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GLOSSARY

ACC	Advanced City Car
ADA	Advanced Driver Assistance
ADAS	Advanced Driver Assistance Systems
BCR	Benefit Cost Ratio
CAM	City Application Manual
CC	Cyber Car
CTS	Cybernetic Transport System
Delphi	a structured communication technique, originally developed as a systematic, interactive forecasting method which relies on a panel of experts
Dual-mode	a vehicle that can, for at least part of its journey, drive under automatic control
EDICT	Evaluation and Demonstration of Innovative City Transport, project funded under EU Fifth Framework programme
eLane	driving lane dedicated to use by automated vehicles
ICT	Information and Communications Technology
GIS	Geographical Information System
HTB	High Tech Bus
MARS	Metropolitan Activity Relocation Simulator, a dynamic land use model which simulates the travel behaviour of the population related to their housing and workplace location
MCA	Multi-Criteria Analysis
NPB	Net Present Benefit
NPC	Net Present Cost

O-D matrix	Definition of the number of travellers who commute or the amount of freight shipped between different zones of a region matrix
PE	Patronage Estimator
PPP	Public-Private Partnership, typically describing a government service or private business venture which is funded and operated through a partnership of government and one or more private sector companies
PRT	Personal Rapid Transit
RP	Revealed Preference
SP	Stated Preference
TOAST	Technology Options Appraisal Summary Table
TOD	Transit Oriented Development

EXECUTIVE SUMMARY

The CityMobil project “Towards Advanced Transport for the Urban Environment” aims at achieving a more effective organisation of urban transport, resulting in more rational use of motorised traffic with less congestion and pollution, safer driving, a higher quality of living and enhanced integration with spatial development. It aims to do so by promoting the introduction of advanced technologies into the transport environment. The concepts, methods and tools developed are being validated and demonstrated in a number of different European cities under different circumstances. Sub-project SP2 “Future scenarios” has the aim of investigating how automated road transport systems fit into the expected scenarios for advanced urban transport in the future, and in particular how they will contribute to sustainability. A number of tools for cities and operators are being developed to analyse transport requirements and potential impacts. These include a series of context scenarios over the period to 2050, a set of passenger and freight application scenarios which indicate the contexts within which different technologies are most likely to be effective, a tool for predicting patronage for new technologies, a business model for assessing the financial viability of technology projects, a sketch planning model for assessing the overall impact of these technologies in cities, and guidance on how to overcome the key barriers to implementation. This City Application Manual is designed to help cities make good use of these tools, and to provide general guidance on the approach which cities might adopt to deciding whether to consider new technologies and, if so, how best to apply them. The text is aimed at policy makers and their advisers. References are provided for those who need more detailed information. Each chapter provides a short description of a particular stage in the policy formulation process, the relevant tools from CityMobil, and examples of their use.

1 INTRODUCTION

The CityMobil project 'Towards Advanced Transport for the Urban Environment' aims at achieving a more effective organisation of urban transport, resulting in more rational use of motorised traffic with less congestion and pollution, safer driving, a higher quality of living and enhanced integration with spatial development.

It aims to do so by promoting the introduction of advanced technologies into the transport environment. The concepts, methods and tools developed are being validated and demonstrated in a number of different European cities under different circumstances.

Sub-project SP2 'Future scenarios' has the aim of investigating how automated road transport systems fit into the expected scenarios for advanced urban transport in the future, and in particular how they will contribute to sustainability. A number of tools for cities and operators are being developed to analyse transport requirements and potential impacts. These include:

- Series of context scenarios over the period to 2050,
- Set of passenger and freight application scenarios which indicate the contexts within which different technologies are most likely to be effective, a tool for predicting patronage for new technologies,
- Business model for assessing the financial viability of technology projects,
- Sketch planning model for assessing the overall impact of these technologies in cities,
- Guidance on how to overcome the key barriers to implementation.

In particular the sketch planning model has been used to provide illustrations for four cities: Gateshead (UK), Madrid (ES), Trondheim (NO) and Vienna (AT) of the potential contribution of each technology.

This City Application Manual is designed to help cities make good use of these, and to provide general guidance on the approach which cities might adopt to deciding whether to consider new technologies and, if so, how best to apply them.

Each chapter provides a short description of a particular stage in the policy formulation process, the relevant tools from CityMobil, and examples of their use.

The text is aimed at policy makers and their advisers. References are provided for those who need more detailed information.

The chapters are presented in a logical order, considering in turn, by chapter number:

1. Introduction
2. Likely Context
3. Application Scenarios
4. Strategic Options
5. Implementation Barriers
6. Estimating Patronage
7. Strategic Modelling
8. Business Case
9. Multi-Criteria-Analysis
10. City Applications
11. Suitable Strategies
12. Conclusions
13. References

Figure 1 shows a flowchart detailing the contents and information presented in the City Application Manual, including the 3 main parts, background information, tools and models, and additional. This is preceded by the introduction and followed by the conclusion and references.

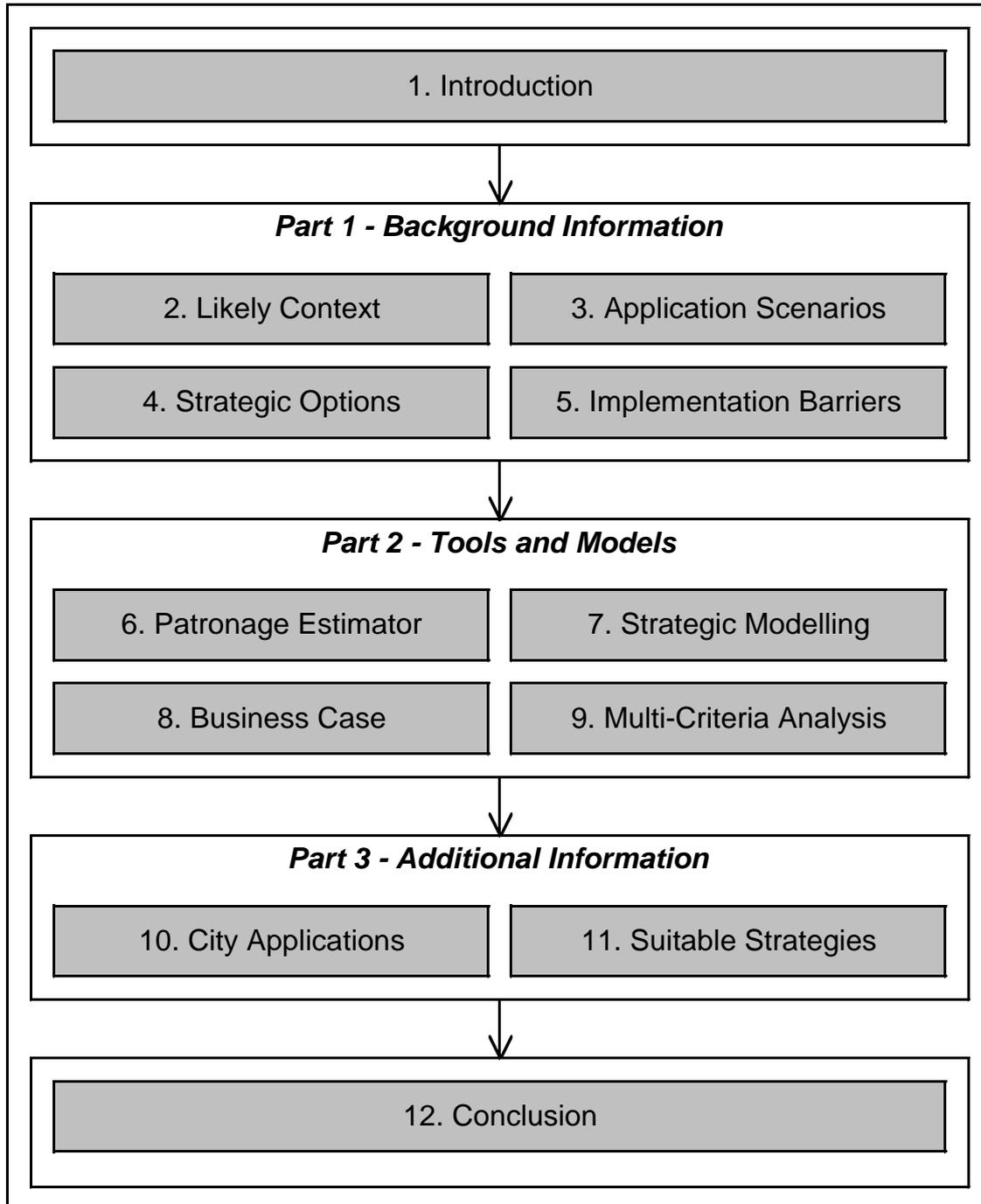


Figure 1: Flowchart of CAM Contents

PART ONE: BACKGROUND INFORMATION

2 LIKELY CONTEXT

With the exception of some automatically operated metro systems (Paris, London, Lille, Turin) and some recently introduced automated buses and people-movers (Clemont-Ferrand, Eindhoven and Capelle aan de IJssel), transport systems in the present-day European city are mostly of a traditional type, i.e. manually driven by a human driver.

The CityMobil project looks ahead, envisioning a growing urban mobility in the long term, and a city environment where advanced transport technologies are introduced to support people and goods mobility. Visions of the future are based on the analysis of likely trends and critical uncertainties which may influence a regime shift, with the adoption of the new technologies on a large scale, and how this regime shift should be supported by long term city planning and implementation measures.

Figure 2 and Table 1 below show the envisioned regime shift from non-automated to automated road transport modes, as the transition from traditional driving and riding systems - with humans driving the vehicles - to new advanced systems where the vehicles are automatically driven (always or at least for part of the journey, as in the “dual-mode” options).

The regime shift envisioned is that from non-automated to automated road transport modes. This is summarised in the figure below as the transition from traditional driving and riding systems - with humans driving the vehicles - to new advanced systems where the vehicles are automatically driven (always or at least for part of the journey, as in the “dual-mode” options).

	with driver	automated
private (individual) transport	private car (+ADA)	private car in automated environment
individual transport service	public car (+ADA) (taxi, car sharing)	automated public car
shared transport service	minibus (+ADA)	automated minibus
collective transport service	bus (+ADA)	automated bus

Figure 2: Transition from Manual to Automated System

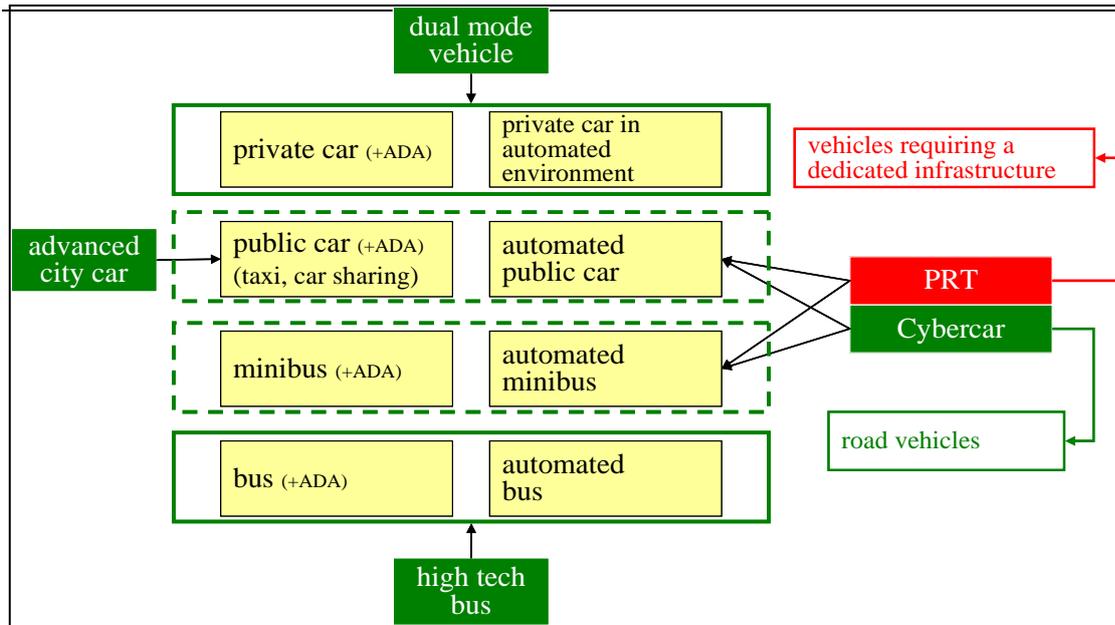


Figure 3: Characterisation of Key Vehicle Systems

Table 1: Regime Shift to New Advanced Systems

Road transport mode:	Traditional systems:	New Advanced Systems:	
	Non automated (with human drivers)	Assisted (with human drivers)	Automated (without human drivers)
Driving	Car (individual use) Car sharing Car pooling	Advanced city cars	Dual mode vehicles (i.e. vehicles which can be driven manually or shift to automated driving)
Riding	Taxi Collective taxi Public transport (bus, tram, metro, train)		Cybercars (i.e. small cars that are only driven automatically) Personal Rapid Transit (i.e. people-movers on separated tracks without drivers) High-tech buses (i.e. buses without drivers)

The new assisted and automated transport systems will contribute to answer to the new mobility demands of the future society, as they promise to improve the efficiency of road transport in urban areas, and to help achieving the “zero accident” target and minimise nuisances as a result of automated driving. The latter, being more regular and easily controlled than human driving, is inherently a form of “eco-driving” which will contribute also to reduce pollution in the city context.

This chapter discusses the need to understand the context in which such systems might operate, and the process for visioning such future contexts.

In summary, the exercise of visioning the future for automated road transport needs to be based on the following elements. For CityMobil, they were considered in a two-stage Delphi survey involving the consortium experts:

- **Demographic variables:** total population trend; population ageing; working age population; female employment rate, immigration.
- **Economic variables:** GDP growth (two-way influence), employment, fuel price, share of knowledge intensive services.
- **Societal variables:** household size, share of urban population, urban sprawl (of households, business, shopping malls), revitalisation of inner cities.
- **Sustainability and security concerns:** accessibility and territorial cohesion; congestion; safety; energy efficiency; air pollution and climate change; noise; consumption of space for parking and driving.
- **Complementary policies:** these are other policies which might reinforce or affect the new advanced systems, such as: land use planning measures; transport and ICT infrastructure measures; attitudinal and transport demand management measures; car sharing schemes; walking and cycling strategies; high quality public transport; teleworking and flexible time schedules; urban freight terminals and management measures. These are further discussed in Chapter 4.

For CityMobil, these elements were considered in a two-stage Delphi survey involving the consortium experts. The results of the first stage of the Delphi survey were used to filter out the most predictable elements from those more uncertain. Indeed, the sources of uncertainty were twofold:

- Uncertainty about the future evolution: will the element under scrutiny be more or less important in the 2015/ 30/ 50 horizons? For instance, will land use planning measures be widely put in place by the majority of European cities or not?

- Uncertainty about impact that the future will have on successful adoption of new automated technologies, e.g. will population ageing have a positive or negative influence, or no influence at all, on diffusion of automated road technologies?

As it emerged from the first stage survey results, the elements whose evolution in the long term appears more predictable include: population ageing, growing urbanisation, growing congestion, air and noise pollution, global warming and road safety problems. These are all elements having a high influence on the adoption of automated transport options, because they increase the opportunities for the application of the new technologies in the long term. A second stage of the Delphi survey was then needed to consolidate the visions of the future, and indicate what are the most important issues to consider in relation to each trend as follows:

Population ageing. The growing elderly population in Europe (over 65 years) will find it difficult to adopt cybercars if they are not friendly enough. However, ADAS would facilitate the driving experience of the elderly and PRT and High-Tech Buses are expected to provide more flexible and comfortable services for the elderly.

Economic vitality. The provision of a wider range of mobility options (PRT, cybercars, etc.) will increase the accessibility and the attractiveness of the urban environment. Investments in new automated transport schemes would be probably accompanied by large investment in the renovation of city centres, which will contribute to increase the economic vitality of the town. Of course, a favourable context of economic growth would be needed to allow for more innovative projects to be realised. Although the economic prospects (GDP growth) are uncertain on the long term, the likely increase of fossil fuel prices will facilitate the adoption of automated or semi-automated energy saving vehicles.

Urbanisation. Urban sprawl tendencies on one side, and the tendency towards a revitalisation of the inner centres of the large urban regions on the other side, will both contribute to increase the opportunities for the adoption of new automated transport systems. A larger suburban population would increase the pressure on local government and public transport operators to provide more suburban public transport services based on automated systems (traditional systems are not viable in low-density suburbs, while the operational – drivers - costs would be abated in the automated systems). More attractive “24 hours 7 days per week” open city centres would require as well more flexible on demand public transport which can be more economically provided by cybercars or PRT systems.

Besides the above mentioned factors, which can have a broad influence over the diffusion of the new automated transport systems across different cities, there are also more specific features of the urban context to be considered: city size, urban topography, the transport infrastructure already in place and the structure of the city economy. These are all elements which differentiate the urban context, and can make it more or less suitable for the implementation of the different typologies of automated transport systems.

It makes sense to envision a number of urban contexts in which the various options of automated transport may fit differently. The city typology suggested for this purpose is presented in Figure 4 below.

