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Scenarios for Automated Road Transport

Common Methodology

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Executive summary

The present report deals with the methodological aspects regarding the definition of the evolutionary scenarios of automated road transport systems. Both the methods relative to the general vision of the future and those relative to the definition of specific scenarios for real context applications are defined. The methods relative to defining the explorer concept scenarios are also presented.

As for the "vision of the future" the proposed approach is based on a step-by-step process that, starting from the output of the WP 2.1 State of the art, is aimed at defining alternative visions of the future in relation to current and prospective urban transport paradigms and concepts, the context variables that can influence the evolution (for example the general economic development, changing lifestyles, fuel prices, etc.) and their degree of predictability. One of the elements that characterize this methodology is the participation of experts (project partners) in the identification and evaluation processes, using specific questionnaires, of relevant trends and key uncertainties. Such involvement thus ensures the active participation of the partners and the sharing of results.

As for the passenger and goods application scenarios two generally similar approaches are proposed. Due to the nature of passenger transport versus freight transport, the steps are different, but the output of both approaches contain comparable formats. In the first, relative to passenger transport, a distinction is made between transport concepts and traffic concepts. Both concepts linked to the transport demand will form the passenger application scenarios in Task 2.2.2, of which the most promising will be presented in the same task. The second (freight transport) is based on a process structured in four phases that, starting from the analysis of 15 real urban contexts in which innovative urban goods distribution projects have been set up, arrives at a definition of the application scenario identifying the area of the logistics chain where the most significant potential for automated transport lies.

Although different, the two approaches maintain the following common points:

- both take into account, as the initial point of analysis, the Task 2.2.1 Visioning of the future output;
- both use the same urban area typology;
- both produce a limited number of application scenarios relative to real urban contexts describing the results in the same way via specific flow-charts and/or schemes, textual description, images.

Finally, with regards to the explorer scenario, it represents an instrument for scenario evaluation. The methodology described in the present report is limited to the identification of the "concept" through the definition of the functional specifications.

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”.

It illustrates the methods used by the partners involved in the above mentioned WP 2.2 in defining the evolutionary scenarios for Automated Road Transport Systems and its objective is to supply a common methodological base to harmonize the different activities carried out by the different partners for the same WP 2.2.

The report is divided into four principal sections corresponding to the WP 2.2’s four tasks:

- “a vision of the future”, describes the methods used in the detection and analysis of the general trends, of their level of determination (level of predictability) and of three alternative future scenarios (optimistic, business-as-usual, pessimistic) at three different points in time (2015, 2030, 2050);
- “passengers application scenarios”, describes the methods used to identify a limited number of possible application scenarios, in different real urban contexts, relative to transport of passengers;
- “freight application scenarios”, describes the methods used to identify a limited number of possible application scenarios, in different real urban contexts, relative to transport of goods;
- “scenario explorer concept”, describes the methods used for defining the functional specification for a scenario explorer, that is a set of procedures for scenario evaluation.

2 A vision of the future

The methodology for “visioning the future” of road automated technologies will take stock of the state-of-the-art review (Deliverable 2.1.1) description of:

- Technological systems (the road automated transport options).
- Typology of passenger and freight automated road transport services.
- Typology of city layouts which are deemed suitable for the implementation of automated road transport services.

Starting from the state of the art, visions of the future will be deployed through a sequence of steps:

1. identification of the issue of concern, i.e. urban transport concepts and innovations based on road vehicle automation;
2. identification of the context variables predisposing to the usage of innovations based on road vehicle automation;
3. characterisation of the context variables according to their degree of predictability and impact;
4. description of three alternative visions of the future: A) “Optimistic”; B) “Business-As-Usual”; C) “Pessimistic”. The visions will consider the three horizon years of 2015, 2030 and 2050;

5. checking of the viability of innovations against the alternative visions of the future and analysis of stakeholders' strategic behaviour.

2.1 Issue of concern

The issue of concern is identified with the description of current and prospective urban transport paradigms and concepts, with a particular focus on the innovations based on road vehicle automation. The following description in based on the NETMOBIL cluster projects outputs, and the definitions provided therein of "**transportation paradigms**" and "**urban transport concepts**". Transportation paradigms include:

- **Unimodal traffic behaviour**: most transport users still act along traditional unimodal traffic behaviour lines. They have made a major choice in transport opportunities. Based on a long-term decision process they have either bought or leased one or more cars per household and therefore have constant and easy access to an individual vehicle. Otherwise they purchased a transit ticket for using collective transport. This might be a transit pass often based on a monthly or even an annual agreement. For both, the car owner as well as the transit pass user, once they have purchased their major transport solution, first of all they direct their life and their lifestyle along the opportunities that the specific transport solution delivers, and second, they usually don't take the other opportunity mush into consideration or at least very seldom.
- **Multimodal Traffic Behaviour**: due to modern lifestyles some customers have already shifted into another transportation paradigm. These customers are in a situation to afford certain flexibility provided by using both, individual and collective modes by using them in a way where they can appreciate the benefits of both options by choosing the more convenient and comfortable one at the time, depending on actual availability, distance and time. But whenever they decide to take the flexibility and convenience offered by the train for example, for a longer ride from city to city and maybe at the same time support their environmental concerns, their individual vehicle is parked back home. For this, they still have to pay all the fixed costs (more or less equal to 70% of the overall cost). In this case then, they effectively pay twice. The opportunity is only available to people who can afford the cost of the convenience and luxury (middle-class and up in Western civilizations).
- **Intermodal Traffic Behaviour**: much more flexibility is offered by the opportunity to decide each day on the best individual travel solution. Therefore, customers don't buy their own car, but rather buy a transit pass for their basic mobility. They buy this from a local mobility portal which provides customer-oriented and customised mobility packages including options for collective transport solutions and individual vehicles related to their individual needs. In this case, the customer can combine different modes into one trip, for example enjoying long, fast trips in collective transport modes such as trains, while using individual vehicles obtained from local Point of Docking to get to and from the stations and other modal interchanges. So, the customer always stays flexible taking into account real-time traffic conditions, considering time and monetary trade-offs, and meeting his private expectations that specific day.

The latter "intermodal" paradigm supports new traffic concepts, and in particular the innovations based on road vehicle automation which fit within four main classes of systems: (i) Advanced driver assistance systems (ADAS) for cars, (ii) Personal Rapid Transit (PRT), (iii) Advanced bus systems, and (iv) Cybernetic Transport Systems (CTS).

Broadly speaking, a **transport concept** is the set of services provided, enabling technologies and framing conditions. Examples of transport concepts that are conventional and dominant, in terms of market penetration, are the car used as private transport means, and the bus used as a public transport means. An innovative concept is car sharing where a car is used as a public, rather than private, transport means. The innovations which were addressed in the NETMOBIL cluster research, on the one hand, can improve existing transport concepts (like in ADAS applied to private cars, and in advanced bus systems where automation is used in bus rapid transit systems). On the other hand, they can provide wholly new transport concepts in terms of type of service provided (like PRT and CTS which provide on-demand capability).

