### Implementation specification for new extended traffic management and freight distribution management functionality

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<td>Author(s)</td>
<td>Alberto Zambrano, Lola Alacreu</td>
</tr>
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GLOSSARY

APA policy: access and priority assignment policy
APO: access and priority offer
FDMS: fright distribution management system
GUID: globally unique identifier
OBE: on-board equipment
OGE: on-goods equipment
RSU (RSE): road-side unit (equipment)
UTC: urban traffic control
1 Introduction
The aim of this work package is to specify a generic implementation of new solutions for urban freight traffic management and freight distribution management based on generic and local requirements coming from other work packages.
Specifically, this deliverable describes the specifications of the software interface that enables the interoperability between the On Board Unit, Road Side Equipment and the Management Centres (Urban Traffic Management Centre and Freight Distribution Centre), by means of open services. These functionalities will be demonstrated in the final workshop in Trondheim October 14th.

2 Objectives
WP3 addresses generic solutions for the implementation of the required extended functionality in the traffic management and freight distribution management systems. Such functionality will depend on interoperability with both the existing systems and the on-board systems.

The work package takes the intermediate framework architecture from WP5 as input, while it also provides new requirements as input to the framework architecture.

This deliverable presents the results of the work taken in tasks 3.1 and 3.2, namely:

- The implementation of extended traffic management functionality for urban freight by means of generic specifications of the implementation of the new traffic management functionality and its interoperability towards the extended freight distribution management system
- The implementation of new freight distribution management functionality by means of generic specifications of the implementation of the new freight distribution management functionality.

3 Links with others tasks
There are significant links between WP3, WP4 and WP5. ETRA has the main responsibility for the task of defining feasible specifications for a system implementing the functionality investigated in the project. Based on these specifications, Q-Free will be responsible for the On Board Unit software development and SINTEF for the central management software development of the demonstration.
4 Specifications

4.1 Overall system description

The system described by this specification supports the following functionalities:

- **Access and priority policies management**: this document describes a system that adapts the access policies to certain areas in an intelligent manner, taking into account real-time incidents and road status as well as individual vehicle characteristics, thus allowing the definition of highly versatile access policies.

- **Access control over controlled areas**: the specifications contained within this document also define a feasible mechanism to implement the control based on these kinds of policies.

- **Integration between the FDMS and UTC with access control purposes**: the proposed system integrates the necessary functions of the FDMS and the UTC, with the objective of including the usual activities of the transport companies in the access control and traffic control activities, thus increasing their added value both to the transport operators and the traffic managers.

- **Integration between the FDMS and UTC with resource booking and traffic planning purposes**: taking benefit of the deployed technologies, which allow an efficient communication between UTC and the freight delivery vehicles, and their control for traffic management and access control purposes, these specifications propose an enhancement to traditional resource booking services and traffic management tasks, using the information about planned freight deliveries to increase the efficiency of the roads and of the transport operators tasks.
Figure 1 Full UTC and FDMS database supporting the system
4.2 Functionalities

4.2.1 Access control

4.2.1.1 Definition of controlled areas

In order to deploy an appropriate access control scheme, the city is geographically divided into smaller entities, thus decentralising the access control management. The city can be considered as one area, or divided into several areas, depending on the size of the city, the degree of decentralisation that authorities want to achieve, and the former organisational scheme used for traffic management purposes. By dividing the city into several areas, the amount of information the vehicles have to deal with, as well as the complexity of the system, can be reduced. This way, the system becomes more scalable.

Inside each of the areas, smaller ‘controlled areas’ are defined. These controlled areas are the specific parts of the city that may need access control. Examples of controlled areas are:

- Industrial parks

![Figure 2 Controlled access areas](image-url)
• City centre
• Green zones

These controlled areas are delimited by a set of road links (i.e. streets), to which the access control applies. By delimiting the controlled areas by using physical road elements the control is not defined over a land area, but over a set of roads that provide access to the area that must be controlled. This way, the specified access control is applied to actual road sections, thus allowing a precise definition of the road sections the access policies apply to. There exist certain situations where vehicles must be checked or may receive some information prior to their entrance to some of the controlled areas. For instance, access to certain areas may be restricted to a maximum amount of vehicles at once. In order to cover such cases, the access control management defines the concept of “Approaching areas”. The approaching areas are optionally surrounding areas linked to one or more controlled areas. Their definition is similar to the definition of a controlled area (i.e. a set of road links).

Figure 3 shows the existing relationships between the different elements existing in the definition of the controlled areas. It reflects the division of the city into one or more areas (for scalability purposes), each of which can contain a set of controlled areas. Since access control is performed over these controlled areas, the specific access policies refer to them.

Figure 3 APA policies specification
Figure 4 shows an example of a controlled area that is defined (i.e. delimited) by a closed set of road links. In this example, streets surrounding the city centre are chosen as boundaries of the controlled area; APOs must therefore be checked when a vehicle driving through this boundary is detected.

4.2.1.2 Access control management through APA policies

The access control is applied to each of the controlled areas by applying an active APA policy.

The APA policy sets the default access right to its referred controlled area (access allowed/forbidden), together with a set of constraints over vehicle properties that extend the default permission.

The objectives of the access control are essentially two:
1. To limit the access of the freight vehicles to certain parts of the town in an intelligent manner, offering a flexible way to manage the access control
2. To provide feedback to the vehicle routing systems and the drivers, allowing them to optimise/adapt their trips through the city

Two kinds of parameters may affect the actual access rights of a vehicle:
1. Static parameters: these refer to properties of the vehicle that are unchanging during the present trip (e.g. vehicle dimensions and weight)
2. Dynamic parameters: these refer to characteristics of the road or of the vehicle that may change during the duration of a normal trip (e.g. traffic jams, incidents, cargo...)