CITY TYPOLOGY
<p><i>Small to medium size monocentric city</i></p> <ul style="list-style-type: none"> ➤ Less than 500.000 (small) or between 500.000 and 1.000.000 inhabitants (medium). ➤ More than 50% jobs concentrated in the inner city ➤ Presence of a dominant historic city centre and downtown business district ➤ Radial transport infrastructure
<p><i>Large size monocentric city</i></p> <ul style="list-style-type: none"> ➤ More than 1.000.000 inhabitants ➤ Growing population in the suburbs and declining population in the inner city (urban sprawl) ➤ More than 50% jobs concentrated in the inner city ➤ Radial transport infrastructure
<p><i>Medium to large size car oriented polycentric city</i></p> <ul style="list-style-type: none"> ➤ Between 500.000 and 1.000.000 (medium) or more than 1.000.000 inhabitants (large). ➤ Less than 50% jobs concentrated in the inner city ➤ Presence of self-contained towns and tangential transport infrastructure in the suburbs ➤ More than 50% of daily journeys to work by car
<p><i>Medium to large size alternative transport oriented polycentric city:</i></p> <ul style="list-style-type: none"> ➤ Between 500.000 and 1.000.000 (medium) or more than 1.000.000 inhabitants (large). ➤ Less than 50% jobs concentrated in the inner city ➤ Presence of self-contained towns and rail/PT network transport infrastructure in the suburbs ➤ Less than 50% of daily journeys to work by car
<p><i>Network city region</i></p> <ul style="list-style-type: none"> ➤ More than 1.000.000 inhabitants. ➤ Presence of a network of specialised towns not hierarchically related to the central city ➤ Presence of road and/or rail network infrastructures linking all the towns (grid network) ➤ Significant share of bi-directional daily journeys to work between the towns

Figure 4: City Typology

3 APPLICATION SCENARIOS

3.1 Introduction

Application scenarios define the contexts in which an application of an advanced technology is most likely to be appropriate, for passengers or for freight. They involve a combination of:

- an urban context (from Chapter 2);
- specific transport demand features;
- a CityMobil technology.

The passenger and freight application scenarios are based on an analysis of the benefits for:

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

3.2 Types of Technology and their Services

Inside CityMobil five mobility concepts are defined. These mobility concepts were used to identify promising passenger application scenarios. In order to identify the promising application scenarios the following steps were followed. First the benefits for the mobility concepts were identified from different perspectives, secondly the concepts were combined with the transport demand variable. This second step resulted in an O-D matrix for different urban contexts, where for each potential urban trip the most applicable technology(ies) were identified.

The urban context can be defined, based on Chapter 2, in terms of the following urban areas:

- 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

Table 2 identifies the various urban contexts as origins and destinations. For each O-D combination the potential CityMobil mobility concepts have been identified. Potential concepts have not been identified for every cell, often simply because CityMobil concepts

cannot supply the needed transport demand for these trips or the application of a mobility concept would cost too much and therefore not be cost effective.

Table 2: Transport Demand Matrix

Destination: ..Origin:	City centre	Inner suburbs	Outer suburbs	Suburban centres	Major transport node	Major parking lot	Major service facility	Major shopping facility	Major leisure facility
City centre	ACC Cybercar PRT DMV								
Inner suburbs	HT-bus (ACC)								
Outer suburbs	HT-bus (ACC)	DMV	Cybercar DMV						
Suburban centre (within an intermediate distance range)	HT-bus (ACC)			HT-bus PRT					
Major transport node (e.g. airport, central station)	ACC HT-bus	HT-bus	HT-bus	HT-bus	PRT				
Major parking lot	Cybercar				Cybercar PRT	Cybercar PRT			
Major educational or service facility (e.g. University campus, hospital)	HT-bus				Cybercar PRT	Cybercar PRT	Cybercar		
Major shopping facility	HT-bus				Cybercar PRT	Cybercar PRT		PRT	
Major leisure facility (e.g. amusement parks)	HT-bus				Cybercar PRT	Cybercar PRT			Cybercar PRT
Corridor	DMV HT-bus	DMV HT-bus	DMV HT-bus	DMV HT-bus					

3.3 Urban Movement

3.3.1 Passenger Applications

Based on Table 2 for each mobility concept application scenarios have been described. For each concept more than one application scenario is envisioned resulting in 10 application scenarios.

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

Cybercar

The first scenario that emerges from the above mentioned benefits and urban contexts is the Cybercar as a new form of public transport in 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 kilometers.

Another possible scenario is an outer suburb where conventional public transport is not an option because of the low density causing 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 point to keep in mind is the maximum distance which should not exceed 2-3 km, one way.

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 for 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 (as 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 modes with each other. This will reduce the need to get all stops and parking lots within walking distance of each other and allow better interchanges between these modes.

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 neighborhoods. The bus serves as a connection between these neighborhoods 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.

Dual Mode Vehicle

The first passenger application scenario that can be deduced from the above benefits and the urban contexts is 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 likely.

3.3.2 Freight Applications

For freight a slightly different approach was used which was based on a literature review as well as an analysis of different European cities. This analysis resulted in the formulation of five skeletal scenarios for freight which were combined with the CityMobil technologies into application scenarios.

The five skeletal scenarios for freight are the following:

1. Just In Time refilling shops from remote warehouses
2. Drop-off point for last-mile deliveries at houses/small offices
3. A combination of passengers and goods handling
4. Transfer between logistic nodes e.g. seaport and railway
5. Transportation of problematic goods, e.g. waste

These skeletal scenarios were then combined with the CityMobil applications and combined into application scenarios.

Advanced City Car

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 optimizing 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.

Cybercar

One context is the city centre or inner suburbs. Specifically equipped consolidation points are organised 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 specialised lanes.

Another context is a restricted area such as a hospital. 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.

A third context is the city centre, inner or outer suburbs where collection of urban waste can be optimised. 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. A similar model can be proposed for collection of hospital waste at a hospital centre composed of many pavilions.

PRT

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 urbanised areas. Round-the-clock distribution is possible.

High-Tech Bus

The application scenario is almost the same as 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 impact on densely urbanised areas. Round-the-clock distribution is possible. The main difference from PRT is that the requested frequency of shipments is lower and consolidation/deconsolidation activities are possible.

Dual Mode Vehicles

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 times a day (at fixed times or on request) with pre-selected small containers for each destination loaded on dual mode vehicles.

4 STRATEGIC OPTIONS

4.1 The Role of New Technologies in a Wider Strategy

CityMobil is focusing on the role of new technologies, including cybercars, personal rapid transit, high technology buses, advanced city cars and dual mode vehicles. While each of these has a potential role in helping to meet urban transport policy objectives, it is generally accepted that no one policy instrument on its own will solve the transport problems of cities.

Instead, the focus increasingly is on combining policy instruments to form packages of measures, sometimes referred to as integrated strategies. In such strategies, each policy instrument has a contribution to make on its own, but each can also enhance the others by reinforcing its impacts or by overcoming some of the barriers to its implementation.

A well studied example is the combination of public transport enhancements and road pricing, as practised in London, Singapore and Stockholm. Road pricing on its own can be very effective in reducing congestion and improving the environment, but it is widely unpopular and may have an adverse impact on some groups in society such as those on lower incomes. Public transport improvements on their own can improve accessibility and help those with special needs, and are likely to be popular, but are often too expensive to implement. When combined, road pricing provides the income to finance public transport, while the public transport improvements provide alternatives to the car, meet the needs of those who would otherwise be disadvantaged, and increase the popularity of the overall package.

The question addressed in this chapter is which types of policy instrument might best complement new technologies in one or more of these ways. We start by reviewing the range of policy instruments available, then consider the results of our Delphi survey of experts' expectations of the roles of these policy instruments.

4.2 The range of policy instruments available

The specific classes of measures which can be considered include:

- 1. Land use planning measures:** These range from the large scale planning of whole settlements down to the detailed design of urban design features such as buildings and 'streetscape' features. These include the following: settlement planning, settlement size and containment, urban concentration / densification, location policy linked to accessibility, transit oriented development (TOD), car free developments, development control. Land use planning measures can take a long time to take effect. The conversion of existing building stock and neighbourhoods takes place at a slow rate of change – a typical figure for the rate of turnover of the urban fabric is 1% per year. Therefore, the switch from, say, a policy of maximum housing density and minimum parking standards to a policy of minimum housing density and maximum parking standards will take some years to have an effect, since a large proportion of the existing urban development will already be laid out to previous standards. On the other hand, this long term nature means that land use planning measures can set the physical pattern upon which mobility patterns are based for generations. Put another way, once good practice has been invested in, it is less easily undone.
- 2. Transport and ICT infrastructure and traffic engineering solutions:** These include both the provision of new transport and Information Technology infrastructures and the measures to improve the efficiency and safety of the usage of existing infrastructures. Depending on local geographic situations and on existing drivers of mobility demand, traffic engineering may suggest local improvements such as underpasses; channelisation of traffic flows, one-way patterns, priority rules, speed limits, exclusion of certain classes of vehicles from certain areas; rules for parking, access, permitted turns, and time of day restrictions. Traffic control includes computerised traffic control systems operating on the basis of real time detection of traffic flows and individual vehicles. These systems in particular can be also organised to give priority to public transport. In this category must be included also the future upgrading of road infrastructure with the IT systems needed to support automated transport.
- 3. Transport pricing policies:** Pricing policies can impose a charge on vehicles, with the aim of reducing volumes of traffic and relieving congestion, pollution, accidents, wear and tear and noise. The charge may be proportional to travelling time, distance travelled, time parked or number of times a boundary around a centre is crossed. Pricing policies

also affect the fares charged for public transport, and simplified fares systems. These are considered further in (7) below.

4. **Attitudinal and transport demand management measures:** People's behaviour influences the way they travel; car use may be a status symbol, many prefer living far from urban centres or are not well informed on alternative choices they can make. Attitudinal measures aim to change users' understanding of transport problems and alternatives to mobility, thus inducing changes in travel patterns. In addition to more specific attitudinal measures, transport demand management measures aim at managing and influencing transport demand without changing the existing infrastructure. The main measures include communication campaigns (to increase awareness and improve information), company travel plans (to decrease demand on mobility), ridesharing (to minimise solo car use) and flexible working hours (to improve time sharing).
5. **Car sharing:** One promising development in Europe over the past few years has been the emergence and diffusion of organised forms of car-sharing, which severs the relationship between car ownership and car use. Users gain access to vehicles by subscribing to an organisation, be it a co-operative, an association, or a firm, that owns and operates a pool of cars. Use is regulated by explicit rules, and members pay for their trips according to their actual use of the system. As such, car sharing schemes are mostly private initiatives, and are not classified as government policy measures. However, local governments or public transport operators may actively support the creation of car sharing schemes to contribute to urban transport sustainability goals, by subsidising or organising them. The spreading of car sharing may be a key factor in developing a market for new automated vehicles.
6. **Walking and cycling strategies:** The levels of walking and cycling are affected by hilliness, climate, culture and social acceptability, but to a lesser extent than might be thought. Given the right conditions, people will switch to making short journeys by walking or cycling which can improve quality of life and sustainability in urban areas where a large number of the journeys are short. A key issue is the creation of a pedestrian and cycling friendly approach to site development as an important pre-requisite for the successful development of walking and cycling strategies. These often include the improvement of safety and attractiveness of cycle tracks and footpaths. Another key factor is the availability of city-wide cycle networks and improved links to public transport.

7. **Developing high-quality public transport:** Improving the quality of urban public transport is obviously an important complementary policy, especially to the extent that automated transport services will be able to increase feeder transport. Such measures include new rail and light rail lines, bus rapid transit, improved service levels and quality, and more attractive fare structures. However, the deteriorating financial situation of the municipalities has made the financing and provision of public transport from public budgets increasingly difficult. To this end, new means of financing public transport services and infrastructure – including revenue use from transport pricing - are being applied. Another key factor to improve the quality of urban public transport is the already rapid dissemination of new technologies for intelligent transport systems. These support the introduction of flexible and user friendly information systems and charging schemes for road traffic as well public transport services.

8. **Teleworking:** Teleworking can influence the demand for transport only if a sufficient number of potential telecommuters is available. Individuals and employers frequently describe their jobs as unsuitable for telecommuting because part of their job description requires the presence at headquarters. However, a wide range of tasks may exist that are highly suited to telecommuting, such as administration, data processing, accountancy, writing of reports, systems analysis and consultancy. A focus on telecommuting will encourage employers to permit their employees to carry out these functions at home, and provide the facilities for doing so. Employer benefits include reductions in the requirement for office space and parking.

9. **Urban freight terminals and management measures:** City logistics encompasses all the logistics processes and operations in urban areas, taking into account the operational, market, infrastructure and regulative characteristics of the urban environment. Moreover, city logistics forms an integral part of interurban and international logistics chains. A distinctive feature of the urban freight management is the establishment of *city logistic terminals* or *urban distribution centres*. A city logistic terminal is a place for transshipment from long distance traffic to short distance (urban) traffic where the consignments can be sorted and bundled. Its main purpose is to achieve a high degree of collection of goods flows in order to supply efficient transport from the terminal to the city centre and vice versa.

4.3 Experts' views on the relevance of these complementary instruments

There are a lot of potential complementarities between the introduction of automated transport and other policies. However, the first round of the CityMobil Delphi survey showed a clear pattern of responses only for the complementary role of land use planning, transport and ICT infrastructure and transport pricing measures, which were seen by the majority of respondents as having a positive influence on automated transport.

The influence of the other measures – including attitudinal and transport demand management measures, car sharing schemes, walking and cycling, high quality public transport, teleworking and flexible time schedules, urban freight terminals and management measures – was more open to question.

Table 3 shows the main statements stemming from the first round of the Delphi survey, concerning the contribution of complementary policies to the successful adoption of automated transport technologies, and the range of views elicited in the second round of the Delphi exercise.

Table 3: Experts Views

FIRST ROUND STATEMENTS	I AGREE	I DO NOT AGREE	I DON'T KNOW
LAND USE PLANNING MEASURES ARE CONSIDERED IMPORTANT TO FACILITATE THE CONCENTRATION OF THE POPULATION IN URBAN AND SUBURBAN CENTRES WHICH MAY BE MORE EASILY SERVED BY CYBERCARS OR PRT SYSTEMS, OR THE CONCENTRATION IN PROXIMITY OF ROAD AXES WHERE HIGH TECH BUS SERVICES MAY BE PROVIDED, WHILE ARE LESS IMPORTANT FOR THE DIFFUSION OF DUAL-MODE VEHICLES.	71%	5%	24%
FOR THE MAJORITY OF RESPONDENTS, ICT INFRASTRUCTURE AND TRAFFIC ENGINEERING ARE NECESSARY TO ALLOW IMPLEMENTATION OF AUTOMATED TRANSPORT SYSTEMS, FOR SECURITY, SAFETY AND RELIABILITY REASONS. ALL SYSTEMS WILL NEED TO WORK WITH EXISTING SYSTEMS. ONLY PRT, RUNNING ON ITS OWN SEGREGATED INFRASTRUCTURE WILL BE LARGELY SELF CONTAINED AND INDEPENDENT. HIGH TECH BUSES WILL REQUIRE MUCH THE SAME INFRASTRUCTURE AS THE CURRENT GENERATION OF GUIDED BUSES.	95%	0%	5%
TAXATION AND PRICING ON PRIVATE CARS WILL ENCOURAGE PUBLIC MODES GENERALLY: STRONGLY FOR CYBERCARS AND PRT, WHILE PROBABLY LESS SO FOR DUAL MODE VEHICLES UNLESS THEY ARE PART OF A CAR SHARING SCHEME.	90%	0%	10%
AS IT CONCERNS CAR SHARING , ANY AUTOMATED TRANSPORT SYSTEM REQUIRES A CHANGE OF MENTALITY WITH RESPECT TO CAR-OWNERSHIP, AND SO THE INSTALMENT OF GOOD CAR SHARING SCHEMES MAY BE ESSENTIAL TO DETACH PEOPLE FROM THE CONCEPT OF OWNING THEIR OWN VEHICLE. HOWEVER, CAR SHARING SCHEMES USUALLY HAVE A VERY SMALL IMPACT ON THE TOTAL URBAN MOBILITY.	57%	10%	33%
AS IT CONCERNS THE RELATION WITH WALKING AND CYCLING STRATEGIES , IT HAS BEEN NOTED THAT IMPROVED ACCESS TO PT STOPS AS PROVIDED BY CYBERCARS AND PRT SYSTEMS MAY WELL REDUCE THE NUMBER OF WALKING TRIPS SO THAT A STRATEGY TO ENCOURAGE WALKING MAY HAVE A PERVERSE EFFECT BY REDUCING PRIVATE CAR USE, AND INCREASING PT USE, BUT NOT ACTUALLY INCREASING WALKING.	52%	10%	38%
URBAN FREIGHT TERMINALS AND MANAGEMENT MEASURES WILL HAVE A POSITIVE IMPACT ON THE ADOPTION OF AUTOMATED FREIGHT TRANSPORT. A GREATER CONCENTRATION OF CARGO WILL GIVE ENOUGH CRITICAL MASS FOR INTRODUCING NEW SYSTEMS.	80%	0%	20%
HIGH QUALITY PUBLIC TRANSPORT ONLY ACTS ON COLLECTIVE TRAVEL, AND IT MAY CONTRIBUTE TO REDUCE NOT ONLY THE USE OF PRIVATE CARS BUT ALSO OF MORE INDIVIDUAL AUTOMATED TRANSPORT SOLUTIONS (CYBERCARS, DUAL VEHICLES)	55%	25%	20%

The results of the second Delphi survey confirmed substantially the findings of the first one. It is a general opinion that the most important complementary policies are ICT infrastructure and equipments, which are considered necessary to allow implementation of automated transport systems by 95% of the respondents; taxation and pricing to discourage private car use (90%), urban freight terminals and management measures providing more opportunities for the adoption of automated freight transport (80%), and finally the adoption of land use planning strategies facilitating the concentration of population in urban and suburban centres (70%).

