Scenarios for Automated Road Transport
Passenger and freight application scenarios

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Executive summary

The present report deals with the definition of passenger and freight application scenarios as a combination of:

- an urban context;
- specific transport demand features;
- a CityMobil technology.

Both the passengers and freight application scenarios are based on an analysis of the benefits for:

- the passenger, the transport operator and the society in the passengers case;
- the driver, the transport operator and the society in the freight case.

As for the passengers case, 10 application scenarios are identified; it can be said that all concepts contribute to a more sustainable urban transport system. Depending on the problem the different concepts come to mind. For example for a strict shuttle function a PRT might be the best solution, if more flexibility is needed a cybercar might be of better use. The main conclusion is that if a city experiences a problem with air pollution these new concepts might serve as a solution to increase quality of life in a neighborhood. Secondly the automated forms create a great possibility to make public transport payable again in low density areas, where also the speeding up of the current network is a great second possibility to reduce the total travel time.

As for the goods case, a set of 5 skeletal scenarios are identified together with a wider set of application scenarios. The skeletal scenarios represent 5 main classes of scenarios where the type of automation technology is not specified; each of them corresponds to specific trends and needs in the urban freight transport sector: for example, the scenario \textit{JIT refilling of shops} corresponds to the increasing real estate costs in urban area, to the difficulties for the shops to have free space for stocks, to the difficulty of predicting instant demand. The application scenarios are a combination of the skeletal scenarios with CityMobil technologies and all represent possible answers/solutions to the trends/constraints/needs mentioned above. The benefits of the CityMobil technologies in the freight case could make the application scenarios win-win solutions:

- on one side the transport operator could increase the transport productivity and possibly reduce the transport costs, which are the main factor of competition in the urban freight transport sector;
- on the other side, the public authorities could obtain less pollution and an increased level of safety of the road transport.

Last but not least, the driver: both in the passenger and freight case driving an automated vehicle (when the driver must be on-board even if there are automated driving functionalities) could be more comfortable than driving manually, thus in turn reducing the risk of accidents.

Although different, the two sectors (passengers and freight) maintain therefore strong common points and the CityMobil project will verify whether the above mentioned potential benefits can became real advantages for the concerned stakeholders.
1 Introduction

The present report concerns the CityMobil project “Towards advanced transport for the urban environment”, sub-project 2 “Future Scenarios”, work package 2.2 “Scenarios for automated road transport”.

Unlike D2.2.2, where the results of a Delphi analysis have been described and long term trends and scenarios have been developed, this deliverable illustrates the most promising passengers and freight “application scenarios” based on an analysis both of the transport demand and supply in urban area. An application scenario is defined here as a combination of a transport service (based on a CityMobil technology), a type of urban area and specific transport demand characteristics.

The report is divided into two principal sections:

- the first one (chapter 2) is devoted to possible application scenarios, in different types urban contexts, relative to transport of passengers. After a description of different basic road-based mobility concepts, this section analyzes the role of automation and introduces new innovative mobility concepts enabled by the CityMobil technologies (chapter 2.2). Through a supply-oriented approach, the benefits of these CityMobil concepts/technologies are subsequently analyzed for the passenger, the transport operator and society and the contribution that they give for a more sustainable urban transport system is underlined (chapter 2.3). In chapter 2.4 the viewpoint is from the transport demand side: by creating an origin-destination matrix with a number of typical urban contexts the usefulness of mobility concepts as a service between this origin and destination is established. The combination of the transport supply and demand, as sketched in chapters 2.3 and 2.4, finally gives rise to a set of passenger application scenarios (chapter 2.5).

- The second one (chapter 3) is devoted to possible freight application scenarios and corresponding innovative logistics schemes. After a short methodological description, the main development trends behind the transformation of the city, of the structures of commerce and the demand for freight transport generated by these is identified in chapter 3.2 (through an analysis of 30 European urban areas where innovative city logistics projects have been implemented). Chapter 3.3 describes freight skeletal scenarios, which are sets of possible scenarios defined in terms of transport demand features, logistic schemes and types of urban context (no specific automated transport technology is indicated here). Freight application scenarios are finally identified in chapter 3.4, as a combination of skeletal scenarios with CityMobil technologies, analyzing where these technologies maximize the benefits for the driver, the freight transport operator and the society. All the scenarios are based on loading/unloading operations done manually; a potential step forward in the automation process is described in chapter 3.5 were additional specific technological components are shortly introduced.

2 Passengers application scenarios

An important question of city authorities might be: what type of new technology in our transport system will improve the accessibility of our city, without the enlargement of traffic and environmental problems? City authorities are looking for sustainable improvements of the transport system, and the technologies CityMobil is offering can help. The link between these sustainable improvements and technologies is in application scenarios: descriptions of applications in a certain urban configuration.
This chapter describes the promising passengers application scenarios for CityMobil.

2.1 Methodological description

An application scenario is defined as a combinative description of a transport service and a type of urban context. The technologies that are suitable for these combinations are part of the scenarios as well. A park and ride shuttle in the centre of a large city, using cybercars in a demand-responsive mode is an example of a passenger application scenario. The main goal of these scenarios is to describe the transport systems in a functional way, and not, for instance in a technical way. The focus of users of the system is the starting-point: whether a vehicle is riding on rubber or steel wheels is not important from a passenger’s point of view, for example. Functional characteristics, like the availability of a transport possibility (e.g. is there a waiting time? how long will I have to wait?), are far more important for passengers.

So, application scenarios are positioned in the centre of vehicles, services, urban areas, etc., Figure 1 illustrates this position.

Figure 1: Position of application scenarios in the transport system

This scheme has been the basis of the work in this task, and will be explained in the subsections below.

Passenger application scenarios focus only on transport service and transport demand pattern of passengers.

Order of discussing the concepts

Every mobility concept has its own benefits and every urban area has its own demand and requests for specific benefits. These two are matched with the five concepts of CityMobil and this will create promising passengers application scenarios. First the mobility concepts are further elaborated to create a better understanding of their functioning and their advantages. Secondly the benefits are matched with these concepts, which will show in return the promising scenarios.
2.2 Mobility concepts

Mobility Concepts deal with the interaction between travellers and vehicles, as opposed to traffic concepts, that deal with the interaction between vehicles and infrastructure, see Figure 2.

Figure 2: Mobility concepts and traffic concepts

Basic mobility concepts

Categorizing mobility concepts starts with looking at availability and use of vehicles.

Regarding availability, there are two categories:
- private vehicles: the vehicle is always available. The traveller uses the same vehicle for subsequent trips and the vehicle is not used by others in between. Examples are a private car or a (private) bicycle.
- public vehicles: the vehicle is shared by subsequent users (like a taxi or a car sharing programme), or also during the trip (like a bus or a shared taxi). The traveller uses different vehicles for subsequent trips.

In addition, we distinguish between three ways vehicles can be used during the trip:
- individual use: no vehicle sharing during trip. Examples are a private car or a taxi. Note that a vehicle that is used by a group of interrelated travellers (e.g. a family or a group of colleagues travelling to the same business meeting) is regarded as ‘individual use’.
- shared use: few travellers share the same vehicle. Examples are a shared taxi or a minibus.
- collective use: many travellers share the same vehicle. Examples are buses, metros and trains.

Combining both groupings, we end up with four basic mobility concepts:
- private (individual) transport: private availability, individual use
- individual transport services: public availability, individual use
- shared transport services: public availability, shared use
- collective transport services: public availability, collective use
If we limit ourselves to road-based concepts, those four basic mobility concepts could be referred to as: private car, public car, minibus and bus. Note that for reasons of readability, in this context the word ‘bus’ not only refers to the vehicle ‘bus’, but also to the collective transport service that uses the bus. The same goes for the minibus. The difference between bus and minibus lies at the level of ca. 20 passengers.

The same can be done with rail-based mobility concepts (or, more in general: physically guided mobility concepts). The collective rail transport service could be referred to as a ‘metro’, the shared rail transport service as a ‘minimetro’. As rail concepts are not regarded in CityMobil, we will omit those concepts in further analyses, with one exception the PRT, which needs a dedicated guideway.

Figure 3 shows the four basic road-based mobility concepts, and the way they are defined.