In order to distribute the solution as much as possible, the following approach is followed to achieve the evaluation of the APA policies and the specification of the access rights to every single vehicle:

1. The access control database contains a predefined set of APA policies for each controlled area, associated to certain schedules
2. The APA policy planner receives real-time information (parameters) about the road status, and decides whether to apply the corresponding predefined APA policies or special policies. The APA policy planner can be as complex as necessary; possibilities go from a human operator specifying APA policies manually upon certain circumstances, to an automatic process of evaluation over the real-time road status. The output of the policy planner is a set of active APA policies (one applying to each controlled area), each of them only containing constraints over static parameters
3. Since they only refer to static constraints, these APA policies can be individually evaluated by each vehicle. As a result, the vehicle will generate a set of APOs allowing it to access the suitable controlled areas. The different access rights can then be communicated to the driver via wireless communication, and the routing systems of the vehicle can use this information to optimise the route.

4. In addition, in case the driver needs extra access rights in order to perform the delivery, it will be possible to request the UTC for an APO certificate in exchange for the corresponding fee.
The mechanism shown in Figure 6 above makes the active APA policy available to each vehicle. Therefore, OBEs can evaluate the policies to get the APOs that apply to them. Nevertheless, since APA policies are of a dynamic nature (they can change on a scheduled basis, or sporadically due to incidents on the road), OBEs must check periodically the validity of their APOs. Therefore, a mechanism to re-evaluate the APA policy when the APA policy planner changes the active one becomes necessary.

Since the system must be as decentralised as possible, in order to guarantee its simplicity and scalability, the UTC equipment cannot be in charge of monitoring the policies of each individual vehicle. This responsibility is therefore distributed among the vehicles themselves. The APA policy planner will attach to every APA policy it activates a Globally Unique Identifier (GUID). In case they detect that a new APA policy has been activated, they will request the new contents and re-evaluate their access rights.

In addition, it is worth noting that OBEs will also need to re-evaluate the policies every time their own properties change. This is likely to happen during any transport operation, when cargo is picked up or delivered (APA policies can refer to cargo policies).

4.2.1.3 Access control database

The access control concept described in the sections above is implemented in a relational database containing the following information:

- `cityProperties`: stores descriptive information about the city that deploys the Smartfreight system, in a property/value pairs manner. The information can include contact information to city management teams and other relevant city-level information.
- `areas`: stores the list of areas in which the city is divided
- `controlledAreas`: stores a list of the controlled areas with restricted access control that exist in the system, referencing them to their corresponding area
- `approachingAreas`: stores a list of approaching areas, associated to the controlled areas
- `controlledAreasBoundaryLinks`: stores the list of road links defining the limits of the controlled areas.
- `approachingAreasBoundaryLinks`: stores the list of road links defining the limits of the approaching areas.
- `controlledAreasProperties`: stores descriptive information about the controlled areas, in a property/value pairs manner. This information can include services or facilities available on the controlled area for instance.
- `APAPolicies`: contains a list of APA policies. An APA policy is defined as a set of constraints over the vehicle properties that need to be evaluated in order to decide whether access permission must be granted or denied. Each APA policy is tied to a controlled area, and it is valid during a certain schedule (defined as day of the week and a timeslot). The APA policy defines the default access permission of vehicles (column “defaultAllowed”) as well.
- `APAPoliciesConstraints`: contains the set of constraints over properties of the vehicles and traffic status. Each constraint is defined by a column indicating the property being evaluated, the value of the property that is actually being evaluated (column “value”), and a flag indicating whether this value must be considered a maximum threshold (column “ismaxvalue”).
4.2.1.3.1 List of possible controlled areas properties

The controlled areas can be restricted access resources of the road network, holding areas, public transport lanes, etc. The "controlledAreasInformation" table is open to contain all kind of information data that can be useful for the users. The database is structured in such a way that further data types can be added to the system if it becomes necessary. The following table shows some examples of this information.

<table>
<thead>
<tr>
<th>Subarea Property</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Owner</td>
<td>Organisation that owns the controlled area (local government, private organisation...)</td>
</tr>
<tr>
<td>Authority</td>
<td>Organisation responsible for managing the controlled area (local government, private organisation...)</td>
</tr>
<tr>
<td>Facility element</td>
<td>Identifies a facility that is present in the controlled area (hostel, showers, restaurant, petrol station, freight delivery lot...)</td>
</tr>
</tbody>
</table>

4.2.1.3.2 List of vehicle properties evaluated in APA policies

As explained before, the APA policies basically consist of a set of constraints over some properties of the vehicle. By comparing these constraints with the actual vehicle properties, the effective access control can be determined. Some examples about the properties included in this evaluation are shown in the table below. The database is structured in such a
way that further properties can be easily added to the system in case they become necessary.

<table>
<thead>
<tr>
<th>Vehicle Property</th>
<th>Description</th>
</tr>
</thead>
</table>
| Emission Standard | Classification of vehicle’s level of emissions according to the European emission standards  
  1. Euro 0  
  2. Euro 1  
  3. Euro 2  
  4. Euro 3  
  5. Euro 4  
  6. Euro 5  
  7. Euro I  
  8. Euro II  
  9. Euro III  
  10. Euro IV  
  11. Euro V |
| Fuel type | • Diesel  
  • Gasoline  
  • Bio fuel  
  • Electricity  
  • Hydrogen |
| Goods type | GPC code (“segment” level)  
  • 70000000 Arts/Crafts/Needlework  
  • 68000000 Audio Visual/Photography  
  • 77000000 Automotive  
  • 54000000 Baby Care  
  • 53000000 Beauty/Personal Care/Hygiene  
  • 83000000 Building Products  
  • 74000000 Camping  
  • 67000000 Clothing  
  • 66000000 Communications  
  • 65000000 Computing  
  • 58000000 Cross Segment  
  • 78000000 Electrical Supplies |
<table>
<thead>
<tr>
<th>ADR Hazard Class</th>
<th>Dangerous cargo identifier</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1. Explosive substance or article</td>
</tr>
<tr>
<td></td>
<td>2. Gases</td>
</tr>
<tr>
<td></td>
<td>3. Flammable liquids</td>
</tr>
<tr>
<td></td>
<td>4.1 Flammable solids, self-reactive and desensitised explosive</td>
</tr>
<tr>
<td></td>
<td>4.2 Substances liable to spontaneously combust</td>
</tr>
<tr>
<td></td>
<td>4.3 Substances which, in contact with water emit flammable gases</td>
</tr>
<tr>
<td></td>
<td>5.1 Oxidizing substances</td>
</tr>
<tr>
<td></td>
<td>5.2 Oxidizing peroxides</td>
</tr>
<tr>
<td></td>
<td>6.1 Toxic substances</td>
</tr>
<tr>
<td></td>
<td>6.2 Infectious substances</td>
</tr>
</tbody>
</table>