Car sharing is still considered a useful complement to the introduction of new automated transport technologies, but only by 57% of the respondents. Finally, there is a low level of consensus – slightly more than 50% - on: a) considering high quality public transport services as potentially in competition with new individual automated transport solutions, e.g. cybercars and dual-mode vehicles, and b) the introduction of cybercars and PRT feeder systems as something which may ultimately reduce walking.

It will be for individual cities to select the most appropriate complementary measures to match their requirements. The following section and the case studies in Chapter 7 provide some examples of what can be done.

5 IMPLEMENTATION BARRIERS

5.1 Benefits and barriers

New technologies can be expected to benefit the urban transport system in several ways, but they will also experience barriers to implementation, which need to be overcome. This chapter considers the approach to policy implementation, and ways of overcoming social, political, financial and legal and institutional barriers.

5.2 Policy implementation

The introduction of new transport systems presupposes an appropriate process and good dialogue between politicians, planners and transport providers to identify objectives and strategies. Lack of an agreed plan can become a crucial barrier to implementation. It is also important to put the new transport system into the correct context; the new system will in most cases be supplementary and will not replace conventional solutions.

Information about the benefits of the new automatic transport systems should reach the planners, the decision-makers and the society. Politicians deal with unpopular actions and must be able to explain the benefits of these new systems and how they will affect the local community and disturb the city environment. The systems may be accepted only if they can drastically solve problems related to for example, traffic congestion, safety levels and pollution.

In deliverable 'D4.5.1 Integration of the CityMobil technologies into the existing transportation system' of the CityMobil project a methodology is described for optimal integration of the chosen technology into the existing environment. In this methodology five different perspectives are chosen to identify potential barriers which need a solution. Furthermore, CityMobil deliverable D2.5.3 also deals with barriers and gives guidelines how to overcome these.

The important bottlenecks which do exist and must be issued by the proper authorities in order to achieve a complete integration of this new system are the following:

- Legislation on driverless vehicles and their interaction with other road users
- Legislation and insurance of users privacy in future customized services

- Real-time adaptation of the service to overwhelm demand peaks
- Automated infrastructure status monitoring to support efficient maintenance

Automated transport systems are environmentally friendly and safe. Their extensive utilisation should lead to a substantial reduction in private car usage. The absence of a driver could make the system cheaper than conventional systems, implying at least lower operating costs and so forth. Automatic transport systems can solve many of the challenges urban developers are facing now.

Any demonstration carried out should be precise about the motives for implementing a new system. It is also important to measure and report how well the new systems perform in practice. Successfully implemented projects would give such systems a good reputation. Information campaigns and other forms of publication of results could become a powerful tool in order to make decision-makers aware of gains to be expected by automatic transport systems.

5.3 Social barriers

5.3.1 Environment

City Environment

The system could potentially become aesthetically intrusive in a city environment. This must be considered as the system is designed. This could be due to the system's degree of "futuristic appearance", space utilisation, and mismatch with architectural style of historical city centres, noise, etc.

City Image

City image can be related to an existing transport system, e.g. the cable pulled tram in San Francisco. Introducing a new system can thus interrupt a city image in a negative way, even though the system itself is regarded as not being visually intrusive. The design of vehicles and infrastructure would have to be complementary to the aesthetics of historic buildings, and help maintain the city's identity. A pilot system should prove to be effective and not being visually intrusive. However, if a pilot proves wrong, this could represent a significant barrier for suitability to full scale introduction in other cities.

Local Business Environment

If innovative transport systems deliver on all counts, they could have a huge positive impact for city and town centres and the businesses located there. It could also bring potential benefits in encouraging redevelopment and new buildings in focal centres that would be positive for existing business. However, on the other side, the failure of a scheme would cast an extremely negative view on a town or city (Netmobil 2004).

Security concerns

One of the major public concerns when driving on eLanes or using driverless vehicles will be the security and safety levels.

eLanes

The driver level of scepticism depends on whether he/she feels uncomfortable by letting the electronic systems control his/her dual mode vehicle when using open or dedicated eLanes. The individual acceptance can vary according to cultural background, driving experience, capability to drive properly on eLanes and to use on board systems. The public belief in new innovative systems relies on confidence levels when using such systems. The drivers' population who will have access to dual mode vehicles or to cars with a certain level of automation must be well informed about the technology contained in the vehicle. A special driver's licence for dual mode vehicles could also in the future give the safety required to drive such cars in mixed traffic.

Driverless

The automated vehicle's user can be reticent to travel with no driver for safety and security reasons. People must be made to understand that the superior safety of automatic transport systems (without any driver) will overweigh present, familiar systems where a driver is personally in charge of the vehicle. Until it is the general opinion that an automatic system can be just as safe, or even safer, than traditional systems, it might be necessary to keep a driver and face extra cost due to lack of public acceptance. Information about existing systems would eventually convince people.

Misuse and terrorism

The possibility for a terrorist to use the automatic vehicle to transport bombs in a busy urban centre could be one of the insecurity feelings that can slow down the implementation of these systems. The security levels especially for cybercars and PRTs should be adapted to the risk of terror attacks. Monitoring the inside and outside areas with cameras and television

systems should be provided in order to protect individuals. The security level should be assured by a central control desk that cannot allow a vehicle to circulate with no passengers or in an unauthorised way.

5.4 Political barriers

Some situations require a combination of means to make the automatic transport system work in association with the rest of the transport system. This might require politically unpopular actions, like extra parking fees, limited access to certain areas for some transport groups and so forth. In these cases information about how the transport system is meant to work as a united system and how the different instruments are fitting in the greater system is important.

5.4.1 Operational Level Scepticism

The project may provoke apprehension on who will operate and administrate, perhaps finance the implementation of the new transport systems in a viable way. The city authorities may also be worried about the coexistence with other local transport systems and normal traffic. The vulnerability of the transport systems in bad weather conditions may cause doubts and reticence from some local decision makers. Doubts on technical efficiency and the consequences in case of systems' failures can slow down the cities' approval.

5.4.2 Employment Impact

If the new systems replace or compete with existing transport systems, there is a risk that some of the staff might become redundant. It is therefore important to introduce the system along with a plan that covers such issues. The reduced number of jobs related to vehicle operation will be compensated by an increased number of jobs within other areas of driverless systems. Other compensatory actions can also be taken in a period of transition.

5.4.3 Election Periods

Election periods could interfere with the planning or implementation of these new transport systems. The politicians can be reticent to link their political success to a particular project. The project's execution can also be slowed down by a complex combination of policy instruments.

5.5 Financial barriers

Both the authorities and the public have barriers against different advanced and innovative transport systems for various reasons. This manifests itself through investment resistance and lack of general user acceptance of the systems.

The financial situation is one of the main obstacles towards implementing automatic transport systems, especially in the initial phase (as the uncertainty is greatest in that phase). There is a greater financial risk to be one of the first to implement new systems. Later implementations have the advantage to avoid pitfalls and learn through earlier experiences.

Financial risks relate to robustness of cost/revenue forecasts and the likelihood of future financial viability and of obtaining funding for implementation.

The severity of the financial barriers in different European cities and the actual constraints that they implicate can slow down the transport implementation progress. If the public funds cannot cover the totality of the project expenses, the European Union encourages involving the private sector in project financing.

Potential solutions to the financial barrier might include Public-Private Partnerships (PPP) and financial restructuring. A PPP is essentially a relationship between actors, which may be used in situations where the respective authorities lack the resources (e.g. financial, organisational, knowledge, skills) to overcome delaying and or hindering implementation.

Financial Restructuring refers to the adaptation of existing financial structures or creation of new structures. It applies where the financial structure is hindering the processes of design/planning and implementation. This seems to be the case in situations where municipalities are competing with each other for financial resources.

Furthermore mechanisms influencing the competition between different transport systems and transport providers such as pricing strategies and subsidies should be used actively to promote new transport solutions.

5.6 Legal and Institutional Barriers

5.6.1 Acceptance in national law

Modification of law

Politicians can be reticent when a project implies important law modifications, as the authorisation of driverless vehicles in normal traffic. This requires an important political implication. The public road legislation is actually based on the presence of a driver responsible for the vehicle; therefore an adaptation of the national road traffic regulations by each country's government is necessary.

Certification

One of the most important implementation barriers is the absence of a dedicated certification system, to prove to stakeholders that the systems indeed are safe. For many different technical systems procedures and standards exist, that deal with the analysis of the safety and with the certification of these systems, but for automated transport systems such standards do not yet exist. Within the framework of the CityMobil project a set of certification procedures have been developed that in future could develop into generally accepted certification procedures (preferably on a European level). The procedures have been evaluated in the CityMobil Rome demonstrator and some other automated transport systems and have shown to be a useful tool in convincing stakeholders that automated systems are safe. The procedures are described in CityMobil deliverable 2.5.2: Certification procedures for automated transport systems.

5.6.2 Privacy Issues

Video surveillance

The surveillance data should be treated with concern and respect to the legislation for transport users' privacy. Individuals' trust in the system and their confidence on how the data processing is organised should be considered as a main goal. It is important to limit the monitoring and registration of people and activities to what is necessary in order to respect people's right of privacy.

Identification of passengers

Passengers can use a smart card as a means of payment for public transportation. The card can be personalised with a photo and name of the card holder. It can be reloaded at station tickets and automatic ticket machines. Personal data handling is not regarded as a major barrier against the dispersion of automated modes of transit. Data must be stored in places with limited access. The information should not be stored longer than required. Data should

not be used for other purposes than it was intended to and passengers must get information about how data is collected, saved and used.

Some European Data Protection Authorities plead for the right to anonymous public transport travel. As a consequence, a smart card can be issued together with a second card with a photo and name of the user. Thus, the smart card does not contain personal information on the user. The new system does not allow identification of travel patterns of individuals. The nominative card will only serve for controls at selected stations.

PART TWO: TOOLS AND MODELS

6 ESTIMATING PATRIONAGE

6.1 Introduction

The essential first step in designing an new transport mode is to estimate likely patronage. To this end, CityMobil has developed a Patronage Estimator, which provides initial estimates. More comprehensive approaches are described in Chapter 7.

6.2 The Patronage Estimator

The alternative patronage estimator is a GIS (Geographical Information System) based application that predicts the use of a public transport system. Travel demand can be estimated for both existing systems and for new technologies (e.g. automated services). The objective of this application is to be able to make quick rough estimates of what an (automated) public transport service could attract in terms of trip numbers. The tool may be helpful in the process of selecting service trajectories. The demand for the system is calculated based on socio-economic data, the properties of the service and travel behavioural characteristics in the region. The approach for the alternative patronage estimator deviates from the classical four-step approach (1 production/ attraction, 2 distribution, 3 mode choice, 4 assignment) which includes a mode choice model that estimates the use of the different transportation modes. The alternative patronage estimator focuses on the use of (only) the considered public transport system, without explicitly estimating demand for other modes. The application starts by importing the required input data into the model:

- Socio-economic data include the number of inhabitants/households, data on income and car ownership, employment rate and the number of workplaces.
- Public transport service data including network infrastructure: location of public transport stations & network connections and the frequency, waiting time, mean trip speed, reliability and capacity of the service.
- Travel behavioural characteristics including (i) trip distribution as a function of trip distance, (ii) mode choice as a function of the proximity to public transport stations and (iii) trip distribution as a function of proximity to public transport stations.

These travel behavioural parameters are dependent on the quality and characteristics of the considered public transport system (frequency, headways, mean trip speed, capacity, mean trip length, reliability, punctuality, image, etc.).

For existing public transport systems, travel behavioural parameters are derived from empirical data in the literature. For new systems (e.g. automated services) these parameters are determined or calibrated based on the results of surveys and stated preference research. Such research should reveal how the considered travel behavioural parameters are affected by the properties of the new service. An example of stated preference research can be found in Section 7.2.

The model determines productions from and attractions to all individual stations of the considered public transport service. Productions are distributed over the different destination stations, attractions over the different origin stations. The output of the model is an origin-destination matrix predicting the daily amount of trips between all stations of the considered public transport service.

Summarizing, the alternative patronage estimator efficiently predicts travel demand for (only) the considered public transport system, based on a tractable number of parameters. The use of other transportation modes is not explicitly estimated. A fuller description is provided in CityMobil deliverable D2.2.6: Alternative Patronage Estimator.

6.3 Case study

As an example, the alternative patronage estimator is used to predict travel demand for the High-Tech bus schemes of the Tyne & Wear region as described in Chapter 6 of the 'Tyne and Wear MARS modelling results' document (D2.3.1: Modelling Background Report).

6.3.1 Input

First, a GIS map of the Tyne and Wear region is imported into the model. The case study area is divided in 54 separate zones. For each of these zones, the GIS map includes socio-economic data on population density, employment rate, number of workplaces and car ownership. The different bus stations and network connections are defined on the GIS map, as indicated in Figure 5 below:

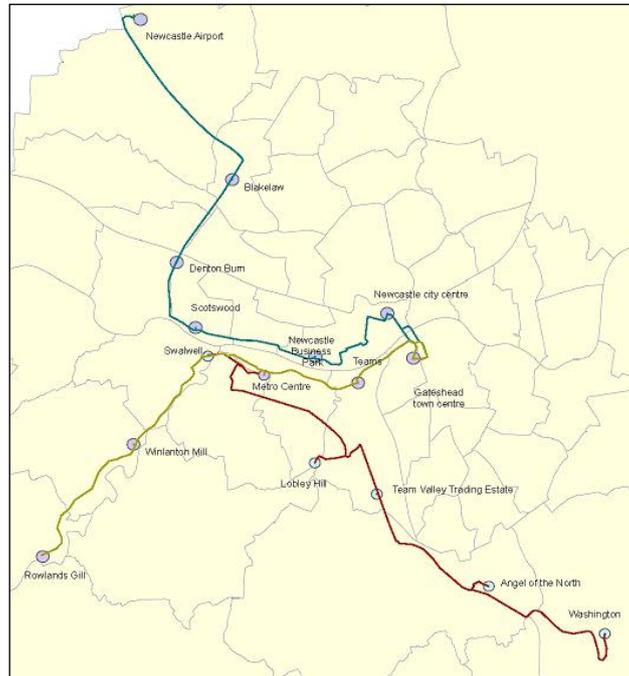


Figure 5: Bus Station and Network Connections

Zone/Area related travel behavioural parameters for High-Tech bus are adopted from those for a regular bus service, which are derived from empirical data in literature (source: Research on bus transportation behaviour in Belgium, (PHL, 2001a) and (Toint et al., 2001)). Mode choice related travel behavioural parameters are adopted from MARS modelling results (D2.3.1, Chapter 6).

6.3.2 Output

Output of the alternative patronage estimator is a travel demand forecast for each of the considered High-Tech bus routes. The results are presented in Origin-Destination matrices predicting the daily amount of trips from origin stations (matrix rows) to destination stations (matrix columns).

As an example, Table 4 represents the amount of trips on a daily basis for the High-Tech bus route between Newcastle Airport and Gateshead Town centre:

Table 4: Daily Trips for the High-Tech Bus Route

Amount of trips (daily basis)								
From \ To	NC Airport	Blakelaw	Denton Burn	Scotswood	NC Bus Park	NC city centre	Gateshead	Prod's (sum)
NC Airport	0	787	878	147	79	30	3	1915
Blakelaw	297	0	164	101	127	74	10	779
Denton Burn	391	194	0	26	122	110	17	870
Scotswood	443	806	178	0	73	142	27	1678
NC Business Park	247	1049	857	76	0	51	21	2296
NC city centre	145	956	1205	232	81	0	4	2612
Gateshead TC	13	101	143	32	20	1	0	309
Attractions (sum)	1537	3892	3424	615	502	408	81	10457

7 STRATEGIC MODELLING

7.1 The information needed

In this chapter we discuss in more detail ways of estimating the likely impacts of a new public transport technology, and of using that process interactively to help specify the preferred system in more detail.

In order to decide whether a new technology will contribute effectively to a city's transport system, information is needed on three inter-related attributes:

- demand for travel;
- supply of transport facilities (from the point of view of the users); and
- supply of transport operation and provision (from the point of view of transport operators).

Demand-side attributes: All trips are a result of a number of choices made by travellers, including choices between alternative modes, times of travel, and routes. Some of these choices may be more constrained than others, for example if the traveller has no car, or if a particular mode is not in operation at a particular time of day. Travellers also have individual preferences which influence their travel choices, for example preferring to pay a higher fare for a shorter journey time.

When assessing the impacts of new technologies within cities, it is therefore important to understand the characteristics of the population, to gain an insight into the existing and future preferences and choices that may be made in relation to the new modes, and the subsequent impacts this may have on other transport modes, the transport system as a whole, and in the longer term, the city as a whole (for example possible changes in land use, the environment, the economy). These population characteristics include age structure, income, car ownership, journey purpose and employment characteristics.

The principal challenge is to predict the attractiveness of a form of transport of which most travellers have no experience. Stated preference techniques offer one approach, but depend on a realistic representation or, ideally, a pilot of the new technology to guide respondents. These are discussed in Section 7.2.

Supply-side attributes: user perspective: These include fare levels and structures; payment method; factors associated with the service, such as access and waiting times, journey time and speed, route, headway and reliability, wait-time; factors associated with the vehicle, such as comfort, cleanliness and occupancy rate; quality of stops, stations and waiting areas; and other factors such as the provision of information and ease of interchange.

Supply-side attributes: operator's perspective: These include capital costs; factors associated with the initial system installation, such as land availability and suitability and infrastructure requirements; operational costs; capacity; service provision; and interaction with other modes, traffic and pedestrians.

Some of the supply-side attributes, such as the route, stations and vehicle type will probably have been specified beforehand. Others, such as the number of vehicles needed, the frequency, travel time or speed and revenues will depend on the performance of the transport system as a whole and on the demand. Conversely, demand will depend on many of these supply-side attributes. Accurate prediction will therefore require complex analysis tools, or models, which represent the interaction between demand and supply.

