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SUSTAINABLE DEVELOPMENT, GLOBAL CHANGE & ECOSYSTEMS  
INTEGRATED PROJECT – CONTRACT N. 031315**



**CONCEPTS, ELEMENTS AND PROCESSES  
INVOLVED IN VARIOUS AUTOMATED SYSTEM  
OPTIONS**

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## 1 Executive summary

The objective of CityMobil project is the study of new advanced modes of transport for urban environments, in order to achieve higher quality services in the future. This quality can not only be measured in the traditional terms of reliability, low congestion, low travel times, etc. CityMobil project also considers the reduced pollution emission, enhanced safety, higher quality of life and integration as quality factors of an urban transport system.

The tasks taken within sub-project 4 (Operational issues) are focused on the analysis of the new opportunities and services arising from the modern means of transport proposed in CityMobil, and the determination of the management and operational aspects that should be created or modified in order to support the new services and integrate them within the transport structures present nowadays.

This document presents part of the results of work package 4.1 “Operational Management”. The objectives of this WP are to identify and define the elements/concepts, processes/relations and the required organisational arrangements of the new Advanced Urban Transport systems in order to set the common basis of all the work to be developed in the rest of SP4.

In this task, the management and operational architectures that support the present urban transport systems has been analysed in detail, in order to identify which elements and processes must be modified or added in order to get a global framework able to support the new CityMobil transport services and permit their integration with the rest of transport services. The result provided is a guideline of an Advanced Transport Architecture, which integrates the traditional requirements of transport system with the new requirements and opportunities brought by the modern systems.

## 2 Introduction

### 2.1 Objectives of SP4 and WP4.1

The main goals of CityMobil Sub-project 4, Operational Issues, are:

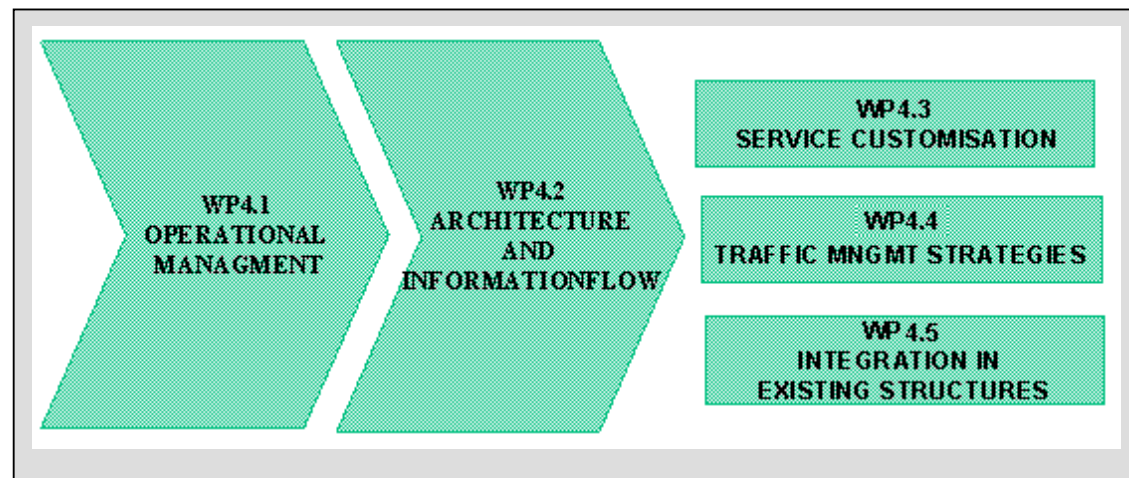
- Addressing operational issues of Advanced Urban Transport Systems (AUTS).
- Assessing and influencing how these issues will have a direct impact on the overall system performance, acceptance and sustainability.
- Reduction of congestion and improvement of environment by means of AUTS.
- Enabling a safer and more efficient mobility by means of AUTS.
- Addressing the usability of AUTS, since by the end of the day anybody should be able to use them.

SP4 will therefore extend the current requirements, strategies and policies of urban mobility to the new AUTS that CityMobil is going to study. Hence, methods and tools from infrastructure planning to real time fleet management are involved in the operational management of the new transport systems proposed by CityMobil.

To achieve its goals, SP4 is decomposed into 5 WP's.

- 4.1 Operational Management
- 4.2 Architecture and Information flow
- 4.3 Service Customisation
- 4.4 Traffic management Strategies
- 4.5 Integrating automated transport in an existing structure

These WP's interact as indicated in the following figure:



**Figure 1: Work Flow in SP4**

This report addresses the current work in WP4.1, Operational Management. The objectives of this WP are to identify and define the elements/concepts, processes/relations and the required organisational arrangements [of the new Advanced Urban Transport systems] in order to set the common basis of all the work to be developed in the rest of SP4.

## 2.2 Advanced Urban Transport System

The new AUTS to be investigated in CityMobil are:

- Personal Rapid Transit (PRT): small fully automatic vehicles operating on dedicated guideways to segregate them from pedestrians and other traffic, as for example in the Heathrow demonstration.
- High-tech Buses (HTB): buses on rubber tyres, operating like a tram or BRT (bus rapid transit) on lanes with a light infrastructure using electronic guidance either for automation or for driver assistance (support in manoeuvres). An example will be demonstrated in Castellon.
- 'Dual mode Cars (DMC): developed from present vehicles but able to support both fully automatic and manual driving. The first applications of automatic driving will be for relocation of shared cars using platooning techniques but these vehicles could become full cybercars in specific areas or infrastructures.
- Cybercars or Cybernetic Transport Systems (CTS): small autonomous vehicles for individual or collective transportation of people and goods, for specific areas such as city centres with little or no interaction with other (manual) vehicles.
- Advanced City Cars (ACCs): new city vehicles integrating zero or ultra-low pollution mode and driver assistance such as ISA, parking assistance, collision avoidance, stop&go, guidance, etc. These vehicles should be small and should also incorporate access control system coupled with advanced communications system in order to keep the vehicle "connected" with Infrastructure, like TCC (traffic Control centre) or other vehicle, helping possible integration into innovative services like car-sharing or car pooling.

For an understanding of the potential influences of these new systems on operations, it is helpful to clarify the characteristics of the different systems in terms of their offering e.g. public (and if demand responsive (DRT)) or private transport, automatic or manual driving; and their requirements for special infrastructure e.g. a dedicated guideway or priority lane to segregate them from other traffic and/or pedestrians.

In practice, the distinction is not always clear, but a useful starting point is provided by the table below. This shows separate columns for each system and, in particular, distinguishes the HTB and DMC systems separately under automatic and driver control. For each system, the table then shows whether they are suitable as private or public modes, whether they need a special infrastructure and if so whether it needs to be a dedicated guideway or a ('lightly equipped') priority lane, whether the system can run mixed with other traffic or needs to be segregated, and whether it can be operated in automatic or manual modes.

**Table 1: Characteristics of the different systems AUTS**

	PRT	HTB Auto mode	HTB Driven	DMC Auto- mode	DMC Driven	CTS Cybercars	Adv. City Cars
<b>No pax</b>	~ 5	20 +	20 +	~ 5	~ 5	5 – 20	~ 2-3
<b>PT mode</b>	Y (DRT)	Y	Y	?	?	Y (DRT)	?
<b>Private mode</b>	N	N	N	Y	Y	?	Y
<b>Needs guideway</b>	Y	N	N	N	N	N	N
<b>Needs priority lane</b>	N	Y	N	Y	N	N	N
<b>Needs no special Infrastructure</b>	N	N	Y	N	Y	Y	Y
<b>Segregated</b>	Y	Y	N	Y	N	N	N
<b>Mixed</b>	N	N	Y	N	Y	Y	Y

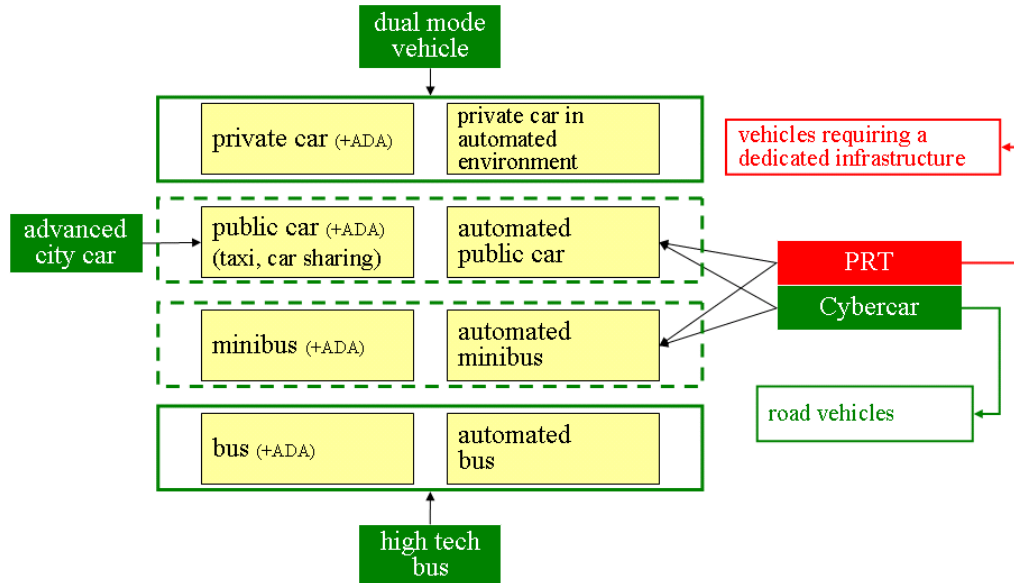
The table helps to clarify the extremes, ie PRT (small vehicles, demand responsive public transport, fully automatic, fully segregated, running on a dedicated guideway) vs ACCs (small vehicles, private transport, manually driven, running mixed with other traffic on conventional roads).

The systems in between show the possible variations, from advanced Hi Tech Buses and Dual-Mode Cars, both of which require priority lanes to operate in fully automatic (i.e. driverless) mode, through to Cybercars/CTS which can be small or large vehicles, private or demand responsive public transport, fully automatic, needing no special infrastructure and can (in principle) run mixed with other traffic on conventional roads.

### 2.3 Scenarios

Today Urban transport system has some degree of automation just in Public transport sector where Automatic Metro (like VAL) are quite diffused and some Guided System have just passed the experimental phase. On the other hand there are some experience and best practise cases where ITS (Intelligent Transport System) have demonstrated the possibility to help for meeting Transportation strategic objectives like reduce pollution, congestion and accidents. So it would be quite natural to think that in the future there will be more and more automation also in synergism with the expansion and diffusion of ITS system.

In deliverable 2.2.3 – *Scenarios for automated Road transport*, the CityMobil mobility concepts are presented. The following picture summarise what CityMobil is thinking at.



A quite recent workshop of ERTRAC (5-6/12/2006) tried to identify which would be the research need in the transport domain, for the next years and to do so he tried to define a sort of suitable “road map” for the mobility up to 2030.

Some of the discussion performed within that workshop are very useful to better understand the possible “context-scenario” where AUTS system will be more or less diffused and available for the normal users.