- 50000000 Food/Beverage/Tobacco
- 63000000 Footwear
- 87000000 Fuels
- 51000000 Healthcare
- 72000000 Home Appliances
- 47000000 Homecare
- 73000000 Household Kitchen Merchandise
- 75000000 Household/Office Furniture/Furnishings
- 81000000 Lawn/Garden Supplies
- 89000000 Live Animals
- 88000000 Lubricants
- 61000000 Music
- 64000000 Personal Accessories
- 10000000 Pet Care/Food
- 79000000 Plumbing/Heating/Ventilation/Air Conditioning
- 85000000 Safety/Protection – DIY
- 91000000 Safety/Security/Surveillance
- 71000000 Sports Equipment
- 62000000 Stationery/Office Machinery/Occasion Supplies
- 92000000 Storage/Haulage Containers
- 60000000 Textual/Printed/Reference Materials
- 84000000 Tool Storage/Workshop Aids
- 80000000 Tools/Equipment – Hand
- 82000000 Tools/Equipment – Power
- 86000000 Toys/Games
7. Radioactive material
8. Corrosive substances
9. Miscellaneous dangerous substances and articles

<table>
<thead>
<tr>
<th>Property</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width</td>
<td>Total width, including trailer (metres)</td>
</tr>
<tr>
<td>Length</td>
<td>Total length, including trailer (metres)</td>
</tr>
<tr>
<td>Height</td>
<td>Total height, including trailer (metres)</td>
</tr>
<tr>
<td>Gross weight</td>
<td>Total weight, including trailer (kilograms)</td>
</tr>
<tr>
<td>Number of axles</td>
<td>Number of axles of the freight vehicle</td>
</tr>
<tr>
<td>Presence of trailer</td>
<td>Variable stating whether the vehicle uses trailer or not</td>
</tr>
<tr>
<td>Booked resources</td>
<td>see 4.2.2</td>
</tr>
</tbody>
</table>

Table 1 Properties evaluated in APA policies

4.2.1.4 Real time traffic situation and access control

The different controlled areas could need special policies in case certain incidents are detected in the road network. These incidents include all the possibilities that affect the traffic flow in a negative way, as, for instance:

- Roadwork
- Accidents
- Special events
- Congestion...

Following the system structure presented in section 4.2.1.2, it is the APA policy planner, which manages this kind of information, which overrides the pre-programmed policies when necessary.

As explained before, the implementation and complexity of this element will be dependent on the specific necessities of the town. For instance, the APA policy planner in a small town could simply be a human operator making decisions upon the actual status of the traffic, while a bigger town could be interested in implementing an intelligent system connected to the traffic sensors in order to automate these kinds of decisions. The following table contains some possible inputs to the APA policy planner.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle intensity</td>
<td>Intensity of the flow of vehicles (veh/hour) in a given road at a given time. It is a metric of the capacity of the road that is being used.</td>
</tr>
<tr>
<td>Road occupancy</td>
<td>Percentage of time any vehicle is located over a given point of the road. Together with vehicle intensity, it provides a metric of the</td>
</tr>
<tr>
<td>Input</td>
<td>Description</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Average speed</td>
<td>Average speed of the vehicles circulating on a road</td>
</tr>
<tr>
<td>Average queue at traffic lights</td>
<td>Average size of the queue of vehicles formed in a given crossroad when traffic lights turn red</td>
</tr>
<tr>
<td>CCTV</td>
<td>Real-time road situation based on live video</td>
</tr>
<tr>
<td>Emergency services notifications</td>
<td>Notifications of major incidents coming from emergency services</td>
</tr>
</tbody>
</table>

Table 2 Inputs to the APA policy planner

4.2.1.5 Occupancy control of a controlled area

Another important functionality of an access policy is its capability to limit the access of a subset of vehicles (for instance, vehicles carrying hazardous goods entering a tunnel) up to a maximum number at once. Due to the nature of this parameter, it changes dynamically as vehicles move within the controlled area. Therefore, it cannot be included as part of a normal APA policy (which, as stated in section 4.2.1.2, only includes constraints over properties that can be evaluated by the vehicles). A special mechanism is necessary to control this parameter.

Since the amount of vehicles inside the controlled area is limited, the system must check this constraint and communicate the suitable message to the approaching vehicles before they arrive at the controlled area. The concept of approaching area, described in section 4.2.1.1, can be used for this purpose.

In order to implement this kind of control, specific equipment needs to be deployed in the accesses to the controlled area and to the approaching area. A set of Road Side Units (RSU) will be in charge of detecting and polling the approaching vehicles and making the decision of granting access or requesting the vehicle to move to a waiting area, which must be located before the entrance to the controlled area.