There are, however, a number of short cut methods which can provide initial estimates of key attributes. In this chapter we consider in turn:

- the use of stated preference methods to estimate demand
- strategic models which include outputs from the stated preference exercise and microsimulation modelling (see chapter 11)
- a short cut method using a strategic model.

7.2 Using stated-preference for assessing new modes

Given that the CityMobil transport technologies are still not main stream it is very difficult to obtain any revealed preference (RP) data of how passengers behave and hence estimate any demand impacts from such data. Instead we have to turn to stated preference (SP) experiments, which allow us to present a series of hypothetical transport choices to respondents and ask them to state which mode of transport they would choose given the attributes associated with each one. Attributes may include journey time, walk time, vehicle features etc. and these will vary between modes and between choices (an example of an SP choice is given in Figure 6).

For a discussion of SP experiments the reader is referred to Kroes and Sheldon (1988), Pearmain et al. (1991) and Louviere et al. (2000) all of which give detailed descriptions about SP methodology. For now it is enough to know that the key advantage of using SP experiments is that they allow us to explore how innovative modes of travel alter existing travel choices, providing we can make the choice contexts realistic. Another advantage of SP experiments is that they are data rich in that each respondent can be given more than one choice scenario; normally each respondent receives between 10 and 14 scenarios.

Scenario 1	
<p>Bus</p> <p><i>Single Adult Ticket (peak):</i> £1.50</p> <p><i>Walk Time:</i> 10 minutes</p> <p><i>Frequency:</i> 1 bus every 5 minutes</p> <p><i>Journey Time:</i> 25 minutes</p>	<p>High Tech Bus</p> <p><i>Single Adult Ticket (peak):</i> £ 2.50</p> <p><i>Walk Time:</i> 5 minutes</p> <p><i>Frequency:</i> 1 bus every 5 minutes</p> <p><i>Journey Time:</i> 20 minutes</p>
<input type="checkbox"/> CHOOSE Bus	<input type="checkbox"/> CHOOSE High Tech Bus

Figure 6: Example of an SP Choice Scenario

Within CityMobil, we decided to use an online web based interactive survey tool. This was the preferred choice because it allowed the SP to be tailor-made for each respondent by basing the SP choices they would face around their current journey, i.e. current wait time, current journey time etc. It enabled the use of pictures and the option for respondents to access more detailed information about the new modes, something that would not have been possible with a pen and paper exercise. It also had some cost advantages in that printing costs would be minimal (business cards instead of full questionnaires) and data entry costs would be zero since all responses would automatically be recorded via the website.

The online surveys for each of three experiments can be found at the following addresses:

1. Bus vs High Tech Bus: www.its.leeds.ac.uk/BRT1
2. Bus vs CyberCar: www.its.leeds.ac.uk/Cybercar1
3. Walk vs PRT: www.its.leeds.ac.uk/walk1

Once the survey had been conducted the data was analysed and a set of models proposed using specialist software (usually specified by an expert in stated preference). The models

can demonstrate how each attribute of the system is valued by respondents and we look at an example now.

When we come to forecast demand we have to calculate the generalised cost associated with using each type of mode, this is a combination of the monetary cost of using a mode plus the time associated with using each mode, where different types of time (walk, wait and journey time) are valued differently from each other, e.g. wait time is valued the highest as it is viewed as wasted time by a traveller. For a typical journey by public transport the generalised cost function would look something like this.

$$\begin{aligned}
 \text{Bus Trip Generalised Costs} = & \text{ASC (for that mode)} \\
 & + (\text{walk time to the bus stop} * \text{value of that time}) \\
 & + (\text{wait time at the bus stop} * \text{value of that time}) \\
 & + (\text{journey time in the bus vehicle} * \text{value of that time}) \\
 & + (\text{walk time from the bus stop to the destination} * \text{value of that time})
 \end{aligned}$$

The Alternative Specific Constant (ASC) reflects that fact that some transport modes are preferable to others for reasons which cannot always be picked up by individual model attributes. When forecasting market shares we calculate the generalised cost for each mode for each individual to see at what point one mode becomes preferable to the other. To illustrate this better see Figure 7 which presents a graph that illustrates the proportion of all bus and HTB users using High Tech Bus (shown as BRT) for different journey times.

For example around 27% of people prefer HTB to bus when the journey time is 10 minutes; around 36% when the journey time is 20 minutes and 50% when the journey time reaches around 34 minutes. It would appear that whilst people value the higher quality ride elements of the HTB this only becomes a major behavioural factor after a threshold has been reached and the benefits associated with some of HTB's attributes come into their own. In other words the ASC associated with HTB offsets the lower value of journey time associated with HTB in this example.

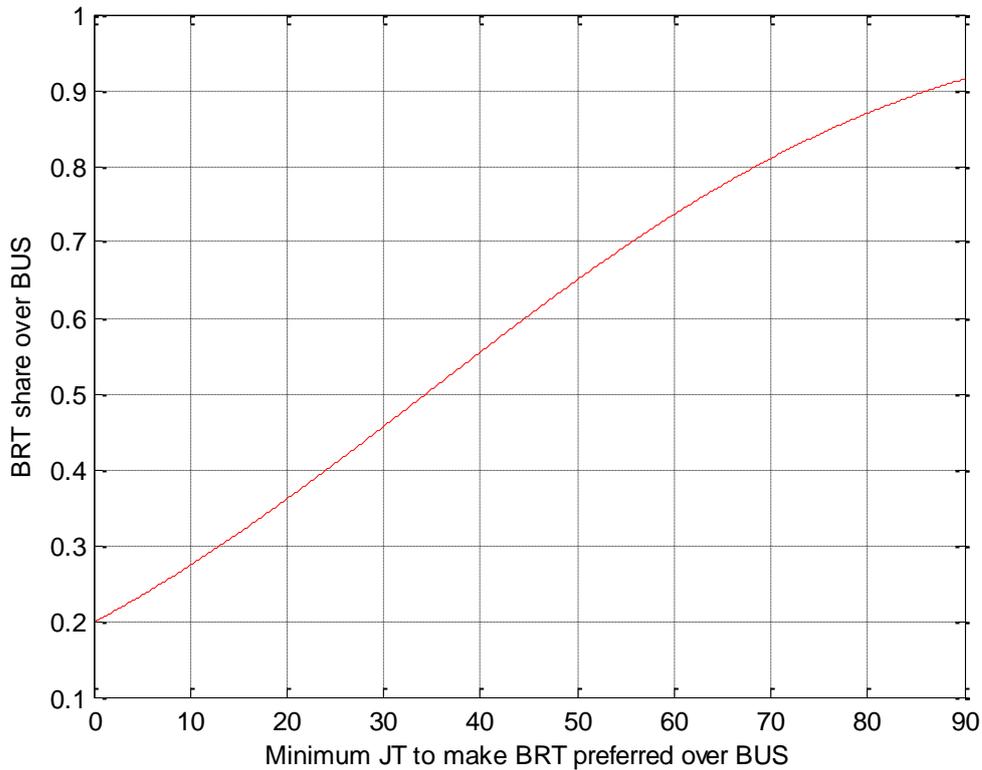


Figure 7: The Influence of ASC on the Comparison of HTB and Bus

7.3 MARS – A strategic policy simulation and optimisation tool

MARS (Metropolitan Activity Relocation Simulator) is a strategic land use – transport interaction model capable of analysing policy combinations at the metropolitan level and assessing their impacts over a 30 year planning period in less than one minute. The model has been transferred to a system dynamics platform VENSIM which provides a transparent approach to model development.

The “flight simulator” approach allows users to change policies and view outputs in a simulation environment with easy to use “slider bars”. Outputs are presented in graphical and tabular format with a new link to animated mapping software (Animap). In addition the user may use the VENSIM optimisation facility to optimise a package of policy instruments against a given set of objectives or targets.

It is aimed at professional transport planners at all levels of responsibility, but also at decision-makers and interest groups. The easy to use model (flight simulator) enables the

planner to look at the impacts of strategic policy combinations interactively with decision makers.

The outputs are generated automatically making discussion over the changes to policy simple, concise and immediate. The optimisation facility may also be used off-line to find optimal combinations of strategies or to aid target setting and to identify potential trajectories for targets.

For more information see Pfaffenbichler et al (2008) or to download an example with installation instructions for the City of Leeds and an example of the optimisation facilities visit: www.ivv.tuwien.ac.at/forschung/mars-metropolitan-activity-relocation-simulator.html

7.4 MARS – Tyne and Wear case study

The Tyne and Wear region is located in the north east of England, close to the border with Scotland. The area is comprised of five local authority districts – Newcastle-upon-Tyne, Gateshead, Sunderland, North Tyneside and South Tyneside. The urban conurbation of Newcastle and Gateshead is the focus for the modelling work, with the other areas featuring in the external zones. In 2005 (the base year for the MARS modelling), Newcastle and Gateshead had populations of 259,000 and 186,000 respectively, of which around 66% and 64% are of working age.

Newcastle and Gateshead are adjacent, with Newcastle located to the north of the River Tyne and Gateshead located to the south. The two cities are highly interdependent with intense commuting flows between the urban centres supported by an interconnected transport infrastructure. The red line on Figure 8 below indicates the existing rail network, with the red dots indicating the Metro stations and blue dots indicating heavy rail stations.

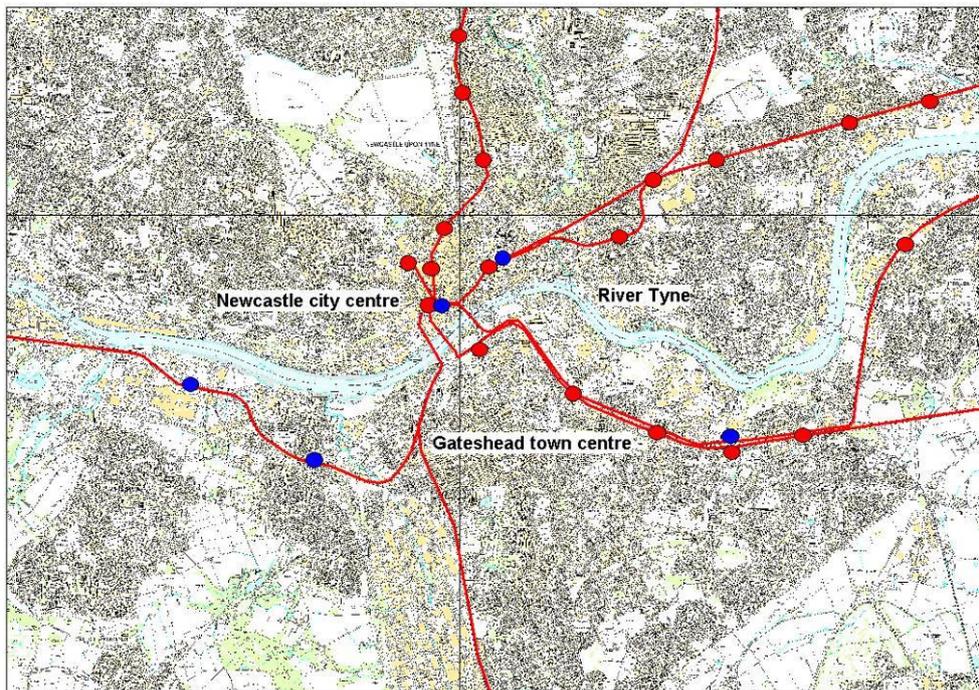


Figure 8: Gateshead and Newcastle

7.4.1 MARS zones

Figure 9 shows the full extent of the 54 MARS model zones in Tyne and Wear. Zones were created based on ward boundaries, and are bounded by a black line. The larger coloured areas containing several wards are the six external zones. The internal zones are shown in close up in the image on the right. Each of the internal zones is based on a single ward within the districts of Newcastle upon Tyne or Gateshead.

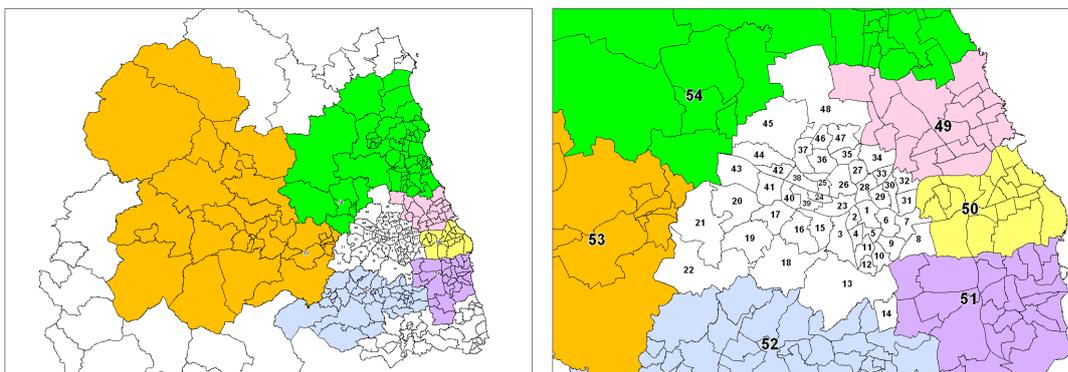


Figure 9: The Tyne and Wear MARS model zones

Table 5 shows the key facts for the high-tech bus, PRT and cybercar transport schemes for Tyne and Wear. Both the high-tech bus scheme and cybercar public transport feeder scheme

are comprised of three smaller schemes which are modelled simultaneously in MARS. More details of the schemes including mapping can be found in Shepherd & Muir (2009).

Table 5: Tyne and Wear new technology scheme attributes

Scheme	Transport Application	Zones	Approximate route length km	Number of stops	Typical distance between stops km	Key areas/ facilities on route
1-3	Total high-tech bus schemes	17,16,1 5,3,13,5 1,45,37, 42,41,4 0,39,23, 21,22,1 9,2,1	50.9	18	3	Metro Centre, Team Valley Trading Estate, Washington, Newcastle Airport, Newcastle city centre. Gateshead town centre
4	PRT (inner city network)	39,15,2 3,28,29, 1,2,3,26	20.7	56	0.3	Metro Centre, Newcastle Business Park, Newcastle Arena, Newcastle cc, St James' Park, Quayside, Marina, Gateshead tc, Saltmeadows, Bensham, Teams
5	Cybercar (inner city network)	39,15,2 3,28,29, 1,2,3,26	20.7	30	0.6	Metro Centre, Newcastle Business Park, Newcastle Arena, Newcastle cc, St James' Park, Quayside, Marina, Gateshead tc, Saltmeadows, Bensham, Teams
6-8	Cybercar (total feeder system)	16,18,5, 6,9,7,8	22.2	36	0.4	Metro Centre, Whickham, Felling Metro station, Deckham, Felling, Pelaw Metro centre, Deckham, Leam Lane

7.4.2 Scenarios and Tests

The schemes were modelled over a total of 30 years, with 2005 as the base year. In all cases the new technologies are introduced in 2010. Tests were conducted for medium and high growth context scenarios, both with and without complementary measures. Just the medium growth tests without complementary measures are reported here. One test is conducted for each new technology in addition to a do-nothing test.

7.4.3 Passenger Application Scenarios

The passenger application scenarios were modelled as follows:

1. **Inner city cybercar:** this system is modelled as an enhancement to the local Metro and rail system in MARS, and is therefore included in the total trips for rail. The following assumptions about performance characteristics were made when modelling this system:
 - Peak waiting time of 5 minutes, off peak waiting time of 3 minutes. It is assumed that there are a fixed number of vehicles on the system and that demand is greater in the peak meaning that the waiting time is higher than in the off peak.
 - Average vehicle speed (including stopping time) of 15km/h. This speed takes into account the time required for vehicles to stop to allow passengers to board and alight.
 - The system is segregated from other traffic

The cybercars have a capacity of 20 passengers.

2. **Cybercar public transport feeder:** this system is modelled as an enhancement to the existing rail system and is therefore included in the total trips for rail. The following assumptions about performance characteristics were made when modelling this system:
 - Peak waiting time of 5 minutes, off peak waiting time of 3 minutes. It is assumed that there are a fixed number of vehicles on the system and that demand is greater in the peak meaning that the waiting time is higher than in the off peak.
 - Average vehicle speed (including stopping time) of 15km/h. The speed takes into account the time required for vehicles to stop to allow passengers to board and alight.
 - The system is segregated from other traffic.
 - The cybercars have a capacity of 20 passengers.
3. **PRT:** this system is modelled as a system in its own right, but will be included in the rail category. It is assumed that PRT will be used as the sole mode for trips within the PRT network or as an access/egress mode for longer rail trips. The following assumptions about performance characteristics were made when modelling this system:

- Peak waiting time of 1 minute, off peak waiting time of 0.5 minutes. It is assumed that there are a fixed number of vehicles on the system and that demand is greater in the peak meaning that the waiting time is higher than in the off peak.
 - Average vehicle speed (including stopping time) of 27.5km/h. The speed takes into account the fact that this mode offers a direct service between origin and destination.
 - The system is segregated from other traffic.
 - The vehicles are demand responsive.
 - The vehicles have a capacity of 4 passengers.
 - The fare structure is the same as for the existing rail system.
4. **High-tech bus:** this system is modelled as an enhancement to the existing bus system, and is assumed to replace the existing bus service on all high-tech bus corridors. Trips by high-tech bus are therefore included in the bus category. The following assumptions about performance characteristics were made when modelling this system:
- The subjective value for in vehicle time is 89% that of an existing bus trip based on our Stated Preference survey.
 - The high-tech bus runs in lanes segregated from other traffic for the entire route.
 - The headway time is 50% that of existing bus services.