The following list of main items for mobility, transport and infrastructure with some target date have been produced by the WS

- Reallocation of road space for collective transport/freight vs. single users (2020-2030)
  - Integration of road space, new vehicles technologies and operating practises
  - Priority allocations/design of roads and pavements
  - Role of new infrastructure
- Influencing road users for sustainable decisions (2010-2020-2030)
  - Integrated understanding of current behaviour/best practise
  - Combine existing evidence to identify gaps/research
  - Interpreting the opportunities to influence individuals and policy makers
  - Implementation of the understandings as part of the iterative process
  - Develop consolidated set of indicators to monitor progress
- Effective information/communication (2010)
  - Quality online data
  - Effective design for all user groups
  - Privacy issues
- Improved quality of Public Transport (2010-2020)
  - Dedicated infrastructure development
  - Understanding new user needs
  - Intermodality
  - New design of vehicles, services and systems

- Costs of urban mobility and financing of infrastructure (2010)
  - Understanding the economic and financial processes for urban transport infrastructure and maintenance
- Urban logistics/freight (2010-2020)
  - New traffic management concepts
  - Integrated urban logistics especially last mile
  - Understanding and influencing behaviour through information
- New traffic management concepts (2010-2020-2030)
  - Online integration of vehicles and infrastructure with network management objectives related to the environment as well as capacity, etc./ new vehicle technology integration
  - Traffic management and control to support more sustainable changes in habits, behaviour and land use
- Land use rationalisation and integration (2020-2030)
  - – Evidence based information on energy consumption, congestion, quality of life etc.
- Demand management (201-2020)
  - Integration of policy and technology
  - Intelligent and dynamic optimisation against new policy objectives
  - Databases and cooperative systems for modelling, business case and decision support
  - Understanding HMI for all involved
  - Development of new policies enabled by technical and social opportunities
  - Understanding impacts of integrated measures including parking, road user charging, ISA, etc.

Once AUTS functionalities and system will be in place the Urban Transport System will be much more complicated and elements and processes/functionalities have to be analysed in details.

### **3 Elements and functionalities of the Urban Transportation System**

Main items of the urban transportation system are:

- Transport mode
- vehicles
- Infrastructure
- Rules
- Systems

This main items can be broken-down into more specific sub-items as follow:

- Transport modes
  - Individual
  - Collective
  - Shared

- pooled
- Vehicles
  - Passengers
  - Freight
  - Emission level
  - Dimension
  - Automation level
- infrastructure
  - transport network
    - road
    - intersection
    - parking facilities
    - traffic restricted zone
    - PT lines
    - Stations
  - Communication network
    - Wired
    - Wireless
- Rules
  - Right
  - Restrictions
  - Charging
  - fees
- Systems
  - UTC
  - VMS
  - CCTV
  - ZTL

On the basis of the previous list of items six “elements” of the Urban Transportation System which are relatively self-containing have been identified and they are summarised as follows.

**Table 2: Elements of the Urban Transportation System**

	Elements of the Urban Transportation System	Features
<b>A</b>	Urban Public Transport System	On-street system (e.g. bus) + HTB Mixed on-street system (e.g. tram) + CTS Off-street system (e.g. underground, light rail) + PRT+CTS
<b>B</b>	Motorised Transport System (Except for PT)	Passenger cars, trucks etc. CTS, ACCs, DMC
<b>C</b>	Non-motorised Transport System	Facilities for Pedestrians and cyclists
<b>D</b>	Urban Road System	Roads infrastructure, Including parking spaces
<b>E</b>	Traffic Management Systems	Signals, Information etc, for increasing the efficiency of

		road space
<b>F</b>	Urban Transportation Organisations	Planning/design, operation, enforcement etc.

### 3.1 Relationship between the elements and processes involved in urban mobility

Previous research, notably that coming from IST KAREN and FRAME projects, as well as TRANSMODEL (a model developed by EC Drive and TAP projects Cassiope, Eurobus, Harpist and Titan) .has defined elements and processes of the European Architecture. This paragraph will show what are the updating and adaptation that European framework architecture has to implement as a consequence of introducing AUTS concepts and related functionalities.

A graphical overview of the elements and processes involved in urban mobility has been produced –see figure in next page-. This figure reflects the 8 main functional areas, already defined by KAREN, where the underlying ultimate goal being moving people and goods efficiently and safely without undue adverse effects on the environment.

Each of the 8 functional areas may relate to more than one of the elements identified in section 2, as shown in the Table below.

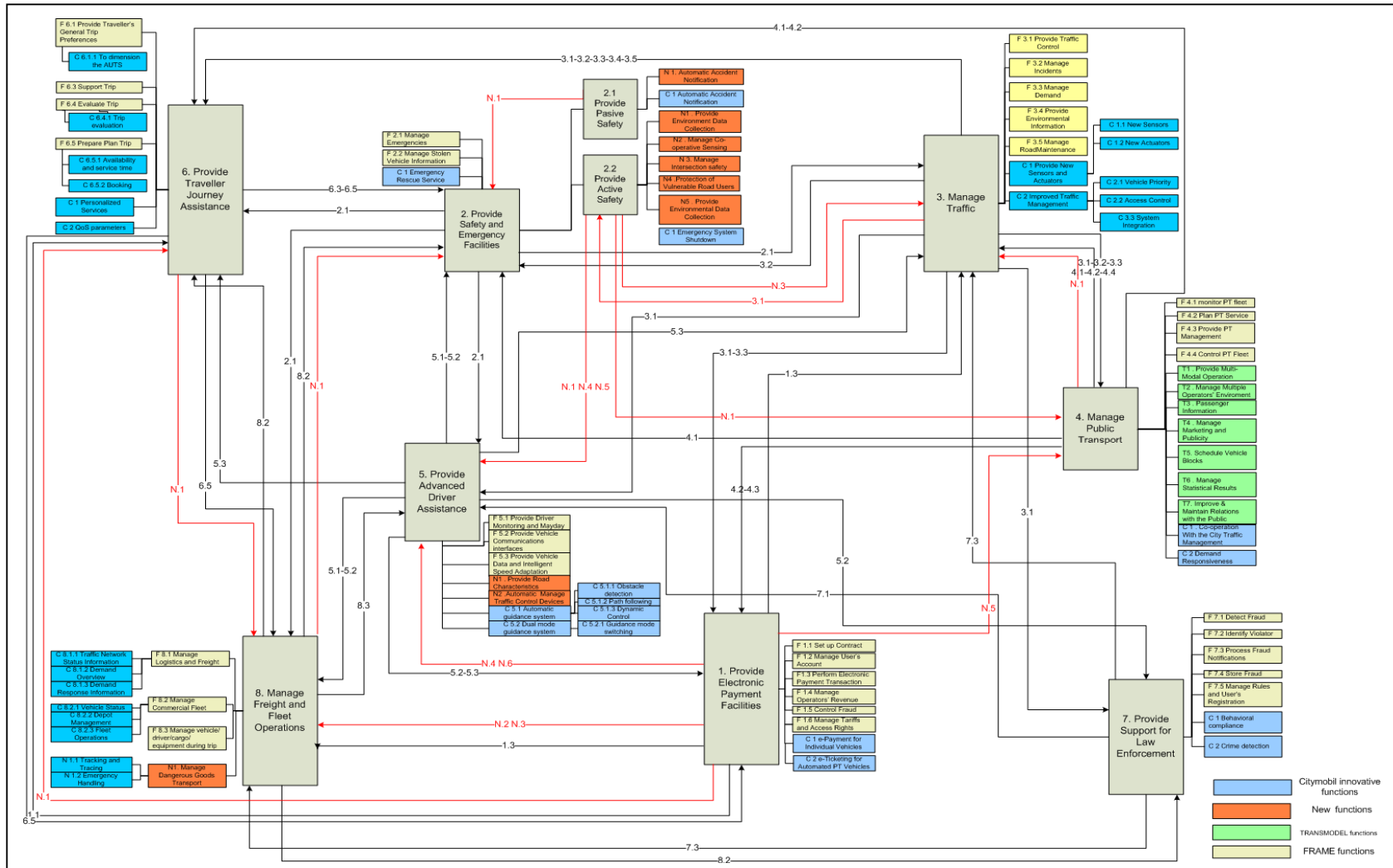
**Table 3: Functional Areas**

Elements  Functionality Areas	A. Urban Public Transport System	B. Motorised Transport System	C. Non-motorised Transport System	D. Urban Road System	E. Traffic Management Systems	F. Urban Transportation Organisation
<b>1. Provide Electronic Payment Facilities</b>	√					√
<b>2. Provide Safety and Emergency Facilities</b>	√	√			√	√
<b>3. Manage Traffic</b>				√	√	√
<b>4. Manage Public Transport</b>	√				√	√
<b>5. Provide Advanced Driver Assistance</b>	√	√		√		√
<b>6. Provide Traveller Journey Assistance</b>	√	√	√		√	√
<b>7. Provide Support for Law Enforcement</b>	√	√			√	√
<b>8. Manage Freight and Fleet Operations</b>		√			√	√

For each of the 8 general functional areas, a number of relevant specific functionalities have been identified, of which some are innovations specific to and/or addressed by CityMobil.

In fig. 2 the general overview of functional areas and relative relationship as they are in FRAME architecture have been “updated” with ‘CityMobil functionalities’ which are marked in blue, and are also reviewed with more detail in the following sections of this report.

Figure 2: General overview of the functional Areas



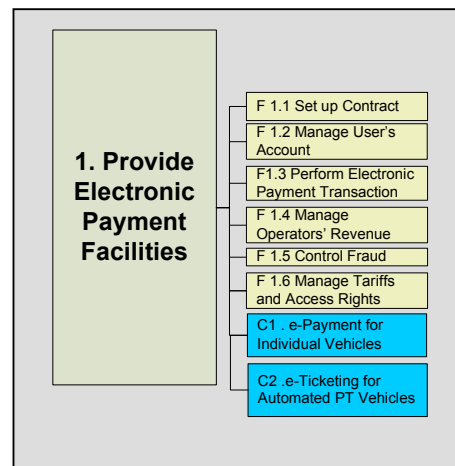
D4.1.1-Concepts, elements and processes involved in various automated system options

## 4 Relevant functional areas

### 4.1 Area 1. Electronic Payment Facilities

Financing is a key issue for any transport system, and in particular the ticketing facilities which enable the access to the transport system only to those entitled to do it and in the conditions regulated by the relevant authorities. This is a particularly sensitive issue in the case of AUTS, where the potential absence of a human agent in charge of collecting –or supervising the collection of- the fares puts a high responsibility on the automated system in charge of doing so.

**Figure 3: Area 1. Electronic Payment Facilities**



Two AUTS-specific topics have been identified under this area:

#### 4.1.1 e-Payment for individual vehicles

##### **- Introduction/ Background**

The introduction of a new kind of small capacity driverless vehicles forces the investigation of new payment systems, where users of the transport systems will interact with automatic interfaces in order to order and pay transport services. These solutions must be easy to use by the passengers. By the other hand, they will be used not only to pay services, but they also will provide the user identification, a very important issue both for customization and security in driverless vehicles.

##### **- Description of Function**

Function 4.1.1 shall provide modern e-identification, e-payment and e-ticketing mechanisms applicable to small capacity, and mostly driverless, vehicles.

##### **- Function Inputs/ Outputs**

Inputs are transport fleet availability, user's identification, user's personal data, user's location, requested vehicle location, source and destination of the trip. Outputs are the providence of service to the user, and an actual movement of the fare cost from the passenger to the transport enterprise.

##### **- CityMobil Systems**

These e-ticketing systems will apply to most new small capacity vehicles (rental ACCs, Cybercars, PRTs). These kinds of vehicles are provided to the user without human interaction. Therefore, an important attention must be paid on security systems and fraud prevention. With this purpose, the system must identify all users of the vehicle and include systems for strange behaviour detection (e.g. abandoned luggage). In addition, a management system must be designed to conduct requested vehicles to the users and to conduct users to the nearest available vehicle.

#### **- FRAME Functions**

This function can be considered as an extension of the FRAME function “1.3. Perform Electronic Payment Transaction”, to which new considerations regarding the new kind of vehicles and new identification requirements are included.

#### **4.1.2 e-Ticketing for AUTS collective vehicles**

##### **- Introduction/ Background**

Specific solutions for e-ticketing in AUTS buses –or collective vehicles in general- need to be developed. These solutions must be compatible with current e-ticketing in ‘conventional’ public transport, and, on top of that must account for the specificities required by AUTS, like service personalisation, dynamic passenger identity management and trade-off between personalisation or enforcement and the right for privacy, etc.