Therefore, NETMOBIL has provided the way to classify and characterise transport concepts in urban transport presented in the table below, which is extremely useful to represent synthetically current and future organisation of urban mobility and to understand the role that technological innovations can play:

Table 1: Basic characterisation of transport concepts in urban transport (Source NETMOBIL – D7)

	INDIVIDUAL PRIVATE		**INDIVIDUAL PUBLIC**			**COLLECTIVE PRIVATE**	**COLLECTIVE PUBLIC**		
Transport concept	Car Motor-cycle /Bicyle Small car	Car pooling	Car rental Motorcycle /bicyle rental Bicyle pools Car sharing Rental of environmentally friendly vehicles	Taxi	Shared taxi	Company bus	Dial a ride	Taxibus	Bus Tram Light railway Metro Automated Guided Transit
Service – space	Door to door	Door to door	Designated parking to designated parking	Door to door	From stop to door	Stop to stop	Door to door	Anywhere along fixed route	Stop to stop, line haul
Service – time	On-demand	Scheduled	On-demand	On-demand	On-demand	Scheduled	On-demand	Scheduled	Scheduled
Vehicle use	Party	Party	Party	Party	Shared with strangers	Shared with strangers	Shared with strangers	Shared with strangers	Shared with strangers
Vehicle drive	Manual - user	Manual – user	Manual- user	Manual – professional diver	Manual – professional driver	Manual – professional driver	Manual – professional driver	Manual professional driver	Manual – professional driver or automatic
Right of way	Mixed	Mixed	Mixed	Mixed	Mixed	Mixed	Mixed	Mixed	Mixed or longitudinally separated or exclusive

Concepts fall under the categories individual/collective and public/private. Transport is **individual** if a vehicle up to 5-6 persons is used, is **collective** if bigger vehicles are used. Transport is **private** if it serves the mobility of those who produce it, is **public** if the mobility service is sold to the public.

The basic characterisation of transport concepts shown in the table above includes the availability of service over space and time, and the types of vehicle use, of vehicle drive and of right of way.

The two concepts that are dominant in terms of market penetration are:

- the conventional individual private transport (mainly cars), which is door to door, on demand and with vehicles used by parties, and
- the conventional collective public transport (mainly buses, tram, metro and commuter trains), which is stop to stop, scheduled and with vehicles shared with strangers.

They are represented at the two extremes of the table, in the first and last columns. These dominant concepts define the existing urban transport regime. In this regime the car and public transport are mostly not integrated as intermodality is not sufficiently developed.

The characterisation is useful to highlight the innovative concepts of transport which are visualised in the table in the columns between the two extremes of motorised individual private transport and public transport solutions. Indeed, the innovations aim to provide the missing link between the conventional collective public transport, very efficient but not very flexible, and the private car, which offers total freedom but at a high cost for the user and society.

Innovative concepts include the following.

- *Car pooling*: where travellers share their individual car for commuting in order to reduce the number of cars with single occupants; can be implemented as a mobility management scheme for companies sharing a ride-matching service.
- *Bicycle pools*: where bicycles are made available at interchange points for employees of companies participating in the scheme; they can be a complement to conventional public transport in particular for short distances within campuses, compact cities, or business districts.
- *Car sharing*: where, instead of privately owning a car, users join a cooperative or commercial car sharing organisation that provides a care-free vehicle when needed; although some car sharing success stories already exist (mainly in co-operation with public transport, taxi operators etc. in Germany, the Netherlands, Switzerland etc.), the overall awareness of the benefits of car sharing as well as the organisational know-how and the currently available technologies (e.g. booking systems, access to vehicles and payment handling through smart cards) for building up a well functioning, reliable and user friendly car sharing system are not yet sufficiently deployed in Europe.
- *Rental of environmentally friendly vehicles*: where public, electric, small vehicles, are offered for rent on a short-term basis; self-serviced forms of these systems have been experimental (e.g. Praxitéle and Liselec in France, Crayon by Toyota in Japan); the schemes can be regarded as a short-range version of car sharing where the use is restricted to environmentally sensitive areas of cities possibly subject to traffic restrictions.
- *Shared taxi*[1]: when one car serves several travellers leaving from a site, usually an airport or train station, to different destinations.
- *Dial-a-ride*[1]: where travellers are picked up from home or some meeting point by minibuses and driven to their point of destination or to a transport node; these

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[1] The concepts referred to here as shared taxi, dial a ride and taxibus may be found under a different denomination elsewhere.

schemes aim at fulfilling special mobility needs, as those of low density areas, night transport, special categories of users like the elderly and the disabled.

- *Taxibus*[1] where minibuses can stop anywhere along a fixed route to pick up passengers.

In addition to these innovative concepts, NETMOBIL D7 describes the following concepts based on semi-automatic or fully automated driving:

- ADAS – Advanced Driver Assistance Systems – for cars
- PRT – Personal Rapid Transit
- Advanced bus systems
- CTS – Cybernetic Transport Systems, divided in two sub-categories: “road-based people movers” and “advanced car sharing”.

These concepts are illustrated in Table 2 below, using the basic characteristics shown in Table 1. ADAS for cars and advanced bus systems are just an evolution of transport concepts based on cars and buses, with semi-automatic or automatic driving replacing manual drive by a user or by a professional driver. Advanced car sharing can be seen as an evolution of the concept of rental of envornmentally-friendly vehicles (which is a short-range version of car sharing). Conversely, PRT and road-based people movers based on cybercars are to be regarded as wholly new concepts in urban transport.

It is important to note that CITYMOBIL SP2 analysis will focus on those concepts which have a direct and potentially sensible impact on “urban transport” – i.e. PRT, Advanced Bus Systems and CTS - while ADAS for cars, whose application is not specific to the urban context, are considered as a complementary technology to the other new urban transport concepts.

Table 2: Characterisation of innovations based on road vehicle automation (Source NETMOBIL – D7)

Innovation	ADAS – Advanced Driver Assistance Systems - for cars	PRT – Personal Rapid Transit	Advanced bus systems	CTS – Cybernetic Transport System	
				Road-based people movers	Advanced car sharing
Service – space	Door to door (or designated parking to designated parking)	Stop to stop, point to point	Stop to stop, line haul	Stop to stop, line haul or point to point	Designated parking to designated parking
Service – time	On-demand	On-demand	Scheduled	On-demand	On-demand
Vehicle use	Party	Party or shared with strangers	Shared with strangers	Shared with strangers or party	Party
Vehicle drive	Semi-automatic - user	Automatic	(Semi)-automatic	Automatic	Manual-user (when driver is on-board), and automatic (for re-distribution among parking places)
Right of way	Mixed	Exclusive	Longitudinally separated	Longitudinally separated	Mixed (when driver is on-board), and longitudinally separated (for re-distribution among parking places)
Transport concept (ref. Table 1)	Car Small car Car rental Car sharing Rental of environmentally-friendly vehicles Taxi Shared taxi	New concept	Bus	New concept	Rental of dual-mode vehicles
Vehicle capacity	Individual	Individual	Collective	Collective or individual	Individual
Service	Private or public	Public	Public	Public	Public

2.2 Characterisation of innovations based on road vehicle automation (Source NETMOBIL – D7)

The second step entails the identification of the context variables predisposing to the usage of innovations based on road vehicle automation. These context variables include supply-side and demand-side factors which are deemed to affect the potential adoption of new road automated technologies in the urban environment.

Demand-side factors will concern in particular the characteristics of the target users and their expected evolution over time, which will depend presumably on some macroscopic trends, such as the ageing of population, income and car ownership trends, employment characteristics and journey purposes. Supply-side factors will include convenience of use of road automated transport against the convenience of other modes, which may depend on some macroscopic variables such as fuel prices, as well as land use patterns and city design features (e.g. compact city environment) suitable for the installation of road automated transport options.

