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CityMobil

Towards advanced transport for the urban environment

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Part IV: The contribution of Automated transport to Urban Sustainability – Results from the CityMobil project

1 Introduction

1.1 Background

CityMobil is a 5 year major research, development and demonstration project conducted within the 6th framework for research and development of the European Commission. It addresses the integration of automated transport systems in the urban environment.

In 2011 the CityMobil project has been finished. CityMobil has demonstrated the potential of advanced transport systems to contribute to sustainable development in real size demonstrations and developed scenarios and simulation tools for their assessment.

This report is the main result of the final CityMobil Work Package (WP) 5.4: Assessment of Automated Road Transport Systems contribution to Urban Sustainability. WP5.4 has been one of the last running WP of the project, has gathered inputs from other CityMobil sub projects and WP's and concludes the CityMobil project by stating whether and under which conditions the advanced transport systems investigated will contribute to reaching urban sustainability. The WP has described a vision and roadmap to urban transport sustainability through the progressive adoption of advanced transport for urban environments. It draws the lines of further development of road transport automation.

1.2 Objectives

The Primary objective of this work package is to answer the question: Would transport automation increase urban sustainability? This objective encompasses several sub-objectives. They are to assess:

- whether automation could contribute to urban sustainability;
- under which conditions automation could contribute to urban sustainability;
- on what time scale could automation could contribute to urban sustainability and how will sustainability be improved as a result of the implementation of automated transport in the urban environment?
- how will sustainability be improved as a result of the implementation of automated transport in the urban environment?

1.3 Structure

The main purpose of part IV of this report is to provide the complete overview and main results of City Mobil. The results are summarised in Part I of the report which forms the basis for the vision and roadmap as presented in parts II and III.

Part IV starts with a chapter introducing the CityMobil project. It describes the context of sustainability, automated transport and how CityMobil has been set up to address the main question how automated transport could contribute to urban sustainability. The following chapters of part III follow the project structure of the CityMobil project. Chapter 3 describes sub project 1: demonstrations. In this chapter the plan and evaluation of the three demonstrations in Heathrow, Castellon and Rome are being described.

Following chapter 4 describes the results of the future scenarios and potential applications scenarios from sub project 2.

Chapter 5 focuses on sub project 3, the conditions under which automated transport could be deployed such as operational, legal and user issues.

Finally chapter 6 goes into the results of the evaluation project. The results of the evaluation work performed in the project are being presented.

2 Advanced transport for urban sustainability

2.1 What is sustainable mobility?

Sustainability or Sustainable development has been commonly defined as "Economic and social development that meets the needs of the current generation without undermining the ability of future generations to meet their own needs" (WCED, 1987). This definition brought together what is now known as the three pillars of sustainable development; economic development, social development and ecological development under one societal goal of sustainability. The TRANSLAND project conceptualised the tensions and interactions between the pillars as shown in Figure 2-1.

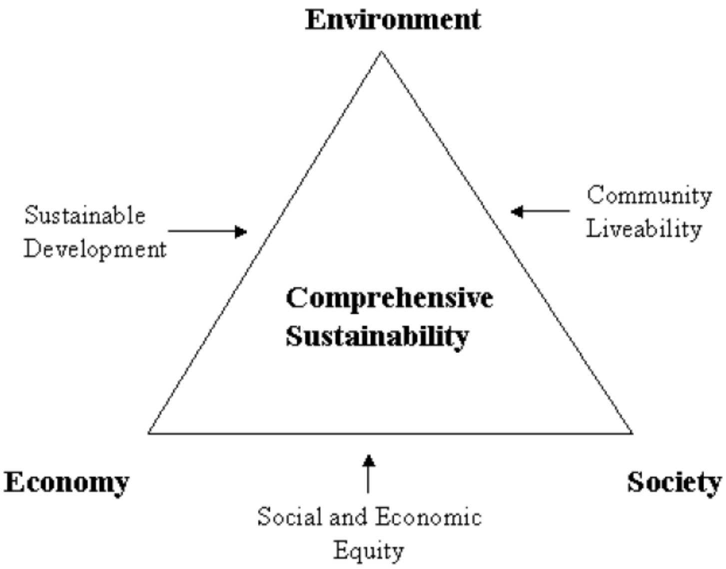

Figure 2-1: Comprehensive sustainability (Source Transland (2000))

Whilst many definitions of sustainable development and sustainable transport exist, the Council of the European Union (2001) has adopted a working definition that guides the development of much of the evaluation framework presented in this document (Figure 2-2).