**Figure 3: Basic road-based mobility concepts**

<table>
<thead>
<tr>
<th>Availability</th>
<th>Use</th>
<th>Road based concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>private (individual) transport</td>
<td>private</td>
<td>individual (or friends, relatives)</td>
</tr>
<tr>
<td>individual transport service</td>
<td>public</td>
<td>individual (or friends, relatives)</td>
</tr>
<tr>
<td>shared transport service</td>
<td>public</td>
<td>shared (small groups)</td>
</tr>
<tr>
<td>collective transport service</td>
<td>public</td>
<td>collective (large groups)</td>
</tr>
</tbody>
</table>

**Automation**

We can regard vehicle automation as an incremental, stepwise innovation process, starting from traditional manual driving, developing via several levels of driver assistance, ultimately ending in full automation, see Figure 4.

**Figure 4: From manual driving to full automation**

manual driving → driver assistance → full automation

This is correct from the viewpoint of traffic concepts (interaction between vehicles and infrastructure). From the viewpoint of mobility concepts however, the question whether or not a driver is needed makes the real difference. Whereas introducing driver assistance surely improves the performance of the mobility system (e.g. with regard to safety, energy consumption or driver convenience), the ultimate control of the vehicle still remains with a driver, even with the most advanced driver assistance system. However, the complete absence of a
Driver (hence, a fully automated system), enables an entirely new class of transport services that can operate with small vehicles and short headways against relatively low operation costs. Also, vehicle logistics can be controlled more efficiently if no driver is needed. So, from a mobility perspective, driver assistance falls in the same category as manual driving, whereas full automation defines a new category of mobility concepts, see Figure 5.

**Figure 5: Full automation enables innovative transport services**

We can now add the new class of fully automated mobility concepts to the basic road-based concepts we defined before:

- The fully automated equivalents of bus and minibus are referred to as ‘automated bus’ and ‘automated minibus’.
- The public car (taxi or car sharing) becomes an ‘automated public car’. Note that the difference between a taxi and a car sharing program disappears when the system is fully automated, for the simple reason that the only distinction between the two is the presence of a professional driver. This distinction becomes irrelevant in the case of full automation.
- The fully automated equivalent of a private car would require an automated environment from every door to every other door, which we consider not realistic. However, where an automated environment exists, we can create facilities that enable operating a private car in this environment.

Figure 6 summarizes the above. Note again that for reasons of readability, in this context the words ‘bus’ and ‘minibus’ not only refer to the respective vehicles, but also to the transport services that make use of those vehicles. The same goes for their automated equivalents. The term ADA refers to the concept of Advanced Driver Assistance, Adaptive Cruise Control and Lane Keeping Assistant are example functions in this category.
Figure 6: Full automation enables innovative transport services

Now, the final step can be made to assign the ‘CityMobil technologies’ to the mobility concepts defined before. The result is shown in Figure 7. Note that every CityMobil technology serves two mobility concepts, which underlines the need of using the precise definitions when talking about application scenarios. It is also interesting that the distinction between PRT and cybercars largely disappears from the mobility concept perspective.

Figure 7: CityMobil mobility concepts

An explanation of the above:
- Cybercars are driverless vehicles that will evolve to operate in streets with mixed traffic. Cybercars can be small (4 persons) or medium-sized (20 persons or so), and can therefore act as an automated public car or as an automated minibus.
- PRT (Personal Rapid Transit) serves the same mobility concepts as cybercars; the difference is that PRT vehicles operate on dedicated guideways to segregate them from other traffic and pedestrians.
- High-tech buses run as ‘automated bus’ on dedicated guideways, but need a driver when operating in mixed traffic. Note that high-tech buses are a kind of dual mode vehicles.
2.2.3 – Passengers and freight application scenarios

- Advanced city cars are equipped with advanced driver assistance systems, but ultimate control remains with a driver. They can act as private cars or as public cars (taxi or car sharing).
- Dual mode vehicles are cars that can be driven manually, but that can also operate in an automated environment, like cybercars do.

In addition to Figure 7, some further adjustments are made:

- In the rest of the analysis for the advanced city car we assume a car-sharing scheme, since it is not likely that people will buy a car, which can be used only in the city. If you buy a car, you would want to use it for all your travels, not only your travels in the city.
- Furthermore it needs to be noted that dual mode is available for all the transport services. In this analysis only the dual mode private car and dual mode collective transport service are considered, as they are respectively labelled as dual mode vehicle and high-tech bus. Next to that, in individual transport service and shared transport service dual mode vehicles could be used as well. Results that are found for dual mode vehicles are sometimes valid for all four dual mode transport possibilities. Nevertheless, in the rest of this report, a dual mode vehicle is considered as private individual transport.
- PRT can also be seen as GRT (Group Rapid Transit) if the number of passengers in the vehicle is larger than 4 persons.

Figure 8: Resulting CityMobil mobility concepts

2.3 Transport supply: benefits of mobility concepts

Mobility concepts describe possible transport systems, the next step is to combine them with a transport service in an urban environment: the passenger application scenarios.

In this section, the specific strong sides of the mobility concepts are described, as transport systems will be most promising in an application where either the passenger, the transport operator or society will experience a benefit by using or introducing this new system concept.
For easy use in other parts of CityMobil, we chose to describe the benefits by the ‘CityMobil technologies’, bearing in mind the underlying mobility concepts. E.g. talking about a high-tech bus, a collective public vehicle system is meant, which is sometimes driven, and sometimes drives automatically.

Each subsection describes the benefits of a CityMobil technology (advanced city car, cyber-car, PRT, high-tech bus, dual mode vehicle). After that the fitness of the concepts is described in the urban context. In section 2.5, all passengers application scenarios are presented (including an overview). The benefits in the subsections are described for the traveler, transport operator and society successively.

2.3.1 Advanced city car

The benefits of the advanced city car for the driver are the following:

- The driver can remain in the same vehicle or doesn’t have to share it with others at the same time.
- The accessibility level of the concept is very high, because you can go virtually anywhere because the vehicle functions in ordinary traffic as well.
- The main advantage is an increase in safety for the user of the vehicle, because of the advanced driver assistance (ADA) systems that are installed. This will cause fewer accidents and make very complex traffic situations in large cities easier to cope with.

The benefits for the transport operator (which is only applicable if the advanced city car is in a car sharing system) of ADA systems installed in their vehicles are:

- The decrease in damages because of a decrease in accidents, and therefore a decrease in damage costs.
- The increases in safety of their drivers and will allow them to drive safely in narrow and crowded streets.

The benefits for society of these systems are:

- Traffic safety, because it will get safer on the streets.
- Air pollution will decrease as well, because of more efficient and better use of engines.
- Also the possibility to create dedicated parking spaces for these small vehicles is a benefit, because the amount of space required is very small.
- An interesting benefit is the functionality of the system on current infrastructure. Figure 9 shows the increase of road capacity (q in figure, expressed in number of vehicles passing per time unit) when smaller vehicles are used (2 metres or 3 metres shorter). The curves are drawn for two different headways: 1 and 2 seconds. As can be seen, in city traffic, significant road capacity increases are possible, if all cars are shortened. Society can benefit from this because the need for new infrastructure will be smaller.
2.3.2 Cybercar

The benefits of the cybercar for the traveller are the following:

- The cybercar concept is very flexible from the traveller’s point of view. It is working on demand and therefore the amount of waiting time is reduced.
- Secondly because of the full automation of the vehicle, travellers experience a greater comfort without sudden braking and turning.
- The cybercar service can easily made reliable, especially when a dedicated track is used, which enhances the trust of the traveller in this concept.
- The traveller however does need to interchange into the cybercar, but if a parking lot, like in the Rome demonstration, is completely automated the cybercar will be ready at the nearest stop to the parked car.
- Accessibility is an issue with the cybercar concept, which will be discussed below.

The benefits of the cybercar for the operator are the following:

- The costs of employing a driver can be reduced by 50-70% (because only an operator is now needed, controlling more than one vehicle). Therefore the concept if operational is fairly cheap for an operator.
- A second benefit of an automated system is the easy adaptation to changes of the amount of travellers: just add more vehicles to the track if needed. Therefore the flexibility is also from an operator’s point of view a very important benefit.
- The cybercar can function as a feeder system for fast public transport, which will allow transport operators to increase the stop distance of this fast transport. This will reduce costs and increase transport quality, and is especially useful in low-density area’s where a high-density conventional public transport service is not an option.
- The system is relatively flexible, although limited infrastructure is needed, it is fairly easy to add or re-route a part of the track, because mostly the infrastructure will be available already.