The procedure followed by the RSUs is shown in the pictures below. Namely, the steps to be followed are:

1. When a vehicle is entering the approaching area, its vehicle and cargo properties are polled by the corresponding RSU
2. These properties are crosschecked with the list of properties that are being considered in the constraint (for instance, existence of dangerous cargo). As a result, the vehicle can be in two situations:

   a. None of its properties is compromised: the access is granted by default
   b. Some of its properties are compromised: the system needs to evaluate the current status of the controlled area (amount of target vehicles inside the area and waiting to enter it, and maximum amount of target vehicles allowed inside the area at once)

3. In case b, if the system determines that the vehicle must wait outside the area, it sends a message informing of the decision and requesting the driver to wait at the holding area. The system holds a list of the vehicles that are waiting at the approaching area.

4. When a target vehicle leaves the controlled area, an RSU located at the exit detects it and informs the system. In case a vehicle is still waiting at the waiting area, the system will send a message allowing the driver to access the controlled area.
This kind of control does not need the interaction of the UTC. Since it only affects specific areas, which require the existence of roadside equipment, it is advisable to implement it locally. Therefore, a small control system needs to be implemented on these areas in order to get the information from the different RSUs and perform the appropriate decisions. This control system is only locally applied; it can be integrated with the UTC, but this integration is not mandatory. The elements it must contemplate are the following:

- List of RSUs controlling the entrances and exits, in order to allow the central system to take them into account.
- Schedule of APA policies and their properties, detailing which specific properties of the approaching vehicles will require evaluation for this access control.
- Real-time up-to-date list of vehicles currently inside the area.
- Real-time up-to-date list of vehicles stopped at the waiting area, which can be used to notify the necessary access grants as they become available.
4.2.2 Resource booking

One of the objectives of the Smartfreight project is to achieve a considerable degree of integration between the freight delivery and urban traffic control systems, allowing both to get benefits from the integration.

One way of achieving such integration is by efficiently controlling the presence of freight vehicles in the city, their schedules and the resources they are allowed to use. For instance, a city authority could be interested in reducing the presence of freight vehicles during certain periods of the day, and may consider allowing them to use certain normally reserved resources during the night.

An option to achieve the objective shown above would be the integration in a central database of all the resources in the city that are usually used by the freight delivery operators. These resources include in a first instance the loading bays that are present in the city. Nevertheless, this list can be completed with other elements of the city that traditionally are left out of reach of transport operators, such as public transport lanes or certain road corridors. By integrating this information in a single system, two objectives are accomplished:

- On the one hand, the UTC gets information about the loading bays, their opening times, the profile of their users, etc. Better traffic plans can be designed taking this information into account; the UTC could even be allowed to influence the timetables of the loading bays in order to achieve a higher efficiency of the roads.
- On the other hand, the freight delivery operators get a clear idea of the current and forecasted occupancy of the loading bays in the city, which allows them to plan the deliveries in a better way. In addition, they get the chance to use some city-owned resources, such as public transport lanes, at least at certain periods of the day, making their work easier and faster.
Figure 12 shows the subsystems that are involved in the integrated booking system. The advantages that this kind of system presents are the following:

- By integrating the major part of the resources of a city in a single system, the users (i.e. transport operators) get the advantage of having all the information in one place. Their work in investigating resources and planning delivery can be significantly reduced.

- As a result of integrating the booking system with the UTC, new types of resources (public transport lanes, lots at holding areas, etc) can be included in the database, thus incrementing the traditional functionality of this kind of system.

- The booking functionality will be available via electronic communication systems. This feature permits the transport operators to perform bookings beforehand, or adapt their bookings during trips (cancelling, changing slots or reordering deliveries) in order to enhance the efficiency of their work by adapting the bookings to their needs.

- The elements responsible for the traffic control in the city get an additional real-time information source that can become an input to the traffic planning design processes and the decision mechanisms of the APA policy planner.

A feasible information scheme implementing the booking system presented in this section is shown in Figure 13. The most important properties of this scheme are:
- Allows the resources database to grow without restrictions. FDMS and UTC will be the elements responsible for maintaining an up-to-date database of resources and their associated information (e.g. characteristics, availability).

- The availability information of the resources is structured in such a way that vehicles schedules will consider it.

- The database also contains a relationship between the resources and the controlled areas they are located in (in case they are). In this way, if a resource is located inside a controlled area, its related information is linked to the controlled area information, allowing the use of this information as part of the access control mechanism. This relationship is very important, since it allows the access control mechanism described in 4.2.1.2 to take into consideration the existence of a booking ticket as part of the access control restrictions. On the other hand, resources outside any controlled area can be defined as well; this relationship is not mandatory.

![Figure 13 Information scheme supporting resource booking functionality](image-url)
Once a successful booking is performed by any transport operator or OBE, the resourceBookings table must be updated with the information about the new booking. This information contains:

- Identifier of the booked resource
- Allocated timeslot
- Information about client (operator ID and Vehicle Identifier Number)
- Booking code: the system assigns a GUID to the booking operation, and communicates it to the client. The client can identify its booking anytime via this identifier

Since the booking system forms part of the UTC subsystem, the payment for the use of the resources can be managed by the UTC as well. Section 4.3.1 shows a possible mechanism for payment for this kind of service, including pre-arranged contracts with transport operators or sporadic clients.

4.2.3 Monitoring hazardous cargo

Since the list of hazardous items on-board is part of the vehicleProperties message, the UTC can register and keep control over the location of the vehicles carrying a determined type of hazardous cargo. With this purpose, upon the entrance of a vehicle in a controlled area and after receiving the vehicleProperties message, the UTC is able to register the cargo summary in a database for control purposes.

The way this functionality works is described in section 4.3.3.