##### **- Description of Function**

Function 4.1.2 shall provide modern e-payment and e-ticketing mechanisms applicable to collective vehicles (mainly High-tech Buses)

##### **- Function Inputs/ Outputs**

Inputs are trip information (bus line, source and destination points, travel init time), passenger personal data and prepaid-tickets information. Output is a correctly update of passenger prepaid tickets, or an actual movement of the fare cost from the passenger to the transport enterprise.

##### **- CityMobil Systems**

This function applies to high-tech buses. It must provide solutions for two kind of tickets: prepaid tickets (stored in some kind of electronic device owned by the passenger) or single trip tickets (paid at the bus stop or in the bus). To classic payment methods, digital payment methods (via smartcard or mobile phone) are included.

##### **- FRAME Functions**

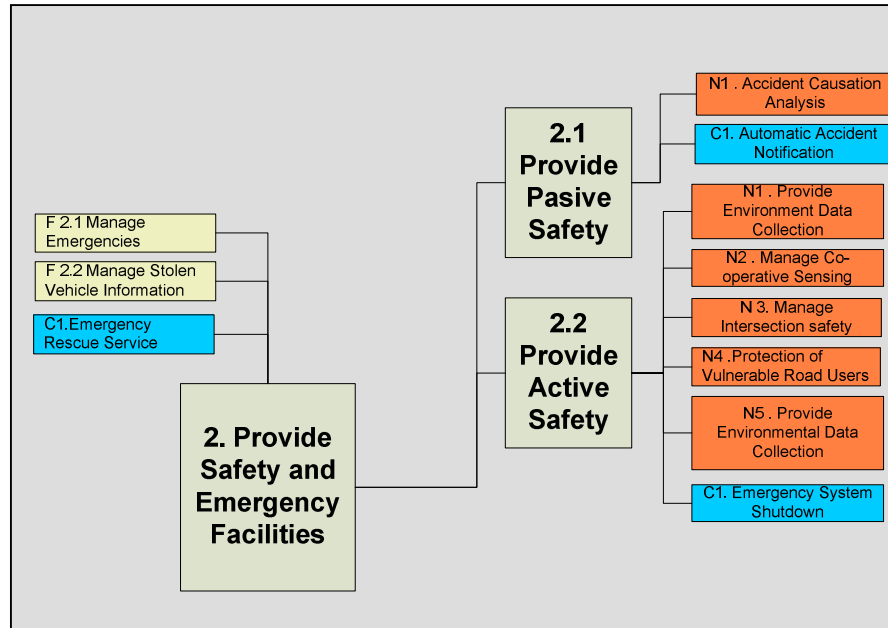
This function can be considered as an extension of the FRAME function “1.3. Perform Electronic Payment Transaction”, to which new considerations regarding the new kind of vehicles are included.

#### **4.2 Area2. Provide Safety and Emergency Facilities**

Safety and security is always a key issue in urban transportation systems. Safety and emergency facilities can play a very important role in reducing fatalities and injuries, and can also help reduce incident-related delays.

The identified functions in Safety and Emergency facilities include “provide passive safety”, “provide active safety” and “manage emergencies”. These are still relevant for the AUTS.

**Figure 4: Area 2. Provide Safety and Emergency Facilities**



Three new functionalities have been identified, mainly associated with driverless vehicles. They are summarised in the Table below for a comparison with the existing functionalities. More detailed descriptions have also been provided.

**Table 4: New functionalities providing Safety and Emergency Facilities**

<b>Passive safety:</b>	
Refers to all design measures (vehicle design and safety systems) that protect the car’s occupants or pedestrians against injury or reduce the severity of injuries in the event of an accident.	
Available Measures:	New Elements
Seat belt; air bag, vehicle design (e.g. crumple zones), infrastructure design (e.g. collapsible signpost)	<b>Automatic Accident Notification (eCall or special systems in AUTS vehicles)</b>
<b>Active safety:</b>	
Refers to everything designed to help prevent an accident from happening	
Available Measures:	New Elements
On-board systems: ACC, Lane Departure Warning, ISA, Collision Warning/Collision Avoidance, Lane-changing Assistance; Parking Assistance; Night Vision Enhancement, anti-lock braking system (ABS), electronic stabilisation program (ESP), voice control system	<b>Emergency System Shutdown</b> (new systems may also be introduced in CyberCars including electronic map based functions for <b>guidance</b> and speed control, and <b>weather adaptive control</b> assistance systems e.g. to slow a vehicle on icy surfaces etc.)
<b>Emergency service:</b> Emergency services refer to public services that deal with emergencies and other aspects of public safety.	
Available Measures:	New Elements
Response team: Fire, medical (ambulance), police Infrastructure: emergency phone; on-vehicle emergency system (e.g. Code Red Radio on London Bus, eCall) and emergency routes to safety	<b>Emergency Rescue Service</b>

In the new AUTS, some vehicles may run on a guided track which may not be readily accessed from the ground. In case of emergencies involving these vehicles, special rescue services may be required. Such a service may need special equipment with specially trained personnel. For example, in the case of a PRT unit breakdown, it could block the guideway and paralyse the whole system. The traditional emergency service may not be able to deal with this, and a special team may be required for such rescue and recovery operations under the new scenarios. Whereas notifying these services is a functionality as part of the functional architecture for the CityMobil systems and has been covered above, this does not constitute a functionality in itself.

#### **4.2.1 Provide Passive Safety: Automatic Accident Notification (involving new vehicles)**

##### ***- Introduction/ Background***

The passive safety measures are used to reduce the negative consequences of accidents when they do occur. One effective measure is to notify the incident as soon as possible. The driverless and ADAS-equipped vehicles may have many different types of sensors which may also be used in a vehicle-based automatic accident detection system. This new functionality will involve the automatic detection of an accident and automatic notification using communication links; e-Call if it is generally available, or a special system if necessary. Issues regarding the extent and severity of incidents/ accidents that must be automatically notified, and the level of response required will need further investigation.

##### ***- Description of Function***

Function 4.2.1 shall provide automatic accident notification for all CityMobil systems by detecting incidents and automatically notifying the responsible emergency services.

##### ***- Function Inputs/ Outputs***

Inputs are location of CityMobil vehicles, location and traffic data (e.g. speed, flow, etc.) of conventional vehicles/ traffic, CCTV images and infrastructure/ vehicle sensor data detecting incidents/ accidents. Outputs are notifications to the responsible emergency services of location and characteristics of accidents/ incidents.

##### ***- CityMobil Systems***

This function applies to all CityMobil systems, where no driver is present in the vehicle, i.e. PRT, DMC and CTS. In the case of HTB and ACC a driver is still present, even if the vehicle might be in automated mode at the time, here only conventional e-Call functionalities are required, but no additional specific functionalities.

##### ***- FRAME Functions***

Accident notification priority is included in the FRAME architecture document as part of a number of functionalities as part of providing safety and emergency facilities, and traffic management, but functionalities for CityMobil systems will not be completely covered by these. Furthermore specific rescue service might be required (e.g. for PRT vehicles on an elevated guideway) and have to be notified.

#### **4.2.2 Provide Active Safety: Emergency System Shutdown**

##### ***- Introduction/ Background***

The entire or partial shutdown of systems may become necessary when continued operation of the system, e.g. a PRT system; poses imminent dangers to passengers and/or the

environment. Such functions are usually required for any highly automated systems. Important issues related to this functionality include, but are not limited to organisational arrangements of responsibilities for a system shutdown, technical implementation of a system shutdown, and system recovery strategies.

#### **- Description of Function**

Function 4.3.3.1 shall provide automatic system shutdown for all CityMobil systems applicable in case incidents/ accidents.

#### **- Function Inputs/ Outputs**

Inputs are detection/ notification of incidents/ accident. Outputs are the full/ partial system shutdown.

#### **- CityMobil Systems**

This function applies to all CityMobil systems, where no driver is present in the vehicle, i.e. PRT, DMC and CTS. In the case of HTB and ACC a driver is still present, even if the vehicle might be in automated mode at the time, therefore a system shutdown would not be necessary.

#### **- FRAME Functions**

Emergency system shutdown is not included in the FRAME architecture document, therefore this has to be created as an additional functionality as part of the functional architecture of the CityMobil systems.

### **4.3 Area 3. Manage Traffic**

Traffic management relates to influencing traffic flows and demand through a range of traffic control measures. These involve:

- i) the detection of road network conditions (traffic, flows, environmental conditions, maintenance etc) and unexpected events like incidents;
- ii) the identification of an appropriate 'management strategy'; and
- iii) the implementation of that strategy using the available measures which generally include traffic signals for controlling traffic, and the communication of relevant additional information to drivers/travellers using (e.g.) VMS, radio broadcast, or web sites to give parking, route guidance and/or diversion advice.

These functionalities relate to road based transport and are recognised in the ITS framework architecture.

The relevance of this for the systems to be studied within CityMobil is set out below.

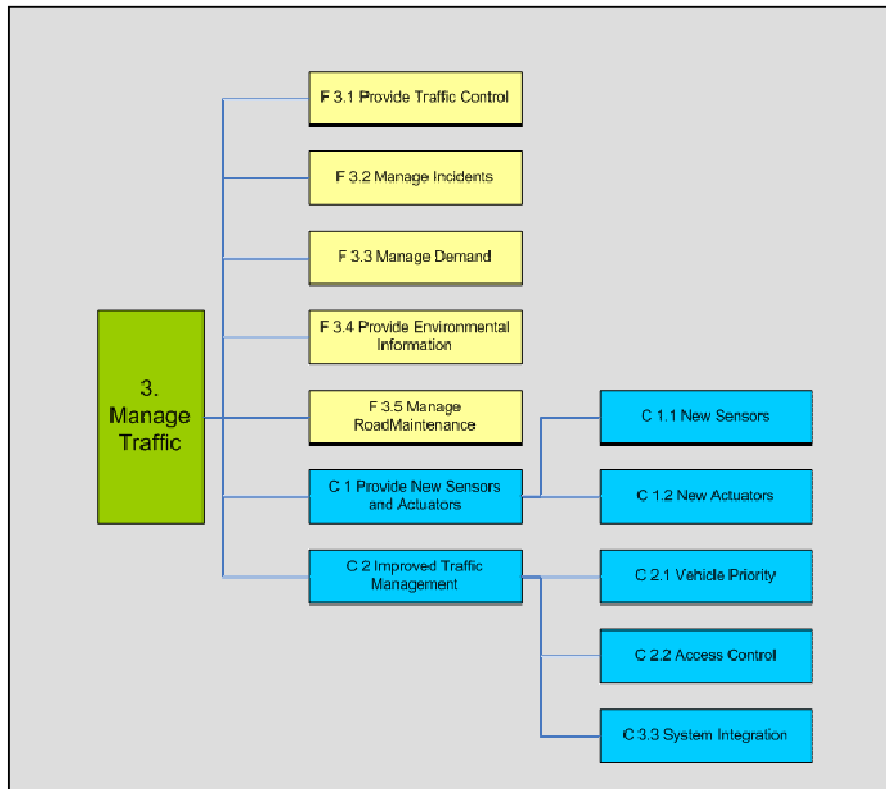
In the following paragraph a first updating of present functionalities of FRAME Architecture and introduction of new functionality emerging from CityMobil are analysed.

Deliverable D4.2.1 Operational Architecture (due in Month 21) will provide more details which will be useful for discussing updating of FRAME Architecture.

Analysis has been performed with the support of FRAME navigation Tool which is available at the following web address:

[http://www.frame-online.net/BrowsingTool/BrowsingTool\\_Version3/HomePage.html](http://www.frame-online.net/BrowsingTool/BrowsingTool_Version3/HomePage.html)

**Figure 5: Area 3. Manage Traffic**



The 5 types of advanced transport systems covered by the CityMobil project are:

- Personal Rapid Transit PRT: small vehicles, demand responsive public transport, fully automatic, fully segregated, running on a dedicated guideway
- High-tech Buses (HTB): large vehicles, public transport, manually driven on conventional roads, but fully automatic and segregated running on lightly equipped priority lanes.
- Dual mode' cars (DMC): small vehicles, private transport but otherwise as HTBs.
- Cybercars (CTS): small or large vehicles, demand responsive public or private transport, fully automatic, needs no special infrastructure and can (in principle) run mixed with other traffic on conventional roads
- Advanced City Cars (ACCs): small vehicles, private transport, manually driven (no automatic mode), running mixed with other traffic on conventional roads

Although these different systems all share some common technologies and functions, the implications for the functional architecture will vary widely.