1 Based on table 9 of CityMobil D2.1.1 State of the art
The benefits of the cybercar for society are the following:

- Local air pollution will be reduced in the city, however the pollution will still be there, because the electricity, which empowers the vehicles, needs to be produced.
- Congestion in the city can be reduced because people park outside the city and will be brought into the city centre by a cybercar. This will concentrate the actual traffic into the city and therefore reduce congestion in the city.
- Also the parking problem can be solved with a cybercar, because the vehicles don’t remain in the city but return to their point of origin to pick up new travellers.
- The quality of life (and looks) in a specific urban area can be raised, by limiting access of certain infrastructure to only cybercars and other slow traffic. Or allowing the cybercar to mingle with professional drivers.
- Traffic safety can increase if the cybercar concept is used, especially because it is fully automated the safety guidelines will be very strict.
- Accessibility is an issue that will be discussed below.

The ultimate goal of a cybercar is the mixing with other traffic. In the end there will be less need for creating extra infrastructure or dedicating infrastructure to the cybercar. However, technology hasn’t come this far yet and only limited mixing is possible (with slow traffic or professional drivers). Therefore a rearrangement/addition needs to be done to the current system to allow the cybercar to serve needed areas. This has a great influence on the accessibility of this concept, because dedicating infrastructure is not always possible, and building new infrastructure not cheap.

2.3.3 Automated vehicles on dedicated infrastructure (PRT)

The benefits of the PRT for the traveller are the following:

- The PRT concept is a flexible mobility concept from the traveller’s point of view. It is working on demand and therefore the amount of waiting time is reduced. The PRT will arrive at the stop without blocking the throughway for other vehicles to prevent congestion around stops.
- Secondly because of the full automation of the vehicle, travellers experience a greater comfort without sudden braking and turning; especially on a dedicated track it is very visible where the vehicle is going.
- The traveller however does need to interchange into the PRT, but if a vehicle is already waiting when a traveller arrives at the stop this shouldn’t pose a problem.
- The range/accessibility of the concept depends on the amount of dedicated infrastructure that is built for the concept. This has a great influence on the acceptability and use of the concept.

The benefits of the PRT for the operator are practically the same as the cybercar:

- The costs of employing a driver can be reduced by 50 – 70% (because only one operator is now needed). Therefore the concept if operational is fairly cheap for an operator.
- A second benefit of an automated system is the easy adaptation to changes in the amount of travellers; just add more vehicles to the track. Therefore the flexibility is also from an operator’s point of view a very important benefit.
- The range of the PRT depends on the amount of infrastructure that is built for the concept.
The benefits of the PRT for society are the following (and also look quite similar to the cybercar):

- Local air pollution will be reduced in the city, however the pollution will still be there, because the electricity, which empowers the vehicles, needs to be produced.
- Congestion in the city can be reduced because people park outside the city and will be brought into the city centre by a PRT. This will concentrate the actual traffic into the city and therefore reduce the congestion in the city.
- Also the parking problem can be solved with a PRT system, because the vehicles don't remain at a stop but return to their point of origin to pick up new travellers (or can be parked at a convenient spot if necessary).

Accessibility of the PRT is an issue, because the concept is normally operated at a different level than other traffic (e.g. +1) and therefore new infrastructure is needed. The counterpart however is that the speed is far greater compared to the cybercar, because there is no interference with other traffic, this increases the frequency and shortens the travel time.

### 2.3.4 High-tech bus

The benefits of the high-tech bus for the traveller are the following:

- Better service and comfort because of precision docking and service from the bus driver when the bus is driving automated.
- Reliability because of free lanes.
- The traveller needs to interchange, because there is no door-to-door service with these vehicles, but the decrease in travel time will probably solve this problem.

The benefits of the high-tech bus for the operator are the following:

- The high-tech bus is very flexible therefore the bus has a large range. Routes can be easily adapted if this is necessary, since the bus can also drive on existing infrastructure.
- The driver can, when the bus is driving automated, provide better service to the passengers.
- Reliability because of free lanes.

The benefits of the high-tech bus for society are the following:

- Traffic safety will increase because the bus drives more precisely and is equipped with new safety technologies.
- The bus lanes can be constructed narrower as a result of the precise steering, which saves space.
- The bus is also cleaner because an intelligent and anticipating driving strategy is used to control the engine Therefore it is a solution for air pollution.

On the automated lanes the speed of the bus can be high and therefore the range of this concept increases.

### 2.3.5 Dual mode vehicle

The benefits of the dual mode vehicle for the traveller are the following:
- The main benefit for the driver is the combination of good accessibility and safety, especially in areas where the technology function is used.
- The driver can stay in his own car, which will increase acceptability and adds comfort for the driver.
- Frequency and reliability are not an issue here, because the concept is always available to the driver at all times.

The benefits of the dual mode vehicle for the technology area operator are the following:
- An increase in the capacity of the road network, because the vehicles can drive closely together.
- Increase of the traffic safety in the technology area.

The benefits of the dual mode vehicle for society are the following:
- The air pollution will decrease slightly in the area where this technology is applied. However the vehicles will drive in conventional mode in the other areas. The concept is however a little bit cleaner overall, because of all added technology.
- The congestion will decrease, because the automated vehicles drive on reserved lanes, utilising techniques to optimise the traffic flow, e.g. platooning. This not only increases road capacity it also makes it easier to re-route vehicles or dedicate lanes for congested directions.
- The overall accessibility of the concept is endless, since it is actually a normal car, which is allowed to drive on “automated” vehicles lanes. The automated accessibility is as big as the automated area is. The overall accessibility of the city is increased neither decreased.
- Traffic safety will increase when the technology is used, because less driver mistakes will be made.

2.3.6 Conclusions
Concluding from the above stated possible passengers applications scenarios it can be said that all concepts contribute to a more sustainable urban transport system. Depending on the problem the different concepts come to mind. For example for a strict shuttle function a PRT might be the best solution, if more flexibility is required a cybercar might be of better use. The main conclusion is that if a city experiences a problem with air pollution these new concepts might serve as a solution to increase liveability in a neighbourhood. Secondly the automated forms create a great possibility to make public transport payable again in low-density areas, where also the speeding up of the current network is a great second possibility to reduce the total travel time.

2.4 Transport demand: urban context

In section 2.3 the viewpoint is from the transport supply side, where in this section the transport demand side is the focus. What is the value of the mobility concepts while different trip types in different urban environments are considered?

The matrix
By creating an origin-destination matrix with a number of typical urban contexts the usefulness of mobility concepts as a service between this origin and destination is established. The
urban contexts are presented in the matrix as origins in the rows and destinations in the columns. In the diagonal cells of the matrix are the trips, which start and end in the same type of context. The urban context types that are used are:

- city centre
- inner suburbs
- outer suburbs
- suburban centres
- major transport nodes
- major parking lots
- major educational or service facilities
- major shopping facilities
- major leisure facilities

The main criterion used to identify the above typologies is the presumably different space-time profile of the travel demand generated on the O-D connection of concern. Depending on density of population at origin and on the density and different typologies of activities which attract people at the destination, there would be different time profiles of travel demand - e.g. shopping malls show different peaks from universities, hospitals, city centres etc. – and this has to be taken into account when assessing the fitness for purpose of the application scenarios.

The matrix had to be fitted with the mobility concepts as mentioned below:

- Advanced city car (ACC)
- Cybercar
- PRT
- Dual mode vehicle (DMV)
- High-tech bus (HT-bus)

The cells in the matrix on the diagonal mean the journeys within the city centre, within the inner suburbs, etc. The off-diagonal cells include the trips connecting different types of context, e.g. the city centre with suburban centres, a parking lot with the city centre, a suburban centre with a railway station etc.

A somewhat special typology is that of “corridors” which do not correspond to an O-D concept as the other typologies. The corridors are therefore represented in a different way, as an additional “origin” row element without the correspondent “destination” column: the corridor is seen as crossing through, suburban centres, outer suburbs, inner suburbs and perhaps also the city centre (it depends on how large the city centre is and whether it is severed by an highway), while it is considered not relevant for the other contexts.

As can be seen in the matrix, which is presented below, only half of the matrix is filled. This is because it is assumed that if a trip is performed one way it will be performed in the return direction as well.

