicle Location	< 1 kB	10 sec	
4	Trip Plan Data	< 500 kB	On request	
5	Rest Zone Dialogue	100 kB	On request	

Due to the mobility of the vehicle a wireless communication link with a high coverage is recommended, e.g. GSM/GPRS or UMTS.

Group 4: Dataflows between Terminators and CoSy TF Mobile Personal Device

#	Name	approximate size	Interval	remarks
1	Traveller location	< 1 kB	1 sec	
2	POI&PS Information	< 1 kB	30 sec	
3	Map Data for Trip Plan	< 500 kB	On request	
4	Trip Plan Dialogue	< 100 kB	On request	

The same requirements as above apply, a wireless communication link with high coverage like GSM/GPRS or UMTS.

3.2 The ‘Traffic adaptive crossing’ example

3.2.1 Definition of the system/service(s)

Basic functionality of the system:

The system is a simple traffic crossing being controlled dynamically. It shall detect vehicles approaching the intersection and adapt the traffic signals accordingly. The system shall calculate the timings according to management strategies received from the TCC and submit current traffic data to the TCC. Furthermore it shall transmit current stop and go information to all Vehicles, (e.g. Audi Travolution, as shown in Figure 4).

Vehicles shall be able to request priority, particularly emergency vehicles but also all other vehicles at night times or low peak. Vulnerable road users (e.g. pedestrians, cyclists) are not considered in this example.

Figure 4: Audi Travolution [5]

Services:

For the Traffic Adaptive Crossing four Services have been identified.

- S1 – Green light information / Stop & Go Information and the remaining red-light time

  Broadcast of remaining red and green light times to all drivers approaching the intersection

- S2 – Green light request emergency

  High priority for emergency vehicles

- S3 – Green light request private

  Benefits during night time and low peak for all vehicles

- S4 – Traffic adaptive signalling

  The service will implement traffic adaptive signalling to minimize congestion and waiting times at the intersection.

A full description of the Services is provided in Appendix B.

3.2.2 Defined User Needs

Table 7: Selected User Needs for the Traffic Adaptive Crossing

Number	Description
5.2.0.4	The system shall receive an indication from the emergency vehicle of its need to be given priority at each set of traffic signals before its arrival in the immediate vicinity.
6.4.0.3	The system shall know where it is within the road network.
7.1.0.10	The system shall be able to manage traffic in all or part of the road network using a methodology that is appropriate for urban roads, e.g. using traffic lights at junctions and with the possibility of incorporating facilities for pedestrians to cross the road in a controlled manner.
7.1.0.2	The system shall be able to implement identified control strategies that conform with specified policy.

Number	Description
7.1.0.5	The system shall manage road traffic in such a way that congestion (travel time) may be reduced.
7.1.0.8	The system shall enable the data that it stores to be extracted by an operator onto a variety of media and used for other purposes, or by other organizations.
7.1.1.1	The system shall be able to monitor sections of the road network to provide the current traffic conditions (e.g. flows, occupancies, speed and travel times etc.) as real time data.
7.1.1.4	The system shall be able to monitor traffic flow at, and the operation of, the road intersections of the network over which it has the control.
7.1.3.1	The system shall enable a TCC operator to control possibly remotely infrastructure elements (e.g. traffic lights, VMS).
7.1.3.5	The system shall enable TCC operators to make temporary changes to the normal control strategy in real-time.
7.1.3.8	The system shall provide TCC/TIC operators with controlled access to all relevant systems.
7.1.4.5	The system shall be able to provide priority to selected travellers (e.g. PT, emergency vehicles, cycles, pedestrians) through the road network, including on motorways (when applicable).
7.1.8.1	The system shall be able to transmit information to a vehicle to update its on-board database.
7.1.9.1	The system shall be able to provide green wave management for all vehicles.
7.1.9.2	The system shall be able to minimize delays of all vehicles using adaptive signal control
7.1.9.3	The system shall be able to grant priority to selected vehicles (e.g. PT, emergency vehicles) at an intersection controlled by some form of traffic signals.
7.5.2.1	The system shall enable a road-side unit to receive information on the status of traffic signals.
7.5.2.4	The system shall be able to determine the queue length in front of traffic signals in urban areas.
7.5.2.5	The system shall enable the traffic signal controller to determine the expected arrival time of a vehicle at the junction using data received from that vehicle (e.g. current location and speed profile, estimated time of arrival).

3.2.3 Functional Viewpoint

Figure 5 shows the System Context Diagram for the Traffic Adaptive Crossing. Within the system there is the Local Control Centre (a detailed description of sub-systems and their locations is provided in the Physical Viewpoint) connected to an ordinary traffic light and a roadside vehicle detection unit.

Based on the User Needs listed in the previous chapter, the following Functions have been selected.