For both cybercar schemes, PRT and bus, the walking distance to the stop was estimated by assuming an average pedestrian walk speed of 5km/h, and using mapping software to measure the distance from the zone centroid to the relevant stop or station.

7.4.4 Results

Area Wide Results

These results are for the whole modelling area, including all internal and external zones. Table 6 and Table 7 show the number of trips in 2035 (the final modelling year) for the do-

nothing test, and the percentage change in trips when each of the new technologies are introduced.

Table 6: Index of 2035 area wide peak trip changes (M0=100)

	Do nothing	Inner city cybercar	Cybercar feeder	PRT	HT Bus
Car	477163	99.9	99.4	99.6	99.9
Bus	118093	99.6	98.3	98.9	101.3
Rail	42102	103.8	114.7	109.5	99.6
Slow*	82200	99.5	98.4	98.7	99.3

*Slow includes walking and cycling

Table 7: Index of 2035 area wide off peak trip changes (M0=100)

	Do nothing	Inner city cybercar	Cybercar feeder	PRT	HT Bus
Car	979288	99.6	98.5	99.0	99.8
Bus	216909	98.8	97.6	97.4	101.7
Rail	94928	106.7	112.9	128.0	99.4
Slow	284152	98.3	94.0	96.2	99.0

In both the peak and off peak the introduction of the CC feeder had the greatest impact in terms of reducing car trips, although this also resulted in the greatest reduction in slow mode trips.

Local Area Results

These results are just for the zones in which the technologies are located as shown in Table 5. Table 8 and Table 9 show the number of trips in 2035 (the final modelling year) for the do-nothing tests, and the percentage change in trips when each of the new technologies are introduced.

Table 8: Index of 2035 local area peak trip changes (M0=100)

	Inner city cybercar zones		Cybercar feeder zones		PRT zones		HT Bus zones	
	Do-nothing	Technology test	Do-nothing	Technology test	Do-nothing	Technology test	Do-nothing	Technology test
Car	3932	98.0	2411	91.8	3933	96.1	18623	99.2
Bus	1887	93.8	786	73.9	1888	89.3	4789	144.0
Rail	951	188.7	161	293.2	952	268.6	2190	97.6
Slow	5943	95.7	734	77.7	5943	91.8	2521	96.0

Table 9: Index of 2035 local area off peak trip changes (M0=100)

	Inner city cybercar zones		Cybercar feeder zones		PRT zones		HT Bus zones	
	Do-nothing	Technology test	Do-nothing	Technology test	Do-nothing	Technology test	Do-nothing	Technology test
Car	5810	92.4	5267	71.4	5810	87.2	28340	98.4
Bus	3360	81.1	1706	50.7	3361	69.7	6226	187.5
Rail	7473	147.6	644	270.7	7474	331.8	8265	96.5
Slow	28887	87.5	1861	54.9	28888	76.8	8800	93.2

In both the peak and off peak the introduction of cyber car feeder results in the greatest percentage decrease in car trips, but also the greatest reduction in slow mode trips.

7.4.5 Conclusions

This case study illustrates the application of the MARS model, and the wide range of inputs and outputs which it facilitates. The conclusions below are drawn from the case study, and illustrate the types of guidance which can be provided. In CityMobil itself, similar tests were conducted for three other cities. Deliverable 2.3.2: Modelling Background Report presents the full set of results, and discusses their wider implications.

Across the technologies, the introduction of high-tech bus in Tyne and Wear results in the greatest increase in bus trips in both the peak and off peak. The greatest decrease in car trips results from the introduction of cybercar feeder. The greatest increase in rail trips results from cybercar feeder in the peak and PRT in the off peak. Cybercar feeder gives the greatest reduction in slow trips in the peak and off peak. Inner city cybercar in the peak and HT bus in the off peak result in the lowest decrease in slow mode trips. It is likely that the introduction of the new technologies has a minimal impact at an area wide level because the schemes cover a comparatively small proportion of the whole study area.

7.5 Comparing the MARS and Patronage Estimator (PE) results

The Tyne and Wear HT bus results from MARS and the patronage estimator are compared in

Table 10.

Table 10: Comparison of 2010 MARS bus trips versus PE bus trips

Test	MARS bus trips	PE bus trips	% difference
Do-nothing	15054	12131	19%
HT bus introduction	24264	1816	25%

This shows that the number of bus trips forecast in both the do-nothing and HT bus test are greater when using MARS than with the patronage estimator. However, the results from both models are the same order of magnitude.

7.6 MARS Filter Approach: modelling innovative means of transport

7.6.1 Background

As an alternative to using stated preference surveys, we can make an initial estimate of the demand for new technologies by using current demand models and by assuming that technologies act in a similar manner to existing systems.

For example the larger cyber cars and High Tech bus could be seen as close to normal bus while Personal Rapid Transit (PRT) could be more like Metro or Light Rail. A simple tool has been developed to test the design parameters of some of the systems for simple specific trips.

A good example of this approach is when implementing a cyber car as a feeder where an external evaluation to identify some preconditions for its implementation can be carried out to get a "feeling" for how and where it would be sensible to implement a CC system.

7.6.2 The tipping point tool

The tipping point tool is based on the internal functions of the MARS model (Section 7.3) to model the access and egress time to existing conventional public transport. In general every transport model represents the supply side of a specific means of transport by the

generalised cost or transport resistance which represents the transport user's choice for a certain means of transport.

A Cyber Car feeder system is a system where small, driverless vehicles run on a network to pick up people wherever they want to board and bring them to the next public transport stop. This means of transport can be used to reduce the walking time to the next public transport stop and replace it by a motorized trip. It is obvious that such a system can only deliver an advantage to the transport system users where the walking time to the next public transport stop is above a certain threshold.

7.6.3 How the generalised costs for a public transport trip are calculated in MARS

In MARS, which includes a zone based transport model, a public transport (pt) trip for an origin – destination (OD) pair consists of the following individual (cost) parts:

1. Average walking time to the next pt stop origin zone
2. Average waiting time for the pt service origin zone
3. In vehicle time (OD)
4. Changing time (OD pair dependent)
5. Egress time destination, and
6. Fare costs.

For all time related cost parts of such a public transport trip so called subjective time valuation factors are applied to express the trip part specific discomfort.

$$f_{jPT} = t_{W,to,i} * SV_{W,to} + t_{W,i} * SV_W + \sum t_{DR,ij} + \sum t_{Ch,ij} * SV_{Ch} + t_{W,from,j} * SV_{W,from} + R_{C,ij}$$

$t_{W,to,i}$ Walking time from source i to public transport stop in zone i

$SV_{W,to}$ Subjective valuation factor walking time from source to public transport stop

$t_{W,i}$ Waiting time at public transport stop i

SV_W Subjective valuation factor waiting time at public transport stop

$t_{DR,ij}$ Total driving time from source i to destination j

$t_{Ch,ij}$ Total changing time from source i to destination j

SV_{Ch} Subjective valuation factor changing time

$t_{W,from,j}$ Walking time from public transport stop to destination

$SV_{W,from}$ Subjective valuation factor walking time from public transport stop to destination

$R_{C,ij}$ Impedance from costs travelling from i to j

$$R_{Cij} = \frac{C_{PTij}}{\alpha * Inc_{HH}}$$

α Factor for willingness to pay (=0.17)

Inc_{HH} Household income per minute

Implementing a cyber car system replaces now at the origin the points 1+2 of the list:

1. Average walking time to a cyber car boarding point in the origin zone
2. Average waiting time for the cyber car
3. In vehicle time cyber car possible cyber carfare
4. Average walking from cyber car stop to pt stop in the origin zone
5. Average waiting time for pt origin zone.

The rest of the trip is treated in the same way as a "normal" pt trip presented in the friction formula. As can be easily seen, depending on some CC parameters there must exist a tipping point (a minimal walking time) below which a CC system is not sensibly implementable, since the generalised cost of walking will be lower than the usage of a CC. On the other hand, above this threshold value, an implementation of a CC system as a feeder system for public transport could be a good idea.

Parameter variation – scenario testing

In the basic scenario the following assumptions are made: The pedestrian walking speed is assumed to be 4 km/h. The average walking time to the next pt-stop is 5 minutes; the average waiting time for pt is 8 minutes. For the cyber car system the following assumptions are made. The average walking time from the origin to CC stop is estimated to be 1 minute. The average CC vehicle speed is assumed to be 15 km/h, the average waiting time for a CC vehicle is 1 minute, and the average walking time from a CC-stop to a pt stop is 1 minute, too. Information regarding the household income are typical values for UK case studies; the price for a single CC trip was assumed to be 60 Euro cents.

Tipping point analyses			
Using (walking) to PT		Using a cybercar (CC)	
pedestrian speed (km/h)	4	walking to CC (min)	1
avg. walking to PT (min)	5	avg. speed CC (km/h)	15
equivalent walking time (min)	5	avg. waiting for CC (min)	1
avg. waiting time for PT (min)	8	IVT CC (min)	1.066667
		avg. waiting timefor PT (min)	9
		avg. walking time CC to PT (min)	1
		cost	9.680672
Resistance		Other constants	
resistance walking	12.26875	resistance walking	0.905911
		resistance waiting CC (PRT values)	0.955741
resistance waiting PT	38.52416	resistance IVT CC	1.066667
cost	0	resistance changing CC	58.94246
resistance total traveltime	50.79292	cost	9.680672
resistance total including cost	50.79292	resistance total traveltime	61.87078
		resistance total including cost	71.55145
		Color codes	
difference total traveltime	-11.08	results	
difference total including cost	-20.76	changeable parameters	
		traveltime	
		costs and traveltime	

Figure 10: Tipping Point Tool

Based on the assumptions shown in Figure 10 an In-Vehicle-Time (IVT) for the CC of 1,066 minutes is calculated. Since the CC can not go directly to the pt-stop, the transport system user still has to walk a short distance to the pt-stop. In this example 1 minute was assumed. Since there is no change in frequency in the pt system, the average waiting time of 8 minutes stays the same as in the pt scenario, but we have to add the additional walking time of 1 minute, which results in total to an average waiting time of 9 minutes. In addition, in this example it was assumed that a single CC trip costs about 0.6 Euro. In the boxes headed "Resistance" one can see the resulting resistance values for each individual part of the trip.

The total resistance for this basic CC scenario sums up to a value of 71.55 (including fare costs) which is significantly higher than a walking trip to pt (50.79). Based on this basic scenario set up several parameters can now be tested to find scenarios where the use of a CC system could be beneficial for a transport system user. For more information see Deliverable D2.3.1: Modelling Background Report.

8 DEVELOPING A BUSINESS CASE

8.1 Introduction

A business case is the basis for the economic justification of any new scheme. It takes into account all the factors that need to be considered, and presents them in a way that is easy to understand. It also facilitates a comparison of alternatives in order to assess value for money. An alternative may be a “do nothing” or “business as usual” scenario, or it may be an alternative transportation system. Either way, the results of a business case are needed to show the funding partners if their investment will be worthwhile.

Deliverable D2.4.1: Generic Analysis Tool for Business Cases describes a tool that has been developed for assessing the business case for new automated transport systems. The tool itself is provided in the form of an Excel Spreadsheet together with a User Guidelines document. They are stand alone items, available from the project.

The business case tool described here is based on the results of a literature survey of earlier economic analyses undertaken in association with the development of new automated transport systems, and of previous guidelines developed to assist in the economic and value for money assessments of new transport systems and schemes.

From this literature review a list of criteria and a methodology have been developed for the assessment both of a wider “transport case” that includes details of the background, policy and context, and the social costs and benefits that are needed to enable a local authority partner to assess a scheme, and also for a more focussed “business case” that considers only cash flows and is needed separately to satisfy the funding partners.

The approach adopted basically provides for a comparison of a new, i.e. CityMobil system with a conventional alternative, e.g. bus scheme through a structured set of questions that are designed to build up the transport and business cases for each system. The process then provides a formal framework for the appraisal of the two schemes in terms of relative costs and benefits, and the use of a TOAST (Technology Options Appraisal Summary Table) methodology that uses professional judgement to rate and weight the various benefits, intangibles, impacts and risks of the alternative schemes, and produces ranking figures that enable the two options to be compared. The use of the TOAST enables a more complete

assessment as compared to just relying on a purely economic evaluation using benefit-cost ratio figures, and facilitates an assessment of value for money.

8.2 Methodology

The spreadsheet tool takes the user through a structured set of questions that are designed to elicit the information and data needed to build up the transport and business cases for two alternative schemes, one based on a CityMobil system (e.g. Personal Rapid Transit (PRT) or Cybernetic Transport System (CTS)), the other a conventional alternative, such as a bus or tram scheme. The questions ask the user to provide:

- Statements of the Problem(s) to be solved.
- Statement(s) of relevant Policy objectives,
- An appreciation of the Context,
- An appreciation of the Physical opportunities and Constraints,
- An understanding of the Scheme and Operational factors,
- An analysis of the Benefits (both quantifiable and non-quantifiable)
- Any other intangible benefits and disbenefits (e.g. revenues lost on existing services)
- An appreciation of the Capital cost,
- An appreciation of the Operating costs.

8.3 Benefit Cost Ratio

During the process of the user inputting information and data in response to the questions, certain calculations are performed, so that at the end all the parameters that can be quantified can be combined in the calculation of the benefit cost ratio (BCR) for a scheme, and given by:

$$\text{BCR} = (\text{NPB} - \text{NPC}) / \text{NPC}$$

where:

NPB = Net Present Benefit

NPC = Net Present Cost

Two BCR figures are provided: a business benefit-cost ratio made up from actual cash flows i.e. costs, revenues and other income; and a total benefit-cost ratio that includes the cash flows and also those benefits to society, such as travel time savings, if they are available (e.g. from a MARS modelling exercise as in Chapter 7) and are input to the spreadsheet by the user.

All values are present values, i.e. measured over the lifetime of the project (say for example, 30 years) and then discounted (using an appropriate discount factor e.g. 6%) to the present day. This shows the extent to which a scheme is likely to cover the sum of its amortised capital and annual operating costs.

8.4 TOAST and Value for Money

An assessment of value for money (VfM) must then be made, and is greatly assisted by the TOAST (Technology Options Appraisal Summary Table) methodology provided. This allows the user to use his/her professional judgement to rate (and also to weight, if desired) the various benefits, intangibles, impacts and risks of the alternative schemes.

Factors taken into account in the TOAST include:

- user time savings
- system reliability
- system punctuality
- image/attractiveness
- saved vehicle operating costs
- accident savings
- saved pollutants
- jobs generated
- non-user benefits
- other system benefits
- compliance with objectives
- barriers and risks to implementation.

The spreadsheet then uses the rate and weight figures given for each factor to calculate a ranking figure. The different rankings for the two alternative schemes enable the two options

to be compared. The use of the TOAST enables a more complete assessment as compared to just relying on a purely economic evaluation using the BCR figures, and facilitates an assessment of value for money.

8.5 Outcome

The results are finally summarised in a summary table which shows the key features of the alternative systems including the types, numbers and carrying capacities of the vehicles needed, the length of the route, if a special guideway is required, the number of stations/stops, the average vehicle speeds and passengers waiting times, business and total BCR values and the TOAST ranking.

Decisions should then be possible for the funding partners from a consideration of the cash flows revealed by the Business BCR analysis, plus any additional funding needed, and of any subsidy required.

For the business case there is, in principle at least, no need for a comparison of alternative schemes, or for a full appreciation of the background, i.e. policy and context, and social benefits. In practice however, it is thought highly unlikely that a (local) government partner in particular would, or could commit to funding a particular scheme without the larger view and justification provided by these additional details and the Total BCR figure.

8.6 Notes on usage

The tool is designed for use at several levels:

At a basic level, it is designed to assess the business case for a new transport system. It does this by collecting information about expected cash flows and calculating a business benefit-cost ratio. It is expected that this result should generally be sufficient for the funding partners.

At a second level it provides the facility to collect additional information that is needed in order to answer the additional questions that can be expected from the (local) government partners. This additional information is designed to reveal details of the background, policy and context of the scheme, and to recognise social costs and benefits where the information

can be provided. It also suggests that the scheme should be considered in comparison with a conventional alternative scheme such as a bus, and provides a TOAST methodology for assessing their relative value for money.

At a third level the tool is designed to be useful as a design tool, and two particular features are provided to assist the user:

- The tool contains “simulations” (see chapter 11) of PRT and CTS systems so that the user can specify a system in terms of either user needs e.g. required performance characteristics such as average, minimum, and maximum in-vehicle travel times and waiting times; or of system design parameters such as the size of vehicles (passenger carrying capacity) and the number and speed of vehicles required for the operation. The simulations also facilitate testing of a range of „what if. questions so that effects of changing demand, network length or vehicle carrying capacity can be easily answered;
- The tool provides guidance on a range of information and parameters taken from real life examples, such as data on the costs of different systems. The tool has been developed to be comprehensive, so that the methodology and lists of criteria encompass a full range of factors that should be taken into account in a scheme evaluation. However, at the same time the tool has been designed for use at a „high level. and can, for example, easily be used in a first pass with incomplete and unrefined data to get an initial and rough idea of a business case.

In addition the tool can be used in an iterative process through varying and refining the values for a number of different input figures in order to assess the effects of these alterations on the overall BCR and TOAST results. This will help to determine the optimal system operating characteristics to be taken forward for a full design.

And finally: a caution. The tool will produce a business and a transport case, but it is not a transportation model. It does not provide a mechanism for estimating likely passenger demand. Nor does it provide a mechanism for estimating the quantifiable benefits such as user time savings or reductions in accidents and vehicle operating costs. Methods for doing so are dealt with separately in Chapter 7 of this manual.