Experts from different companies participating in SP2 of CityMobil filled the matrix. While considering the mobility concepts for each cell in the matrix, the experts were asked to make a distinction between ‘possible mobility concept’ and ‘promising mobility concept’. The resulting matrix is a combination of all mentioned promising mobility concepts and all possible mobility concepts that were mentioned by more than one expert in the same origin destination cell. In addition, logical promising mobility concepts resulting from section 2.3 were added. Empty cells mean that for this origin-destination combination no promising mobility concept exists.
Table 1: Transport demand matrix

<table>
<thead>
<tr>
<th>Destination:</th>
<th>City centre</th>
<th>Inner suburbs</th>
<th>Outer suburbs</th>
<th>Suburban centres</th>
<th>Major transport node</th>
<th>Major parking lot</th>
<th>Major service facility</th>
<th>Major shopping facility</th>
<th>Major leisure facility</th>
</tr>
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<tbody>
<tr>
<td>City centre</td>
<td>ACC</td>
<td>Cybercar</td>
<td>PRT</td>
<td>DMV</td>
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<tr>
<td>Inner suburbs</td>
<td>HT-bus (ACC)</td>
<td></td>
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<td></td>
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<tr>
<td>Outer suburbs</td>
<td>HT-bus (ACC)</td>
<td>DMV</td>
<td>Cybercar</td>
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<tr>
<td>Suburban centre</td>
<td>HT-bus (ACC)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Major transport node</td>
<td>ACC</td>
<td>HT-bus</td>
<td>HT-bus</td>
<td>PRT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Major parking lot</td>
<td>Cybercar</td>
<td></td>
<td>Cybercar</td>
<td>PRT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Major educational or service facility</td>
<td>HT-bus</td>
<td></td>
<td>Cybercar</td>
<td>PRT</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Major shopping facility</td>
<td>HT-bus</td>
<td></td>
<td>Cybercar</td>
<td>PRT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Major leisure facility (e.g. amusement parks)</td>
<td>HT-bus</td>
<td></td>
<td>Cybercar</td>
<td>PRT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corridor</td>
<td>DMV</td>
<td>HT-bus</td>
<td>DMV</td>
<td>HT-bus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Looking at the matrix it shows that the city centre apparently experiences the most problems, because it gets the most attention (all but 1 concept is mentioned). On the other hand it might be the case that most mobility concepts are suitable for usage in the city centre. Furthermore there are no connections from the major facilities to the living areas, which especially for shopping and education is interesting, this could be interpreted as the assumption that conventional modalities (car, bicycle, feet) are still the most feasible ways to get around. Also connections between facilities are not seen as a feasible option. The feasible options are discussed by means of the different concepts.

The concept of advanced city car has quite a specific need of high density, the order of magnitude suggested are cities like Paris or Milan. This means that not every city centre is fit for an advanced city car-sharing scheme (indicated in the matrix by entries in brackets).
2.5 Passengers application scenarios

The combination of the transport supply and demand, as sketched in sections 2.3 and 2.4, shows the following promising passengers application scenarios. These scenarios are discussed in order of the mobility concepts.

2.5.1 Application scenario: advanced city car

The scenario that can be envisioned looking at the benefits and urban context is advanced city cars being available outside the city centre for sharing. The locations where the car is available are situated either at the edge of the city centre or a major transport node. The city is very crowded (very car oriented/motorbike oriented) and/or difficult to access (no large access avenues, small and hilly streets, etc.), but is so dispersed that automated transport is not an option. Also air pollution is a problem, but not that big yet. Thirdly the building of new infrastructure is impossible because of e.g. historical reasons. The size of the city is very large, in order of magnitude of metropolises like Paris and Milan.

If a city has features like described above it is feasible to implement advanced city cars as a solution for the mentioned problems.

If you think for example of Rome where the building of new infrastructure is difficult because of the archaeological remains in the ground a vehicle that uses the existing infrastructure is interesting.

2.5.2 Application scenarios: cybercar

The scenarios that emerge from the above mentioned benefits and urban contexts are the cybercar as a new form of public transport in either very crowded inner cities with a parking problem and very small and congested streets, where the range of the cybercar is a maximum of 2-3 kilometres.

Another possible scenario is an outer suburb where conventional public transport is not an option because of the low density and therefore relative high costs of employing drivers. In this scenario the cybercar functions as a feeder system towards a high-speed public transport network.

A third possible scenario is to serve as a shuttle function between a parking lot or a major transport node and other major facilities, like a university, shopping centre or an event hall.
The main thing to keep in mind is the maximum distance, which should not exceed 2-3 km, one way.

2.5.3 Application scenarios: PRT

The possible scenarios that emerge from the PRT concept are areas where it is very busy and building underground is not a possibility due to historical or geological reasons. In other words old city centres where there is a need to take the cars or conventional buses out of the city. Due to the need of segregated infrastructure, the city must offer enough space to build this segregated track.

A second possible scenario is to serve as a shuttle function between a parking lot and a flight terminal (like in the Heathrow demonstration) or an event hall (or large shopping centre) to allow more distance between parking and activity. The PRT could actually go into the shopping centre and have several stops there as well.

The last scenario that can be envisioned is the PRT inside a major transport node, connecting the different modalities with each other. This will reduce the need to get all stops/shops and parking lots within walking distance of each other and allow better interchanges between these modalities.

2.5.4 Application scenario: high-tech bus

The possible passenger application scenario that emerges from the benefits and the urban context is the possibility of a rapid growing city where the bus lanes extend into the new neighbourhoods. The bus serves as a connection between these neighbourhoods and the city centre. The bus can also serve between the centre and an airport that is far out of town, or between two remote centres of a city. Adaptation is the main interesting concept of this mobility concept. Therefore it could easily be implemented in an adapting city. Not only the connection between the city centre and the different urban context is feasible, also the connection of a major transport node with the living areas (suburbs) is a feasible option for the high-tech bus.

2.5.5 Application scenarios: dual mode vehicle

The main two passenger application scenarios that can be deducted from the above benefits and the urban contexts are a dedicated highway lane for automated vehicles, to speed up and increase capacity. This dedication can be combined on a corridor with high-tech buses to connect city centres and living areas.

The other possibility is to allow dual mode vehicles to mix with other automated vehicles e.g. cybercars in the city centre. Also the connection between suburbs and within suburbs is a feasible option. An important condition to this permission is that not too many dual mode vehicles can be granted access: otherwise congestion on the cybercar tracks is imminent.
2.5.6 Conclusions
Concluding from the above, Table 2 gives a synthesis of all 10 resulting passengers application scenarios while
Table 3 lists some sustainability aspects for the different scenarios.

### Table 2: Passengers application scenarios

<table>
<thead>
<tr>
<th>Mobility concept</th>
<th>Passengers application scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced city car</td>
<td>Car sharing outside the city centre in dispersed crowded environments</td>
</tr>
<tr>
<td>Cybercar</td>
<td>New form of urban public transport in crowded city centres</td>
</tr>
<tr>
<td></td>
<td>Feeder for high quality public transport in low density suburbs</td>
</tr>
<tr>
<td></td>
<td>Shuttle between parking or major transport node and major facility (e.g. shopping centre)</td>
</tr>
<tr>
<td>PRT</td>
<td>Inner city transport system where building underground is not an option</td>
</tr>
<tr>
<td></td>
<td>Shuttle system between parking and airport terminal or event hall</td>
</tr>
<tr>
<td></td>
<td>Inside major transport node connecting the different transport systems</td>
</tr>
<tr>
<td>High-tech bus</td>
<td>Connection between city centre and suburbs or major facility in adaptive city growing rapidly</td>
</tr>
<tr>
<td>Dual mode vehicle</td>
<td>Dedicated highway for automated vehicles in order to access the city more rapidly</td>
</tr>
<tr>
<td></td>
<td>Sharing the track of cybercar systems in crowded city centres</td>
</tr>
</tbody>
</table>
### Table 3: Aspects of passengers application scenarios