A broad list of relevant contexts should include the following:

1. Economic context
2. Demographic context
3. Social context
4. Land use context
5. Legal and institutional context
6. Technological context
7. Policy context

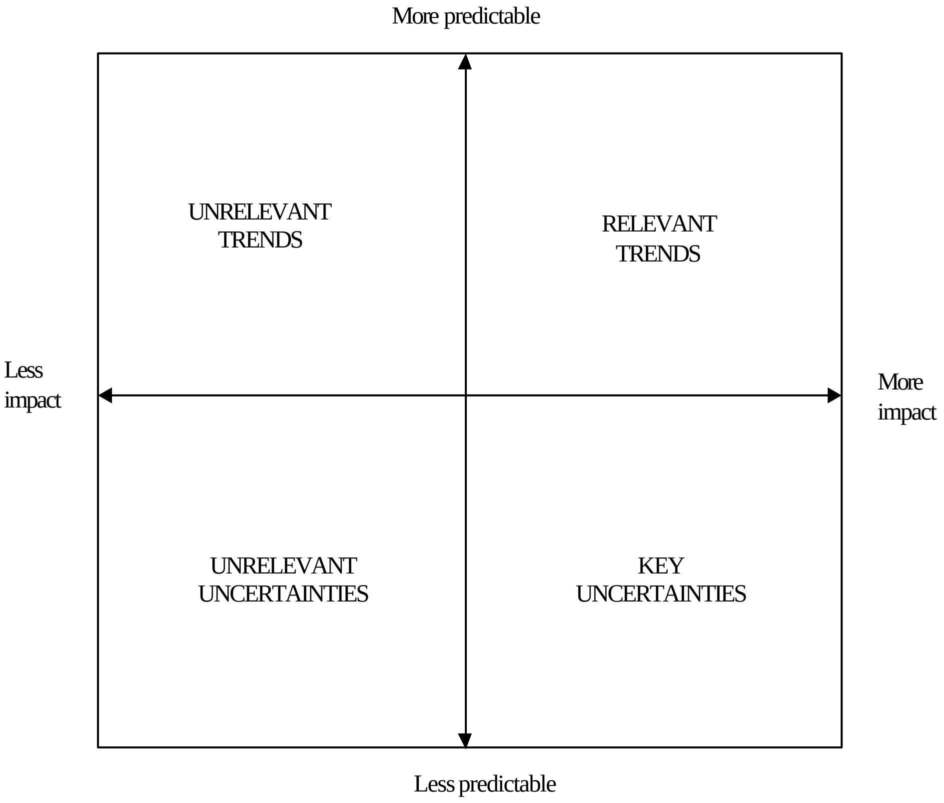
For each context above we need to identify the relevant variables and assess the expected impacts for road automated transport.

For instance, the economic context may include income levels and the associated levels of car ownership, the employment structure, etc.; the demographic context will include changing demography and spatial distribution (e.g. population ageing, migratory flows); the social context will focus on changing lifestyles (e.g. increasing leisure activities, smaller households etc.); the land use context will concentrate on land use and travel needs patterns (e.g. urban sprawl *vs* compact city developments); the legal and institutional context will consider the barriers to the implementation of the new road automated technologies in general and in the urban environment; the technological context shall consider the complementary technologies, such as ADAS and ICT infrastructure (e-driving) and, finally, the policy context will include those urban transport and land use policies which can be classified as "complementary" to road automated transport options because they facilitate the adoption of the new technologies in the urban context.

2.3 Relevant trends and uncertainties

The third step will provide the full characterisation of the context variables according to their degree of predictability and impact on the issue of concern. As depicted in the figure below, predictable context variables with a significant impact are "**relevant trends**" to be taken as predetermined elements in all the alternative visions of the future, while unpredictable context variables with a significant impact are "**key uncertainties**".

Figure 1: Identification of trends and key uncertainties for automated road transport



Relevant trends and key uncertainties should therefore be identified at this stage against the background of less relevant (because their impacts are small) trends and uncertainties. The latter will be no more considered in the subsequent steps. The former will be characterised establishing the degree to which the trends and resolved uncertainties have a negative or positive impact on the issue of concern. The aim is to define the key context variables on the demand and supply side whose evolution is critical to decide the prospective magnitudes of the road automated market niches in the different EU Member States.

The identification and assessment of relevant trends and key uncertainties will be done on the base of the CITYMOBIL SP2 experts judgment, asking them to fill in a questionnaire including a table like the following:

Table 3: Predictability and impact of context variable for road automated transport

Context variables	Predictability	Impact on road automated transport	Time scale
	High *Low*	*High positive* *High negative* *Low* *Unclear*	*When the impact will become relevant ?* *2015* *2030* *2050*
Economic context: GDP level			

Employment …			
Demographic context: Population ageing Immigration …			
Social context: Household size People awareness of environmental, safety issues Leisure activities …			
Land use context: Urban sprawl Compact/polycentric development …			
Legal and institutional context: Legal barriers Institutional barriers Financial barriers …			
Technological context ADAS ICT infrastructure …			
Policy context Transport policies Other policies (land use planning, etc.)			

Predictability will obviously depends on the time horizons, being in principle higher for near horizons (e.g. 2015) and lower for long term horizons such as those of interest for the task of visioning the future, i.e. 2030 and 2050. However, the experts will be asked to judge the **relative predictability**, not to provide absolute levels at each time horizon, in order to facilitate their task.

The impact might be high and positive, high and negative, low or unclear. When the impact is judged to be “low” the context variable is not relevant and dropped from the list of context variables to be taken into account. When the impact is “unclear” the context variable cannot be dropped, but should be retained for further analysis and checking of the key uncertainties considered in the future scenarios.

The time dimension will be taken into account by asking when the impact is deemed to become relevant. The experts may answer choosing among three time horizons: 2015, 2030 and 2050.

In any event, it is important to note that the experts will be asked to judge:

- *the impact of highly predictable changes: one judgment related to the prevailing trends*

or

- *alternative impacts for low predictable changes (which represent the key uncertainties): three judgements related respectively to the situations of "no change", "positive change" and "negative change" of the context variables*.

Besides giving qualitative ranks to the various options (e.g. high predictability, high positive impact etc.), the experts will be asked to provide short motivations of their choices, which will be used later to describe and justify the different future scenarios.

With regard to the key uncertainties, the experts will be asked to provide their subjective feeling about the plausibility of the alternative options, indicating the most plausible one (this is needed to elicit the "business as usual" scenario, see section 2.4 below).

2.4 Alternative visions of the future

Based on the information provided by the preliminary assessment of context variables described in section 2.2 and by the experts questionnaires filled with their judgement of relevant trends and key uncertainties (see section 2.3), the fourth step will build-up three alternative visions of the future: A) "Optimistic"; B) "Business-As-Usual"; C) "Pessimistic".

The approach followed for scenario construction will be the extreme-world method. This creates extreme visions of the future by putting all positively resolved uncertainties in the optimistic scenario and all negatively resolved uncertainties in the pessimistic scenario, while predetermined trends are added to both scenarios. Between the two extremes, a BAU scenario based on the most plausible resolved uncertainties according to expert judgement will be also deployed.