Table 8: Selected Functions for Traffic Adaptive Crossing

Number	Name
2.1.7.	Manage use of Emergency Vehicle
3.1.1.10	Collect Urban Traffic Data
3.1.1.5.10	Provide Urban Traffic Operator Interface
3.1.1.5.13	Output Stop & Go Commands to Urban Roads
3.1.1.5.17	Implement Urban Traffic Commands
3.1.1.7	Urban Traffic Data Management
5.12.7.	Communicate with In-vehicle Systems
9.1.2.	Process Priority Request

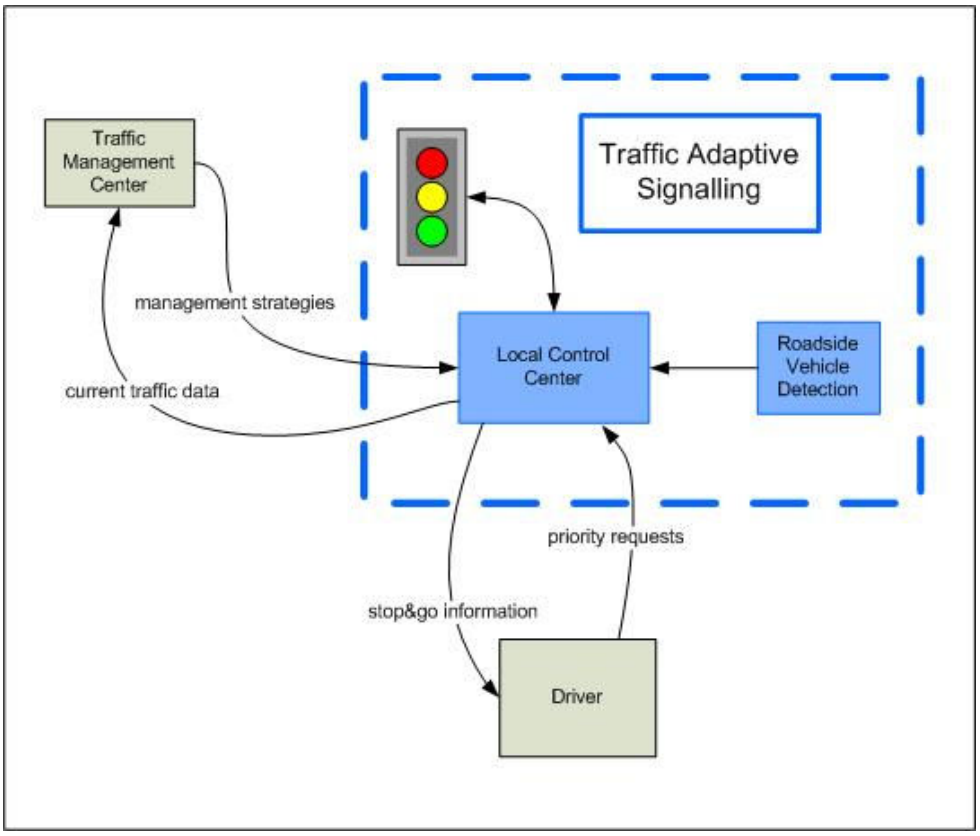

Figure 5: System Context Diagram for Traffic Adaptive Signalling

Although the Traffic Management Centre itself is not within the system, the Functional Viewpoint still includes the minimal functionalities to be provided by a Traffic Management Centre in order to provide the adaptive signalling service according to Management Strategies. The four terminators are outside the boundary of the system (see Figure 6).

A few functions in the System are not actually within the system but represent an interface to a related system which includes extended functionality. One of them is the “Collect Urban Data Function” where a link to actual data input is missing but might be necessary to provide the “Implement Urban Traffic Commands” with actual traffic data to determine useful management strategies. However, the system for one intersection will naturally work with pre-defined management strategies which do not adapt to traffic situations throughout the network.

Another interface is the “Provide Urban Traffic Operator Interface” which may provide the Traffic Operator with the option to implement strategies manually.

The third interface is the “Communicate with In-Vehicle Systems” function, where the actual stop and go input is directed. This function represents an interface somewhere on the vehicle where stop&go information is received and processed or forwarded to whatever functions exist on-board the vehicle.