4.3 Operation of the system

4.3.1 Entrance to an area

The whole process is triggered when a freight vehicle, equipped with an OBE and with a certain destination and booked delivery timeslot, approaches an area where the Smartfreight system is deployed. Once the communication between UTC and OBE is established at network level, the following process will be triggered:

1. The UTC tells the OBE to download the APA necessary for the city/area
2. OBE downloads the access control information (APA policies)
3. UTC sends the vehicle the necessary information to make the access features work. This information includes the controlled areas location and properties, and the active APA policy of the controlled areas under its domain.
4. The OBE will recalculate the route taking into account the received policies. The following cases may occur:
   i. The optimum route either does not go through any controlled areas, or the vehicle owns the necessary default access rights to drive through the controlled areas on its way. In this case, the vehicle can proceed with its optimum route.
ii. The optimum route goes through controlled areas and the vehicle has insufficient access rights to follow it; however, a sub-optimal route through access-allowed areas is still possible.

iii. The optimum route goes through controlled areas and the vehicle has insufficient access rights to follow it, and no sub-optimal route through access-allowed areas is available.

5. In cases b and c, the OBE will be given the possibility of requesting the necessary APOs in order to follow the optimum route. In this case, it will send an access request to the UTC, including the necessary information about the unmet constraints.

6. The UTC will re-evaluate the case of the vehicle, deciding whether
   i. to grant access charging a fee to the corresponding transport operator or...
   ii. definitely deny the access.

7. In case i, the fee is charged to the transport operator account in case an existing contract between the parties exists, and the corresponding APOs are processed in the system and sent to the OBE. In case no valid contract is found, the fee is communicated to the OBE (and further to the transport operator, depending on the company policy), and the vehicle needs to provide payment details.

8. In case ii, a request denial is sent to the OBE, thus forcing it to follow the sub-optimal route or even to cancel the trip in case such a route does not exist.
Route calculation (dependent on access policies) 

- **A)** selected route needs no access certificates
- **B)** selected route needs access certificates

- **Request access certificates?**
  - yes
  - no

- **Payment?**
  - Payment accepted
  - Payment rejected

- **Optimum route**
  - yes
  - no

- **Alternative sub-optimal route?**
  - yes
  - no

- **Sub-optimal route**
- **Cancel trip**

**Figure 14 Route calculation process upon reception of APA policies**
Once a route has been selected, the OBE must check the estimated time of arrival against the delivery schedule. Different possibilities are:

- **ETA << booked timeslot:** OBE will route the vehicle to the hold area nearest to the delivery destination, and will calculate a new route to the destination, providing an estimated departure time to meet the booked timeslot. If possible, OBE could try to negotiate a new delivery schedule with the FDMS.
- **ETA ≈ booked timeslot:** the vehicle continues with its route.
- **ETA >> booked timeslot:** the transport operator cancels the reservation and reserves a new one.

The actual times taken into account for the decision above will depend on the specifics of the delivery destination (mainly size, access possibilities and occupancy).

In addition, the dynamic nature of the APA policies should be kept in mind. As explained in section 4.2.1.2, the active APA policy can be changed because of its schedule or because of the occurrence of certain major incidents on the road. The OBE must take care therefore of assuring that the APA policy held in the vehicle is actually the active APA policy at the area. This is achieved by periodically asking the UTC about the GUID of the active policy. If the vehicle detects that the active policy is no longer its own, the process shown before will be triggered again, and the new active APA policy will be evaluated.

### 4.3.1.1 APA policies message

The message with the APA policies, shown in Figure 14, will contain a list of all the controlled areas belonging to the accessed area, as well as the active APA policies applied to them.

Therefore, the information comprised in this message will comprise the following elements:

- **List of controlled areas defined in the city.** For each:
  - Name/Identifier of the controlled area
  - Location, which is composed by:
    - set of boundary links (latitude/longitude pairs)
  - List of property/value pairs
  - A list of access control details, each element including:
    - Default access right (allowed/forbidden)
    - A timestamp indicating its estimated caducity
    - List of constraints, each defining:
      - the property being evaluated
      - the value being constrained
      - flag indicating whether the value must be considered a maximum threshold.
4.3.1.2 APO message

The APO message, shown in Figure 14, contains the list of access rights that result from the evaluation of the APA policies. The message containing these permissions is formed by the following elements:

- List of APOs, each APO consisting of:
  - A controlled area name/identifier
  - A “valid until” timestamp
  - A UTC digital signature (GUID) validating the APO

4.3.1.3 Evaluation of an access request

Upon the receipt of an access request to a specific area, the UTC will need to decide whether to deliver the APO or not, and its valid timeslot.

APOs on demand will only be delivered to those vehicles paying the corresponding fee. This mechanism can be facilitated by the existence of contracts between the transport operators and the UTC. The UTC will perform the following steps in the decision process:

1. The transport operator of the vehicle is crosschecked against the UTC contracts database.
2. In case no valid contract is found, the fee is sent to the vehicle and the system waits for the payment details. OBE can decide to pay the fee on its own, or the fee can be further communicated to its corresponding freight distribution manager.
3. In case the proper transport operator has a valid contract or the fee is accepted, a reference to the vehicle and its cargo summary is stored in a transport operation table, and the APOs are granted for the current day.
4. In case no proper contract exists and the fee is not paid, the access is denied.

4.3.1.4 Route planning

Once a vehicle enters the area under UTC control, the OBE will receive certain information on a periodic basis that will lead to a recalculation of the route. This information includes traffic statistics and APA policies that may alter the previously calculated route.