Although it is premature to describe the plausible contents of these alternative scenarios[2], we may anticipate how the outcome of the visioning process will look like with the help of the following figure:

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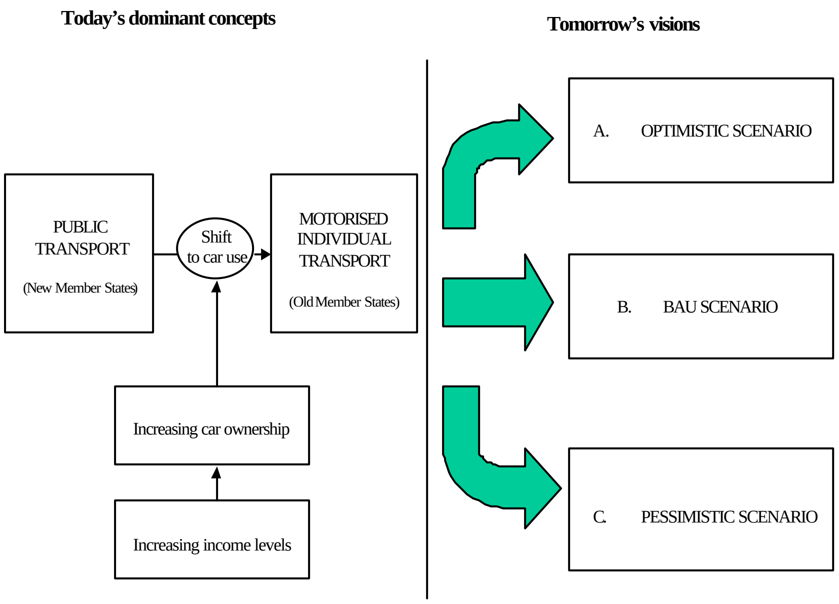
[2] This will be the subject of CITYMOBIL Deliverable 2.2.2 "Scenarios for urban mobility and innovative road transport systems"

Figure 2: Visioning of the future of urban mobility and automated road transport systems



This figure has been inspired by the roadmap towards full driving automation included in Appendix 1 to NETMOBIL Deliverable 1. Indeed, the today's dominant urban transport concepts are public transport services and private car use. The former is still prevailing in some cities of the New EU Member States, but with the increasing income levels which are pushing forward car ownership levels in those countries, we currently see an increasing shift towards motorised individual transport, which is by far the dominating paradigm in the cities of the old EU Member States.

Based on the NETMOBIL roadmap to the future, three paths have been identified which can lead to full driving automation in large parts of the road network:

- driving assistance techniques on passenger cars,
- driving assistance and dedicated infrastructure for commercial vehicles,
- new forms of urban transport (advanced car sharing and cybercars).

While in the business as usual and, even more, in a pessimistic scenario the road automated technologies will remain bounded to very specific application contexts and niche markets – e.g. holiday parks, links between a central car park and a business district or an historic city centre, links between an airport rail station and the airport terminal building, links between a rail station and a university – in the optimistic scenario the three concurrent paths can lead to a large interoperable road network in the long term future.

The following is an excerpt of the vision presented by NETMOBIL: "if we accept and extrapolate the developments which are taking place in the three different sectors, we could end up in fifty years with a road network which will be split into two. One network will be reserved (mostly, there can be some possible access to certain manual vehicles) to fully automated vehicles (public or private, for passengers or for goods) which will allow on demand transport with some form of access control to avoid congestion. This network will concern mostly the existing streets (possibly redesigned) in dense areas which have decided to limit the use of traditional vehicles and new light dedicated infrastructures where the automated vehicles could run safely at high speed and high throughput. The other network will be the "manual" network where automated vehicles will go under the control of a driver (with more or less assistance) and traditional (manual) vehicles will also be allowed. "[3]

However, besides considering the visions already produced by other projects as those clustered in NETMOBIL, the CITYMOBIL project will produce original scenarios based on the results of the Delphi survey involving the SP2 experts.

In order to discriminate the pessimistic and optimistic scenarios the experts will be asked to assess the impacts of the key trends and uncertainties against a set of transport sustainability criteria. These criteria will be identified taking as a main source the definition of "sustainable transport system" endorsed by the Transport Council in its resolution of 4-5 April 2001. The European Union Council of Ministers of Transport has defined a sustainable transport system as one that:

1. Allows the **basic access and development needs** of individuals, companies and society to be met **safely** and in a manner consistent with **humans**, and **ecosystem health**, and promotes equity within and between successive generations.
2. Is **affordable**, operates **fairly and efficiently**, offers a choice of transport mode, and supports a competitive economy, as well as **balanced regional development**.
3. **Limits emissions and waste** within the planet's ability to absorb them, **uses renewable resources** at or below their rates of generation, and **uses non-renewable resources at or below the rates of development of renewable substitutes**, while minimising the impact on the **use of land and the generation of noise.**

Accordingly, the following is the list of criteria against which the experts will be asked to judge if the expected impacts of the relevant context variables (key trends and uncertainties) on road automated transport are "positive" or "negative":

- Accessibility
- Safety
- Human health
- Ecosystem health
- Equity
- Efficiency
- Minimising emissions
- Minimising waste
- Minimising noise
- Minimising land consumption
- Use of renewable/non renewable resources

2.5 Viability of road automated transport options and stakeholders' strategic behaviour

The alternative visions of the future for automated road transport shall be finally used to test the viability of the current "business perspective" for four categories of innovations based on

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[3] cfr. NETMOBIL, Deliverable 1 State of the Art: Related Projects, Appendix 1: Roadmap towards full driving automation, January 2004, page 57.

road vehicles automation identified in Section 2.1 above against the plausible futures represented in the scenarios. We remind that the four categories of concern are:

1. PRT – Personal Rapid Transit
2. Advanced bus systems
3. CTS – Road-based people movers
4. CTS – Advanced car sharing

A business perspective should specify three major elements of a business's attempt to be successful:

- The competitive advantage which is aimed for, for instance against conventional transport modes.
- The distinctive competences on which the competitive advantage is based.
- The growth mechanism, i.e. a positive feedback loop that would make the business more and more successful.

The specific advantages of PRT, advanced bus systems and road-based people movers over conventional systems in a number of application contexts have been analysed in the NETMOBIL project, and are summarised in Table 4 below[4]. Conventional systems are those which a decision maker can choose to use instead.

Table 4: Public transport systems based on road vehicle automation: competing systems and advantages

Innovation	Application context	Competing conventional system	Main advantages on competing system
Personal Rapid Transit	Circulator in commercial areas and business districts, feeder in new development areas	Low-frequency bus	Lower and more reliable waiting times (target 90% of passengers within 1 minute) No street congestion No intermediate stopping More direct travel to destination (less detours) Comfort and privacy like cars Higher safety due to absence of conflicts with other traffic
Advanced bus systems	Main-haul section of road public transport network	Light rail	Lower capital costs (4-8 M€ per km[1] vs 15-20 M€ per track-km[2]) Higher flexibility for alignment and disruptions (deviations possible) Higher commercial speed No transfer with dual mode operation
Road-based people movers	Line-haul feeder and shuttle services	Low-frequency bus	Lower and more reliable waiting times No street congestion
		AGT	Lower capital costs (0,5 to 4 M€[3] per km vs 17[4] M€ per track-km)

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[4] This reproduces Table 7.1 of NETMOBIL Deliverable D7, page 106.