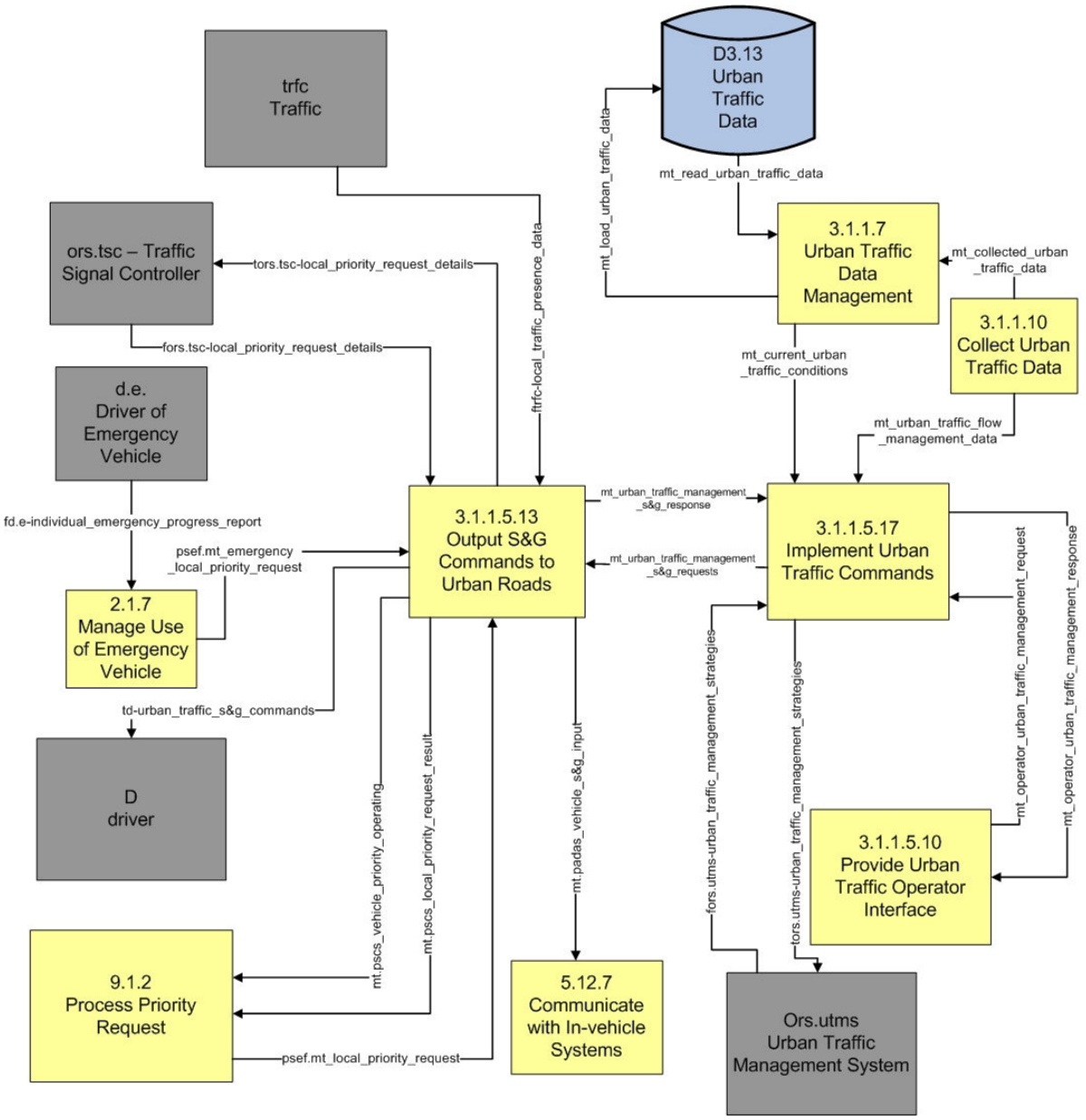

Figure 6: Functional Viewpoint Traffic Adaptive Crossing

3.2.4 Physical Viewpoint

There are four sub-systems in the Physical Viewpoint, see Figure 7. One is installed centrally, one at the roadside and one in the vehicle.

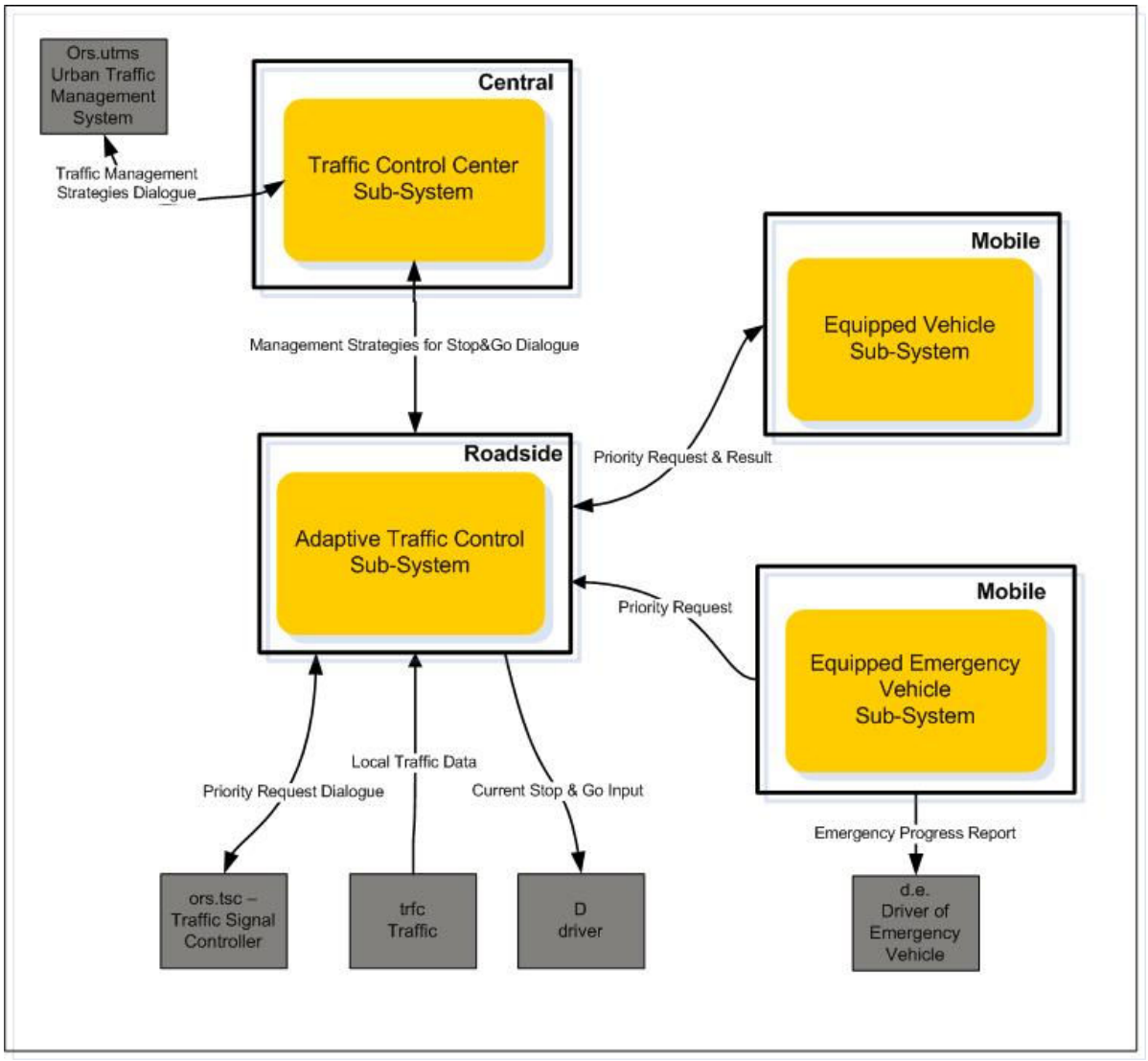

Figure 7: Physical Viewpoint Traffic Adaptive Crossing

The following table shows the allocation of functions to sub-systems.