The existing functionalities from the framework architecture, and indeed the architecture itself, are probably sufficient as they stand to cover the more conventional developments, in particular:

- guided Bus Rapid Transit systems and
- Advanced City Cars

In contrast, the other 3 more advanced systems that require particular infrastructures will require the architecture to be expanded to cover new functionalities which are to be identified as part of this research.

Note however that PRT, if wholly segregated, can be considered to be essentially the same as a rail (e.g. metro) system, while if it is only partly segregated (e.g. runs partially on street), can be considered to be essentially the same as an LRT system.

The appearance of new semi and fully automated vehicles brings up new opportunities for designing a modern and highly customized traffic management system by introducing new technology. The possibilities opened up by these 'new sensors' and 'new actuators' functions may lead to quantitative and qualitative improvements in the way current traffic management systems operate. Furthermore, a number of specific topics will be addressed.

#### **4.3.1 New mobile sensors**

##### ***- Introduction/ Background***

This functionality would relate to the potential offered by AUTS to use the advanced vehicles as mobile sensors. This means that, while in operation, all the on-board systems AUTS vehicles incorporate can be used to collect data e.g. travel times and send them to the Traffic Control Centre. Current traffic management, based on external infrastructure measurements, can be improved by providing more information about every single vehicle and adding a certain degree of intelligence to single vehicles. This feature will be available in new vehicles, such as ACCs or HTBs that will become "mobile sensors".

##### ***- Description of Function***

Function 4.3.1 determines which kind of devices and sensors can be developed and installed in new vehicles in order to provide the management traffic system with useful real time information, while respecting strictly the users privacy.

##### ***- Function Inputs/ Outputs***

Inputs to this function are provided by each vehicle's sensors (current speed, current location, route to be followed, lane detection, travel times, distribution of the nearest vehicles...). Outputs correspond with all actions taken to improve traffic flow (vehicle speed regulation, vehicle steering control, customized traffic control actions, specific traffic situations forecasting...).

##### ***- CityMobil Systems***

These new measures apply to those vehicles proposed in the CityMobil project that aim to become the main part of the future, not segregated and rail-less traffic. In first instance, these vehicles will be both ACCs and HTBs. Nevertheless, DMCs and CTSs will also include these systems as they get introduced in use.

The main devices for these purposes include location systems (e.g. GPS), automatic driving assistance systems and vehicle-vehicle/vehicle-infrastructure communication systems.

##### ***- FRAME Functions***

This function provides an enhancement to FRAME functions considered in the 3<sup>rd</sup> area (Manage traffic). Concretely, 2<sup>nd</sup> (Provide traffic control), 3<sup>rd</sup> (Manage demand) and 5<sup>th</sup> (Manage road maintenance) functions can obtain benefits from the new amount of information the Traffic Control Centre would receive, due to the implantation of sensors and communication devices in the vehicles.

### **4.3.2 Provide new actuators**

#### ***- Introduction/ Background***

Traditional actuators used for traffic control/management include traffic lights or VMSs (Variable Messages Signs).

In the framework of AUTS, however, the traffic management system receives a lot of highly detailed information about current state of the different roads. This could allow the management system to adopt a new traffic control approach, where traditional general actuators will be substituted by specific-vehicle control actions (“virtual actuators”). In other words, instead of setting a traffic light in red for all vehicles, the traffic control system will have the possibility to transmit to each individual vehicle what it specifically can or has to do in a given situation. Doing this for all the vehicles in the network will probably take a very long period. However, AUTS offers the possibility of achieving this in a shorter term, at least for a subset of the vehicles in the network

#### ***- Description of Function***

This ‘new actuators’ function establishes the possibilities of a future traffic management system to obtain highly detailed information about the state of every single vehicle on the road, and therefore provide customized control signals to each vehicle. This system would enhance the capacity of roads by helping to relax the vehicles flow.

#### ***- Function Inputs/ Outputs***

Inputs and outputs are highly related to those explained in function ‘new sensors’ (see 4.3.1), since both functions have a common objective.

Inputs to this function are provided by each vehicle’s sensors (current speed, current location, route to be followed, lane detection, travel times, distribution of the nearest vehicles...). Outputs correspond with all actions taken to improve traffic flow (vehicle speed regulation, vehicle steering control, customized traffic control actions, specific traffic situations forecasting...).

#### ***- CityMobil Systems***

In order to successfully implant this kind of traffic management, improvements on the traffic control infrastructure must be taken. These improvements include the implantation of vehicle-infrastructure-vehicle communication systems, and the development of data processing units that make feasible the decision of individual control action over every single vehicle (or platoon of vehicles).

Doing this for all the vehicles in the network will probably take a very long period. However, AUTS offers the possibility of achieving this in a shorter term, at least for a subset of the vehicles in the network (i.e. the ACCs).

#### ***- FRAME Functions***

This function provides an enhancement to FRAME functions considered in Area 3 area (Manage traffic). Concretely, FRAME Functional Areas 3.1 (Provide Traffic Control) and 4.1 (Provide Environmental Information) will benefit from the implantation of the proposed system, since a Traffic Control Centre will have a high amount of useful information to plan traffic with, and a higher capacity to efficiently distribute and control vehicles.

### **4.3.3 Vehicle Priority**

#### ***- Introduction/ Background***

With the implementation of advanced transport systems within the existing transport system infrastructure, priority has to be given to the automatic systems (at signal controlled junctions and at merging areas between separate and mixed use parts of the network). For this new traffic control strategies have to be developed.

#### **- Description of Function**

This Function shall provide vehicle priority to CityMobil systems at merging areas and signal controlled junctions through traffic management measures.

#### **- Function Inputs/ Outputs**

Inputs are the location of the CityMobil vehicles in mixed use part (=request to give priority), or the location and traffic data (e.g. speed, flow, etc.) of CityMobil vehicles in separate part (for merging), and the location and traffic data (e.g. speed, flow, etc.) for conventional vehicles/ traffic, and signal control settings. Outputs are setting signals, operating barriers, or opening platoons of CityMobil vehicles to allow merging/ priority for CityMobil vehicles.

#### **- CityMobil Systems**

This function applies to HTB, CTS, and DMC. Priority at signal controlled junctions applies to all three systems (for DMC only when considering an urban closed e-lane) in the case of operating in a mixed use environment or when crossing a lane with conventional traffic at a junction. Priority/ access between mixed use and separate areas applies to HTB and CTS, but is different for DMC. When considering a closed e-lane concept vehicle priority also relates to check of vehicle functionalities ('health check') and platooning and merge/ de-merge on the e-lane, there is also some overlap with access control.

#### **- FRAME Functions**

Vehicle priority is included in the FRAME architecture document as part of a number of functionalities, relating to traffic management and control, in view of giving priority to e.g. public transport vehicles and emergency services, But the functionalities required for CityMobil systems will not be completely covered by these.

### **4.3.4 Access Control**

#### **- Introduction/ Background**

Although some of the advanced transport systems covered as part of the CityMobil project are able to operate in mixed traffic with conventional modes of transport, other systems require segregated infrastructures (stations, high speed lanes). For these accesses control measures have to be in place.

#### **- Description of Function**

This Function shall provide access control for CityMobil vehicles when entering a segregated infrastructure from a mixed environment through traffic management measures.

#### **- Function Inputs/ Outputs**

Inputs are location of CityMobil vehicle in mixed use part (=request to give priority), or location and traffic data (e.g. speed, flow, etc.) of CityMobil vehicles in separate part (for merging). Outputs are operating barriers, or opening platoons of CityMobil vehicles to allow merging/ access for CityMobil vehicles.

#### **- CityMobil Systems**

This function applies to HTB and CTS for access between mixed use and separate areas, but is different for DMC. When considering a closed e-lane concept vehicle priority also relates to check of vehicle functionalities ('health check') and platooning and merge/ de-merge on the e-lane, there is also some overlap with access control.

#### **- FRAME Functions**

There is overlap between this function and the FRAME function F.3.3 Manage Demand. The former is specifically related to access control measures involving the new infrastructure created by AUTS. F.3.3 is more concerned with the implementation of demand management strategies that aim to re-distribute traveller demand between modes of transport.

### **4.3.5 System Integration**

#### **- Introduction/ Background**

As described above, new infrastructure and functionalities have to be developed in order to ensure a smooth operation of advanced transport systems as part of the multi-modal transport system. But these cannot be implemented as stand alone systems; they have to be integrated with the existing traffic control systems.

#### **- Description of Function**

This new function provides systems and tools to successfully introduce the new investigated advanced transport systems within the present transport services context, searching for a feasible integration of new and current systems.

#### **- Function Inputs/ Outputs**

Inputs and outputs of this functionality relate to all traffic and vehicle data required to integrate the operation of all CityMobil systems into the existing traffic management and control system.

Inputs to this function are services offered by both present and new developed systems. Outputs are cooperative and not incompatible services offered by the Traffic/Transport Management Operator to citizens.

#### **- CityMobil Systems**

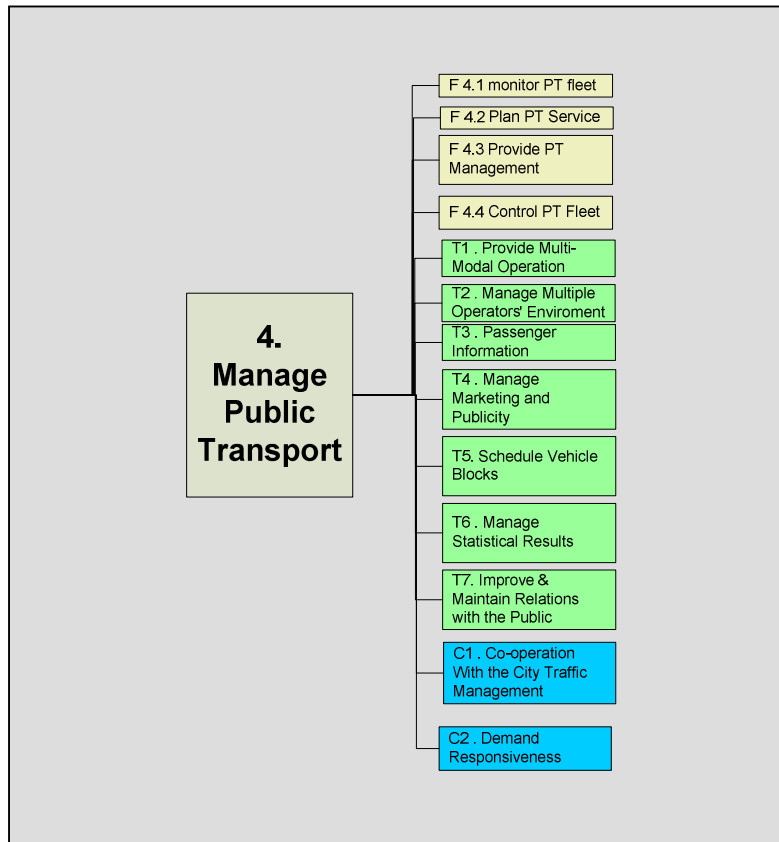
This functionality relates to all CityMobil systems that require specific traffic management and control functionalities, including PRT, HTB, DMC, and CTS, but not ACC.

#### **- FRAME Functions**

A System Integration function is a completely new addition to the functions described in the FRAME architecture. FRAME already defines a series of services that modern traffic management systems are recommended to provide. CityMobil adds new functionalities that complement or enhance the previous ones, and is therefore responsible of the design of a feasible integration program.