8.7 Worked example for PRT in Tyne and Wear

The summary output of the results obtained from the use of the Business Case Tool in the Tyne and Wear case study presented in Section 7.4 is shown in *Table 11* below. Here the tool was used to compare a PRT scheme with a conventional bus scheme.

The results show the key features of the alternative systems including the types and numbers of the vehicles needed, the length of the route, if a special guideway is required, the number of stations/stops, the average vehicle speeds and passenger waiting times, business and total BCR values and the TOAST ranking.

Table 11: Summary of results for the Tyne and Wear case study

CityMobil - Business Case Analysis Tool						
Result Summary				CityMobil System		Conventional Transport System
Transport mode/ vehicle	From list	⇒	n/a	PRT		Bus
Number of vehicles	#	⇒	n/a	429		25
Type of guideway	From list	⇒	n/a	Separate Lane/Guideway		Existing Road
Length of guideway	[m]	⇒	n/a	20700.0		20700.0
Number of stations/stops	#	⇒	n/a	56		28
Average vehicle speed	[km/hr]	⇒	n/a	31.8		20.0
Average trip times	[min]	⇒	n/a	5.8		12.0
Average waiting times	[min]	⇒	n/a	0.3		5.0
Vehicle.kms / hour	[veh*km/hr]	⇒	n/a	8416.2		
Trip production / hour	[pax*km/hr]	⇒	n/a	4645.0		
Average vehicle spacing	[m]	⇒	n/a	48.3		
Business BCR Value	-	⇒	n/a	1.25		0.81
Total BCR value	-	⇒	n/a	1.25		0.81
TOAST rating	7-point-scale	⇒	n/a	4.52		2.15

Such results can be used as an initial indication to funding partners of the viability of the options considered. In the case of the PRT case study, the BCR of 1.25 shows the scheme will return a positive cash flow and so should be economically viable without subsidies.

The figure is probably lower than would normally be expected for a scheme to commence, but this is largely because the quantifiable social benefits such as user time savings have not been included in the BCR calculation, but taken into account in the TOAST instead.

The TOAST rating is therefore correspondingly higher. Even so, a comparison of the BCR with that of the conventional bus system suggests that PRT would be a more financially viable option in this case. This argument is further enhanced by the higher TOAST rating of PRT when compared to bus.

Table 12: Sensitivity analysis

Benefit Cost Ratio		Demand factor				
		0.8	0.9	1	1.1	1.2
Cost factor	0.8	0.96	1.18	1.39	1.60	1.81
	0.9	0.90	1.11	1.32	1.52	1.71
	1	0.85	1.05	1.25	1.44	1.62
	1.1	0.79	0.99	1.18	1.36	1.54
	1.2	0.75	0.93	1.12	1.29	1.46

There will inevitably be some level of error in the forecast of demand and in the assumed costs for PRT input into the tool. Table 12 shows the benefit cost ratios as demand and costs are varied by +/- 20%. Here we can see that a 20% lower demand with 20% higher costs will reduce the benefit cost ratio to 0.75.

Conversely if demand is increased by 20% and costs reduced by 20% the BCR rises to 1.81. Given the wide range of BCR it would be prudent to exercise some caution when assessing the business case and the range of BCRs should be presented to the decision maker as here.

9 MULTI-CRITERIA-ANALYSIS

9.1 Introduction

Chapter 8 describes a Business Case Tool which provides a simple appraisal of the principal costs and benefits of alternative options. Once a fuller assessment of an option's performance has been made (for example, using the MARS model described in Chapter 7), it is common practice to carry out a fuller evaluation. This chapter describes the Multi-Criteria Analysis (MCA) approach adopted in CityMobil.

MCA is a tool to support decision making on choosing policy options by condensing the information on systems. outcomes to the criteria most relevant to decision makers. It is an objective led approach and the key criteria need to be defined in advance. For the CityMobil project, the main objectives were to develop systems that deliver sustainable urban transport solutions; hence our main criteria were social, environmental and economic sustainability.

There are a variety of MCA techniques which can deal with different types of data, e.g. qualitative or ordinal, and which use different approaches in aggregating the information. The approach adopted for the MCA in the CityMobil project for comparing advanced urban transport systems is a weighted summation (or linear additive) method.

This approach has the advantages of robustness of results, effectiveness and lower complexity compared to other approaches (DETR, 2000). It requires that performance measures obtained from the analysis of the systems are transformed into commensurate scores which are then multiplied by weights and summed up to an overall score for each system. The MCA comprises the following steps:

1. Selection of key criteria and indicators
2. Determination of value ranges
3. Determination of weights for criteria
4. Calculation of performance matrix
5. Scoring and weighting
6. Sensitivity analysis

These steps are described in more detail in the following sections with examples of their application in the CityMobil project.

9.2 Selection of Key Criteria and Indicators

The selection of indicators for the multi-criteria analysis started with a comprehensive list of criteria and corresponding indicators as part of the overall evaluation framework of advanced transport systems as described in Deliverable 5.1.1: Evaluation Framework of CityMobil.

These evaluation criteria reflect the major objectives of the project in achieving sustainability goals as well as the best possible practical implementation of new technologies. The criteria are divided into six evaluation categories: acceptance, quality of service, transport patterns, social impacts, environment, and economic impacts. For their measurement, a list of 64 indicators has been proposed.

The main objective of the MCA in CityMobil is to assess the achievement of sustainability goals by introducing advanced transport systems in cities. Therefore, the implementation orientated criteria have been dismissed from the MCA and the focus lies on the outcome of economic, environmental and social criteria.

In order to reduce the complexity of the MCA and avoid redundancies, the remaining list of 32 indicators was further condensed to nine key indicators that measure the outcome for the main sustainability criteria. These indicators have been calculated as part of the outcome of the MARS modelling and business case analysis for the scenarios. They are listed in *Table 13*.

Table 13: Indicators used in the MCA

Criterion	Indicator	Indicator Information	Data source in CityMobil
Social			
Improving Mobility	Accessibility of key services [%]	Percent of population able to access key locations in set time increment	MARS: number of workplaces which you can reach from a zone weighted by generalised costs
Improving Equity	Low income zones non-car accessibility [%]	Accessibility to key locations based only on the population living in low income zones of city and non-car use.	MARS, see above for non-car use and low income
Improving Safety	Number of accidents	The number of accidents per year	MARS, directly
Environmental			
Reducing Energy Consumption & Climate Impacts	Annual CO ₂ emissions	Total annual emissions due to transport activities (direct and indirect)	MARS, well to wheel
Reducing Local Air Pollution	Annual NO _x + PM10 emissions	Total annual emissions due to transport activities (direct and indirect)	MARS, pump to wheel; unweighted addition of NO _x and PM10 emissions
Reducing Land Take	Change in area classified as urban	The amount of land being converted from Greenfield or agricultural land to urban due to direct (infrastructure construction) and indirect effects.	MARS, change in built-up area
Economic			
Reducing Congestion	Average delay in person hours	Journey times lost due to congestion during peak hours	MARS, trip time peak; aggregate of all modes
Reducing Transport Costs	Financial result	Financial benefit-cost ratio including investment, maintenance, operation and revenues	Business Case Tool, BCR
Improving City Economy	Economic vitality index of target zones	Change of number of households and service employments in target zone (e.g. city centre)	MARS, sum of the number of households and workplaces

9.3 Determination of Value Ranges

In order to make the results for the different criteria comparable, the performance results for all criteria are assigned scores (or partial utility values) on a harmonized scale. In the CityMobil project, linear value functions transforming the performance values into scores ranging between 0 and 100 are applied.

These value functions need to be defined on value ranges that extend over the difference between the worst (least preferred = 0) and best (most preferred = 100) possible outcome of the city-wide scenarios. Thus, the score for each indicator i is calculated using the following formula:

$$\text{Score}_i = 100 * (\text{Result}_i - \text{Worst case}_i) / (\text{Target}_i - \text{Worst case}_i)$$

In a single city application, these value ranges could be defined in a discursive process between decision makers and planning experts.

The value ranges for the selected criteria in CityMobil have been determined based on previous model results and values from literature in order to establish the same decision basis for all cities.

Best performance results were mainly derived from national or international targets for these indicators, while worst results were based on previous negative developments as well as worst case scenarios. *Table 14* summarises the value ranges used for the indicators in the CityMobil MCA.

Table 14: Value ranges for indicators used in the MCA

Criterion	Indicator	Worst Value	Best Value
Social			
Improving Mobility	Accessibility of Key Services [%]	Static	+15%
Improving Equity	Low income zones non-car accessibility [%]	- 20 %	+ 30 %
Improving Safety	Number of Accidents	Static	- 50 %
Environmental			
Reducing Energy Consumption & Climate Impacts	Annual CO ₂ emissions	+10%	-25%
Reducing Local Air Pollution	Annual NOx + PM10 emissions	-25%	-80%
Reducing Land Take	Change in area classified as urban	+20%	Static
Economic			
Reducing Congestion	Average delay in person hours	+25%	-20%
Reducing Transport Costs	Financial result	< 1	1.5
Improving City Economy	Economic vitality index of target zones	-10%	+ 5%

These target ranges are set for a future time period, in our project the time horizon is 30 years. Due to the model results potentially exceeding this range, scores below 0 (negative below worst case) and above 100 (overachievement of target) are possible, as reported in

Figure 11.

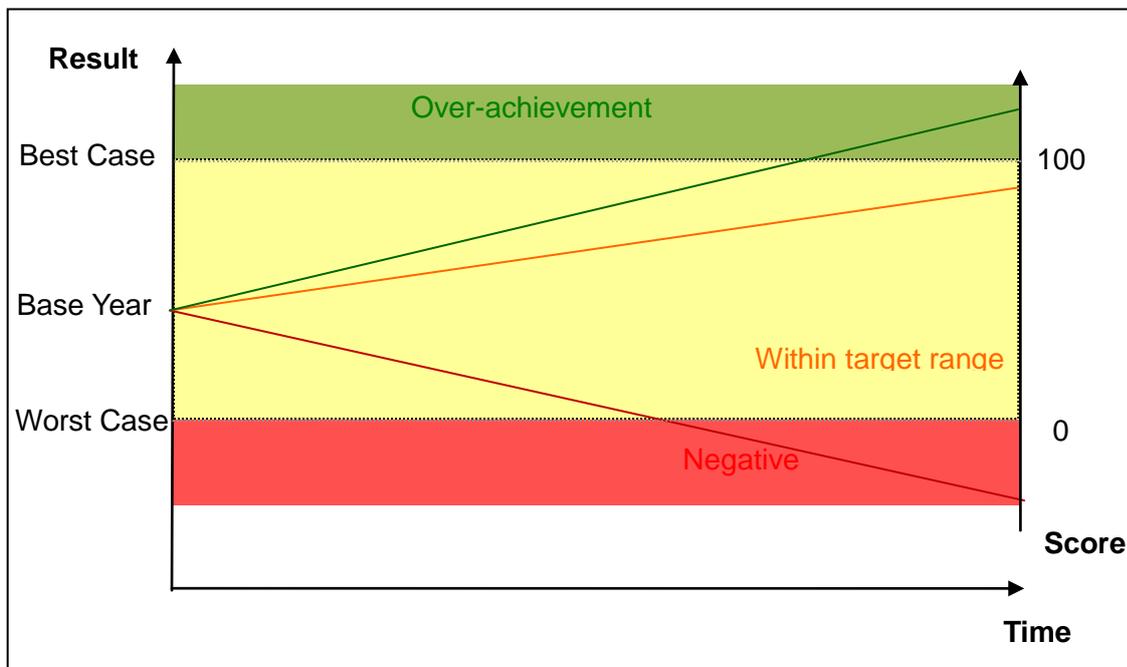


Figure 11: Possible Scores for Model Results

9.4 Determination of Criteria Weights

The weighted summation MCA requires the definition of weights for criteria used to monitor against the key objectives of sustainable urban development. There are various methods to obtain weights from the decision makers, e.g. ranking, paired comparison, direct rating or graphical scales methods. The above methods all share a similar approach to deriving their measurements. Most often a questionnaire is given to respondents to fill out, or a group panel of experts/stakeholders meet to rank or rate criteria.

The weights for the criteria in CityMobil have been determined in a written survey of participants of the project using the swing weighting method. This method asks respondents first to rank the criteria in order of their preference for changing from a least preferred to a most preferred level and then to assign points to each criterion expressing the importance of its change in relation to the highest ranked one. The advantage of the swing weighting method is that it explicitly asks the respondents to consider the range of performance values for each criterion.

A questionnaire which asked respondents to rank and subsequently score these indicators was then designed in Excel incorporating interactive elements in order to support the swing weighting method. The questionnaire is available in English and German. It was sent to participants of the CityMobil project, in particular to the representatives of the cities for which MARS models (Chapter 7) were developed and to the Reference Group.

From the responses we established average values for weights which will be applied in the MCA for a cross-city comparative evaluation of the advanced transport systems. In addition, from a comparison of the answers from different groups we extracted values for weights for a sensitivity analysis as well as differentiated weights for each the four cities in order to reflect local preferences. These values are summarised in Table 15.

Table 15: Value Ranges for Indicators used in the MCA

Group	Weights [%]								
	Mobility	Equity	Safety	Energy	Air Pollution	Land Take	Congestion	Costs	City Economy
Average	14.14	8.91	13.79	13.27	13.63	8.56	11.66	7.01	9.03
For Local Applications									
Gateshead/UK	15.14	8.18	13.11	14.26	10.93	9.40	12.78	7.99	8.21
Trondheim	19.62	9.23	7.46	13.27	19.50	8.45	10.19	6.21	6.08
Vienna	10.59	10.21	14.72	12.61	15.06	11.84	6.52	7.38	11.07
For Sensitivity Analysis									
Congestion priority	11.10	4.64	14.57	11.16	14.10	8.00	16.46	6.79	13.18
Mobility priority	15.81	8.73	13.74	10.55	12.08	7.31	12.37	8.23	11.17
Environment priority	11.86	9.15	13.87	16.95	15.74	10.25	10.70	5.36	6.12

9.5 Outcome of the MCA

The outcome of the MCA is a weighted score for each scenario, technology and city. These scores allow us to rank the alternatives and also identify which indicators contribute most to the results.

In the final step, a sensitivity analysis can be conducted in order to test the stability of results under the variation of valuing and weighting functions. The different viewpoints on the importance of sustainability criteria are explored through the application of the differentiated weights. These results will be described in Deliverable 5.3.1a Evaluation Report of the Ex-Ante Study. In order to give an impression of the types of result that will be provided, the following section describes an example application for the Gateshead case study.

9.6 Case Study Application for Gateshead

Based on the performance results for the sustainability indicators that have been provided by the MARS model and business case tool, scores for each indicator are calculated based on the formula described above.

The resulting scores for the case study area in Gateshead can be found in Table 16. The options tested are described in Section 7.4. It has to be noted that a score of 50 denotes a neutral result, greater than 100 exceeds expectations of the best possible results, and less than 0 is below worst expectations.

Table 16: Resulting Scores for the Gateshead Case Study

Gateshead	Medium without accompanying Measures						Growth,
	Do Nothing	Cybercar (inner city)	Cybercar (PT feeder)	PRT	High tech bus	DMV (city wide)	
Results	Scores						
Social							
Accessibility of Key Services	19.09	21.03	45.22	25.68	21.43	21.52	
Low income zones non-car accessibility	67.46	58.93	109.12	68.13	69.43	68.26	
Number of Accidents	-16.43	-15.90	-14.28	-15.12	-16.04	-19.44	
Environmental							
Annual CO ₂ emissions	67.46	68.18	70.48	69.21	67.98	66.30	
Annual NO _x + PM10 emissions	73.41	73.59	74.19	73.85	73.54	73.05	
Change in area classified as urban	97.07	97.07	97.07	97.07	97.07	97.07	
Economic							
Average delay in person hours	63.86	64.27	65.54	64.91	64.31	76.28	
Financial result	50.00	129.00	124.00	152.00	-8.00	50.00	
Economic vitality index of target zones	62.68	62.69	62.67	62.68	62.69	62.68	
Total weighted score (Local)	50.32	56.48	64.61	60.13	46.40	51.75	
Rank	5	3	1	2	6	4	
Total weighted score (Average)	50.32	55.62	63.91	59.06	46.96	51.57	
Total weighted score (Congestion)	50.67	56.10	61.56	58.98	47.29	52.40	
Total weighted score (Mobility)	48.75	55.03	63.52	58.79	44.69	50.16	
Total weighted score (Environment)	52.44	56.40	64.43	59.42	50.01	53.46	

From the table it can be seen that the largest variations in scores between the different solutions are achieved for the accessibility indicators and financial results. In particular, the cybercar as feeder to public transport can score above expectations for non-car accessibility in low-income zones, and cybercar and PRT achieve high scores for financial results. Because there is already an increase in accidents in the do-nothing scenario compared to the baseline, all schemes score negative for this criterion, although all achieve an improvement to the do-nothing situation. All environmental indicators show slight positive results as do reductions in congestion and improvements in the economic vitality of target zones. The best financial results can be achieved with the PRT solution, while the High-tech bus scores slightly negative on this indicator. Applying the local weights for Gateshead from the survey, the most favourable solution is the cybercar as PT feeder. The main drivers for

this are the good results on accessibility, which are also weighted highly in this case study application, see the figure below. Since all other scores of this solution are better than all others, the cybercar as PT feeder is the dominant alternative even when applying different weights. Figure 12 shows the weighted results for Gateshead.