Sub-System	location	Number	Name
Equipped Emergency Vehicle	Vehicle	2.1.7	Manage use of Emergency Vehicle
Equipped Vehicle	Vehicle	9.1.2	Process Priority Request
Traffic Control Center Sub-System	Center	3.1.1.10	Collect Urban Traffic Data
Traffic Control Center Sub-System	Center	3.1.1.7	Urban Traffic Data Management
Traffic Control Center Sub-System	Center	3.1.1.5.10	Provide Urban Traffic Operator Interface
Traffic Control Center Sub-System	Center	3.1.1.5.17	Implement Urban Traffic Commands
Adaptive Traffic Control Sub-System	Local	5.12.7	Communicate with In-vehicle Systems
Adaptive Traffic Control Sub-System	Local	3.1.1.5.13	Output Stop & Go Commands to Urban Roads

The Equipped Emergency Vehicle Sub-System manages the priority request of the emergency vehicle, the Equipped Vehicle Sub-System manages the priority request of private vehicles. The manner in which the result of the priority request and the current stop & go signals are actually presented to the driver is not part of the architecture and will therefore not be in one of the Viewpoint descriptions.

The Traffic Control Centre Sub-System requests and receives Traffic Management Strategies from the Terminator Urban Traffic Management System.

The Adaptive Traffic Control Sub-System requests and receives Traffic Management Strategies from the Traffic Control Centre for calculating the signalling times. The Terminator Traffic submits local traffic presence data and represents whatever sensor or traffic monitoring system is installed at the particular intersection.

The terminators Driver of Emergency Vehicle and Driver are self-explanatory.

3.2.5 Communications Viewpoint

Within Traffic Adaptive Crossings there are three kinds of physical data flows – internal data flows, external data flows from and to terminators and external data flows from / to the interfaces described in the Functional Viewpoint above.

Internal dataflows:

#	Name	approximate size	Interval	remarks
1	Management Strategies for Stop & Go Requests	100 kB	30 sec	

The communication link may be wired or wireless, already existing communication networks such as GSM/GPRS or even WLAN also fulfill the purpose.

External dataflows from and to Terminators:

#	Name	approximate size	Interval	remarks
1	From Traffic: Local traffic data	< 1 kB	1 sec	
2	From / To Traffic Signal Controller: Priority Request Details	< 1 kB	1 sec	
3	From Driver of Emergency Vehicle: Emergency Progress Report	10 kB	10 sec	
4	To Driver: Stop & Go Commands	1 kB	100 msec	time-ciritical
5	From / To Urban Traffic Management System	10 kB	On request	

For Stop&Go commands transmitted to drivers a failsafe communication link is essential, as incorrect information has a high safety risk.

External dataflows from / to interfaces:

#	Name	approximate size	Interval	remarks
1	From / To “Provide Urban Traffic Operator Interface”		Interval-based	
2	From / To “Communicate with In-Vehicle Systems”		Interval-based	
3	From “Collect Urban Traffic Data”: Traffic Data		Interval-based	

As these dataflows are from / to non-specified interfaces, no communication requirements can be specified.

4 Conclusions and Recommendations

FRAME provides a proven System Architecture methodology which can be the basis for making choices when creating ITS applications. While creating a System Architecture sub-set from the FRAME Architecture its results remain technology-independent, but provide sufficient information to be used in public tenders. The Software Tools provided to support the creation of the System Architecture comprise a Selection Tool to select all the necessary functionalities to be included, and a Browsing Tool to navigate within the FRAME Architecture and elaborate the respective insight and information detail.

The Creation of the Functional Viewpoint is fully supported by the Selection Tool, the remaining Viewpoints are created subsequently. By creating Sub-Systems and Modules within the Physical Viewpoint complementary functionalities can be grouped and the resulting physical dataflows allow a first assessment on data sizes, data rates and communication needs for the Communications Viewpoint. The examples of the initial cooperative systems applications for motorways and traffic adaptive crossing show the potential of the methodology used and the tools provided, and provide the starting point whereby the full benefits for EU ITS development be realised.

As can be seen from the documented examples of cooperative ITS, previous project work can be taken up and adapted at a later point in time, which is specifically interesting in the transport domain, where IT systems need to operate for long times compared to the technology development cycles.

Using the FRAME Architecture supports a common approach within the European Union, taking a step towards interoperability and integrated ITS. Due to the principles of subsidiarity no technological or organisational structures are mandated and it can therefore be used by anyone within the European Union without preference to any specific technology or organisational setting.