## **4.4 Area 4. Manage Public Transport**

### **Figure 6: Area 4. Manage Public Transport**



#### 4.4.1 Co-operation with the City Traffic management

Since AUTS falls to a large extent within the area of Public Transport, specific provisions will be necessary to coordinate it with the traffic management area in the overall framework of the urban mobility system.

##### **- Introduction/ Background**

With the introduction of enhancements in both the Public Transport and the Traffic Management areas, a new function is needed to efficiently combine both areas, leading to a better environment where public and private transport can both benefit.

##### **- Description of Function**

Function 4.4.1 shall provide the coordination between the Traffic Management area (including the new proposed services) and the Public Transport area, in order to achieve a good quality public transport service employing the advantages of the new frame of Traffic Management.

##### **- Function Inputs/ Outputs**

Inputs of this function are traffic related information (provided by the Traffic Management area) and public transport fleet state information (provided by other functions in the Public Transport area). Outputs are indications to both areas in order to assure a high quality public transport service minimizing negative effects over private traffic.

##### **- CityMobil Systems**

This area will apply firstly to the HTBs, which are nearest to a practical implementation. In this area, for example, the system could be coordinated to provide priority to public buses over private traffic.

In a second step, this function will be more important as driverless vehicles become more widely introduced in public transport services.

#### **- FRAME Functions**

The FRAME architecture already suggests a certain degree of information exchange between the Traffic Management area and Public Transport services. This function goes beyond that, proposing interaction of both areas to actively combine them and reach a higher level in quality of public transport by using all new tools and information available.

#### **4.4.2 Demand Responsiveness**

AUTS will offer new possibilities to adapt PT services to meet the demand. In the best case the vehicle can be waiting for the passenger – as opposed to what happens today with public transport - and at the very least flexibility, convenience and personalisation will be offered to the passenger. Booking a trip or a vehicle for the route and the time the passenger wishes should definitely be easy.

##### **- Introduction/ Background**

Classically, public transport systems offer a low level of personalization. They are based on fixed schedules and fixed stops. This can change with the introduction of AUTS which will offer new possibilities to adapt to the demand.

##### **- Description of Function**

The 'demand responsiveness' Function will meet the requirements of a modern Transport System to be easier to use by users and easier to manage by Transport Providers.

##### **- Function Inputs/ Outputs**

Inputs to this function are provided by public transport users (planned trips, location of users, date and time when transport is required...). Outputs of this function are a specific schedule and delivery plans to provide service on demand to all users.

##### **- CityMobil Systems**

This function applies mainly to public transport systems involving PRTs, rental ACCs or DMCs, and CTSs. These small capacity vehicles are more suitable to offer taxi type services, which are the ones that can be more customized for the user, and provided flexibly at selected times, dates and locations.

In these cases, vehicles can be waiting for the passenger (as opposed to what happens today with public transport). At the very least flexibility, convenience and personalisation will be also offered to the passenger.

##### **- FRAME Functions**

FRAME Function 4.2 (plan PT service) manages the planning of pre-scheduled transport services. This function still applies to, for example, HTBs. The new function, however, points at a taxi-like service, adding quality to the Public Transport System.

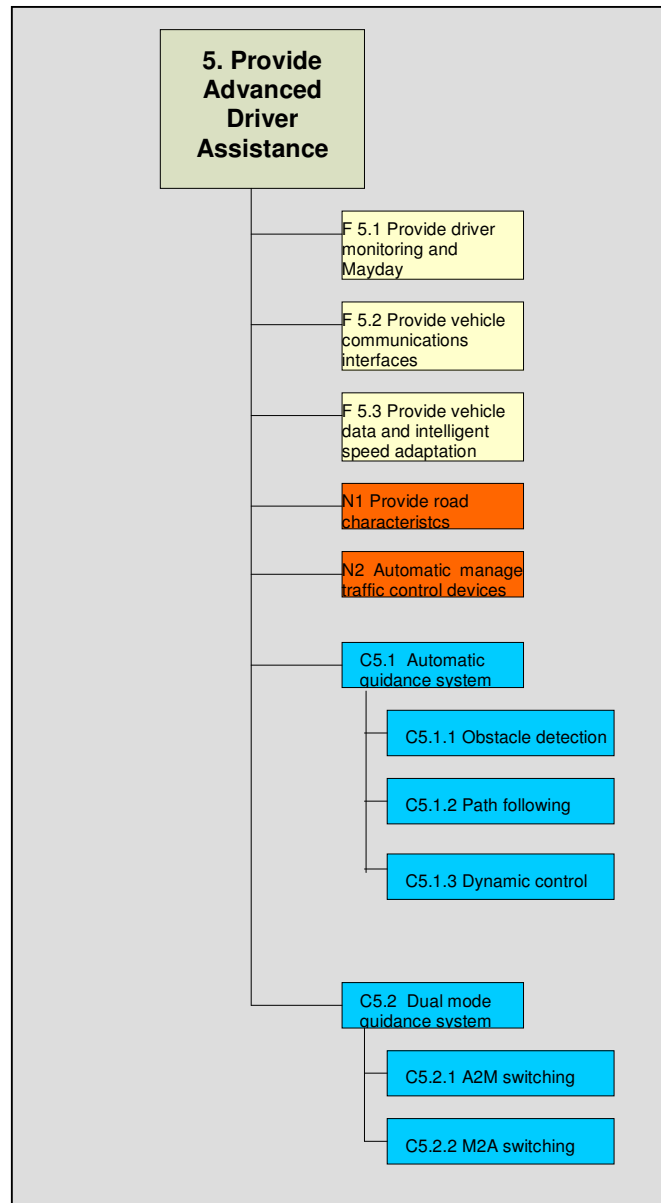
#### **4.5 Area 5. Provide Advanced Driver Assistance**

All AUTS types covered by the CityMobil project need driver assistance systems in order to safely operate in mixed traffic and dedicated lanes. In some AUTS these systems assist a driver directly, while in AUTS which are driverless, the systems are nevertheless needed to support a virtual driver. Different driving assistance modalities should be considered to be applied on three kinds of vehicles:

- Fully autonomous vehicles (Cybercars and PRT);
- Dual mode vehicles providing autonomous driving control in specific situations (DMC, HTB).
- Vehicles providing assistance under continuous human driver control (ACC).

New driver assistance technologies must be developed for both fully autonomous and dual mode vehicles.

**Figure 7: Area 5. Provide Advanced Driver Assistance**



Autonomous AUTS vehicles must be equipped with a safe and reliable automated guidance system, integrated with the overall urban transport system, i.e. other autonomous or dual mode vehicles and infrastructures. As the system is fully automated, no intervention of the user is taken into account, even if remote and manual emergency control procedures should be provided anyway. Main features of the guidance system can be separated in the following three sub-functions, which can be implemented in fully autonomous vehicles and in dual mode vehicles for autonomous guidance operations.

Dual mode vehicles such as DMC and HTB must be equipped with a driving assistance system which has two distinct operative states:

- Traditional manual guidance, under human driver's control;

- Automatic guidance (where allowed) under driver supervision.

When dual mode vehicles are operating in automatic guidance mode, an automated system such as the one previously described, takes the complete control of the vehicle.

A key aspect is represented by the switching procedure between manual and automatic states: the “switch” event must be safely managed by a simple and effective user interface providing different kind of information:

- Where automatic guidance can be enabled;
- Where automatic guidance must be disabled;
- Where and when a transition must/can occur;
- What is the current system status (manual, automatic, switching).

#### **4.5.1 Obstacle detection**

##### ***- Introduction/ Background***

Within the autonomous guidance system it is necessary to introduce a function that provides obstacle detection in order to integrate the AUTS themselves into the overall urban transport system.

##### ***- Description of function***

The obstacle detection function shall detect any object present in the vehicle’s surrounding area, in order to avoid collisions with other vehicles, pedestrians, road infrastructures or any kind of obstacle present along the planned path.

##### ***- Function Inputs/Outputs***

Laser, radar and camera-based sensors can be used to detect possible obstacles and then trace their position and motion, so that dangerous situations can be detected and safely avoided e.g. by stopping the vehicle.

Several aspects should be taken into account:

- The position of the obstacle must be determined with an accuracy of a few centimetres, according to the sensors adopted;
- The detection refresh rate must be high enough to allow a safe avoidance manoeuvre in case of unexpected moving obstacles;
- The detection range must be consistent with the maximum allowed speed and the scenario in which the AUTS should be used. Higher speeds require long range sensors, while open scenarios with intersections require a wider field of view.

The obstacle detection function is strictly related with the vehicle dynamic control system for obstacle avoidance manoeuvres. For this reason, data provided by sensors must be processed by a central unit in order to feed the control system with reliable data and then to establish an efficient interface between the two sub-systems.

Therefore the inputs for this function are the scenario detected by the sensors and the data collected by the vehicle dynamic control system.

The output is the position (and the motion) of any obstacle in the vehicle’s surrounding area with an accuracy of a few centimetres. The output is used by the function Vehicle Dynamic Control System (see 4.5.3 below), which automatically controls steering, throttle and brake actuators, determining longitudinal and lateral motion of the vehicle.

##### ***- CityMobil Systems***

This function applies to fully autonomous vehicles (CTS), and to dual mode vehicles (DMC) for autonomous guidance operations.

#### **- FRAME functions**

An Obstacle detection function is not included yet in the FRAME architecture so it can be added as a new CityMobil functionality.

### **4.5.2 Path following**

#### **- Introduction/ Background**

The introduction of new AUTS vehicles such as HTB and dual-mode cars entails the need of a function that provides path following, in order to segregate these vehicles from the normal urban transport system. New advanced driver assistance control strategies have to be developed and new technologies have to be investigated.

#### **- Description of function**

An accurate position monitoring system must be provided, in order to keep the currently planned path and to remain within the dedicated lanes or areas. Suitable solutions could be provided by electromagnetic transponders placed along the dedicated paths, or digital cameras which identify lane boundaries and path location

#### **- Function Inputs/Outputs**

Vehicles should be capable of recognizing and following the correct path autonomously, using only the data provided by the advanced navigation system, and without any user intervention.

The path following function can be separated in several sub-functions:

- Path detection;
- Trajectory definition;
- Trajectory following.

For the path detection sub-function, a vehicle-infrastructure interaction must be established in order to determine the vehicle position with respect to the path to be followed. Above-mentioned electromagnetic or video sensors must gather positioning information with a refresh rate high enough to control the vehicle at the maximum speed allowed by the scenario.

The trajectory definition consists in processing raw sensors data using specific algorithms in order to obtain an accurate prediction of the trajectory to be followed by the vehicle. Also in this case the delays introduced by data processing must guarantee vehicle control reliability.

Once the trajectory has been defined, the dynamic control system must be driven in order to follow the path resulting from the previous sensing and processing activities.

The inputs for this function are the data collected from the sensors (e.g. electromagnetic or video) - with an adequate refresh rate - and from the infrastructure, in order to determine the relative position between the vehicle and the path to be followed..

The outputs are the results of the algorithms used to determine the path to follow and the trajectory. These outputs are used by the function Vehicle Dynamic System (see next section), which automatically controls steering, throttle and brake actuators, determining longitudinal and lateral motion of the vehicle.

#### **- CityMobil Systems**

This function applies to the CityMobil Systems that need to be segregated into a dedicated lane or follow a planned path. The HTB and the Dual-mode cars are the best candidates for using this new functionality, because both require separate lanes to operate in fully automatic (i.e. driverless) mode, but it can be extended to other systems such as CTS that run in dedicated areas of a city centre.

#### **- FRAME functions**

Obstacle detection function is not included yet in the FRAME architecture

### **4.5.3 Vehicle dynamic system control**

#### **- Introduction/ Background**

In order to safely operate in mixed traffic and dedicated lane scenarios, a driverless AUTS vehicle of the CityMobil project must be equipped with a dynamic control system that allows the vehicle to automatically control steering, throttle and brake based on the data collected by the previous sub-systems.