<table>
<thead>
<tr>
<th>Advanced city car</th>
<th>Sustainability</th>
<th>Accessibility / Range</th>
<th>Costs of implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car sharing available at central locations for rental/use</td>
<td>Reduce air pollution, because smaller and cleaner vehicles</td>
<td>Like an ordinary car on current infrastructure</td>
<td>Small, only vehicle investment</td>
</tr>
<tr>
<td>Cybercar</td>
<td>Reduce local air pollution significantly</td>
<td>Currently limited access infrastructure needed – eventually mixing with other traffic</td>
<td>First moderate investment in infrastructure and vehicles</td>
</tr>
<tr>
<td>Parking problem urban city centre or not functioning PT-network</td>
<td>Reduction in pollution significantly</td>
<td>Limited access infrastructure needed, but easily implemented in new neighbourhoods.</td>
<td>First moderate investment in infrastructure and vehicles</td>
</tr>
<tr>
<td>Low density neighbourhoods connecting to high-speed PT-network</td>
<td>Reduction in pollution significantly</td>
<td>Maximum range 2-3 km, one way. New infrastructure needed, eventually mixing with other traffic</td>
<td>First moderate investment in infrastructure and vehicles</td>
</tr>
<tr>
<td>Major facilities connected to major transport node or parking lot</td>
<td>Reduction in pollution and parking problems</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRT</td>
<td>Reduce local air pollution significantly</td>
<td>Dedicated infrastructure needed – limits the range</td>
<td>High start costs because of investment in infrastructure</td>
</tr>
<tr>
<td>Historical city centre, with crowded small streets or parking problem.</td>
<td>Reduce local air pollution significantly</td>
<td>Dedicated infrastructure needed – limits the range</td>
<td>High start costs because of investment in infrastructure</td>
</tr>
<tr>
<td>Event hall or flight terminal connected to parking lots.</td>
<td>Reduce local air pollution significantly</td>
<td>Dedicated infrastructure needed – limits the range</td>
<td>High start costs because of investment in infrastructure</td>
</tr>
<tr>
<td>Major transport node connecting the different modalities</td>
<td>Increase of PT-use and therefore less car use</td>
<td>Dedicated infrastructure needed – limits the range</td>
<td>High start costs because of investment in infrastructure</td>
</tr>
<tr>
<td>High-tech bus</td>
<td>Reduce air pollution, but that depends on the vehicle chosen.</td>
<td>Relatively flexible because it can drive on existing infrastructure as well.</td>
<td>High investment in vehicles, but relative low infrastructure investment, just a few adjustments</td>
</tr>
<tr>
<td>New neighbourhood and city centre (or two outlaying centres)</td>
<td>Reduce air pollution, but that depends on the vehicle chosen.</td>
<td>Relatively flexible because it can drive on existing infrastructure as well.</td>
<td>High investment in vehicles, but relative low infrastructure investment, just a few adjustments</td>
</tr>
<tr>
<td>Major transport node connected with suburbs</td>
<td>Reduce air pollution, but that depends on the vehicle chosen.</td>
<td>Relatively flexible because it can drive on existing infrastructure as well.</td>
<td>High investment in vehicles, but relative low infrastructure investment, just a few adjustments</td>
</tr>
<tr>
<td>Dual mode vehicle</td>
<td>If speeded up there is no air pollution benefit</td>
<td>Flexible on all infrastructure, but needs specific infrastructure for technology use</td>
<td>Investment in technology and dedicated lanes is necessary</td>
</tr>
<tr>
<td>Dedicated highway</td>
<td>Slight reduction in air pollution and noise in technology area</td>
<td>Flexible on all infrastructure, but needs specific infrastructure for technology use</td>
<td>Investment in technology and combination with other infrastructure investment</td>
</tr>
<tr>
<td>Mixed automated vehicles</td>
<td>Slight reduction in air pollution and noise in technology area</td>
<td>Flexible on all infrastructure, but needs specific infrastructure for technology use</td>
<td>Investment in technology and combination with other infrastructure investment</td>
</tr>
</tbody>
</table>
3 Freight application scenarios

This chapter is dedicated to defining and describing freight application scenarios. It illustrates the results of an analysis based mainly on a survey carried out in 30 cities and intended to chart the main development trends in the urban freight distribution sector and to identify hypothetical but probable future scenarios in which conventional freight transport systems can be replaced, at least partially, by automatically-guided transport systems.

3.1 Methodological description

The method of work adopted to identify the application scenarios is based on a process divided into 4 phases, as described in detail in deliverable D2.2.1 “Common Methodology:

Figure 10: Structure of the analysis process

The initial phase of the analysis comprised a survey that involved the mapping of 29 innovative projects in the urban freight distribution sector (29 European cities and a Japanese city), together with a synthesis of the main literature available on the subject (information and data about the projects were collected by directly contacting the involved authorities; furthermore CSST take part to the European project BESTUFS – www.bestufs.net – since 2000 and represents the national contact point in Italy). All thirty projects examined were of an innovative nature: these reflect mainly experimental solutions – obtained by combining investment and complementary measures – adopted by the individual municipalities in an attempt to restrict the negative impacts of urban freight traffic and its contribution to congestion, atmospheric pollution and occupation of public ground.

On the basis of these activities, a summary was made of the main ongoing development phenomena as regards the structure of the city, the structure of commerce and the demand for urban freight transport.

According to the analysis of these projects, 5 “skeletal scenarios” were also identified which represent five corresponding categories, real families of scenarios from which the final application scenarios can be extracted.

The last phase of the process consisted of identifying the application scenarios, combining CityMobil technologies with skeletal scenarios identifying the zones of logistic flow with the highest automation potential.
3.2 **Main trends in urban freight distribution: survey of 30 innovative urban distribution projects**

This chapter illustrates the main development trends behind the transformation of the city, of the structures of commerce and the demand for freight transport generated by these, identified by examining 30 urban areas (29 European and 1 Japanese).

It is the effects induced by these transformations that have generated the need for municipalities to implement innovative projects intended to:

- improve the efficiency of distribution logistic flow
- reduce congestion, atmospheric pollution and occupation of public ground

The cities examined are listed in the figure below:

**Figure 11: List of cities examined**

They represent a broad selection of urban structures and road networks in 11 countries. The figure below shows – as an example - some maps of the above listed cities.
Figure 12: Different types of urban areas

Analyzing the structure of the shape of the cities, it is possible to identify two opposed development patterns:

- “urban sprawl”, based on wide “horizontal” development of the city
- the “compact city”, based on vertical development, corresponding to concentration of the density of the city and of the activities carried out in this.

Analyzing the city according to a “functional” criterion, it is possible to distinguish another two patterns of urban development:

- functional zoning, which corresponds to division of the urban territory into zones in which different activities are carried out; consequently, residential activities are concentrated in one urban area and working activities in a separate area from the first, etc.
- mixed land use, which corresponds to mixed use of the territory; in this case, different activities co-exist in the same territory.

The analysis of the above urban areas showed that none of the above models seems to dominate in relation to the others. Therefore, it appears that all the different urban development models are present and, in some cases, coexist inside the same urban or metropolitan area.

However, it is possible identify a certain evolution towards growing **metropolization**, i.e. a growth in the dimensions of the metropolises.

At the same time, it is possible to observe:

- the birth and development of new urban centers, located mainly close to major peripheral interconnection road nodes;
- re-organization of old centers, mainly in a central position in relation to the urban area, with far-reaching structural and functional renewal of public and private buildings and of road networks.
These changes generate specific impacts on the structures of commerce, i.e. on the structures that originate the demand for urban freight transport. In particular, in parallel with the co-existence of different urban development models, it is possible to observe the development and co-existence of different distribution and sales patterns, as shown in the figure below.

**Figure 13: Urban development and of commerce**

The figure below represents the traditional city, characterized by a fragmented structure of commerce (the black small dots represent neighbourhood shops) with a capillary transport network managed by suppliers (in particular wholesalers) - who may deliver directly or via courier. In this model, it is the traders who, very often, pick up the goods directly from the manufacturer. Consumers benefit from the typical advantages of neighborhood shops, can reduce travel and transport by car.

**Figure 14: Traditional fragmented structure of commerce**

However, the ongoing evolution leads to a different pattern in which, as mentioned above, different models coexist:
Numerous sales points remain in the city center while in the suburbs local supermarkets are more frequent. Many retailers participate in organized structures, some of which are equipped with a central warehouse. In this case, the central structure uses internal transport systems. In some cases, the logistic function is delegated to a specific company.

The set of developments outlined above, together with the rising real estate costs, changes in lifestyles, increasingly wide-scale adoption of measures to regulate use of the city, tend to influence the evolution of freight transport demand.