5 References

[1] http://www.coopers-ip.eu/, accessed June 17th, 2011

[2] http://www.cvisproject.org/, accessed June 17th, 2011

[3] http://www.safespot-eu.org/, accessed June 17th, 2011

[4] http://www.eimpact.info/results.html, accessed June 17th, 2011

[5] http://www.inautonews.com/audi-travolution-project-minimizes-red-lights-and-emissions, accessed August 29th, 2011

Appendix A - CoSy TF 1st priority services – definition

ID	Service Area	Service Name	General functions	data sources	Road type applied	User		Providing Information/Instruction			Break-Down
						User group	Objective	Message content	Condition for starting the service	Condition for terminating the service	
S1	Safety - Related	Hazardous location notification	The purpose of the service Hazardous-location notification is to warn drivers through HMI against upcoming bad weather road conditions such as slippery roads, fog, rain, etc. It is a safety service primary for highways and will inform the driver about upcoming danger that can't be visually cognised by driveror unforeseeable change in the weather conditions. The system will be based on evaluation of measurements for weather information along the TEN-T Road Network. The driver will only receive information from the system when it is relevant based on the vehicles direction and location. The information will be sent from the traffic management centre to Road Side Unit to inform the driver or directly from a vehicle that detect, for example black ice through V2V communication.. In the latter case, the information could also be sent to the traffic management centre, in order to start processes to solve the hazard (if possible).	DIRECT DATA SOURCES: * TCC Decision Support System * Road Operator INDIRECT DATA SOURCES: * infrastructure weather sensors * external weather information provider * incl. predicted data (hourly, 72h horizon) * all data sources can provide parts or all of the following content: - air temperature - dew point - rel. Humidity - road surface temperature - sustained wind - peak wind - wind direction - snow line - precipitate (type, amount) - fresh snow - visibility - cloud base - barometric pressure - hourly prediction for next 72h * vehicle sensor data (event based, <10sec, dT) - fog lamps - temperature - wiper activity - location * police * road maintenance centre	Motorways (including tunnels and bridges)	Drivers on motorways	To increase driving safety by making drivers aware of the situation and be prepared for the hazard condition	1) Service identifier (N) 2) detailed cause of trigger (e.g. weather condition type) 3) Current time (N) 4) Location and direction of the road sections affected (N) --> point, section, direction (N) --> lane (O) --> length (O) 5) Severity of current weather condition (O) --> severity (O) --> reduced sight indicator (O) --> slip hazard (O) --> appearance [full, partial, direction] (O) --> passable [yes/no, vehicle type restriction] (O) --> damage hazard to vehicle (O) 6) Severity of predicted conditions incl. time indicator (O) --> see 5) 7) estimated delay (O) 8) message time-to-live * link to VSL, lane management services for recommendations/instructions	As soon as possible weather hazard is reported by a reliable (either established source, or verified FCD messages) source	Terminated by TCC on the basis of reliable sources.	Step 1: Information/data about the accident can be collected from various, reliable internal/external sources including driver reports (automatically or manually), CCTV or others. Step 2: Weather condition is analysed/diagnosed by processing the collected data. Step 3: Based on the results from data processing, an action (or set of actions) is automatically executed or provided to the road operator for confirmation. Step 4: Road operator confirms action, if needed. Step 5: Transmit the warning/information to the affected drivers on the specific road segments via a language independent format. At mean time, providing the information to TISP for warning other road users (e.g. through web information for pre-trip planning). Step 6: Display message at the OBU according to priority and requirements Step 7: Retransmit message according to requirements to ensure that new vehicles also get the information
						Other traffic information providers	To provide other road users with weather warning specific interface (O)	1) Service identifier (N) 2) detailed cause of trigger (e.g. weather condition type) 3) Current time (N) 4) Location and direction of the road sections affected (N) --> point, section, direction (N) --> lane (O) --> length (O) 5) Severity of current weather condition (O) --> severity (O) --> reduced sight indicator (O) --> slip hazard (O) --> appearance [full, partial, direction] (O) --> passable [yes/no, vehicle type restriction] (O) --> damage hazard to vehicle (O) 6) Severity of predicted conditions incl. time indicator (O) --> see 5) 7) estimated delay (O) 8) message time-to-live * link to VSL, lane management services for recommendations/instructions			Step 8: Update message content when new information is available. Step 9: Stop service if terminating condition is valid
								(N)ecessary (O)ptional			

ID	Service Area	Name of Service	General functions	data sources	Road type applied	User		Providing Information/Instruction			Break-Down
						User group	Objective	Message content	Condition for starting the service	Condition for terminating the service	
S2	Safety-Related	Traffic jam ahead warning	The service "Traffic jam ahead warning" will warn the driver when approaching the tail end of a traffic jam. The purpose is to avoid rear end collisions by informing the driver in advance approaching a tail. It is primary most relevant for highways. The information will be sent to the approaching vehicle by both V2I and V2V communication and the approaching vehicle will forward the information to vehicle behind. The driver will be warned through the HMI by visual, audio or signals.	DIRECT DATA SOURCES: * TCC Decision Support System * Road Operator INDIRECT DATA SOURCES: * roadside traffic sensors and detection technologies * CCTV (closed-circuit television) -> video stream -> automated image processing analysis * historical & predicted data - traffic flow diagrams * police, fire dept. and highway authorities (e.g. patrols) -> position, direction -> traffic situation -> lane bans, instructions -> accident scene cleared * vehicle(s): - passenger calls - FCD (event based, notification latency < 10sec) -> average speed -> position	Motorways (including tunnels and bridges)	Drivers on motorways	To increase driving safety by making drivers aware of the congested traffic and be prepared for the condition.	1) Service (N) 2) detailed cause of trigger (O) 3) Current time (N) 4) Severity [classification, estimated/observed queue length, delay time, average speed] 5) location of congestion tail end, estimated propagation speed 6) Recommendations/instructions [link to VSL, Lane management services, recommended next link] (O) 7) Estimated time to congestion fading (O) 8) message time-to-live (N)	As soon as an congestion is reported by a reliable (either established source, or verified FCD messages) source.	*As soon as congestion fading is reported by a reliable (either established source, or verified FCD messages) source. * Service timeout (insert empirical value from road operator)	Step 1: Information/data about the congestion can be collected from various reliable internal/external sources including driver reports (automatically or manually), CCTV or others. Step 2: Traffic condition is analysed/diagnosed by processing the collected data. Step 3: Based on the results from data processing, an action (or set of actions) is automatically executed or provided to the road operator for confirmation. Step 4: Road operator confirms action, if needed. Step 5: Transmit the warning/information to the affected drivers on the specific road segments via a language independent format. At mean time, providing the information to TISP for warning other road users (e.g. through web information for pre-trip planning). Step 6: Display message at the OBU according to priority and requirements Step 7: Retransmit message according to requirements to ensure that new vehicles also get the information Step 8: Update message content when new information is available (e.g. update queue end position regularly) Step 9: Stop service if terminating condition is valid
						Other traffic information providers	To provide other road users with traffic congestion information specific interface (O)	1) Service identifier (N) 2) detailed cause of trigger (O) 3) Current time (N) 4) Location and direction of the road sections affected (N) 5) Severity [classification, estimated/observed queue length, delay time, average speed] 6) location of congestion tail end, estimated propagation speed 7) Recommendations/instructions [link to VSL, Lane management services, recommended next link] (O) 8) Estimated time to congestion fading (O) 9) message time-to-live (N)			
								(N)ecessary (O)ptional			