	Point to point feeder network	Low-frequency bus	Lower and more reliable waiting times No street congestion More direct travel to destination (less detours)

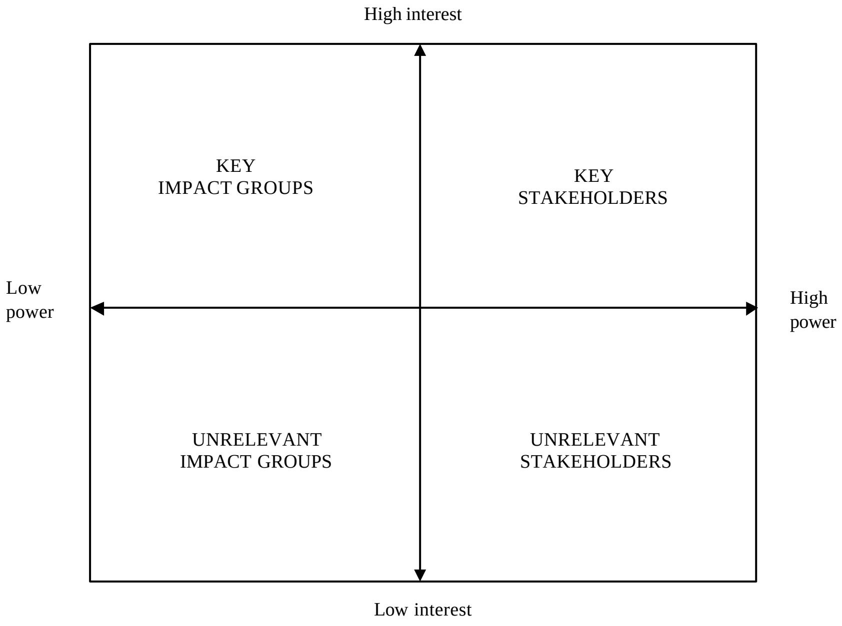
1 Source: IRISBUS based on CIVIS system and Levinson et al. (2003a) based on Rouen case. 2 Source: EDICT (2004) based on Swedish cases. 3 Source: CYBERMOVE project. 4 Source: EDICT (2004) based on US cases.

A significant barrier to the development of any innovation is the perception that it is more difficult and expensive to implement them than it really is. If public and industry decision makers perceive that these innovation are futuristic, they would not invest in them and the perception would become a self-fulfilling prophecy. It is therefore important, as final step of the visioning of the future process, to involve the relevant stakeholders and add in the picture forecasts of the strategic behaviour and actions of individuals and/or organisations.

Indeed, most of the elements addressed so far as “context variables” are exogenous, in that the predetermined trends and key uncertainties are not under the control of the individual, group or organisation whom they will affect. This is surely true for the main economic, demographic, social and land use context variables. However, other elements have to do with areas where the individual/group/organisation has some form of control, i.e. they are decision or strategy options. These decision options are equally important elements to be identified and assessed, evaluating their robustness against the range of constructed scenarios. They will probably include some of the variables identified in the legal and institutional, technological and policy contexts.

A way of identifying the relevant stakeholders and capturing degrees of their potential involvement and intervention is to construct for each of the four innovations based on road vehicle automation a matrix such that shown in the figure below:

Figure 3: Identification of stakeholders’ involvement for automated road transport options



In order to be successful in the implementation process and ongoing business the new automated road transport technologies must add benefits to all stakeholders and the latter should be made early aware of the potential benefits. The main stakeholders' categories are:

- Users, drivers
- Operators, manufactures
- Policy actors/authorities
- Citizens and the society at large

Based on a literature review and secondary sources, the key stakeholders and impact groups involved in each of the four business perspectives – PRT, Advanced bus systems, road-based people movers and advanced car sharing - will be identified and a first appraisal of their plausible actions and behaviours against the alternative scenarios will be done.

For instance, on one hand policy actors at EU, national or local level might enhance the viability of road automated transport by eliminating current legal barriers to the diffusion of automated driving. On the other hand, measures like parking and road pricing or rationing introduced by local authorities may "push" more travellers to innovative public transport systems which would represent a "carrot" making more acceptable for travellers the "stick" of pricing or rationing. The integration with pricing and rationing measures would also benefit the financial profitability of the new public transport systems because the number of users would increase. Moreover, in a longer term perspective, short-range car sharing used in environmentally sensitive areas can be the initial niche market for cars with fully automated capabilities. This type of car sharing is very promising as many cities might be tempted to restrict access to all non zero pollution vehicles if an alternative with specific, city-oriented vehicles is offered by car sharing organisations.

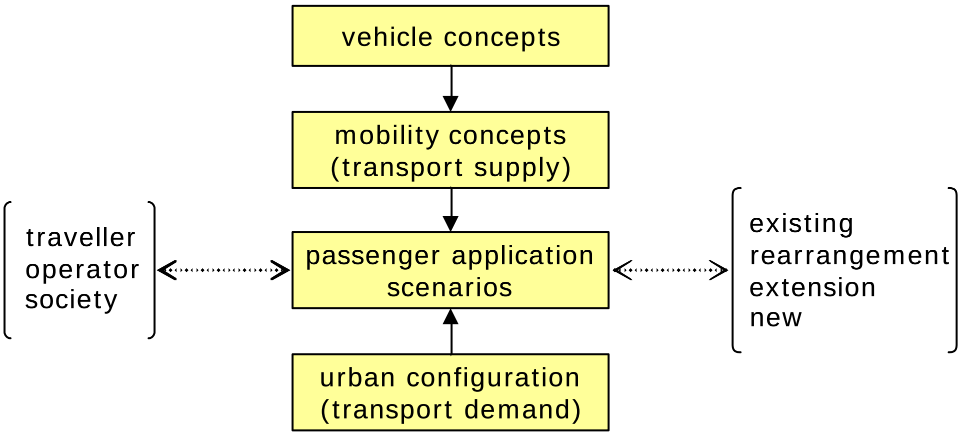
This first appraisal of the options available for the different key stakeholders and of the consequences of the alternative visions for the key impact groups will be used later in the CITYMOBIL project, to frame the analysis and empirical investigation of the user and stakeholders acceptance.

3 Passengers application scenarios

An application scenario is defined as a combinative description of a transport service and a type of urban area. 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 on 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 4 illustrates this position. In the figure, at the left side, the actors who are influenced by the application scenarios are shown: the traveller himself, the transport service operator and society (interested in accessibility and environmental aspects). The right brackets indicate the forms the application scenarios arise from: as a replacement of an existing transport service, as part of a rearrangement of the transport system, as an extension of existing transport service or as a totally new form of transport.

Figure 4: Position of application scenarios in the transport system



This scheme will be 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. As a counterpart, freight application scenarios will be discussed in section 4. The output of passenger and freight application scenarios will be of the same type, to ensure that the results are comparable, and to be used in the same way.

3.1 Vehicle concepts

In the state-of-the-art report (deliverable 2.1.1), five types of vehicle to be used in Citymobil are mentioned:

- cybercars
- high-tech buses
- personal rapid transit
- advanced city cars
- dual-mode vehicles

These types of vehicles have different properties, as is shown in table 5 (empty cells to be filled in task work).

Table 5: Vehicle concepts with properties

	cybercars	*high-tech buses*	*personal rapid transit*	*advanced city cars*	*dual-mode vehicles*
size vehicle	small - middle	large	small	small	based on a normal car
type of service	individual or collective			carsharing services	individual use and carsharing services
type of 'load'	passengers or freight				
application area	e.g. city centres			city	
operation	autonomous	automated or driver assistance	fully automated	driver assistance, access control & advanced communications	manually and fully automated
guidance		electronic			
power				zero or ultra-low pollution	
vehicle-road		air tire on road			
infrastructure		preferably on own track	dedicated infrastructure		
level		in principal street level			
speed					

3.2 Mobility concepts (transport supply)

The next step is to classify two different interaction:

- transport concepts: interaction between passenger and vehicle
- traffic concepts: interaction between vehicle and infrastructure

With transport concepts, the following properties are distinguished:

- the availability of transport: individual or shared. A private car is individually available, whereas a shared car is shared available.
- the collectiveness of transport: individual or collective. Travelling by private car is in most cases travelling individually, while travelling by bus is collective. Different passengers, often with different origins and destinations, are joining one particular vehicle.
- the scale of collective transport: small or large. The number of passengers per vehicle defines this property. In many cases small scale collective transport is demand responsive, whereas large scale collective transport uses fixed timetables.
- the drive mode: drive or ride. Is the vehicle steered by the passenger himself, or not. In the latter case, a chauffeur can be available or the vehicle is driven automatically.