The main effects in terms of evolution of the urban freight transport demand are summarized in the figure below:
Figure 17: Main developments in the demand for freight transport

Firstly, it is possible to observe a growing increase in the quantities of freight transported (ton x km), driven by increased consumption and the phenomenon of metropolization.

A second major aspect detected concerns the underlying logic of logistic distribution flows: a “push” type logic (in which the sales points sell the products, as regards quantity and quality, according to requests generated upstream) is being replaced by a “pull” type logic: in this case, the sales points issue orders (in quality and in quantity) according to the effective requirements of the end customer. In other words, what already happens in the industrial logistics sector is being adopted in the commercial field.

This evolution is also accompanied by the development of “just-in-time” logistic flows in which reduction of warehousing space (ever more expensive due to soaring real state prices) is combined with adoption of the ever more diffused just-in-time approach.

A fourth element that contributes to delineating the development scenario is the increased frequency of orders due, on the one hand, to application of a stock reduction policy by commercial and manufacturing firms and, on the other, to the gradual development of new forms of commerce (e-commerce, home deliveries).

Although frequency increases, the volume and average weight of the deliveries tend to decline.

Lastly, a final development trend is reflected in the growing demand for personalization of the method of delivery of goods to the stores, each of which seeks to optimize its logistics in an ever more competitive market.

This search for logistic optimization is based mainly on reduction of logistic costs, as shown in the figure below which illustrates the main factors of competition of the urban logistics services market:
Figure 18: Main factors of competition on the logistics services market

<table>
<thead>
<tr>
<th>COMPETITION FACTORS</th>
<th>Type of goods</th>
<th>Food</th>
<th>Non food</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Necessity products</td>
<td>Luxury products</td>
<td></td>
</tr>
<tr>
<td>Transport prices</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Reliability of transport</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Integrated transport, warehousing, order management, packing, labelling, handling and other logistic functions</td>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Transport time</td>
<td>4</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Service regularity</td>
<td>5</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>Use of information technology applications (vehicle location, etc.)</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Integrated transport and warehousing operations</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Provision of special equipment</td>
<td>8</td>
<td>14</td>
<td>10</td>
</tr>
<tr>
<td>Limitation of damage or loss of loads</td>
<td>9</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>Quality of operative personnel</td>
<td>10</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>Ability to negotiate price changes</td>
<td>11</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>Financial position of carrier</td>
<td>12</td>
<td>12</td>
<td>14</td>
</tr>
<tr>
<td>Others</td>
<td>13</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>Availability of equipment</td>
<td>14</td>
<td>11</td>
<td>12</td>
</tr>
</tbody>
</table>

In an attempt to summarize the most significant aspects, the table below provides a synthesis in which some of the key development trends of the city and of commerce are correlated with urban freight transport variables.

Figure 19: Impacts on urban freight transport variables

<table>
<thead>
<tr>
<th>Key trends in evolution of the City and commerce</th>
<th>Urban freight transport variable</th>
<th>Average weight and volume of deliveries</th>
<th>Frequency of deliveries</th>
<th>Length of Single trips</th>
<th>Organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase in complementary measures in urban freight transport</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Increase in the cost of selling and storage spaces</td>
<td>-</td>
<td>++</td>
<td>0</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Development of organized commerce (Franchising)</td>
<td>+</td>
<td>0</td>
<td>-</td>
<td>++</td>
<td></td>
</tr>
<tr>
<td>Increase in home deliveries / Mail order sales</td>
<td>-</td>
<td>++</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Modification of the purchase behaviours</td>
<td>-</td>
<td>++</td>
<td>0</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td><strong>Total impact on urban freight transport variables</strong></td>
<td>-</td>
<td>++</td>
<td>0</td>
<td>++</td>
<td></td>
</tr>
</tbody>
</table>

++ = Strong increase + = Increase 0 = No effect - = Strong decrease - Decrease
The last column of the table reveals that logistic optimization (sought by all sector stakeholders) implies significant organizational changes.

The developments highlighted as regards transport demand generate various immediate effects: on the one hand, an increase in logistic costs which the stakeholders in the logistic flow try to remedy with organizational changes; on the other, an increase in the number of vehicles used for urban freight transport.

Figure 20: Main effects of the ongoing developments

This second effect is a source of concern especially for local public authorities responsible for managing urban space, traffic and for reducing congestion and pollution.

This has resulted in numerous innovative projects in the urban freight distribution sector (both through private and public initiative) and opens up potentially interesting spaces also for automatic transport systems.

In the next chapter we will therefore define “skeletal scenarios”, i.e. families, types of application scenarios that provide space for these innovative transport systems.

3.3 Freight “skeletal” scenarios

3.3.1 Foreword/link with previous sections

Prior developments of the research have highlighted various general goods transport trends (growing volumes, increased frequency, personalization of services), also examining their impacts in particular as regards urban and peri-urban transport. This focus is certainly justified by the many problems affecting old town centers and metropolitan areas and also by incorporation of infrastructures and production sites in the urban fabric due to growth of the cities.

With regard to the drivers of change, tension on costs/prices and requirements of service reliability have been identified in the previous phases as sector-specific internal factors; shippers and logistic operators are particularly sensitive to these factors. These drivers generate relatively slow changes, usually of an incremental type and restricted to specific spheres of
influence tied to the limits of control of each subject; furthermore, these subjects tend to be hostile to making major investments, especially those without fast Return On Equity/Return On Investment and, therefore, tend to give priority to investments in organization rather than in dedicated automation at individual sites.

These on-going, general changes in goods transport are accompanied by many initiatives launched by local authorities who, in particular, are tightening up regulation of transport especially in city centers and this in some cases fast pattern of change imposes non-marginal modifications.

The changes introduced envisage solutions that involve investments (Urban Distribution Centres, low-emission fleets, specialized areas, on-line systems, etc.), complementary measures (time slots, weight/profile restrictions, specific tariffs etc.).

The development of local (/central) regulations would seem to be the main driver of possible developments towards automatic transport solutions, even if this trend will not, presumably, be fast. Although the complementary measures of the local authorities increase the probability of development of innovative applications in this environment (especially old city centers), the urban context (usually consisting of residential/commercial areas) would not appear to be naturally “inclined” towards automation and may make application of these more complex; therefore, certain models may be applicable first of all in more homogenous contexts (exhibition grounds, airports, business parks, etc.), without this, however, excluding possible future transferability.

In this context, possible transport automation skeletal scenarios have been identified, inserted both in a more general automated flow and also as individual components of a flow of which we have tried to schematize the main logistic elements.

3.3.2 Skeletal scenarios identification criteria

To identify skeletal scenarios, attention was directed to the consideration that automation is usually justified (economically) in situations in which it promotes high level efficiencies (main driver: shippers and logistic operators) or when it permits compatibility with strict constraints (main driver: regulatory subject).

Examples of conditions of efficiency may be a high number of transports if these are carried out at costs that would be very high using conventional systems due to the number and qualification of the necessary resources, difficulties tied to shift work and replacement, the complexity/number of accessory operations in the case of conventional systems, etc.

Examples of situations of constraint may be associated with space/time conditions (for space, for example, the layout of the places, shortage of space for conventional methods of operation, the existence of automatic transport systems for persons, etc.) and as regards time (for example, the need for synchronization with other operations, use of night-time hours, etc.), regulatory (for example, the need for segregation and/or control, etc.), problematic objects (for example, goods with ecological constraints, hazardous goods etc.), authorization requirements (type of vehicle, timetables, etc.); in the general framework of constraints, regulatory components are particularly important due to the effects outlined above.

More probably, the combination of these elements (efficiency and constraints) may generate situations that justify automatic transport of goods and effective implementation of applications.

3.3.3 Skeletal scenarios

An option list of a certain number of possible automatic transport situations is provided below, classified according to type of logistic flow in which transport is inserted; these situations (skeletal scenarios) may be combined (also with several options) with other logical categories.
already considered in other parts of the study (old town center/periphery, secure/not secure area, operator interaction, type of infrastructures, etc.) and converted in application scenarios.

At first sight, the most interesting applicability in which specific situations will be exemplified (anticipated here) will give priority to locations in old town centers or in circumscribed, specialized environments.

1) **JIT refilling of shops**

Shops and public concerns have very limited free space (for example, in old town centers or in high cost areas such as airports) or have problems of investment tied to managing vast assortments with high level coverage (for example, chemists or bookshops) and the impossibility of predicting instant demand (for example, exhibition grounds).