ID	Service Area	Name of Service	General functions	data sources	Road type applied	User		Providing Information/Instruction			Break-Down
						User group	Objective	Message content	Condition for starting the service	Condition for terminating the service	
S3	Safety-Related	Road works warning	The service road works warning will inform the driver of ongoing road works and associated obstruction of road traffic in the vicinity through I2V communication. The purpose is to inform the driver in advance to increase his/her awareness and to inform of the potential dangerous conditions at road works. The service will inform about distance to road work, speed limits, etc.	DIRECT DATA SOURCES: * TCC Decision Support System * Road Operator INDIRECT DATA SOURCES: 1) short-term / long-term scheduled roadworks: - road maintenance plan - scheduled events (daily, weekly, monthly) - road maintenance centre phone call 2) roadwork monitoring: roadside traffic sensors and detection technologies CCTV (closed-circuit television) -> video stream -> automated image processing analysis 3) roadwork trailers, winter maintenance or heavy load vehicles - provide regularly updated position - trajectory - size and vehicle type	Motorways (including tunnels and bridges)	Drivers on motorways	To make drivers aware of the situation and prevent following accidents and congestion caused by bottleneck road	1) Service identifier (N) 2) detailed cause of trigger (O) 3) Current time (N) 4) Location, direction, length and lane of the road sections affected (N) 5) Recommendations/instructions [link to VSL, Lane management services] (O) 6) time when roadwork installation starts (O) 7) time until roadwork scene cleared (O) 8) recommended diversion route (O) 9) message time-to-live (N) 10) expected delay (O)	The warning strategy starts according to the roadwork trip start or notification from the maintenance centre.	* Call / Message from Roadwork Trailer or Maintenence Centre that roadworks are finished. * Roadwork scene clearing validated by operator via CCTV * Service timeout for planned roadworks for TISP (e.g. 1 month)	Step 1: Information about roadworks is given by plan, roadwork trailer or maintenance centre. Step 2: Generate warnings according to planned warning strategy. Step 3: Transmit the warning/information to the affected drivers on the specific road segments via a language independent format. At mean time, providing the information to TISP for warning other road users (e.g. through web information for pre-trip planning). Step 4: Display message at the OBU according to priority and requirements Step 5: Retransmit message according to requirements to ensure that new vehicles also get the information Step 6a: Monitor roadwork on a regular basis or continously Step 6b: Update message content when new information is available (e.g. update roadwork position regularly) Step 7: Stop service if terminating condition is valid
						Other traffic information providers	To warn other road users of the roadwork specific interface	1) Service identifier (N) 2) detailed cause of trigger (O) 3) Current time (N) 4) Location, direction, length and lane of the road sections affected (N) 5) Recommendations/instructions [link to VSL, Lane management services] (O) 6) time until roadwork scene cleared (O) 7) recommended diversion route (O) 8) message time-to-live (N) 9) expected delay (O)			
								(N)ecessary (O)ptional			

ID	Service Area	Name of Service	General functions	data sources	Road type applied	User		Providing Information/Instruction			Break-Down
						User group	Objective	Message content	Condition for starting the service	Condition for terminating the service	
S4	Traffic Efficiency	Decentralized floating car data	The service Decentralised floating car data will, based on information from other vehicles, inform the driver with advice about the conditions along his further route as example reroute around traffic jams. Most vehicles are equipped with large numbers of sensors in the vehicles which collects a lot of information from the vehicles as speed and location. This information will be collected and aggregated in a database and be used to give an overview of the traffic situation and to inform the driver about the conditions. This is a service for the road authorities which gives them an overview of the current information on the network based on information from the vehicles.	• CAN accessible in-vehicle sensors (car kinematics eg wheel speeds, ABS/ASR/ESP state, rain sensor) • OBU internal sensors (eg. Temperature or acceleration sensor) • additional sensors attached to OBU (eg. Fog light status and emergency flasher - if not coded on CAN)	Complete road network	TCC	Enhance TCC data base with FCD to improve event detection and area coverage due to complementary nature of FCD (accident detection, hazardous road conditions, end of traffic jam, fog,..).	Periodic Messages : 1) Temporary randomised Vehicle ID (N) 2) Vehicle Type (N) 3) Vehicle Position (N) 4) Timestamp (N) 5) Vehicle Speed (N) 6) Vehicle Heading (N) 7) Vehicle ambient temperature (O) Event triggered Messages: 1) Temporary randomised Vehicle ID (N) 2) Vehicle Type (N) 3) Vehicle Position (N) 4) Timestamp (N) 5) Type of Trigger Sensor (e.g. ESP activation) (N) 6) Value of Trigger Sensor (N) 7) Type and Value of other accessable in-vehicle sensors specified in "Data sources" (O)	powering on the OBU.	power off.	The gathering of floating car data shall be done permanent and cyclically. Step 1: read data from in-car network Step 2: read data from OBU internal and external sensors. Step 3: combine/associate/calculate the various data to extract the wanted information. Step 3: do a plausibility check at OBU Step 4: transmit the data according to the Key Requirements Step 5: ACK transmission at TCC or RSU Step 6: Collect data at TCC or RSU and fuse with Infrastructure sensors or other FCD sets Step 7: If extacted information (traffic flow, road surface...) is verified, update TCC data base
								(N)ecessary (O)ptional			