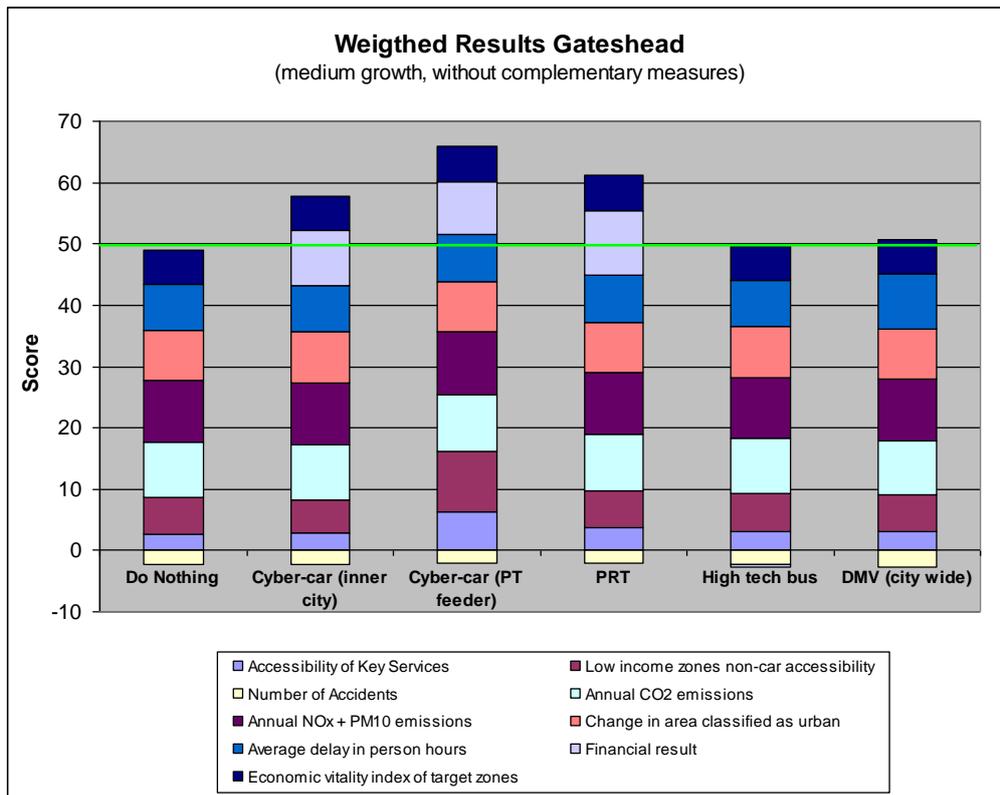


Figure 12: Weighted results for the Gateshead Case Study

10 CITY APPLICATIONS

10.1 The VOLTair Methodology Approach

The VoLTair methodology is a land planning approach, identifying how automated road transport systems can contribute to more sustainable mobility. It gives tools to the decision-maker to implement the right innovative transportation system with regard to the cities own needs. The purpose of this is to improve the understanding of the assessments done through the strategic modelling by a complementary planning approach. Therefore, in terms of urban planning, the VOLTair methodology has been designed to provide a full set of detailed recommendations to each city to implement a new mobility system. The VOLTair methodology has already been used and improved in various research projects (Cybermove, Mobivip, etc.) and studies. It has been proven that it is particularly efficient for implementing innovative transportation systems. The aims of the VOLTair methodology are to:

- define strategies for the cities;
- give guidelines for integration of selected applications scenarios to each city;
- elaborate recommendations for city strategies in complement to the assessments through the strategic modelling.

The VOLTair methodology is based on a general "top-down" process of urban transport planning and integration, similar to what cities refer to concerning conventional modes. Its originality stands in the high complementarity of the two approaches developed by city planners :

- the *functional approach*, directly related to transport planning and operating;
- the *societal and environmental approach*, including a larger panel of urban planners, such as urban designers, sociologists, ergonomists, economists.

The term "planning" in this methodological guide relates to the various analyses that have to be made before passing on to the implementation phase and the term "integration" stresses the fact that an urban transport system has to be integrated in an existing transport network and in a present urban context.

Conceived as a methodological guideline for city decision-makers, the general process of urban transport planning and integration refers to the following strategy:

"First identify and define the necessary functions and links to be assured on the global city perimeter and then pick the right tool for the right place. Only later is it possible to

dimension the best possible transport system in adequacy to the best possible city development scenario".

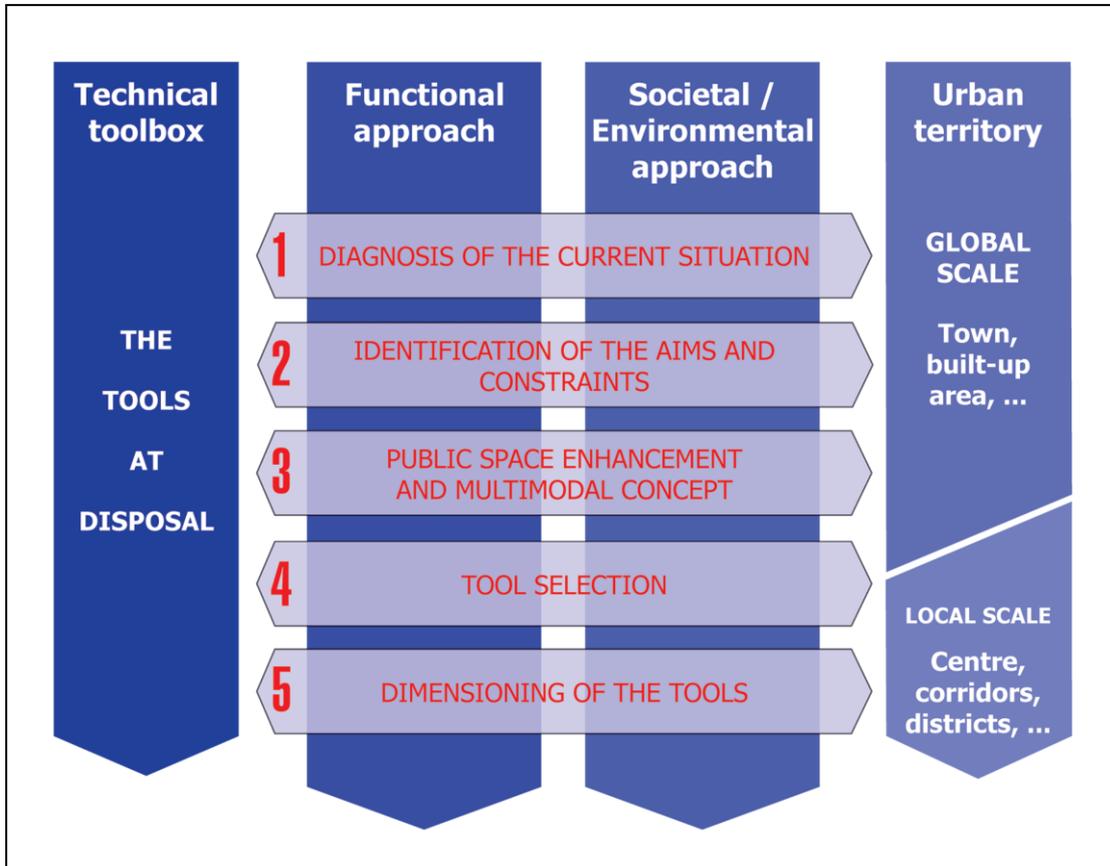


Figure 13: Overview of the VOLTair Methodology

The five steps of the general process of urban planning and integration are illustrated in the figure above. These five steps are:

- Diagnosis of the current urban situation
- Formulating and identifying the aims and constraints
- Defining city specific public space enhancement and multimodal concept
- Selecting the tool for each new or improved identified functions addressed
- Dimensioning of the tools on a local scale

The successful application of this methodology requires an early involvement of the right decision-makers. Each of the five steps has a specific purpose and therefore need to have its

results validated before continuing to the next step. Local decision-makers have to participate in the planning process in order to gain support for the scheme.

10.1.1 The Global Scale

The first three steps of the general process of urban transport planning and integration are to be considered on a global urban scale. As a first step, the diagnosis aims at analysing the current situation and at highlighting the existing problems. It is important to be aware that many stakeholders have different points of view and perceptions of the current issues. The main purpose of the problem analysis is therefore to gain agreement from stakeholders on the main problems. This established on the basis of information on the current transport supply and demand and the land-use planning.

The second step consists of formulating general aims and identifying constraints to be taken into consideration. Once the existing situation has been identified and before the planning phase starts, it is essential to know from local decision-makers what projects are currently being worked on, what strategy is being pursued, what are the political priorities, etc. The purpose is to identify the available room for manoeuvre and to set technical priorities.

Once the main issues and goals are assessed, the third step is to define a city specific public space enhancement and multimodal concept, including a city-tailored functional vision of the mobility system.

Such an instrument has to be based as much as possible on functionalities offered by existing transport networks. As illustrated in Figure 14, the innovative transport systems are to be evaluated as part of the existing transport network.

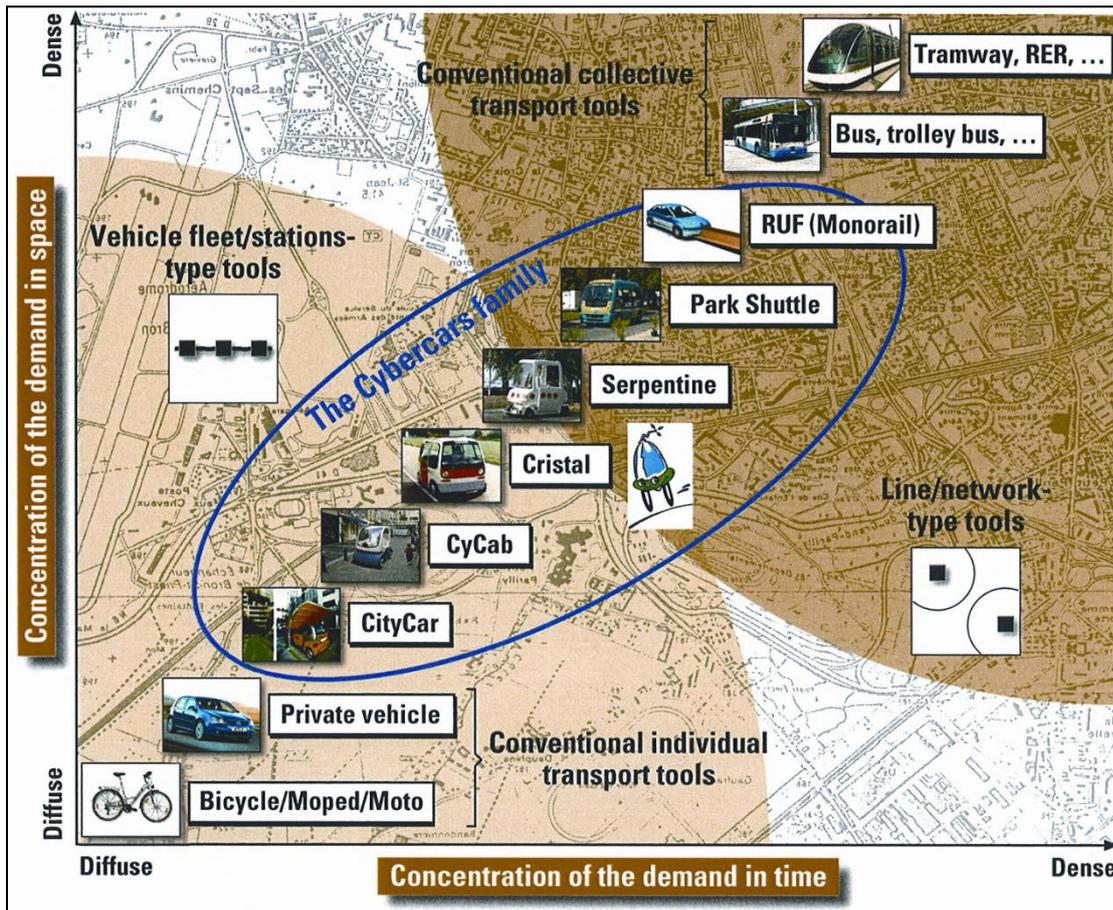


Figure 14: CityMobil Systems as Part of the Transport Network

10.1.2 The Local Scale

Defined on a global scale, the public space enhancement and multimodal concept allows identification of certain sectors for which the transport service to be offered remains to be decided upon. If for certain links or functions specific constraints exist (e.g. when a transport tool already exists or when a projected tool was identified as a constraint), the tool selection still has to be discussed.

Various tools exist and not all are suited to meet all needs. On the one hand a line-operated collective transport will most certainly be a best possible match in an urban corridor with a high density demand. On the other hand, the same tool will hardly provide a reasonable and satisfying solution to serve a low density demand on a relatively wide-spread area. As the fourth step of the planning and integration process the tool selection has to be considered on a local scale, although interactions with the entire urban area exist, e.g. in terms of fleet compatibility and operation. Some criteria to be considered to select the appropriate tool are

shown in the following figure. This step has to be carried out for each new identified function to be addressed as they appeared in the concept.

At the moment in our cities road accessibility for newly developed areas is primarily ensured per default. For such areas, the choice of an alternative transport tool highly depends on the will of decision-makers to offer something else than roads and parking, etc. Even the best suited tool in a given specific context has no chance to be implemented if it lacks local support.

For the purpose of the CityMobil project, the VOLTair methodology is not applied for itself, but spread into two parts in order to take the right inputs and give the appropriate outputs for the global project, as shown in the figure below.

The first three steps of the methodology are used to elaborate global city strategies, taking into account the specified scenarios. This process is mainly based on the same data as the ones for the strategic modelling and completed by some qualitative inputs provided by the cities.

The integration of the different applications scenarios for each city is based on their definition, their selection for the strategic modelling and completed by the fifth step of the methodology.

Finally, thanks to the previous results and the tests conducted after the strategic modelling, recommendations for city strategies are concluding the application of the VOLTair methodology (as shown in *Figure 15*).

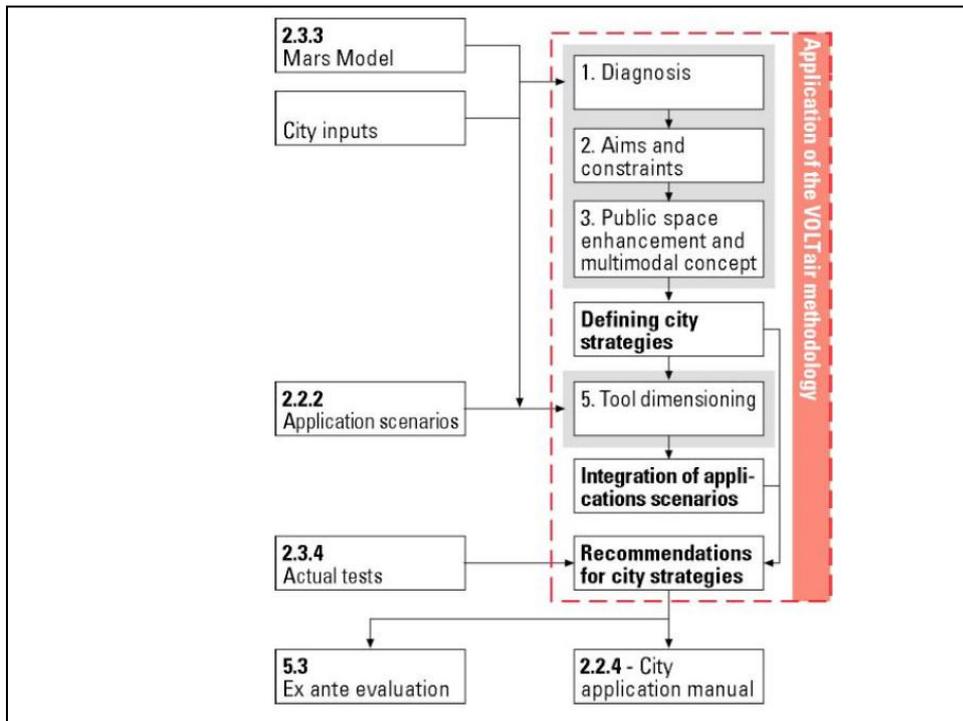


Figure 15: Context of the VOLTair Methodology

The VOLTair methodology does not aim at replacing the local planning processes. Therefore it is important to emphasise that the objectives and constraints in CityMobil are orientated towards innovative mobility rather than toward the objectives and constraints a city faces when developing its own mobility or global strategy.

10.1.3 Conclusions

Often city authorities start analysing possible solutions when the problems already appeared, either when problems are clearly visible or when urban projects are quite advanced. Probably the most counterproductive way to approach urban issues is to assume one's solution is the best without considering other points of view. It is therefore highly recommended to:

- understand what the decision-makers' local concerns are (only this way can they be the initiators of the planning process and feel involved in it)
- assess these problems in a more global framework
- aim at developing a general transport and urban development policy where particular interests converge into a general public matter

- first define a global and functional vision of tomorrow's city before developing detailed measures to be implemented on a local scale.

11 DETAILED DESIGN

11.1 Introduction

In traditional planning applications, micro-simulation tools have been used to estimate small scenarios like an improved intersection design. This is due to their increased need for input data as well as for computational resources. However, both of these burdens are likely to become lighter in the long run, because of the ever improving availability of data and due to the fast increases in computation speed of the today's computers – together with the superior modelling quality of microscopic tools this will give their application the required boost.

This is especially true for applications such as those put forward by CityMobil, related to automated transport. Since automated transport works on the microscopic level of either individual vehicles or on the planning of fleets, micro-simulation is well suited for the assessment of automated traffic and transport. Within CityMobil, micro-simulation has been used so far in a more traditional context. This is due to the fact that CityMobil was not intended to work on detailed studies, but to give a general overview and recommendations that foster the implementation of automated technologies in the transport system.