<table>
<thead>
<tr>
<th>INPUT</th>
<th>Source</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Map database</td>
<td>Satellite navigator</td>
<td>List of nodes and links of the road network. Each link has a default cost assigned</td>
</tr>
<tr>
<td>APA policies</td>
<td>APA policies message (UTC &gt; Vehicle)</td>
<td>Definitions of the city access policies, as defined in section 4.2.1.1</td>
</tr>
<tr>
<td>Geographical location of the controlled areas</td>
<td>APA policies message (UTC &gt; Vehicle)</td>
<td>As defined in section 4.2.1.1</td>
</tr>
</tbody>
</table>
Offline statistical traffic information

Traffic status message (UTC > Vehicle)

For each important link, a cost factor calculated with offline statistical data is defined to modify the standard cost, in order to provide more accurate data for the routing algorithm (see Annex D. Notes to routing algorithm, traffic situation and access control for details on cost factors and route calculation)

Real-time traffic information

Traffic status message (UTC > Vehicle)

For each important link, a cost factor calculated with real-time traffic flow data is defined to modify the standard cost, in order to provide more accurate data for the routing algorithm (see Annex D. Notes to routing algorithm, traffic situation and access control for details on cost factors and route calculation)

<table>
<thead>
<tr>
<th>OUTPUT</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A) Optimum route</td>
<td>Optimum route with no access limitations</td>
</tr>
<tr>
<td>B) Optimum route through controlled-access controlled areas + Extra access rights required + Alternative route through accessible areas</td>
<td>In case no route is available through accessible areas</td>
</tr>
<tr>
<td>C) Optimum route through controlled-access controlled areas + Extra access rights required</td>
<td>In case no route is available through accessible areas</td>
</tr>
</tbody>
</table>

Table 3 Route planning algorithm - Inputs and outputs

The routing algorithm will perform the following steps:

1. According to the real-time and offline traffic information, the algorithm will calculate the optimum route. No APA policy is considered at this step.
2. The city APA policies will be checked against the optimum route. Two possible results exist at this point:
   a. The vehicle is allowed to circulate through all the points of the route. The optimum route is therefore viable, and the process finishes.
   b. The vehicle needs extra access rights in order to perform the optimum route.
3. In case b, the process goes on storing the optimum route and the list of controlled areas requiring extra access rights.
4. A new route is calculated taking into account the APA policies, avoiding non-accessible areas. Two situations are possible:
   a. Such a route exists, and is stored as “Alternative Route”
   b. Such a route does not exist. The OBE is therefore forced to ask the UTC for APOs.
The algorithm will result in one of the following three possibilities:

A: Optimum route without controlled areas
B: Alternative route without controlled areas + optimum route through controlled areas
C: Optimum route through controlled areas

The figure below shows the complementary information that is necessary at a UTC level in order to perform the route assistance. It basically contains:

- Network physical information: list of roads (links) and intersections (nodes), and information about their location and type, maximum speed, etc (comprised as a cost factor of the link)
- Link cost modifiers, calculated upon statistical and real-time traffic flow information, necessary for providing an intelligent routing support

More details can be found in Annex D. Notes to routing algorithm, traffic situation and access control.

Figure 16 UTC database tables supporting the traffic status-aware routing algorithm

4.3.1.5 Access policies evaluation

The access policies of the city are evaluated as part of the route calculation process. This evaluation consists in taking the defined set of constraints for a given time and controlled area, and checking it against the vehicle properties.
In case a vehicle has the necessary conditions to be allowed to access a controlled area, the process will generate an APO (i.e. an access certificate) which can be further used by the vehicle to claim for its access rights.

<table>
<thead>
<tr>
<th>INPUT</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access policies</td>
<td>Definitions of the city access policies, as defined in section 4.2.1.1</td>
</tr>
<tr>
<td>Controlled area</td>
<td>Id of the controlled area to be evaluated</td>
</tr>
<tr>
<td>Vehicle properties</td>
<td>The same properties detailed in section 4.2.1.3.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>OUTPUT</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>APO (access certificates)</td>
<td>If the vehicle is allowed to enter a certain controlled area, the process results on an APO that can be further used by the vehicle to demonstrate its access rights</td>
</tr>
</tbody>
</table>

Table 4 Inputs/Outputs of the APA policies analysis

The evaluation will differ slightly in the cases where a controlled area allows access by default, or forbids it. In the first case, the constraints define prohibitions, and failing to meet one constraint is enough to forbid the access to a vehicle; in the second one, the constraints define requirements, and therefore all constraints must be met in order to get access rights.

The evaluation should include the verification of the digital signature attached to the booked resource property of the vehicle.

The following figure shows the procedure that must be followed in order to evaluate the access rights to a single controlled area.
4.3.2 Access to a controlled area

The following mechanism is initiated by the RSEs located at the entrance of the controlled areas, which detect and poll the vehicles entering the controlled area.

The RSEs will ask the vehicles for their identification information and their set of access certificates, with the purpose of checking whether they actually have permissions to access the controlled area.
Upon the reception of the APOs, the RSE or UTC (depending on the level of disaggregation of the system) will register the vehicle and check its access rights by checking the existence of a suitable APO for the accessed area. In case the vehicle has not enough access requirements, it is registered in an offender’s database for traffic enforcement purposes.

### 4.3.3 Access registry

In certain situations, the entity in charge of controlling access to certain controlled areas will be interested in keeping a registry of the freight vehicles that have entered the area, and some of their properties. This information can be used for information or enforcement purposes, and allows the UTC to monitor certain vehicles as they go through determined areas (see section 4.2.3).

With this objective, the UTC database is extended with the necessary elements to store the information about the accesses and the properties of the related vehicles. This information can be polled by the RSEs to the OBE installed in the vehicles, as part of the access process shown above in this section. It includes:

- Information about the access (time and point of the entrance and exit)
- Properties of the vehicle
- Summary of the cargo (total weight and list of hazardous items)
- Relationship to a before-hand contract, and information about the transport operator holding it

![Figure 19 UTC database tables supporting the registration of vehicles entering controlled areas](image)

In this case, RSEs will complement the process described in Figure 18 with the request of the vehicle properties list.
4.3.3.1 Vehicle properties message

The message containing the vehicle properties is formed by the following elements:

- List of vehicle properties, in a property-value format
- Cargo summary
  - Total weight of the cargo
  - Details about hazardous elements in cargo (type and weight)
- Details about booked resources
  - Id of the booked resource
  - Booking code (GUID)
  - Allocated timeslot

4.3.4 Exiting a controlled area

The following mechanism is initiated when the vehicle detects it is exiting a controlled area. It is known from the route calculation step, where nodes inside controlled areas were identified.