ID	Service Area	Service Name	General functions	data sources	Road type applied	User		Providing Information/Instruction			Break-Down
						User group	Objective	Message content	Condition for starting the service	Condition for terminating the service	
S5	Traffic Efficiency	Traffic information and recommended itinerary	The service will recommend a route for the vehicle navigation system to direct the driver around congested locations and to distribute the traffic load on alternative routes. The purpose of the service is to create a better traffic flow by leading the traffic around congested locations. A special use case is the guidance to a parking place, which helps to avoid unnecessary drives searching for a free slot. Another special use case is the guidance of freight vehicles around environmental zones and to avoid low tunnels and bridges with restrictions.	DIRECT DATA SOURCES: * TCC Decision Support System * Road Operator INDIRECT DATA SOURCES: * roadside traffic sensors and detection technologies * CCTV (closed-circuit television) -> video stream -> automated image processing analysis * historical & predicted data - traffic flow diagrams - parking place database * police, fire dept. and highway authorities (e.g. patrols) -> position, direction -> traffic situation -> lane bans, instructions -> accident scene cleared * vehicle(s): - passenger calls - FCD (event based, notification latency < 10sec) -> average speed -> position	Motorways (including tunnels and bridges)	Drivers on motorways	To increase driving safety by making drivers aware of the congested traffic and be prepared for the condition and to distribute the traffic load on alternative routes.	1) Service (N) 2) detailed cause of trigger (O) 3) Current time (N) 4) Severity [classification, estimated/observed queue length, delay time, average speed] 5) location of congestion tail end, estimated propagation speed 6) Recommendations/instructions [link to VSL, Lane management services, recommended next link] (N) 7) Estimated time loss (N) 8) message time-to-live (N)			
						Other traffic information providers	To provide other road users with traffic congestion information specific interface (O)	1) Service (N) 2) detailed cause of trigger (O) 3) Current time (N) 4) Severity [classification, estimated/observed queue length, delay time, average speed] 5) location of congestion tail end, estimated propagation speed 6) Recommendations/instructions [link to VSL, Lane management services,			
								(N)ecessary (O)ptional			

ID	Service Area	Service Name	General functions	data sources	Road type applied	User		Providing Information/Instruction			Break-Down
						User group	Objective	Message content	Condition for starting the service	Condition for terminating the service	
S6	Traffic Efficiency	In-vehicle signage	The service will through V2I communication inform the driver about effective speed limits along the road including special or contextual variations and current valid traffic signs. Also speed recommendations are included. The purpose of the service is to increase the awareness of the driver of the current information on the traffic signs. There are two relevant examples: - Dynamic road signs with alternative routes: In certain cases road operators can switch road signs, displaying an alternative route to a specific destination. If the road sign is switched the operational view is sent to the vehicle as well, to ensure that the in-car system displays the same sign as the real sign outside. - Dynamic maximum speeds: If dynamic speed limits are set by the road operator, this information will overrule the static information.The driver will be informed with the updated information.	DIRECT DATA SOURCES: * TCC Decision Support System * Road Operator INDIRECT DATA SOURCES: * roadside traffic sensors and detection technologies * CCTV (closed-circuit television) -> video stream -> automated image processing analysis * infrastructure equipment - VMS (driver output actuation, status feedback to TCC) - section control * TCC - speed profile - static speed limit database - historical data (traffic flow diagrams) * vehicle sensor data (periodic, every 30sec) - average speed - location * external sources - police	Motorways (including tunnels and bridges)	Drivers on motorways	To inform drivers of current legal speed limit and help them to support the timely adaptation of their speed to upcoming driving conditions.	1) Service (N) 2) Current time (N) 3) Location, direction, lane and length of the referred speed limit zone (N) 4) legal speed limit (N) and type advised/mandatory (N) 5) Vehicle type (N) 6) message time-to-live 7) distance-to-live	Service is continously provided for motorways. After entering the motorway (DAB, GPRS) or the first connection setup (DSRC, IR) the legal speed limit has to be displayed.	Leaving motorway. Time/distance to live exceeded (indication of system error)	Step 1: Speed profile is generated by TCC software Step 2: Code legal speed limits to segments (position, length, vehicle type, lane, direction) according to a standardized protocol and ensure that all segments are covered. Step 3: Transmit legal speed limits to vehicles and VMS. Step 4: Processing of speed messages Step 5: Transmit application-level ACK back to TCC. Step 6: Display of unambigous legal speed limit. Step 7: Retransmit message according to requirements to ensure that new vehicles also get the information (broadcast media)
						other traffic information providers	provide legal speed limits via standardized protocols				
								(N)ecessary (O)ptional			