#### **- Description of function**

This function shall dynamically decide the actuations and actions required in order to automatically control steering, throttle and brake determining longitudinal and lateral motion of the vehicle based on the information provided by the subsystems:

- Obstacle detection
- Path following

#### **- Function Inputs/Outputs**

Information provided by the previous sub-functions represent the inputs for the vehicle dynamic control function, which automatically controls steering, throttle and brake actuators, determining longitudinal and lateral motion of the vehicle.

The automatic steering system must control the steering angle according to the path following sub-function information, in order to keep the right trajectory with an uncertainty of a few centimetres. Hence the steering sub-system controls the lateral dynamics of the vehicle, while longitudinal control is performed by automatic throttle and brake controls.

Longitudinal controls are in charge of keeping the right speed according to road conditions (e.g. traffic density, crossroads, curves, speed limit); in particular, the brake control sub-system should be also capable of performing emergency braking manoeuvres in case of an obstacle detected by the obstacle detection function (4.5.1 above)..

A key feature for the dynamic control sub-function is the real-time response to stimuli coming from vehicle sensors: the reaction time for each control sub-system must be of few milliseconds, to guarantee a safe and comfortable automatic guidance.

Finally, the overall reliability and safety of the sub-system itself must be assured. As this sub-function is responsible for the complete control of the vehicle, fault-tolerance properties must be implemented for all the critical tasks.

The outputs are actuations and actions taken to control the steering, the throttle and the brake.

#### **- CityMobil Systems**

This function applies to fully autonomous vehicles (CTS) and in dual-mode vehicles for autonomous guidance operations.

#### **- FRAME functions**

This function is not covered in the frame architecture so it can be justified as a new function in the CityMobil project.

### **4.5.4 Guidance mode switching**

#### **- Introduction/ Background**

When the vehicle is leaving an area supporting automatic guidance, or when a particular automated manoeuvre is completed, an automatic-to-manual guidance switch must occur.

For this new switching control strategies have to be developed.

#### **- Description of function**

This function shall provide the facilities to switch between the automatic and manual guidance within the dual mode vehicles.

It also shall provide an emergency procedure in order to completely disable the automatic control in case of particularly critical situation or system failures

#### **- Function Inputs/Outputs**

In Automatic-to-manual switching procedure, a user interface is needed to inform the driver about the request of intervention. He must then confirm and take over manual control before the automatic control system can be shut down. The more imminent is the switch event, the more forcefully the advice must be sent to the user. In the event that he fails to respond, an emergency procedure will need to be invoked (see below). It is suggested that, when the vehicle is running in automatic guidance mode, the user cannot autonomously intervene to take back control, but he must wait for a system request of intervention except in an emergency (see below).

In automatic-to-manual procedure the input is the system request of intervention for a manual guidance, while the outputs are the advice to the driver and the activation of the manual control of the vehicle.

In Manual-to-automatic procedure, when a vehicle is approaching an area supporting automatic guidance, a user interface is again needed to inform the driver. Again the system waits for a confirmation before taking over automatic control. In manual-to-automatic procedure the input is the request to activate the automatic control (when the vehicle is approaching an automatic guidance area) and the confirmation of the driver through the HMI.

*Emergency situations:* in dual mode vehicles, the driver must be allowed to override the automatic system in an emergency. In this case, the automated system must recognise a manual intervention from pressure exerted by the driver on the steering wheel, the brake and/or throttle pedals, and consequently leave the control of the vehicle to the driver. Conversely, if the driver fails to respond to a request from the vehicle to take over manual control, a procedure will be needed whereby the vehicle is automatically brought to a stop and parked out of the way of other traffic.

**- CityMobil Systems**

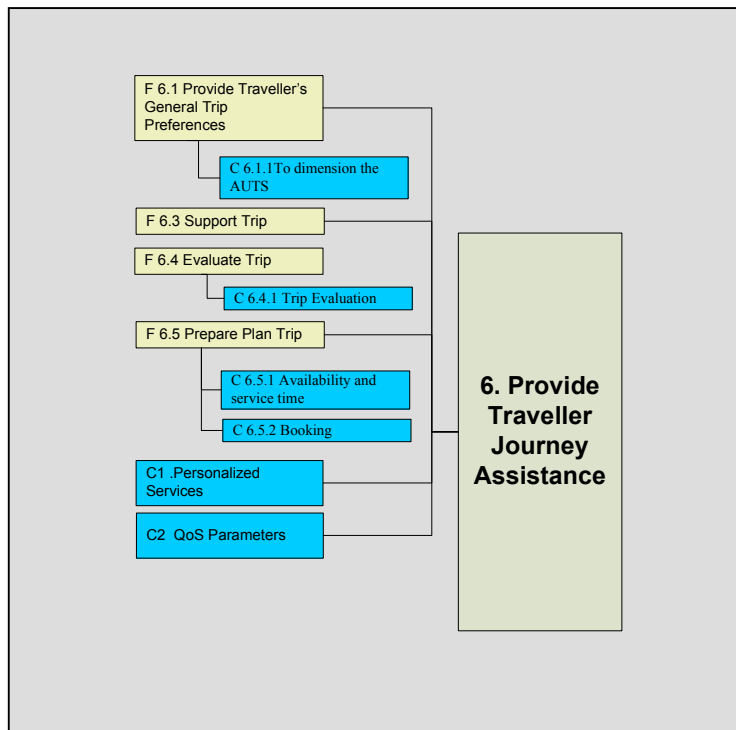
This function applies only to dual-mode cars where it is possible to switch between manual guidance and automatic guidance mode.

**- FRAME functions**

This function is not covered by the FRAME architecture.

**4.6 Area 6. Provide Traveller Journey Assistance**

**Figure 8: Area 6. Provide Traveller Journey Assistance**



Advanced transport systems require a well structured and reliable system to assist the traveller through the whole transport chain with different types of information. The level of information will depend on the complexity of the system and length of travel.

**4.6.1 Traveller trip preferences: To dimension the AUTS**

**- Introduction/ Background**

There is a need for the transport facility provider to have access to data about the trip preferences of the potential users in order to dimension the system both with regards to the total number of vehicles/seats and for route planning purposes. Trip evaluation and travel data is essential in order to optimize the transport system.

**- Description of Function**

This Function 'to dimension the AUTS' will allow the transport facility provider to have access to General Trip Preferences databases in order to constantly improve the personalised services of the AUTS in the interests of users.

#### **- Function Inputs/ Outputs**

Inputs are GTP data that contain trip preferences (the origin and destination points, trip dates and times, trip distribution, and travel time distribution), occupancy per vehicle and number of available vehicles. Outputs are effective changes in location, scheduling, routeing, and vehicles location to provide most cost-effective customised services.

#### **- CityMobil Systems**

This function applies to all five new AUTS investigated in CityMobil. By consulting tailored databases the transport provider can implement new measures in order to enhance its service quality and to optimize the transport capacity of collective (PRT, CTS and HTB) and individual systems. The analysis of preferred boarding points, routeings, and timetables can help to organise a suitable transport system for customers (PRT operating on dedicated guide ways, HTB, automatic DMC). The PRT system for example, takes passengers non-stop from their departure point to their destination by providing immediate response to each passenger trip demand. For shared cars (DMC or ACC) the data analysis can be helpful to identify the target user groups and to organise the fleets of cars in order to meet the specific mobility requirements of the users. For individual and autonomous vehicles, (ACC, CTS, manual DMC), data analysis can provide evidence for parking area requirements that can vary widely from place to place.

#### **- FRAME Functions**

This function is an extension of the function F 6.1 in the FRAME architecture document. It is one of the functionalities related to the transport facility provider in order to let it have data access.

### **4.6.2 Trip evaluation**

#### **- Introduction/ Background**

The success of AUTS will depend on positive experiences from the users. The assistance provided to the travellers is essential for how the traveller appraises the quality of the transport system. Thus, it is important to continuously evaluate the user experiences to maintain the service level and the system attractiveness.

#### **- Description of Function**

Function 'trip evaluation' will be able to study customers' evaluation reports in order to improve constantly the quality of transport services.

#### **- Function Inputs/ Outputs**

Inputs are the users' evaluations of AUTS that can be positive experiences, disappointments or complaints. The measure of customers' satisfaction implies a survey method of the transport service performances. Outputs are new measures in transport services in order to maintain a high level of satisfaction among customers. By interpreting users' appraisals of AUTS and by handling and investigating all complaints, improvements of service quality can be implemented to surpass customers' needs and to meet the users' expectations.

#### **- CityMobil Systems**

This function applies to all AUTS investigated in CityMobil. In collective transport (PRT, CTS and HTB), a better understanding of customers' needs will help to build an easy and efficient transport network system inside cities. The main reasons people use or do not use the proposed transport services will be monitored with the means of a trip evaluation report that can be sent by internet or filled up at different points by interviewers in order to attract new customers. In individual vehicles (DMC or ACC) a questionnaire survey will also be sent regularly to customers or to potential new ones. Customer satisfaction will be regularly evaluated and improved in all new transport services investigated in CityMobil.

#### **- FRAME Functions**

The function is an extension of FRAME function 6.4 and is not included in the FRAME architecture document. It is one of the functionalities related to the transport facility provider, in view of constantly studying travellers' opinions and expectations about transport services. This particular independent function is justified to improve the quality of innovating systems examined by CityMobil.

### **4.6.3 Availability and service time**

#### **- Introduction/ Background**

To obtain a broad acceptability among potential users, it is necessary to have a large amount of vehicles and a flexible system. This requires a real time information system, which keeps track of the fleet and available vehicles, including lead times.

#### **- Description of Function**

Function 'prepare trip' shall be able to assist travellers when choosing trip preferences. The system shall provide real time information about available vehicles (data furnished by FRAME function 4.1 'monitor PT fleet') and alternative service times.

#### **- Function Inputs/ Outputs**

Inputs are trip preferences of travellers using their own travel configuration that contain means of transport, time of departure/arrival, preferred routes. Outputs are trip plans that can be appreciated and changed by customers at any time.

#### **- CityMobil Systems**

This function applies to all systems investigated in CityMobil. The FRAME function 4.1 will be able to detect incidents on board and to track collective and individual fleet vehicles. These stored data shall be sent to the Provide Traveller Assistance Area to establish a real time information system that proposes potential trips in concordance with customers' preferences. Departure and arrival points, real time information about routings and timetables (for PRT operating on dedicated guide ways, HTB and automatic DMC) will be communicated to travellers. The arrival and journey time predictions data are sent in real time to the Provide Traveller Assistance Area to be displayed to travellers and to assist them in planning trips. For shared cars (DMC or ACC) or autonomous vehicles (ACC, CTS, manual DMC) the system shall organise fleet vehicles in order to propose specific bookings in accord with mobility requirements of the customers. The system shall be able to make bookings suitable to the users demand and able to prevent incident or unexpected difficulties such as cars not returned at the scheduled time.

#### **- FRAME Functions**

The function is an extension of FRAME function F 6.5 and is not included in the FRAME architecture document. The function is one of the functionalities related to the transport facility provider, in view of providing real time information about available transport services.

#### **4.6.4 Booking**

##### ***- Introduction/ Background***

An unmanned system requires a robust solution for booking and queue management. It is important to have on-line and instant confirmation of bookings. Advance booking procedures should be available.

##### ***- Description of Function***

The function 'booking' shall propose to customers easy advance online booking procedures in order to avoid any waiting time when booking.

##### ***- Function Inputs/ Outputs***

Inputs are online trip bookings required by each customer at any time. Bookings for other services, hotel accommodation or connections with other means of transport can be included in the reservation. Customers shall be encouraged to book tickets in advance. Outputs are instantly confirmed and guaranteed reservations that shall be saved on individual smart cards by the means of e-tickets.

##### ***- CityMobil Systems***

Advance online booking is required for all AUTS investigated in CityMobil. Passengers can reserve their seats and get e-tickets for any collective transport (PRT, HTB or CTS). The system shall be flexible to allow customers to cancel or change their e-tickets at any time. The smart cards with advanced bookings shall allow customers to store tickets without payment until the day of travel. For autonomous vehicles (DMC, CTS and ACC), the users can book online in advance a vehicle at their preferred boarding points.