In table 6, these properties are set out in columns and rows. The cells define the transport concepts, which are labelled by one or two examples (Citymobil vehicle concepts are printed in bold italic).

Table 6: Transport concepts, with examples (Citymobil vehicle concepts are printed in bold italic)

	drive	ride (chauffeur)	ride (automated)
individual availability, individual trip	car, ***dual mode vehicle***, ***advanced city car***	car with chauffeur	***dual mode vehicle***
shared availability, individual trip	car sharing	taxi	***PRT***
shared availability, collective trip, small scale	carpooling	collective taxi, dolmus	***cybercar***
shared availability, collective trip, large scale		public transport (bus, tram, metro, train)	***high-tech bus***, automated metro

With traffic concepts (interaction between vehicle and infrastructure, the following properties are distinguished:

- type of infrastructure: is the infrastructure freely accessible, or is it dedicated for certain types of vehicles or users?
- the level of driving assistance: from manual driving to fully automated.

In table 7 these properties are crossed to get the traffic concepts (in cells, Citymobil vehicle concepts are printed in bold italic).

Table 7: Traffic concepts, with examples (Citymobil vehicle concepts are printed in bold italic)

	manual driving	driver assistance	fully automated
infrastructure with free access	car bus ***dual-mode vehicle***	high-tech car ***high-tech bus*** ***advanced city car***	
infrastructure with limited access	bus		***cybercar*** ***dual-mode vehicle***
dedicated infrastructure		metro train	automated metro ***PRT*** ***high-tech bus***

The next step will be to combine the transport and traffic concepts to mobility concepts, describing the transport supply possibilities.

The innovation in transport supply can be found easily in tables 6 and 7. In table 6, the innovation will be in the most right column. In table 7, it will be in the last two columns.

3.3 Urban and spatial development (transport demand)

The choice of spatial areas will be made in accordance with the spatial areas which are used in the freight application scenarios (see section 4.1). While those spatial areas are selected on their implementation of significant distribution concepts, for passenger application a few other spatial areas will be possibly added to ensure enough situations that can be used. The spatial areas will be quite similar to 15 European city's of parts of them, but will be functionally labelled: e.g. "large city centre" rather than "the centre of Rome", that is, to describe the city's properties in a archetypical way.

The challenge in this exercise lies in the choice of the right properties of cities to be able to distinguish the promising applications in the scenarios. The size of the city and the size of the parking problems in that city for instance will presumably be important indicators for the benefit of transport systems, while urban density maybe is less important.

3.4 Passenger application scenarios

The passenger application scenarios will be a combination of spatial area and mobility concept. E.g. centre of a large city, service to carry passengers from city centre to main train station, operated by small scale collective vehicles.

The goal is to describe only passenger applications which are promising, i.e. applications that have a reason to exist. That means that it is necessary to indicate a market for the application. This market can originate from different ways:

- an existing market: the transport demand is covered by an existing transport system. The reason why a automated system can take over a part of this market can be that the automated transport system is less costly to operate, or causes less liveability problems than traditional transport systems. For passengers the transport service does not change.
- a rearrangement of the transport market: by changing a part of the total transport system, it is sometimes possible to make adjustments to other parts of the system. For instance, it is thinkable that the stop distance of regional bus services can be increased when automated feeder lines are connected to those regional bus stops.
- an extension of an existing market: if it is possible to influence the quality of existing transport services, the market will be influenced as well. For instance, if a bus service is automated, the decreased operational costs can be converted in a higher transport quality (higher frequencies).
- a new market: a new transport system can have properties that are new in the transport market, and which will induce a new transport demand. An illustrative example of such a new transport system is the airplane, which made intercontinental travel a lot easier.

As can be seen in this list, three types of actors are important when considering promising applications:

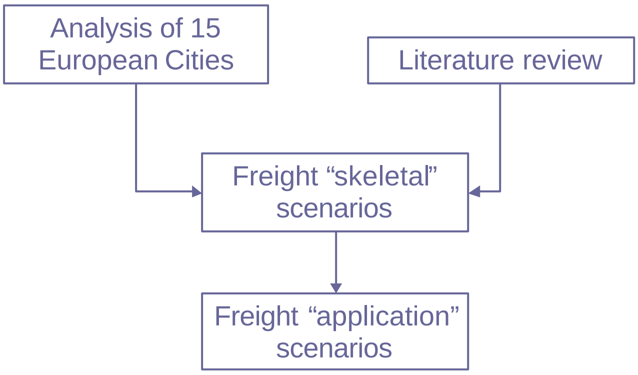
- passengers: when quality is increased, and the increase is suited to travel demand, the demand will increase as well
- transport operators: if the cost of operation decreases by automated transport, operators can choose to implement automation in their systems

- society: if prosperity increases by applications of automated transport, society profits from that. Prosperity can be influenced for instance by less liveability effects or a better accessibility of urban areas.

4 Freight application scenarios

The methodology for defining “freight application scenarios” of road automated transport systems is composed of four steps according to the following scheme:

Figure 5: Four step process for the identification of freight application scenarios



During the entire process a flow of information will be established with SP1 demonstrations in order to take into account CityMobil developments. The following paragraphs give a description of each step of the above mentioned process.

4.1 15 European cities

Freight application scenarios will be analysed reviewing actual trends in the urban freight distribution sector. The basis of such an analysis will be the information collected from 15 significant European cities that have implemented/demonstrated innovative urban freight distribution projects. Each of these projects will be analysed in detail and correlated with the specific urban environment in which it has been implemented.

A specific “town report” will be produced for each project, which will be both a concise “description”, and an “interpretation” of the typology of the adopted solution and the town’s urban environment characteristic.

To this end it will be necessary to identify “clusters” of solutions/urban areas. The projected typologies will be classified in the following categories:

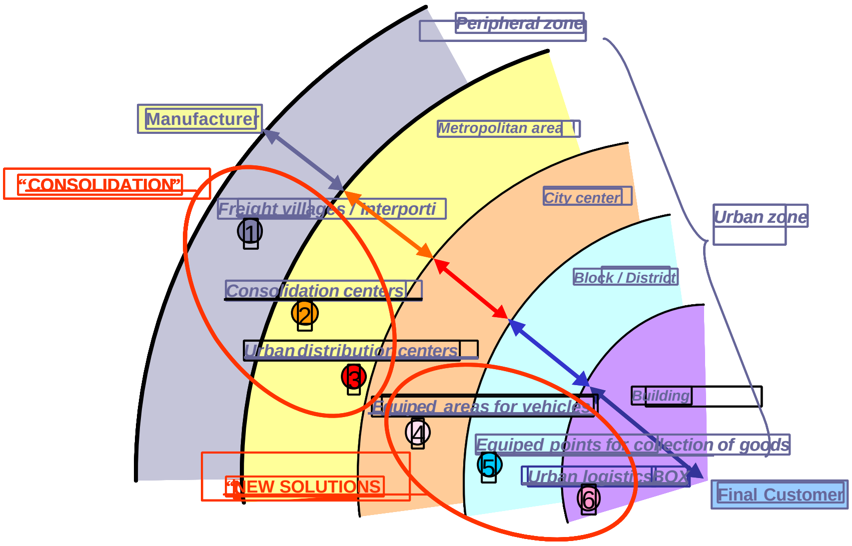
- “Investment” measures, needed to realise the dedicated services and structures, which include:
    - Urban Freight Distribution Centres,
    - Use of environment friendly vehicles,
    - Adoption of telematic systems,
    - Path planning,
    - Pick-up and drop-off points,
    - Automation applications,
    - ….