ID	Service Area	Service Name	General functions	data sources	Road type applied	User		Providing Information/Instruction			Break-Down
						User group	Objective	Message content	Condition for starting the service	Condition for terminating the service	
S7	Value-added	Automatic access control/ parking management (incl. ITP)	**Parking Management** The service will manage parking areas and make it possible for vehicles to book a parking space for loading and unloading, illustrated below. The service will also give the driver required information to find an appropriate parking area for rest and overnight stay and will support them to respect the driving time regulations. **Access Control** The service Access Control will give automated access to vehicles to restricted areas, for example environmental zones in cities where only a specific EURO class are allowed, or giving vehicles carrying dangerous cargo access or denied access to tunnels with specific restrictions. The service will be automatic, no human intervention, and will identify the vehicle and authorise the vehicle to a restricted area. The service can be connected with charging for the restricted areas.	DIRECT DATA SOURCES: * TCC Decision Support System * Road Operator INDIRECT DATA SOURCES: * roadside traffic sensors and detection technologies * CCTV (closed-circuit television) -> video stream -> automated image processing analysis * TCC - speed profile - static speed limit database - historical data (traffic flow diagrams) - parking place database * vehicle sensor data (periodic, every 30sec) - average speed - location - vehicle type	Motorways (including tunnels and bridges)	Drivers on motorways	To inform drivers about available parking spaces on their route.	1) Service (N) 2) Current time (N) 3) Location, direction, lane and length of the referred speed limit zone (N) 5) Vehicle type (N) 6) Loaded goods 7) Estimated time to parking place 8) message time-to-live	As soon as the route is notified		
								(N)ecessary (O)ptional			

Appendix B – Traffic Adaptive Crossing priority services – definition

ID	Service Area	Service Name	General functions	data sources	Road type applied	User		Providing Information/Instruction			Break-Down
						User group	Objective	Message content	Condition for starting the service	Condition for terminating the service	
S1	Traffic Information	Stop & Go Information	The service will transmit stop & go information and remaining red / green light times to all drivers at an intersection.	DIRECT DATA SOURCES: * Traffic Signal Controller INDIRECT DATA SOURCES: * Traffic Control Centre	Intersections on urban and inter-urban roads	Drivers passing through the intersection.	To increase traffic efficiency by enabling drivers to adapt their speed according to the current signaling.	1) Current signal (green / red) (N) 2) remaining time before change of signal (N)	Service is always active	Operator override	Stop & Go Information for whole intersection is broadcasted, vehicle needs to filter which signal affects its way.
								(N)ecessary (O)ptional			

ID	Service Area	Service Name	General functions	data sources	Road type applied	User		Providing Information/Instruc			Break-Down
						User group	Objective	Message content	Condition for starting the service	Condition for terminating the service	
S2	Emergency Services	Green light request emergency	The service will grant emergency vehicles priority when passing through the intersection. The system will transmit the priority request status to the driver of the emergency vehicle.	DIRECT DATA SOURCES: * Traffic Signal Controller * Emergency Vehicle INDIRECT DATA SOURCES: * Traffic Control Centre * roadside detection technologies?	Intersections on urban and inter-urban roads	Drivers of emergency vehicles	To enable drivers of emergency vehicles to go through an intersection without stopping.	Message needs to contain priority progress reports 1)Priority granted / denied (N)	Service is initiated upon emergency vehicle drivers' request	As soon as emergency vehicle has passed through intersection (Service timeout after receiving emergency last progress report by vehicle)	Step 1: Driver sends request Step 2: System determines whether driver is permitted to be given priority Step 3: Priority Processing - priority is given / denied Step 4: Driver is given response to his request
								(N)ecessary			

ID	Service Area	Service Name	General functions	data sources	Road type applied	User		Providing Information/Instruction			Break-Down
						User group	Objective	Message content	Condition for starting the service	Condition for terminating the service	
S3	Traffic Efficiency	Green light request private vehicles	The service will grant private vehicles priority when passing through the intersection, during night times and low peak.	DIRECT DATA SOURCES: * Traffic Signal Controller * Vehicle INDIRECT DATA SOURCES: * Traffic Management Centre * roadside detection technologies?	Intersections on urban and inter-urban roads	Drivers	To grant drivers priority when passing through an intersection during night times and low peak.	Message needs to contain priority progress reports 1)Priority granted / denied (N)	Service is provided upon drivers' request.	As soon as the requesting vehicle has passed through intersection (Service timeout, time is given by time a vehicle usually needs to pass intersection)	Step 1: Driver sends request Step 2: System determines whether driver is permitted to be given priority Step 3: Priority Processing - priority is given / denied Step 4: Driver is given response to his request
								(N)ecessary (O)ptional			

ID	Service Area	Service Name	General functions	data sources	Road type applied	User		Providing Information/Instruct			Break-Down
						User group	Objective	Message content	Condition for starting the service	Condition for terminating the service	
S4	Traffic Efficiency	Traffic adaptive Signaling	The service will implement traffic adaptive signaling to minimize congestion and waiting times.	DIRECT DATA SOURCES: * Traffic Control Centre INDIRECT DATA SOURCES: * roadside traffic sensors and detection technologies	Intersections on urban and inter-urban roads	Drivers	To reduce waiting time and minimize congestions at an intersection and to increase its efficiency.		Service is active as soon TCC decides to activate service.	When operator decides to control the intersection centrally.	
								(N)ecessary (O)ptional			