Once the system receives a leaveSubarea message, the vehicle is unregistered in the UTC database.

4.3.4.1 leaveControlledArea message
The leaveControlledArea message is a simplification of the vehicleProperties message described in section 4.3.4.1, since most of the information contained there is already known by the UTC and its transmission is no longer required. The following information is sent to the UTC:

- VIN (Vehicle Identification Number)

### 4.3.5 Traffic status updates

The UTC is responsible for sending traffic status updates on a regular basis. This information comprises the new real-time cost factors for the routing information, as well as lists of incidents that may affect the access policies.

With every new update, the OBE needs to feed the routing algorithm with the new information to decide if the route to be followed has changed or if the access rights have changed due to a new traffic incident.

#### 4.3.5.1 trafficStatusUpdate message

Each traffic status message contains the following information:

- List of road network links monitored. Each item includes:
  - A link identifier referring to the map database (used by the routing algorithm)
  - A value for its real-time traffic cost factor (see section for more details)

- List of incidents in the UTC-controlled area, each incident consisting of:
  - An identifier of the affected link
  - Severity of the incident

### 4.3.6 Cargo pick-up and delivery

Every time a vehicle picks up or delivers cargo, its characteristics change. This change is not necessarily negligible, since it can directly affect the set of access rights that the vehicle has been granted. For instance, a freight vehicle can be allowed to access the city centre when its trailer is empty; on the other hand, access may be forbidden if it picks up dangerous cargo. Since the element evaluating the APA policies is the OBE, a service making the cargo information of every freight vehicle available to its OBE, and keeping it up-to-date, becomes necessary.

The process is split into two sub-processes:

1. The vehicle is able to keep a detailed control of the goods it is transporting. In order to perform this control, the OBE can directly poll the different on-goods equipments (OGEs). It is responsibility of the OBE to periodically poll the OGEs in order to notice possible changes in the cargo.
2. The cargo summary, performed by the vehicle with the information about the cargo, will be part of the vehicle properties, and therefore may be required to be evaluated as part of the APA policies.

![Figure 22 Messages exchanged between OGE and OBE](image)

The information comprised in the cargoProperties message is:

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>OGE id</td>
<td>Identifier of the OGE (typically associated to a container)</td>
</tr>
<tr>
<td>freightClass</td>
<td></td>
</tr>
<tr>
<td>weight</td>
<td>Kilograms</td>
</tr>
</tbody>
</table>

Table 5 Cargo properties in OGE

The cargoSummary is calculated in the OBE upon the list of the cargoProperties of all the OGEs in the trailer. This summary forms part of the “Vehicle Properties” information. The contents of this summary are:

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>hazardItems</td>
<td>List of hazardous items in cargo, following the ADR classification scheme</td>
</tr>
<tr>
<td>weightHazardItems</td>
<td>Specific weight of each element in hazardItems (Kilograms)</td>
</tr>
</tbody>
</table>

Table 6 Cargo summary
References

1. Marit Natvig, Tor Kjetil Moseng. D5.1 Intermediate SMARTFREIGHT framework architecture. SMARTFREIGHT project FP7-216353, 2009


4. Paul Kompfner et al. D2.1 System Concept Definition. CVIS project FP6-2004-IST-4-027293-IP

Annex A. Message definitions

This annex includes the formal definitions of the messages exchanged by the different elements of the system described throughout the document. The definitions are given in the form of XSD (XML Schema Definition) files.

Access and Priority Assignment (APA) policies

```xml
<?xml version="1.0" encoding="UTF-8"?>
schema targetNamespace="http://www.example.org/APAPolicies"

elementFormDefault="qualified" xmlns="http://www.w3.org/2001/XMLSchema"
xmlns:tns="http://www.example.org/APAPolicies">

<complexType name="ControlledArea">
  <sequence>
    <element name="location" type="tns:Location" maxOccurs="unbounded"></element>
    <element name="properties" type="tns:Property" minOccurs="0" maxOccurs="unbounded"></element>
  </sequence>
  <attribute name="name" type="string"></attribute>
</complexType>

<complexType name="Location">
  <sequence>
    <element name="link" type="int" minOccurs="1" maxOccurs="unbounded"></element>
  </sequence>
</complexType>

<complexType name="LatLonPair">
  <attribute name="latitude" type="float"></attribute>
  <attribute name="longitude" type="float"></attribute>
</complexType>

<complexType name="AccessDetails">
  <attribute name="defaultAccessAllowed" type="boolean"></attribute>
  <attribute name="estimatedCaducity" type="dateTime"></attribute>
</complexType>

<complexType name="Timeslot">
  <sequence>
    <element name="constraint" type="tns:DiscreteConstraint" minOccurs="0" maxOccurs="unbounded"></element>
  </sequence>
  <attribute name="startTime" type="time"></attribute>
  <attribute name="endTime" type="time"></attribute>
  <attribute name="dayOfWeek" type="int"></attribute>
</complexType>

<complexType name="DiscreteConstraint">
  <attribute name="Property" type="string"></attribute>
  <attribute name="Value" type="string"></attribute>
  <attribute name="ValuesIsMax" type="boolean"></attribute>
</complexType>

<complexType name="ContinuousConstraint">
```

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Access and Priority Offers (APOs)

Vehicle properties
Traffic status updates

<?xml version="1.0" encoding="UTF-8"?>
Annex B. OBE database supporting system functionality

The OBE database contains static information about the vehicle, as well as some dynamic information as the GPS data and the cargo summary. Most of its information has to be manually introduced prior to the departure of the vehicle.