Remote stocking of non-shelf supplies can be assumed (at own remote warehouses, storage service centers, wholesalers etc.) with transfer to the sales counters several times a day (for example, at fixed times) or with response to (single) request; the request may be sent via PC or telephone and may trigger immediate automatic or manual preparation (such as, for example, in the preparation of spares for professional computers) and converge in a wire-guided circular train (or other equivalent mean of transport).

The train transports pre-selected containers for each destination (dimensions) labeled with bar-codes that, at each destination, recognize the destination code (or with other technology) and automatically open the destination compartment (mail box type) and unload the container in this.

Transport may be carried out on a specialized path on a service route, at the same level or at a different level (for example, below ground) or on the non-specialized path used by other vehicles and pedestrians (or only pedestrians); the return routes (not all but, for example, only at the end of the shift) may be used to dispose of packaging or various types of waste (possibly with a more modest level of automated handling).

For refilling of bulky objects (for example drinks to public concerns) the operations could be concentrated at suitable times and managed with a more limited level of automation.

Perishable foodstuffs (certainly for frozen foods, if any) could be transferred in refrigerated or adiabatic/high thermal inertia containers.

Remote control systems could be applied for goods of relatively high value (for example, clothing) or problematic goods (for example, chemists).

2) **Drop-off point for last-mile deliveries at houses/small offices**

Specifically-equipped consolidation points can be organized at which to deposit deliveries; if compatible with space available, this could be implemented through exchange of small carts (drop-off full/pick-up empty) with automatic transport, otherwise with unload systems (probably manual due to the different types of packages and the need for sorting and delivery services to the point of arrival); transport may be afforded in various ways, possibly also during the night (in this case, attendance must be assured for loading operations, or unattended automatic systems must be used). The same system may operate as pick-up/delivery terminal for express courier services.

A particular type of drop-off point could be set up in the mezzanines of subway stations with transport in powered load units inside passenger cars on dedicated trips (for example, at the end/start of the day);
3) **Passengers and goods handling**

Use of vehicles for goods and for passengers/goods can be assumed, with simultaneous transport and with partially specialized vehicles or with mixed means; examples of simultaneous conditions of use may be vehicles for primary transfer of persons that require a set of goods to carry out the operations that justify their movement; examples could be a beauty farm at which the guests move from one pavilion to another using automatic vehicles carrying a set of objects to be used on reaching their destination (towels, cosmetics, gymnastic gear, etc.); the objects necessary on arrival can be prepared in boxes with indications of destination; returns may be managed in a similar manner; conditions of asynchronous use may be restocking using cableways with specialized cabins for goods; return journeys are used also in these examples.

Another example could be historic cemeteries that may be equipped with trains that can be used both for the funeral procession and for the coffin and wreaths.

The level of automation of handling operations of the objects forming the loads of goods can be decided as required (but it is unlikely that high levels of automation are easy to justify).

4) **Transfer between logistic nodes**

The integration of seaport logistic nodes with the urban contiguous areas and the shortage of railway links may represent an obstacle to ship-rail inter-modality; this problem can be addressed by handling - at specialized facilities (possibly in tunnels) - load units (mobile crates, containers) in order to bypass densely urbanized areas; in situations of this type, automatic transport may permit round-the-clock distribution of flow, also minimizing other infrastructural investments; a solution of this type is being studied in the case of a seaport terminal-railway terminal link over a geographically short distance that however involves a long distance by road due to a major gradient; in this case, a winning factor would be automated flow including transfer and lifting.

Another example could be connection between production units, for example inside a business park (models already exist especially at business parks specialized in car assembly, even though with relatively limited transport automation components) or with external links (for example, the connection between two Volkswagen sites at Dresden);

Another example could be connection between UDC (Urban Distribution Centre) and service areas in old town centres to be linked with automatic means (possibly also with tram type solutions - see TADIRAM project).

5) **Problematic goods**

In some cases, the handling and transport of problematic goods justifies high levels of automation with a view to process integration and minimization of the inherent risks of the goods.

An example of flow in an urban context could consist of collection of urban waste; a flow could include replacement of full containers with empty containers and transfer of these to the emptying and compaction site; ecological transport permits continuous rotation of these containers with minimum accumulation of waste and a minimum number of containers in the road (terminal operation would be specialized according to differentiation of collection).

A similar model can be proposed for collection of hospital waste at a hospital centre consisting of many pavilions.

A particular example of the transport of problematic goods could be the supply of cash and securities to banks and post offices or withdrawal of cash from commercial concerns for bank deposit.
3.4 Application scenarios: a combination of freight skeletal scenarios with CityMobil technologies

An assignment of ‘CityMobil technologies’ to mobility concepts has been defined in previous chapters (those dedicated to passenger application scenarios; see Figure 7).

A list of benefits for the traveler, the transport operator and the society has been produced in the passengers case for each CityMobil technology (ACC, Cybercar, PRT, High Tech Bus, Dual mode vehicle) and, based on this, application scenarios have been produced (combining mobility concepts with a transport service in an urban environment).

The next subsections will use a similar approach for freight, analysing the benefits of each CityMobil technology in the freight case and trying to match those benefits with the skeletal scenarios producing freight application scenarios. The process is resumed in the following figure where the match between technologies (transport offer) and skeletal scenarios (derived from an analysis of the freight transport demand evolution in urban area) is shown:

**Figure 21: CityMobil technologies and freight skeletal scenarios**

### 3.4.1 Advanced City Car

ACC equipped with advanced driver assistance systems can be used in the freight transport sector; the benefits for the driver, the transport operator and society are basically the same already described in the passengers case (see section 2.3.1).

Specific additional benefits for the driver in the freight case are:

- the driver perform a number of difficult parking manoeuvres during the distribution trips due to the high number of deliveries done per day; the ADA systems that are installed on the vehicles represent in this case a valuable support for him.

Specific additional benefits for the transport operator in the freight case are:

- the transport productivity can be increased because of the reduced time in manoeuvring for parking the vehicle during loading and unloading operations; a reduction of transport costs can therefore be obtained.

Specific additional benefits for society in the freight case are:

- the reduced time for parking the freight vehicles for loading/unloading the goods represents an advantage also for passengers cars which are less disturbed by freight traffic flows; this in turn means less congestion and pollution.
Application scenario

The ACC technology can be associated with the first and second skeletal scenarios: “JIT refilling of shops” and “Drop-off point for last-mile deliveries at houses/small offices”, which represent advanced logistic schemes.

ACC technologies can be also used for optimising the current logistics distribution chains: the urban context is in this case a city centre where both passengers and freight traffic flows co-exist and are very high. The structure of the logistic distribution scheme remains as it is today but the transport performance is increased using ACCs.

3.4.2 Cybercar

The benefits of the cybercars in the freight transport case are quite similar to those related to the passengers case.

Specific benefits for the driver in the freight case are:

- no driver is on-board.

The main specific benefits of the cybercar for the freight transport operator are the following:

- the costs of employing a drivers can be drastically reduced;
- the cybercar can work on demand, therefore on-demand logistics schemes can be implemented (thus meeting users requirements and the specific trends of the urban freight distribution sector underlined in the previous chapters);
- the possibility of adding more vehicles to the track, that is the flexibility of the system, can contribute to optimize the loading factor, therefore reducing costs.

The main benefits of the cybercar for society in the freight case are the following:

- in general we can consider that an optimisation of the loading factor is possible with cybercars, due to the flexibility of the system: only the strictly necessary number of vehicles can be used, thus contributing to the reduction of congestion and pollution.

Application scenarios

The Cybercars technology can be associated to the second, third and fifth skeletal scenarios:

- “Drop-off point for last-mile deliveries at houses/small offices”;
- “Handling of passengers and goods”
- “Problematic goods”.

Three corresponding application scenarios can be selected:

- the urban context is the city centre or inner suburbs. Specifically equipped consolidation points are organized at which express couriers can deposit deliveries at any time during the day or night. People are advised via SMS that the delivery has arrived and can collect the goods at their best convenience. Goods are transported in small load-units with cybercars running on specialized lanes.
- the urban context is a restricted area such as an hospital or a beauty farm composed of different pavilions. Use of the same vehicles both for passengers and goods at the same time is assumed. People and corresponding goods (towels,
cosmetics, gymnastic gear etc.) are transported with cybercars running on dedicated lanes.