##### ***- FRAME Functions***

The function is an extension of the function F 6.5 and is not included in the FRAME architecture document. This function shall provide easy facilities for vehicles and e-tickets reservation.

#### **4.6.5 Personalized Services**

##### ***- Introduction/ Background***

Tomorrow's passengers will have the necessity of getting access to a set of personalised services during their trips. These functions – not necessarily related to transport - will provide customized data in order to improve the traveller's experience.

##### ***- Description of Function***

The function 'personalised services' shall provide customer access to personalised services on board to make the journey particularly appreciated.

##### ***- Function Inputs/ Outputs***



Inputs are customized stored data for each customer related to trips or to personal preferences related to entertainment on board. Outputs are high speed personal information of the particular journey for each customer.

#### **- CityMobil Systems**

For collective vehicles, customers can have a personalised service when booking online or on automatic devices. But on board, the access of a set of personalised services is of more concern for transportation by individual vehicles such DMC, CTS or ACC. ACCs are equipped with advanced electronic systems for driver navigation assistance or fully automatic systems. To facilitate driving inside cities, these cars contain Intelligent Speed Assistance, parking assistance, collision avoidance and stop&go features. Information (congestion, strikes, cultural and sport events) from traffic control centres, from operators or from other road users can offer exclusive facilities (e.g. suitable alternative routes) for driving inside busy cities.

Passengers can also receive different customised information linked to the trip such as future connections and boarding time of the next means of transport (multi-modal journey). Concerning services not related to the transportation function, CityMobil systems can offer a wide range of high speed and real time information on local warning news, weather conditions, maps, bookings, and be able to play music in agreement with customer's taste. Particular preference data could be stored on an e-ID smart card that could be recognised when boarding, and special devices will be able to display a set of personalised services. The transfer of these data can also be realised via mobile phone, MP3, electronic agenda.

#### **- FRAME Functions**

Personalized Services Booking is a new function, not included in the FRAME architecture document.

### **4.6.6 Quality of Service (QoS)**

#### **- Introduction/ Background**

AUTS will make possible – and necessary - the recording and analysis of QoS indicators – e.g. waiting time, service predictability - in order to enable the acceptance of AUTS and its successful deployment.

#### **- Description of Function**

The function 'QoS' is a reliable monitoring system of QoS indicators in order to maintain a high level of transport service quality.

#### **- Function Inputs/ Outputs**

Inputs are QoS indicators stored in databases and analysed. Outputs are the analysis and interpretation of these indicators that can create new targets and measures in Transport services in view of delivering better services for the customers.

#### **- CityMobil Systems**

These indicators can be applied in all AUTS in CityMobil and can concern transport accessibility, usefulness, ease of use and reliability, information availability and comprehensibility, comfort, cleanliness, safety and privacy. Indicators will be defined with acceptable and reasonable thresholds and can highlight some weaknesses in services. Measures of queue lengths or average waiting times and estimation of performances in

terms of predictability for collective transport (PRT, HTB or CTS) will be realised in order to induce positive changes. To satisfy the QoS requirements, some new initiatives or measures will be taken in view of obtaining better indicators and better feedbacks by customers. These new introduced improvements will be evaluated in their turn.

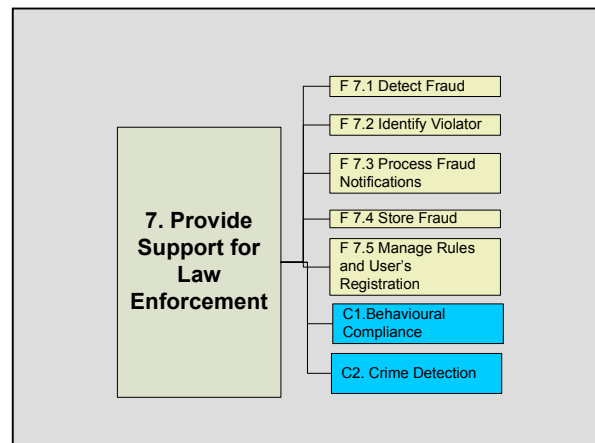
### - FRAME Functions

Quality of Service (QoS) is a new function, not included in the FRAME architecture document. This function contributes to the progress of the service quality of all AUTS.

## 4.7 Area 7. Provide Support for Law Enforcement

Law enforcement refers to all activities for ensuring obedience to the laws and the maintenance of public order. Traffic enforcement is more focused on the governance of driver behaviour to ensure safe and efficient use of road space, whilst law enforcement in an urban transportation system may also include prevention of crime against persons or property.

**Figure 9: Area 7. Provide Support for Law Enforcement**



The main law enforcement targets include but are not limited to:

- Alcohol
- Speed
- Traffic Signs and Signals
- dedicated lane use
- licensing (both driver and vehicle)
- parking
- vehicle emissions
- unlawful driving behaviour such as reckless/dangerous driving, use of mobile phones, seat belts, tailgating etc.
- anti-social behaviour on board public transport or at terminals
- toll and ticket violations

Enforcements are mainly carried out by the relevant authorities (mainly the police), increasingly supported by automatic enforcement aids (e.g. speed cameras, red light

cameras, number plate recognition etc). The current enforcement mechanisms will continue to serve as long as drivers remain responsible for traffic offences. However, with the introduction of driverless vehicles and/or advanced driver assistance systems (ADAS) into the new AUTS, a number of important new issues can be expected. The most dramatic change may be the shift of responsibility from drivers to operators, or to ADAS or their manufacturers. The operators may be required to maintain their duty of care to ensure that driverless vehicles or ADAS systems do not breach regulations enforced by traffic laws. This, however, may not be easy. If the system fails (even supposing that the chance is very small), the question of whether the operators or ADAS manufacturers should be held responsible may arise, together with a number of other legal issues which it may not be possible to address in this work package.

However, even when the system does not fail, there may still arise some issues which need to be addressed. One concerns the behaviour of driverless or ADAS-equipped vehicles. It is conceivable that such vehicles could become frequent 'violators' which may endanger other traffic and will cause heavy disruption for law enforcement system. It will therefore be necessary to ensure that the behaviour of driverless or ADAS-equipped vehicles is compatible with traffic regulations. A new functionality may need to be established to ensure that these vehicles behave properly from point of view of traffic enforcement (Behavioural Compliance).

Another important functionality will be "crime detection", which is of vital importance to maintain a high level of security for any transportation systems. These are described in more detail below.

#### **4.7.1 Behavioural Compliance**

##### ***- Introduction/ Background***

With the introduction of fully-automated vehicles into shared-road scenarios, and with vehicles equipped with many different kinds of driver assistance systems, some vehicles on public roads may be fully or partially controlled by artificial intelligence. Improper settings on these systems may result in the vehicle's becoming the target of traffic law enforcement

##### ***- Description of function***

This 'behavioural compliance' function shall provide facilities to take into account dynamic behaviour and changing of critical parameters such as safe distance, speed limit in order to prevent violation and fraud.

For example the function will provide the customization of thresholds of critical parameters (e.g. safe following distance or speed) related to the variations in the vehicle's path.

##### ***- Function Inputs/Outputs***

If a driverless vehicle (or a vehicle with stop-and-go ACC on) follows a leading vehicle at a pre-set short headway, this may be acceptable in some countries but may be seen, and enforced, as 'tail-gating' in some other countries. Another example is offered by vehicles travelling at an infrastructure-based speed limit, and at the same time exceeding a variable speed limit (applied to that area at that time). If the variable speed limit is mandatory, the vehicle will be in violation.

If the vehicle is working in the right way and all the functionalities have been implemented correctly, if a generic and dynamic event occurs and the vehicle behaviour doesn't follow the rules of the particular scenario, a legal problem must be faced.

The same problems could occur if the vehicle system is affected by a malfunction.

Critical variable parameters can be set off-line, in order to prevent systematic violations of particular regulations, or they can be adjusted in real-time, while the vehicle is operating, via I2V communication in case of particular situations which require temporary restrictions in vehicle behaviour.

For this function it is possible to identify the following inputs:

1. Behavioural vehicle data (speed, lane recognition, safety distance)
2. Behavioural driver data (fastened safety belts, detection of use of mobile phone without earphones)
3. Current norms regulating the stretch of road which the vehicle is going through.

The outputs are:

1. Warning to the driver
2. Notification to law enforcement agency

#### **- CityMobil Systems**

This function applies to fully autonomous vehicles (CTS), to dual mode vehicles in autonomous mode and to vehicles providing assistance under continuous human driver control (AAC).

#### **- FRAME functions**

The 'behavioural compliance' function is in part related to the fraud detection introduced in the FRAME architecture but it is not completely covered, so this function can be justified as a new functionality in CityMobil system.

### **4.7.2 Crime Detection**

#### **- Introduction/ Background**

The driver and a 'mass' of passengers clearly serve as a natural deterrent to both anti-social and criminal behaviour (e.g. assault, damaging properties by etching and graffiti etc) on-board vehicles and at terminals. With the introduction of driverless vehicles with small numbers of passengers (e.g. PRT), anti-social and criminal behaviour may become a more serious issue. It will therefore be necessary to provide additional Crime Detection functionality in the AUTS

#### **- Description of function**

This 'crime detection' function shall provide the facilities to detect crime in the AUTS by monitoring the behaviour of passengers within the CityMobil systems.

#### **- Function Inputs/Outputs**

Crime detection in urban transportation systems can be defined as: 'the identification of anti-social or criminal behaviour through monitoring the transport facilities'. One of the most commonly used crime detection measures in this area is the use of CCTV. At the same time, the increased likelihood of detection also provides a strong deterrent. However, the CCTV

image is usually not processed so that it is not used to detect the crime in real-time, but instead, to provide evidence for ex post enforcement.

Recent advances in CCTV technology and image processing techniques may make it possible to implement real-time abnormal behaviour detection in the future, so that relevant forces may be informed in real time to further help prevent criminal offences. This will be especially useful in driverless systems so that security of passengers can be reassured.

Generally speaking, one valuable force multiplier technology to fight crime detection is intelligent video surveillance (IVS) computer software that can detect threats, crimes, or events of interest in a surveillance video and automatically generate and distribute alerts for those events. This technology exists today and is experiencing commercial success in law enforcement applications world-wide. However, to fully exploit the benefits of such technologies, four specific factors need to converge: more specific IVS applications must be created to solve law enforcement challenges; IVS technology must enable smart devices that can be rapidly and ubiquitously deployed; these devices must proliferate based on applications and infrastructure outside of law enforcement; and law enforcement agencies must adopt new processes and policies to exploit them.

It is difficult to clearly identify the inputs and the outputs of this function. It is possible to assume as input the result of the monitoring activities and as output the identification of anti-social or criminal behaviour within the CityMobil systems.

#### **- *CityMobil Systems***

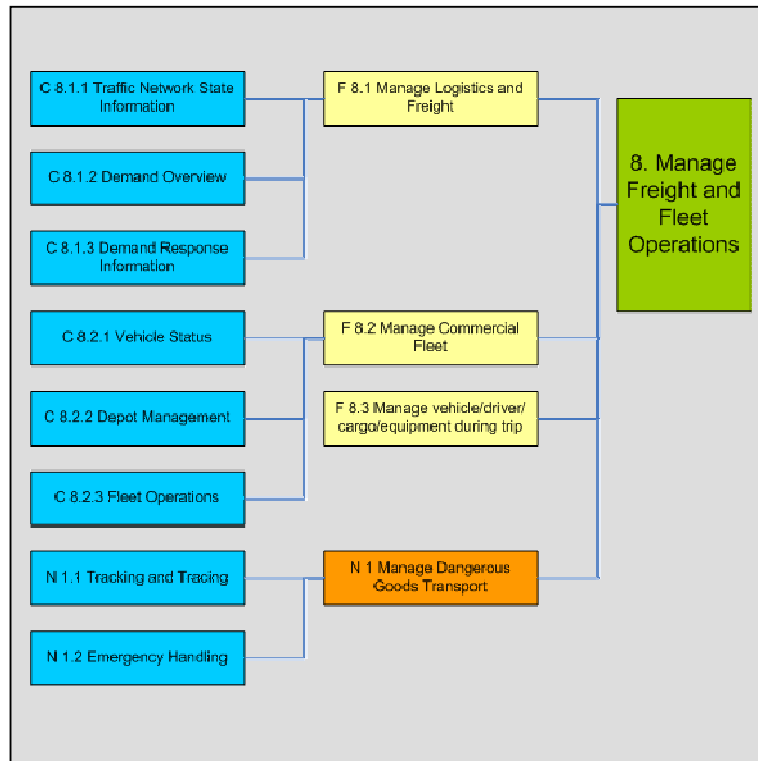
This function applies to CityMobil vehicles with automatic guidance (driverless) and with a small number of passengers (such as PRT) where anti-social and criminal behaviour may become a more serious issue.