- Complementary measures, based above all on administrative actions. Such measures can depend, for example, on the weight/dimensions/emissions of the vehicle and can include:
  - Time windows for access and circulation,
  - Rights of way,
  - Preferential lanes,
  - Road pricing,
  - Parking pricing,
  - …

In the analysis of the above mentioned regulatory measures, the fact that some of them, such as road and parking pricing, are complementary policies of the kinds being identified in task 2.2.1 will be taken into account.

In relation to the parameters used to define "Urban area" clusters, the project's geographical location/extension can be used. The following scheme presents differents types of solutions located in different zones of the urban area:

Figure 6: Zones of urban area / Type of solutions



For example, the following geographical locations can be defined:

- peripheral zone (close to an airport, a motorway junction or an industrial estate or out of town shopping centre, …),
- town centre (only the historic centre or its immediate surroundings),
- specific zone (pedestrian zone, limited traffic zone, …),
- specific roads (bus lanes, fast lanes, …),
- ….

In any case, the typology of urban area will be linked to the area types identified in task 2.2.1..

Another classification of freight distribution projects/solutions is based on the type of promoting parties whatever their involvement. The parties involved can be defined as follows:

- Private bodies (transport and logistics operators, commerce companies, manufacturing companies, …),

- Public bodies (local, regional or national),
- Public-Private partnerships.

The “town report” will contain, in the descriptive part, a brief description in text and significant images of the adopted solutions, whilst the interpretation part will indicate the type of solution, urban area, and promoting party.

Furthermore, the report will supply an overall qualitative evaluation of the relative project costs, efficiency and exportability. The following is an example of a “town report”:

Figure 7: Example of “Town report”

2004 PADOVA (ITALIA)

STATE OF THE PROJECT: Active

INTERPRETATION

INNOVATIVE FREIGHT SOLUTION	URBAN AREA	ACTORS INVOLVED	EVALUATION
Urban distribution center	Peripheral zone	Comune di Padova	🟧 COST
Low impact Vehicles	Town center	Provincia di Padova	
Telematic measures	Whole town	Camera di Commercio	🟥 EFFECTIVENESS
Path planning	Whole town	Interporto di Padova S.p.A.	
Time windows	Town center	Società di trasporto pubblico APS Holding	🟥 EXPORTABILITY
Restrictions by type of vehicle	Town center	10 trasportatori	
Road pricing	Town center		

DESCRIPTION

PROJECT DESCRIPTION

TEXT

4.2 Literature review

A second source of information will be the extensive literature available today on the following points:

- urban policies for freight transport;
- innovative technological aspects including advanced communication and information systems;
- innovative logistic chain organisation schemes;
- noise and congestion caused by freight transport;
- etc..

This will help to gather the latest information and suggestions that can be used for the following phases.

4.3 Freight “skeletal” scenarios

Based on the above a synthesis will be produced developing a matrix “urban-area/freight distribution solution”.

The matrix will have the following structure:

Table 8: Matrix Type of urban area / Type of freight distribution solution

	Type of Freight Distribution Solution			
Type of urban area	Type 1	Type 2	...	Type *n*
Type 1				
Type 2				
….				
Type *m*				

The matrix cells represent the most significant combination comparing urban area and Freight Distribution Solutions typologies.

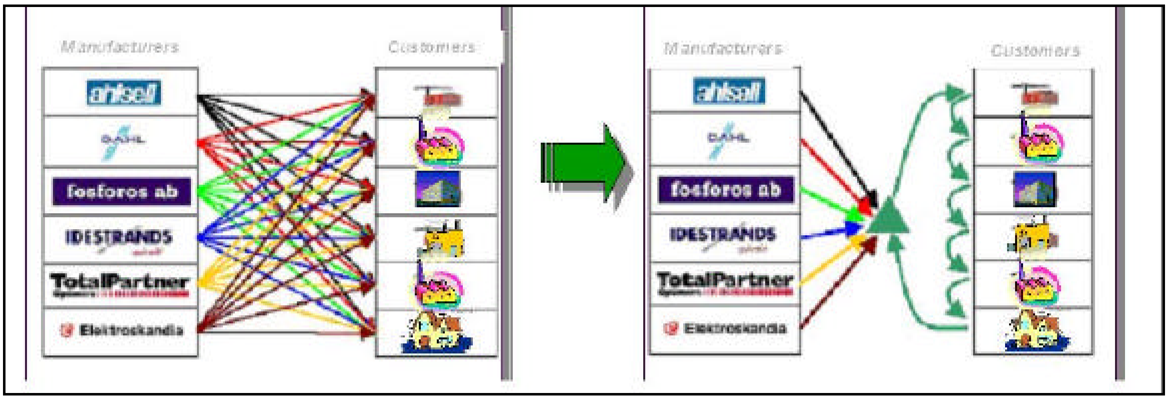
These combinations will form the "skeletal scenarios" that can then be enriched and completed using the information from the literature review.

Each scenario will be described through:

- specific flow-charts and/or schemes (see, for example, the figures below);
- textual description;
- images,

and will form the starting point for the application scenarios definition of the automated transport systems.

Figure 8: Example of scheme for the description of scenarios

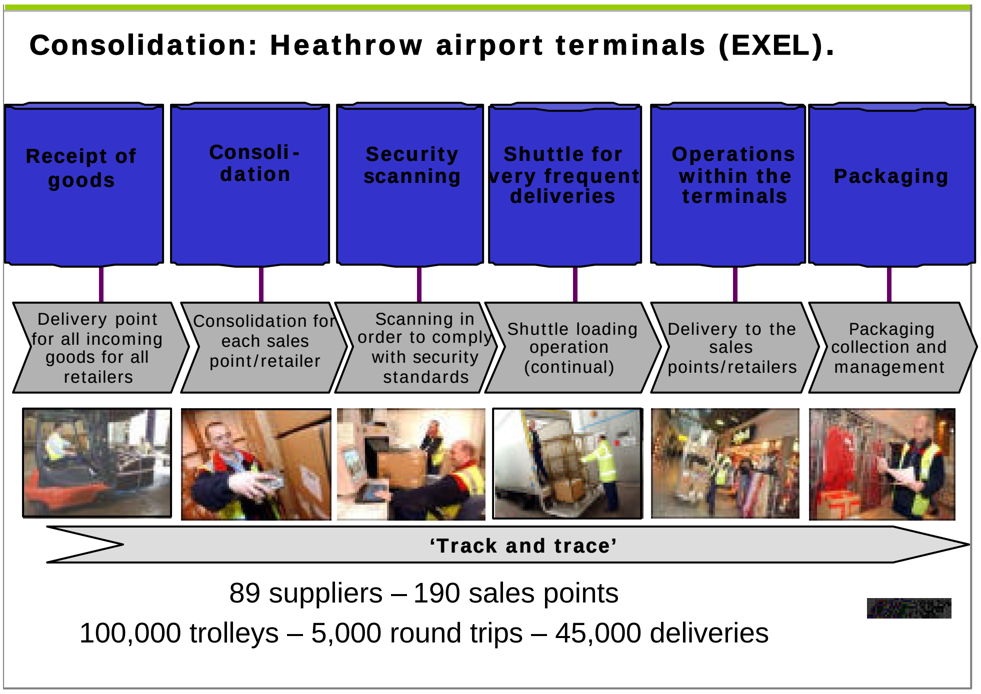


4.4 Freight Application Scenarios

A further step will be the identification, in the above mentioned scenarios, of the potential for automation, that is of the zones of the logistic chain where a combination of transport modes comprising innovative transport applications can replace traditional transport modes.