With regard to automated transport, micro-simulation can either be used in the same context as in traditional planning: it can be used to determine the effect of automated transport on a local level, but here this can be done with high precision, since the parameters of automated transport can be mapped into the microscopic models with high detail and confidence. After that, the parameters that have been modified (like capacities, or prices and travel-times to reach a certain location) by automated transport, can be used within a macroscopic planning tool to do the extrapolation to a large study area under consideration.

Not that far into the future, it will be possible to skip the second step and work directly with a microscopic simulation to determine and assess the challenges of transforming a transport system to a higher degree of automation. In what follows, this section will give two examples which demonstrate how the micro-simulation work has been done in CityMobil.

11.2 CityMobil case studies

The two automated modes that will be regarded in greater detail in this section are the so called dual-mode vehicles and a fleet of cybercars or personal rapid transport. The latter can be used to automate transport in the city centre or to serve as a feeder network for a train station. This means, that the basic optimization gained by these technologies is due to the automated fleet management system that tries to allocate resources in the best possible manner.

Dual-mode vehicles are automated vehicles, which can be driven in normal traffic. When driving along a road which has been equipped as a so called eLane, they switch to the automated mode. The automated mode is defined by a modification of their driving parameters (e.g. automated vehicles drive error-free and with a smaller distance to the vehicle in front), which lead to an overall increase of the road's capacity. Again, it was the task of the micro-simulation to translate this change in the driving parameters to the macroscopic level.

Personal Rapid Transport and Cybercar simulations

As has been described above, PRT and CTS systems can be used to provide transport services to a small network, like e.g. a historical city centre or a feeder network for a large train station. In the latter, it improves the accessibility of the train station, which might lead to an increased share of passengers travelling by train. To assess these benefits, it must of course be possible to simulate all the details needed to arrive at the decision whether or not such a system should be implemented. Therefore, the simulation software must not only simulate the movements of the individual vehicles, but also the fleet assignment process to draw sensible conclusions (how many vehicles and stations are needed to serve a particular demand in a given time), which are the important prerequisites to finally compute the costs and the benefits of such a system.

In CityMobil, an example network depicted in Figure 16 was used. It has been designed originally for Cardiff in the EDICT project. The network length is about 16 km with 26 stations (red points in Figure 16), which are the depots for the vehicles and other equipment, and are the places where passengers can enter and exit the system. Connections (links) between nodes can be either bi-directional or one-way, in the latter case this is indicated in Figure 16 by an arrow.

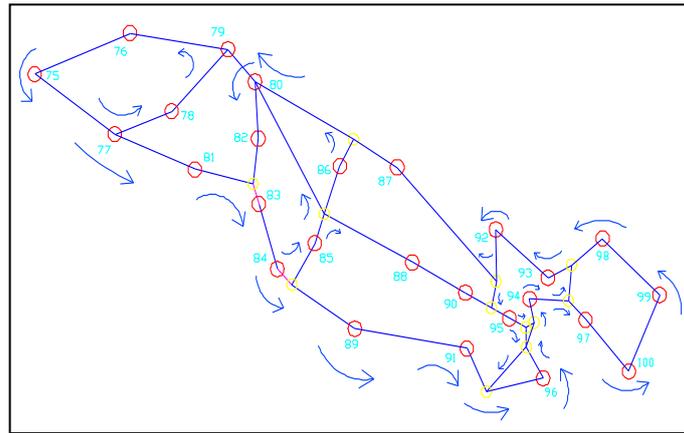


Figure 16: The Cardiff network scheme

The maximum speed of the vehicles is 40 km/h, but a mean speed equal to 36 km/h has been used in order to consider the accelerations and decelerations due to the stops. Vehicles are electric and equipped with a battery. Thus the presence of recharging stations (corresponding to the depots) has been simulated.

Both PRT and CTS have been simulated on the same track (the hypothesis was made that the track and the station platforms were suitable for both systems). The PRT system uses vehicles with a capacity of 4 passengers and a vehicle length of 3.7 meters. Besides, the system is “dedicated” (i.e. the vehicles go directly to the chosen destination, without intermediate stops).

In contrast, the Cybercar system uses vehicles with a capacity of 10 passengers and a vehicle length of 6.0 meters. The system is “shared” (i.e. the vehicles can be used at the same time by users having a different origin and/or destination; thus the vehicles could stop at intermediate stations during a journey).

Simulations have been carried out for ten demand levels (ranging from 1560 requests per hour (req/h) to 15600 req/h) and for one operating hour of the system, corresponding to a peak hour. Each demand level has been simulated for three maximum allowed waiting times at stops (indicating the level of service to provide): 60, 180 and 300 seconds. The maximum allowed waiting time indicates the maximum time that the users are willing to wait for a vehicle.

Typical results are presented in *Table 17* for the PRT system, for four demand levels and the three levels of service.

Table 17: Results of Simulation on Entire Network

Demand level	Max allowed waiting time [s]	N° of requests	N° of vehicles	Mean waiting time [s]	Occupancy rate [occupied_veh*km]	Vehicle run [veh*km/km]	Commercial speed [kph]	Trip production [pax*km/km]
1	60	1564	250	0.22	0.573	293.2	32.4	168.0
2	60	3120	500	0.23	0.586	572.5	31.6	335.4
3	60	4682	750	0.25	0.595	862.9	31.7	513.2
4	60	6242	950	0.27	0.607	1116.6	30.8	677.2
1	180	1564	225	1.35	0.609	281.6	31.1	171.6
2	180	3120	450	1.40	0.605	559.9	31.0	338.8
3	180	4682	700	1.37	0.612	868.8	31.9	531.7
4	180	6242	875	1.43	0.626	1102.9	30.3	690.1
1	300	1564	225	2.57	0.594	292.5	32.2	173.8
2	300	3120	425	2.75	0.613	563.8	31.1	345.7
3	300	4682	625	2.80	0.633	829.6	30.4	525.4
4	300	6242	800	2.77	0.637	1078.5	29.7	687.4

Additionally, Table 18 shows that the number of vehicles necessary to cope with the demand for the CTS is significantly lower than the PRT. Since CTS vehicles can stop at intermediate stations, the travel times are higher than for the PRT system. On the contrary, the mean waiting time at stops for CTS is similar to the ones obtained for the PRT. All the results found so far are summarized in **Fout! Verwijzingsbron niet gevonden.** which helps to compare the two modes.

Table 18: comparison of Performance Indicators

	PRT system	CyberCar system
maximum allowed speed:	40 km/h	40 km/h
vehicle capacity:	4 places	10 places
driving mode:	dedicated	shared
maximum waiting time (scenario 1):	60 s	60 s
Average vehicle speeds (kph)	27,5	19,1
Average trip times (min)	4,06	5,86
Min waiting times (min)	0,28	0,42
Max waiting times (min)	0,38	0,50
Number of vehicles	157	30
Passengers per vehicle	0,702	0,327
Number of stops	718	402
Vehicles kilometres (veh*km / h)	2496,6	581,6
Trip production (pax*km / h)	1733,8	1078,2
Mean vehicles spacing (m)	44,6	233,3

Dual Mode Vehicles

For the dual mode vehicles, altogether three different scenarios have been simulated, which may serve as a typical range of applications that can be done with micro-simulations tools today. The study areas consist of a single intersection to learn about the direct capacity increase at an intersection caused by dual-mode vehicles, a part of the city of York, and the whole city of Magdeburg in Germany (230,000 inhabitants).

The city-wide simulations have been done to figure out how the capacity gain at single interactions transforms into gains in travel-time (and, most likely, reductions in CO₂ emissions) on the level of a whole network. Note, that with the appropriate tools, even the micro-simulation of the transport network of a day for a whole city can be done in less than 30 minutes computing time.

Figure 17, Figure 18 and Figure 19 show the two study areas in York and Magdeburg, respectively, together with the results. The simulations for York have been performed for a varying degree of DMV vehicles and varying levels of demand (but by using a static demand matrix). In contrast, the simulations for Magdeburg used a varying degree of DMV share only.

However, there was a variation in demand given by the variation in the demand matrix over the day since a time-dependent matrix was available. In both cases, travel time is used as the prime performance indicator, and in both simulations had found the result, that with an increasing DMV share the travel time decreases.

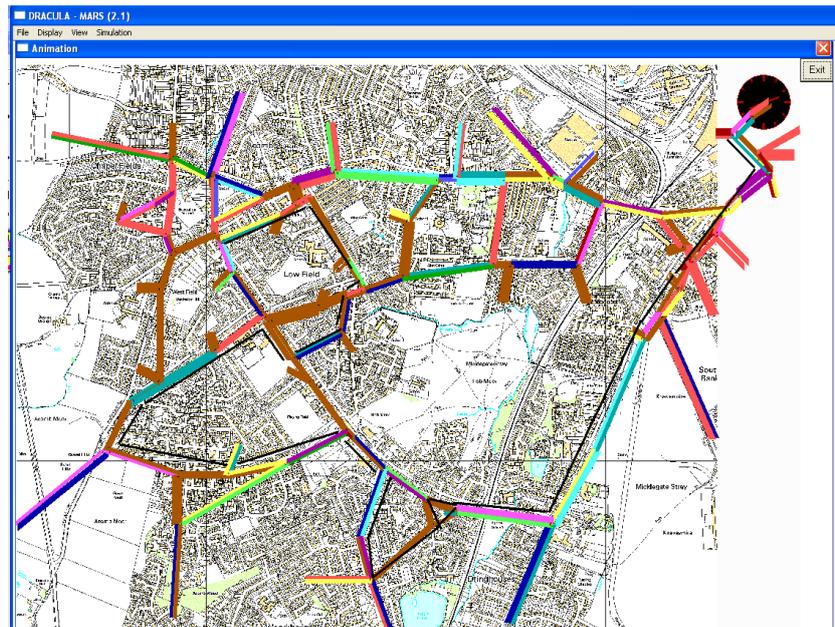


Figure 17: The York Network

The results are summarized by plotting the average travel time as function of DMV share in Figure 18 (York) and Figure 19 (Magdeburg). While the scales differ, the percentage reductions in travel time between zero and 100% penetration of automated vehicles are similar.

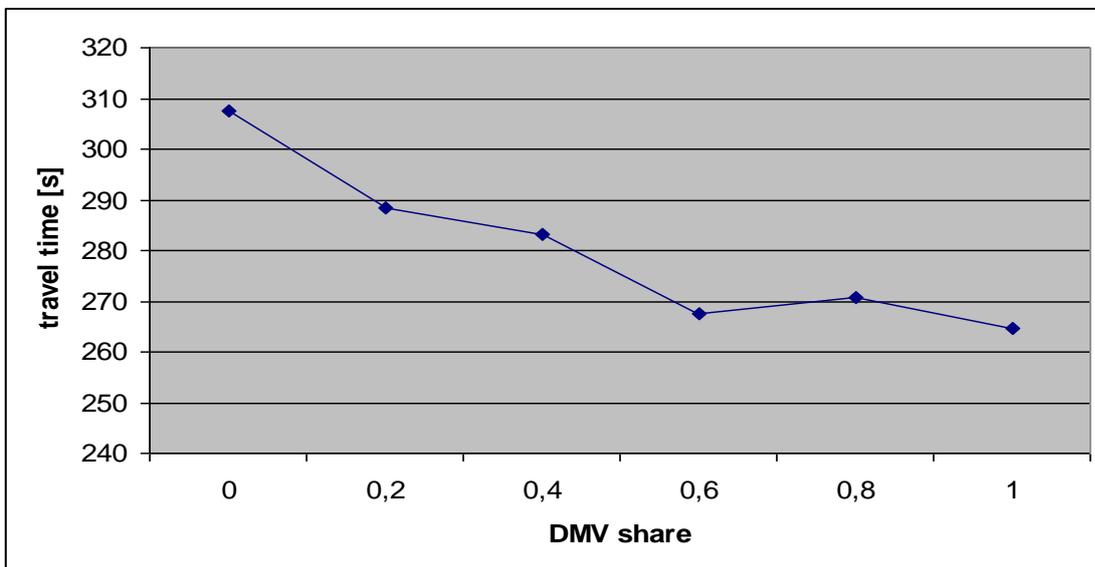


Figure 18: Simulation Results for York

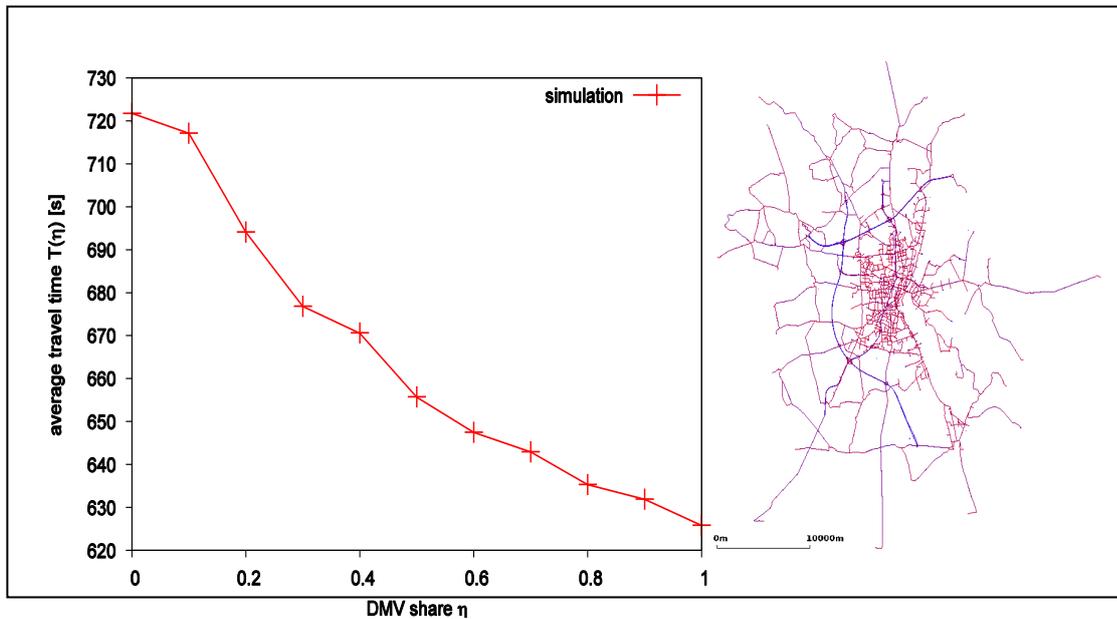


Figure 19: Simulation Results for Magdeburg

Of course, these results depend on the microscopic driving parameters assumed for the dual-mode vehicles. In addition, they do not utilize the full potential of automated traffic, since the infrastructure settings (traffic lights, lane-width, routes) in the simulation used so far are for normal traffic.

11.3 Input from SP4

Microscopic simulations of the CityMobil systems, including PRT, CTS and HTB, have also been investigated in SP4 with regard to traffic management strategies, and reported in Deliverable D4.4.1: New Management Approach in Advanced Urban Transport Scenarios. For CTS schemes, the main opportunity investigated was for 20 seater vehicles operating an on-demand service based on an agent approach in which the cybercars give a “bid” on a request of a passenger by presenting an estimated time of arrival resulting from the “experience” of the car on the route in question. The passenger then simply chooses the car with the smallest of the times given. Simulation results showed the superiority of the cybercar agent approach over a conventional 30 seater shuttle bus service, in terms of the important factors of waiting time, travel time and fuel consumption / emission. For PRT schemes, the main opportunities for traffic management were considered to be from forecasting demand so that the distribution of vehicles in the network could be organised in advance to minimise waiting times. Simulation results show that benefits were obtained from two demand forecasting strategies:

- a local demand prediction tactic for vehicle dispatching would allow vehicles to be dispatched in advance to cover the travel time between a depot and a station and thus reduce passenger waiting time at a station; while
- a long term demand prediction strategy for global network operation would allow the network operation (e.g. relocation of vehicles, number of vehicles in operation) to be ready for rising/falling demands in advance and thus reduce passenger waiting time across the network.

For HTB schemes, the main opportunities were considered to be from providing a demand adaptive service to minimise passenger waiting time. However the opportunity was also taken to consider the benefits of a scheme using advanced compared with traditional buses, and the impacts of the bus lane on conventional traffic. Simulation results confirmed benefits in terms of shortened trip times from improved docking and the use of reserved lanes, and showed that a demand adaptive service provides good results by ensuring reasonable maximum waiting times for users, and ensuring that the overall system capacity (on average) is not exceeded.

12 CONCLUSIONS

Decisions on transport strategy are always difficult. Deciding whether to invest in a wholly new technology is particularly challenging. On the one hand a new transport system can reflect favourably on the image of a city, as has happened with cities which have invested in new trams and driver-less metros. But on the other hand such systems bring with them additional uncertainties. Users do not know how they will perform, and what to expect, and may be reluctant at first to use them. The technology may not be wholly reliable in the initial operation, or may give rise to perceived or real safety risks.

This City Application Manual has been designed to help cities tackle these uncertainties. It provides a series of tools and suggestions for each of the stages of policy development, including:

- understanding future scenarios (Chapter 2)
- identifying the most appropriate applications (Chapter 3)
- considering the wider range of policies within which the new technology might fit (Chapter 4)
- appreciating the barriers and ways in which they might be overcome (Chapter 5)
- predicting performance and patronage (Chapters 6 and 7)
- assessing the business case (Chapter 8)
- conducting a wider appraisal of the options (Chapter 9)
- an alternative urban planning approach to the assessment of city applications (Chapter 10)
- microsimulation of detailed designs (Chapter 11)

It is to be hoped that these tools, and the case study examples, will be of assistance to other cities contemplating the application of new technologies. Further information on any of the material in this Manual can be obtained from Dr. Tom Voge (tom.voge@tmleuven.be).

13 REFERENCES

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CityMobil Deliverable D2.4.1: Generic Analysis Tool for Business Cases.

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