#### **- *FRAME functions***

The detection of fraud introduced by the FRAME architecture does not cover this type of crime detection inside public transport, so it is justified to include it as a new functionality of the CityMobil system.

## **4.8 Area 8. Manage Freight and Fleet Operations**

**Figure 10: Area 8. Manage Freight and Fleet Operations**



With increasing amounts of transported goods each year, the dependency on and the importance of trust-worthy information on current and expected traffic states will become more and more crucial for in-time delivery or reliable arrival times for freight and passengers, respectively. Conventional, automated and track bound transport may use different traffic space, or share the same space for some part of their routes. Transport mode related information is necessary to achieve an optimized routing.

#### **4.8.1 Traffic network state information**

##### ***- Introduction/ Background***

A detailed Level-of-Service picture of consolidated traffic related parameters is necessary, validated and evaluated using former incidents or traffic states. New sensors and new algorithms for building a consolidated picture should be anticipated for the future, as well as a thorough information network. This is closely related to the functionalities of FRAME Functional Area 3, “Manage Traffic”.

##### ***- Description of Function***

The implementation of the function ‘traffic network state information’ shall provide information related to the traffic network state in order to be precise as possible in estimating travel times and scheduling future transport.

##### ***- Function Inputs/ Outputs***

Inputs are traffic information from sensors or traffic management centres, respectively (compare with section 4.3 ‘Manage Traffic’). The information is transported into an overall traffic picture related to transport routes. It can be used by scheduling and disposition algorithms.

#### **- CityMobil Systems**

This function applies to ACC, CTS, and DMC and may serve as an input for estimating arrival times and route choice. It has importance for fleet management of Cybercars since their task is the delivery of goods just-in-time and to minimize travel times.

Traffic data will be collected either via conventional methods, or gathering vehicle information (e.g. average speed) and subsequently delivering it through V2I communication.

#### **- FRAME Functions**

Information integration is included in the FRAME architecture document as part of a number of functionalities, related to traffic management and control. However, a new explicit function is necessary to provide this information to end users. Possibly not only for fleet management, but fleet management is certainly an end user which needs this information.

### **4.8.2 Demand overview**

#### **- Introduction/ Background**

Demand is the motivation for each transport mode. Good knowledge on what is the demand and at what time is essential for efficient planning and routing. Different demand on different services to be used at the same time must be considered.

#### **- Description of Function**

The function provides an overview on the actual and future demand.

#### **- Function Inputs/ Outputs**

Inputs are demand parameters from different sources: by phone, web services, push-for-demand, automatic freight check-in stations etc. Parameters are time to collect, time to deliver, amount of goods / number of boxes, weight, destination etc. Output is going to disposition tools, which differentiate between automatic and non-automatic transport.

#### **- CityMobil Systems**

This function applies to CTS and serves for disposition of vehicles and route choice.

#### **- FRAME Functions**

Demand status may be included as a sub-function for F.8.1 "Manage Logistics and Freight"

### **4.8.3 Demand response information**

#### **- Introduction/ Background**

If fleet management takes into account the actual traffic state or even assumes traffic states derived from historical information, variations usually cannot be anticipated. Since the amount of transported goods will increase in future, the number or / and size of deployed vehicles will increase and have impact on the traffic state. Knowledge on near future freight transport processes will allow more precise scheduling.

#### **- Description of Function**

The implementation of the function 'demand response information' shall provide information related to the near future traffic network state taking capacities for freight transport into account (roads, parking lots, unloading bays etc.). It shall allow estimation, as precise as possible, of travel times and help scheduling future transport and minimize costs.

#### **- Function Inputs/ Outputs**

Inputs are traffic information from fleet management and disposition centres. The information is transported into an overall planning picture related to transport routes. It can be used by scheduling and disposition algorithms. Output shall be an interface providing this information on a network street level.

#### **- CityMobil Systems**

This function applies to ACC, CTS, and DMC and may serve as an input for estimating arrival times and route choice. It has importance for fleet management of Cybercars since their task is the deliverance of passengers and goods just-in-time and to minimize travel times.

#### **- FRAME Functions**

Information integration is included in the FRAME architecture document as part of a number of functionalities, relating to traffic management and control. This function delivers information on near future transport processes which can be included in routeing planning.

### **4.8.4 Vehicle status**

#### **- Introduction/ Background**

The availability of vehicles is basic for disposition and scheduling. The problem may be seen as small, but a number of factors are influencing the availability. These are maintenance and service times, breakdowns while on routes, stops due to regulations of toll, driving bans, environmental causes, and controls and refuelling, slowing down or stopping due to congestion etc.

#### **- Description of Function**

The function 'vehicle status' provides information on the status of each vehicle.

#### **- Function Inputs/ Outputs**

Inputs are the transmitted vehicle statuses. Output is analyzed into speed, waiting time, occupancy eg passenger/freight status etc.

#### **- CityMobil Systems**

This function applies to ACC, CTS, and DMC and may serve as an input for estimating arrival times and route choice. It has a certain importance for fleet management of Cybercars since their task is the delivery of passengers and goods just-in-time and to minimize travel times.

#### **- FRAME Functions**

Vehicle status may be included as a sub-function to "Availability" under FRAME sub-function F8.2 "Manage commercial fleet".

### **4.8.5 Depot management**

#### **- Introduction/ Background**

Depots of different sizes will play a major role in future fleet organisation. According to the expected demand and network state, multiple depots will be distributed throughout the transportation network. The depots must be especially located with respect to the track network of automatic traffic. Large depots will be set up in areas with traditional high demand. They will be away from areas of low demand. To react to this low demand, in time, smaller depots will be installed, down to mini depots with very few vehicles (or even single units e.g. parking or service bays for one vehicle). The distribution of depots in location and size will vary with time.

A distributed network of depots could cause logistic problems which need to be evaluated and, if necessary, resolved.

The system will provide an extension of the automatic services presently available in industrial stores.

In this field the innovation is actually involved in automatic loading/unloading of goods; an investigation is needed on:

- in which direction innovation could be extended,
- and using which technology (for instance Wireless Sensor Network or RFID)

#### **- Description of Function**

Depot management analyses the response times on demand and relates it to the current distribution and size of depots.

#### **- Function Inputs/ Outputs**

Inputs come from the disposition tool, which delivers information on routeing of freight and passengers. A redistribution of depots will be delivered back to the disposition tool.

#### **- CityMobil Systems**

This function applies to CTS and serves for the disposition of vehicles and route choice.

#### **- FRAME Functions**

Depot management may be included as a sub-function of FRAME F8.2 "Manage commercial fleet".

### **4.8.6 Fleet operations**

#### **- Introduction/ Background**

Besides classical tasks to combine demand with transport space, advanced algorithms will be needed to take account of the special requirements of automated traffic and related problems, e.g. priority rules, number of interactions with common traffic, time needed for lane changes, automatic loading stations etc.. Also, the advanced algorithms must take care of maintenance and service times. Additionally, the scheduler and routeing disposition tool must pay attention not to unbalance the system by deploying too many fleet vehicles along the same routes or services.

#### **- Description of Function**

Function 'fleet operations' integrates all available information from actual and near-future traffic states, depot management, vehicle status, demand overview and demand response information into a basis for routing and scheduling algorithms. Its main task is to use the

information to check availability of vehicles, utilization of used network parts and delivering this information back to re-route or re-schedule vehicle operations.

#### **- Function Inputs/ Outputs**

Inputs come from functions delivering information related to routing and scheduling and the routing / scheduling engine. Output is a status message for the requested route and time combination.

#### **- CityMobil Systems**

This function applies to ACC, CTS and DMC. However, ACC and DMC are usually not controlled by a centre. Using the information on traffic state is therefore up to the users. CTS-fleets can be redirected.

#### **- FRAME Functions**

The extracted status information is valuable for all traffic management scenarios. Information integration is included in the FRAME architecture document as part of a number of functionalities, relating to traffic management and control. For fleet management information on fleets must also be integrated and evaluated, and status information must be delivered back to fleet control to adapt routing and scheduling.

### **4.8.7 Tracking and Tracing**

#### **- Introduction/ Background**

Tracking and tracing functionalities become an important issue in modern transport, specially when dealing with transportation of dangerous goods which should be constantly controlled and monitored in order to ensure not only the safety of the cargo itself, but also the citizens safety as many of this goods can be potentially dangerous for the health in case of accidents.

#### **- Description of Function**

This function, tracking and tracing, will allow a central system to check where the cargo is at any time and control what the status of the transported goods is in real time. To achieve this several sensors have to be installed in the vehicles which will provide to the system with the necessary information, such as the position of the vehicle, for tracking or the temperature and state of the cargo for tracing.

#### **- Function Inputs/ Outputs**

Inputs come from functions delivering information related to position, routing and state of the cargo. Output is a status message for the requested vehicle.

#### **- CityMobil Systems**

This function applies to CTS and DMC which are more likely to transport goods or to require tracking and tracing functionalities.

#### **- FRAME Functions**

This functionality is not considered in FRAME, so it has to be integrated as a new CityMobil functionality.

#### **4.8.8 Emergency Handling**

##### ***- Introduction/ Background***

When talking about transportation systems, where accidents can occur, there has to be a protocol to handle any kind of emergency situation. That's why we propose this new functionality 'Emergency handling', which will be used when a dangerous or an emergency situation take place.

##### ***- Description of Function***

This new functionality will have to be used ever when an emergency situation will occur. Many kinds of emergency situations can take place, for example a road accident, a breakdown, or any other incident that may interrupt the correct operation of the system. In these cases the emergency handling function will be used in order to restore the system operation.

##### ***- Function Inputs/ Outputs***

Inputs come from functions delivering information related to incidents or emergency situation that can occur. This information can be obtained by means of sensors or can be manually sent by the drivers of the different vehicles. The Output of this function will be the activation of an emergency protocol.

##### ***- CityMobil Systems***

This function applies to all the systems defined in CityMobil, as any of them can suffer an emergency situation.

##### ***- FRAME Functions***

This functionality is not considered in FRAME, so it has to be integrated as a new CityMobil functionality.

## **5 Conclusions**

Those new transport systems proposed and studied under CityMobil project do offer services whose requirements are not fulfilled by most of the systems utilised nowadays. This document deeps in the requirements of those modern transport means, defining all the functional areas and the functionalities in which the Sub Project 4 will work on. The functional areas described here are based on previous researches done in European Projects, especially in IST KAREN and FRAME projects, which define the necessary elements and processes required to achieve a global interoperating European Transport Architecture. This document completes the former work, adding new functionalities that the previous projects do not cover and are important for developing the new technologies and concepts defined in CityMobil.

The results presented on this deliverable are, therefore, a complete guideline to support the design of an Advanced Transport Architecture. This work supposes the basis to the analysis and development of modern systems transports that incorporate new technologies, such like those proposed on CityMobil project.

## **6 Sources**

### **6.1 Reference List**

1. European ITS Framework Architecture Functional Viewpoint
2. IST KAREN project