The contents of the OBE database can be exposed with the following structure:

- Identification and enforcement information: includes information that allows the authorities to identify the vehicle (VIN and plate number), and that connect it to a physical person (owner) and organisation.
• APA policies-related information: contains all the information that can be susceptible of being evaluated in an APA policy, as well as the different APOs calculated upon the reception of the policies. This information includes:
  o Physical characteristics of the vehicle (height, width, length, weight)
  o Environmental characteristics of the vehicle (type of fuel, engine’s emission standard)
  o Cargo summary
  o List of booked resources and its location
  o List of APOs (access rights), consisting on a set of access rights to certain controlled areas, valid during a certain period of time, and attached to a signature that ensures their validity

• Routing-related information: contains all information necessary to the plan the route:
  o Trip destination
  o Delivery time (desired arrival time)
  o Current position (GPS data)

The cargo summary is automatically performed by the mechanism exposed on section 0.

---

**Figure 23** OBE database supporting the system operation

---

**Annex C. OGE database supporting system functionality**

OGE (on-goods equipment) is special equipment that is attached to the containers carrying cargo. Its purpose is to keep information about the cargo it represents, monitor its status
keeping control of certain variables, and communicate the proper information to the OBE in order to make possible the evaluation of the APA policies involving cargo characteristics.

The contents of the OGE database can be summarized as:

- Item properties
  - Weight of the cargo
  - Global Product Classification code
  - ADR code (hazardous cargo)
- Pick-up and delivery properties
  - Pick-up address
  - Pick-up location coordinates
  - Delivery address
  - Delivery location coordinates
- Handling events
  - Action: loaded, unloaded, stored, delivered
  - Estimated time for the action
  - Actual time when the action takes effect
  - Address and coordinates of the location where the action takes place
- Handling instructions and status monitoring
  - Type of parameter to monitor: temperature, humidity, acceleration...
  - Max. and min. control values
  - Deviation of the controlled parameters (parameter under control going above or below the control values)
    - Timestamp
    - Deviated parameter: temperature, humidity, acceleration...
    - Measured level
Annex D. Notes to routing algorithm, traffic situation and access control

Taking A* algorithm as base of the routing mechanism, the intelligence of the routing algorithm is introduced in the cost function calculation and a classification of the nodes in the urban area that allows suitable filtering of the nodes to be considered.

By assigning dynamic costs to the different links of the transport network, proper routes will be found by the routing algorithm taking into consideration traffic statistics of the system, real-time conditions and access rights. Therefore, the algorithm will implement the following details:

1. When a specific node is reached, the algorithm determines whether it is located inside a controlled access area.
2. In case it is located in a controlled access area its corresponding APA policies are evaluated. Upon this evaluation, two situations can happen:
   - The vehicle has not enough access rights. The node is filtered (it is left out of the decision possibilities)
   - The vehicle has enough access rights. The node is considered for the decision making process
   In order to facilitate and speed-up the process, the access rights are checked once only when the vehicle enters a controlled access area.
3. The algorithm keeps on until destination is reached

Figure 25 illustrates the described process:
In the situation suggested in the figure, there is an access controlled area. For the specific characteristics of the vehicle calculating the route, access is at this moment forbidden. At time $t_x$, the APA policy planner activates a new access policy that allows access to the vehicle. The routing algorithm will perform the following steps:

1. The A* algorithm will operate normally until a node inside the controlled area is reached as possible node of the route ($a_3$).

2. At this point, the algorithm will evaluate the corresponding APA policies. In the example, the access is forbidden at that moment, node $a_3$ is no longer considered by the algorithm and node $a_2$ is chosen as best option.

3. Steps 1 and 2 repeat until destination node is reached.

The process explained above will repeat every time a new APA policy is activated in the area of operation of the vehicle, since new access rights need to be evaluated. Figure 25 shows, at point 3, how the route of a vehicle can be dynamically changed upon the reception of a new APA policy that changes the effective access rights.

**Figure 25 Introducing access policies in the route calculation algorithm**
Regarding the consideration of the traffic status on the route planning process, the A* algorithm can be modified to consider the following points:

- The default cost of a link is its expected travel time in normal conditions. This is calculated offline (and stored in the map database) as

  \[ \text{defaultCost}(i-j) = \text{distance}(i-j) \times \text{allowedMaxSpeed}(i-j) \]

- The default cost of a link can be modified applying two factors:
  - Statistical information of the transport network, calculated offline: for every (important) link, a factor is calculated for several significant timeslots, in such a way that the following equality is accomplished:

    \[ \text{offlineCost}(i-j) = \text{offlineCostFactor} \times \text{defaultCost} = \text{distance}(i-j) \times \text{offlineAverageSpeed}(i-j) \]

    - Real-time statistical information of the transport network.: for every (important) link, a factor is calculated upon real-time information in a regular basis, in such a way that the following equality is accomplished

    \[ \text{rtCost}(i-j) = \text{rtCostFactor} \times \text{defaultCost} = \text{distance}(i-j) \times \text{rtAverageSpeed}(i-j) \]

When this information is available, the real cost of a link is calculated as the default cost, modified by the two traffic-related factors. It is noteworthy to consider that the relative importance of each factor must be dependent on the time remaining to the moment of the prediction. It means, the closer the moment of the prediction, the greater the importance of the real-time factor will be; the further the moment of the prediction, the greater the importance of the offline (statistic-based) cost factor.

The finally applied cost will be calculated as:

\[ \text{appliedCost}(i-j) = \text{defaultCost}(i-j) \times [\text{offlineRelativeImportance} \times \text{offlineCostFactor}] \times [\text{rtRelativeImportance} \times \text{rtCostFactor}] \]

where

\[ \text{offlineRelativeImportance} + \text{rtRelativeImportance} = 1 \]
\[ \text{ offlineRelativeImportance} > 0 \]
\[ \text{ rtRelativeImportance} > 0 \]
Relative importance of the cost factors

Figure 26 Relative importance of factors in traffic status-aware routing algorithm