- the urban context is the city centre, inner or outer suburbs where collection of urban waste can be optimized. The logistic scheme is based on the use of traditional lorries staying in specific stations while a rotation of small waste containers is organised locally with cybercars. Containers transported by Cybercars are loaded/unloaded using a traditional equipment of the lorries (cybercars are not loaded/unloaded). A similar model can be proposed for collection of hospital waste at a hospital centre composed of many pavilions.

### 3.4.3 Automated vehicles on dedicated infrastructure (PRT)

The benefits of the PRT for the driver are the following:

- No driver is on board.

The benefits of the PRT for the freight transport operator are similar to those of the cybercar:

- the costs of employing a driver can be reduced;
- it can work on-demand.

The benefits of the PRT for society are the following (and also look quite similar to the cybercar):

- PRT can be used on specific corridors, where freight traffic flows can be bundled, therefore reducing the interference with passengers traffic flows. Congestion in the city can be in some way reduced because of less dispersed freight traffic flows;
- less congestion can be also produced optimising the use of the areas where PRT stops.

**Application scenarios**

The PRT technology can be associated with the fourth skeletal scenario:

- “Transfer between logistic nodes”;

the application scenario concerns links between specific nodes contiguous to urban areas (inland terminal, seaport terminal, airport, urban distribution centre, manufacturing plant, business park). Load units (containers, mobile crates etc.) are handled at the nodes and transported through PRT, reducing the impact on densely urbanized areas. Round-the-clock distribution is possible.

### 3.4.4 High-Tech Bus

High tech bus can be in this case renamed High-Tech Lorry (just the body is different, the structure and the technology of the vehicle being the same).

The specific benefits of the high-tech lorry for the driver in the freight case are:

- better service and comfort because of precision docking and service from the bus driver when the bus is driving automated;
- reliability because of free lanes.

The benefits of the high-tech bus for the freight transport operator are the following:
• vehicles are bigger than cybercars or PRT, therefore it is possible to perform con-
solidation / de-consolidation activities (less fragmented transport of goods);
• bigger vehicles means in general less vehicles to transport the same quantity of
goods and reduced operational costs;
• routes can be easily adapted if this is necessary, since the High tech Lorry can
also drive on existing infrastructure;
• arrivals at / departures from dedicated stops areas can be optimised through the
automatic driving functionalities (the lorry drives more precisely): this can increase
the transport productivity and reliability;
• on the automated lanes the speed of the lorry can be higher.

The main specific benefits of the high-tech lorry for society are the following:
• one ton x km transported with bigger vehicles produces less pollution;
• one ton x km transported with bigger vehicles produces less congestion;
• traffic safety will increase because the lorry drives more precisely and is equipped
with new safety technologies;
• occupancy of the public areas by stopped vehicles can be drastically reduced
(see figure below).

Figure 22: Bigger vehicles produce less m2*h / delivered ton

Application scenarios
The High-Tech Lorry technology can be associated with the fourth skeletal scenario:
• “Transfer between logistic nodes”;
the application scenario is almost the same than the PRT application scenario: it concerns
links between specific nodes contiguous to urban areas (inland terminal, seaport terminal,
airport, urban distribution centre, manufacturing plant, business park). Load units (containers,
mobile crates etc.) are handled at the nodes and transported through PRT, reducing the im-
pact on densely urbanized areas. Round-the-clock distribution is possible. The main differ-
ence with PRT is that the requested frequency of shipments is lower and consoli-
dation/deconsolidation activities are possible.
3.4.5 Dual mode vehicle

The benefits of the dual mode vehicle for the driver in the freight case are the following:

- automated driving functionalities can increase driving precisions during difficult manoeuvres;
- automated driving functionalities can reduce the fatigue of the driver.

The benefits of the dual mode vehicle for the freight transport operator are the following:

- more comfort of the driver can increase transport productivity.

The benefits of the dual mode vehicle for society are the following:

- traffic safety will increase when the technology is used, because less driver mistakes will be made;
- the vehicles, when, driven on “automated” lanes will not interfere with passenger traffic, therefore reducing congestion and increasing road safety.

Application scenarios

The dual mode technology can be associated with the first skeletal scenario:

- “Just In Time refilling of shops”;

the urban context is a limited access zone, such as a historical city centre or an airport. A remote stocking logistic scheme is assumed (remote warehouse / storage service centre / Urban distribution centre); the transfer of goods is done several time a day (at fixed times or on request) with pre-selected small containers for each destination loaded on dual mode vehicles.

As in the ACC case, dual mode vehicles can also be used for optimising the current logistics distribution chains: the urban context is in this case a city centre where both passengers and freight traffic flows coexist and are very high. The structure of the logistic distribution scheme remains as it is today but the transport performance is increased using dual mode technologies.

Dual mode vehicles can also be considered dual mode trucks. In this case there would be nearly no difference with high tech lorries; dual mode trucks could be also associated to the fourth skeletal scenario “transfer between logistic nodes”. In this case an important societal benefit would be less fuel consumption and CO2 emissions due to platooning on the reserved lanes.

3.5 A step forward in the automation of urban freight transport schemes

The previous chapters have shown how CityMobil-like technologies can be combined with skeletal scenarios for producing application scenarios with different levels of automation.

All the above described scenarios are based on loading/unloading operations done manually. In the freight case, a step forward in the automation process can be done using additional specific technological components.

These technological components (see figures below) all seem to be available and relatively well tried and tested; in particular, automatic handling solutions are frequently found in factories with high level automation and in automatic warehouses. These technological components (roller beds, conveyor belts, robots, etc.) are, potentially, the same as those to be applied in an automatic flow with automatic load/unload elements; the transport components
may also be the same as those of automatic warehouses (which tend to be more suitable for short trips) or others more similar to those tested for the automatic transport of persons; specific solutions can be studied for the various application contexts based on these (or new) components.

**Figure 23: Example of automatic labelling device**

**Figure 24: Example of a component of an automatic handling system**
Figure 25: Example of a component of an automatic handling system

Figure 26: Example of an automatic platform

Just as an example of existing technologies, the figures above show an automatic labelling device and some automatic handling systems that could be used for making loading/unloading operations automated or semi-automated (the market offers today a variety of solutions). The above described technologies can all be used in the freight case increasing the level of automation of all the freight application scenarios.

4 Conclusions
The present report has dealt with the definition of passenger and freight application scenarios as a combination of:

- an urban context;
- specific transport demand features;
- a CityMobil technology.

Furthermore, both the passengers and freight application scenarios are based on an analysis of the benefits for:

- the passenger, the transport operator and the society in the passengers case;
- the driver, the transport operator and the society in the freight case.
As for the passengers case, 10 application scenarios have been identified; it can be said that all concepts contribute to a more sustainable urban transport system. Depending on the problem the different concepts come to mind. For example, for a strict shuttle function a PRT might be the best solution, if more flexibility is needed a cybercar might be of better use. The main conclusion is that if a city experiences a problem with air pollution these new concepts might serve as a solution to increase liveability in a neighbourhood. Secondly the automated forms create a great possibility to make public transport payable again in low density areas, where also the speeding up of the current network is a great second possibility to reduce the total travel time.

As for the goods case, a set of 5 skeletal scenarios has been identified together with a wider set of application scenarios. The skeletal scenarios represent 5 main classes of scenarios where the type of automation technology is not specified; each of them corresponds to specific trends and needs in the urban freight transport sector: for example, the scenario "JIT refilling of shops" corresponds to the increasing real estate costs in urban area, to the difficulties for the shops to have free space for stocks, to the difficulty of predicting instant demand. The application scenarios are a combination of the skeletal scenarios with CityMobil technologies and all represent possible answers/solutions to the trends/constraints/needs mentioned above. The benefits of the CityMobil technologies in the freight case could make the application scenarios win-win solutions:

- on one side the transport operator could increase the transport productivity and possibly reduce the transport costs, which are the main factor of competition in the urban freight transport sector;
- on the other side, the public authorities could obtain less pollution and an increased level of safety of the road transport.

Last but not least, the driver: both in the passenger and freight case driving an automated vehicle (when the driver must be on-board even if there are automated driving functionalities) could be more comfortable than driving manually, thus in turn reducing the risk of accidents.

Although different, the two sectors (passengers and freight) maintain therefore strong common points and the CityMobil project will verify whether the above mentioned potential benefits can became real advantages for the concerned stakeholders.