As an example, let us look at a possible freight skeletal scenario resulting from an "Urban Freight Distribution Centre/peripheral zone" combination close to a large transport hub. Here we look for example at the Heathrow airport terminal case, where an enormous quantity of goods destined for the sales points within the airport are collected, sorted, checked, loaded into special trolleys and distributed, as shown in the following figure:

Figure 9: Heathrow airport terminal case (source EXEL)



Consolidation: Heathrow airport terminals (EXEL).

Receipt of goods	Consoli-dation	Security scanning	Shuttle for very frequent deliveries	Operations within the terminals	Packaging
Delivery point for all incoming goods for all retailers	Consolidation for each sales point/retailer	Scanning in order to comply with security standards	Shuttle loading operation (continual)	Delivery to the sales points/retailers	Packaging collection and management

'Track and trace'

89 suppliers – 190 sales points

100,000 trolleys – 5,000 round trips – 45,000 deliveries

In this context for example, it's possible to foresee the potential use of automatically guided vehicles that would take the goods from the sorting point to the sales points. One could likewise foresee an automated system to transport the packaging (reverse logistics).

The following criteria will be taken into account, at least from a qualitative point of view, for identifying where and when innovative transport systems can be integrated with traditional ones:

- Delivery on time;
- Efficient freight distribution;
- Improved working conditions for the distributors;
- Less heavy traffic in the city;
- Compatibility/common points with SP1 demonstrations.

A limited number of future application scenarios will be therefore derived from a modification of previous existing logistics schemes.

5 Scenario explorer concept

This chapter is devoted to the description of the methodologies that will be used in WP2.2 – Task 2.2.4 for the definition of a scenario explorer concept. The methodology is limited to the functional specification for the concept.

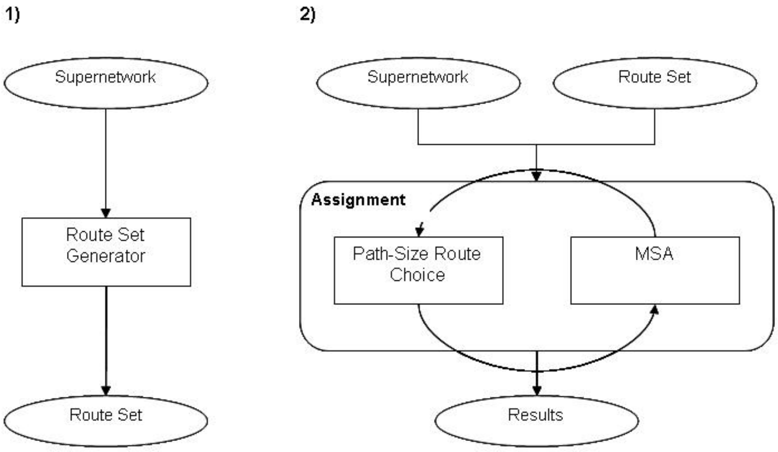
5.1 Working with scenarios

Scenarios explore the possible future shape of the strategic environment. As opposed to forecasting, scenario planning focuses on uncertainties, clarifies risk and results in adaptive understanding instead of a single point projection. Scenarios do not aim to correctly predict the future, but to improve the quality of decision making today by supporting the development of robust strategies. Although scenario planning is more qualitative, the availability of a tool to quantify the effect of different scenarios is useful to facilitate and improve the insight in future developments.

5.2 Definition of 'functional specification'

The functional specification of the scenario explorer will include both a written and a graphical representation of the tool (for a simple example see figure below). The description will specify all the input and output variables and will explain all the algorithms and the required manipulations of the data.

Figure 10: Example of a graphical representation of a simple model



Based on the functional specification a technical specification can be derived which also determines the data format (text files, database…), the user interface etc. This technical specification can then be used to implement the scenario explorer.

5.3 Approach to designing the scenario explorer

In this task, the functional specification for a scenario explorer will be developed. The scenario explorer will allow quantifying the impact on transport of a set of scenarios. This set should at least include a business-as-usual or a 'most-likely' scenario, and two, opposite, extreme scenarios to explore the range within which the evolutions of both the demand-side and the supply-side of road transport can vary. The scenarios are developed in tasks 2.2.1 (general), 2.2.2 (application scenarios for passengers) and 2.2.3 (application scenarios for freight).

The specifications will be developed in a number of steps. First, the type of tool (prediction or evaluation) and the desired output of the tool will be determined in coordination with the users of the tool (e.g. WP 2.3).

A prediction tool requires input for only one base year and predicts the evolution of both the explaining variables and the output for all following years until the time horizon is met. An evaluation tool uses a scenario over the entire time horizon as input and calculates the demand for transport for each year based on the input of that year. The latter option allows more freedom in the definition of the scenarios and is more accurate as no extrapolation is required.

In close coordination with the users of the tool, the output variables will be clearly defined. This definition will include the description of the transport classes for which the demand is calculated, the time step and horizon, the spatial aggregation level etc.

The scenario explorer will focus on evaluating passenger transport.

In a second step the input is specified. The most explaining variables for both the demand-side and the supply-side will be determined with regards to the desired output. This will be done based on the results of WP 2.1, task 2.2.1 and task 2.2.2 and additional desktop research as required. Coordinating with the previous tasks allows us to design the scenario explorer in such a way that the characteristics of the scenarios, as defined in the previous tasks, match the required input for the tool.

Finally, the relation between these input variables and the desired output will be established through literature research. This will allow for applying state-of-the-art algorithms and methodologies. If the existing methodologies do not match the requirements for this project or need minor adjustments, additional statistical analyses can be performed to improve them. The algorithms and calculation methods will be documented unambiguously in the functional specification for the scenario explorer.

6 Conclusions

The present report has dealt with the methodological aspects regarding the definition of the evolutionary scenarios of automated road transport systems. Both the methods relative to the general vision of the future and those relative to the definition of specific scenarios for real context applications were defined. The methods relative to defining the explorer concept scenarios were also presented.

As for the “vision of the future” it is possible to conclude that the proposed approach is based on a step-by-step process that, starting from the output of the WP 2.1 State of the art, is aimed at defining alternative visions of the future in relation to current and prospective urban transport paradigms and concepts, the context variables that can influence the evolution (for example the general economic development, changing lifestyles, fuel prices, etc.) and their degree of predictability. One of the elements that characterize this methodology is the participation of experts (project partners) in the identification and evaluation processes, using specific questionnaires, of relevant trends and key uncertainties. Such involvement thus ensures the active participation of the partners and the sharing of results.

As for the passenger and goods application scenarios two generally similar approaches were proposed. Due to the nature of passenger transport versus freight transport, the steps are different, but the output of both approaches will contain comparable formats. In the first, relative to passenger transport, a distinction is made between transport concepts and traffic concepts. Both concepts linked to the transport demand will form the passenger application scenarios, of which the most promising will be presented. The second (freight transport) is based on a process structured in four phases that, starting from the analysis of 15 real urban contexts in which innovative urban goods distribution projects have been set up, arrives at a definition of the application scenario identifying the area of the logistics chain where the most significant potential for automated transport lies.

Although different, the two approaches maintain the following common points:

- both take into account, as the initial point of analysis, the Task 2.2.1 Visioning of the future output;
- both use the same urban area typology;
- both produce a limited number of application scenarios relative to real urban contexts describing the results in the same way via specific flow-charts and/or schemes, textual description, images.

Finally, with regards to the explorer scenario, it represents an instrument for scenario evaluation. The methodology described in the present report is limited to the identification of the "concept" through the definition of the functional specifications.