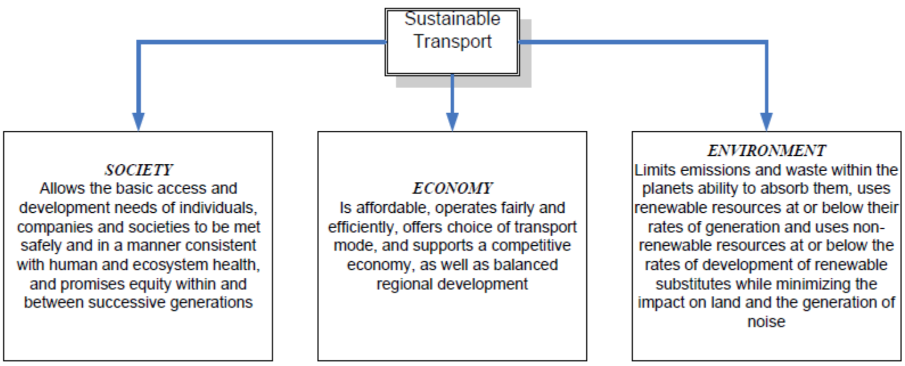

Figure 2-2: Sustainable Transport Definition (Source: Council of the European Union (2001))

2.1.1 Society or 'People aspects'

Mobility and transport are so called enablers. They enable social and human needs (as described by Maslow and Max-Neef (ref.!)) and are essential for well being and economic development. Public transport enables social interaction and provides access to education, employment, health care and social-cultural facilities.

In highly developed society most functions and facilities are concentrated in the spatial structure, thus activities and spaces are spread. These facilities have to be well accessible in terms of travel time and travel time reliability, travel costs, safety and physical accessibility.

These conditions are not absolute and unchangeable, but relative to cultural values and communities. Besides general conditions regarding mobility and transport the aspect of 'equity' (prevention of (social/economic) exclusion) that sets conditions for the accessibility of transport system – especially the public transport system – for children, the elderly, people with a disability and for non car owners and low incomes.

As mobility and the transport system are enablers, they are causing negative effects at the same time such as traffic safety and noise hindrance that affect social well being.

2.1.2 Economy or 'Profit aspects'

The 'profit' or 'prosperity' means that the economical structure has to be durable: it has to continuously – now and in the future – enable social and economical wellbeing. Starting from the point of mobility and transport as enabler for economic system, the system has to be able to effectively process or transport persons (consumers, employers) and freight (fuels, components, half products, etc.) against reasonable financial costs (efficiency), with an acceptable level of reliability and flexibility.

The quality of the transport system can be seen from the point of view of a location (the accessibility for persons and freight), the connecting infrastructure (capacity, chances of congestion) and the user (chains of nodes and links).

2.1.3 Environmental or 'Planet aspects'

The ecological or planet side of sustainability cover many aspects that can be influenced by the mobility and transport system:

- Air quality such as emissions of acidifying pollutants (nitrogen oxides - NO_x, sulfur dioxide - SO_2), substances that are directly harmful to health or through atmospheric reactions (e.g. ozone formation) lead to poor air quality (such as hydrocarbons - HC / VOC / PAH, particulate matter - including PM_{10}, lead - Pb);
- Soil and water quality through deposition of acid rain or air emissions of e.g. NO_x and SO_2, using rainwater to run off and pollution of heavy metals other environmentally harmful substances, the leakage and discharge of harmful substances - for example accidents and transport of pollutants from road, rail, inland and marine, and pollution when disposing of equipment;
- Traffic noise caused by propulsion systems (engines), noise caused by handling and loading / unloading activities - leading to a distortion of nature and / or health;
- Climate, influenced by emissions of greenhouse gases: carbon dioxide - CO_2 – by burning of fossil fuels, methane - CH_4 - through exhaust or leakage use of natural gas as fuel and indirectly through emissions from agriculture (for production of biofuels), nitrous oxide - N_2O - from exhaust gases (e.g. by transformation processes in catalytic converters) and as emissions from agriculture (production of biofuels), fluorinated gases (for the transport in question is especially HFCs, used as refrigerants in air conditioners are used) and emissions of water vapor in higher layers of the atmosphere by aircraft (airtrails);

- Use of finite reserves of natural resources (and the effects of excavation), such as fossil fuels (especially petroleum for transportation), ores steel, aluminum as well as precious metals like platinum for fuel cells).

2.2 Sustainability aspects in CityMobil

The particular focus of CityMobil lies on the *urban* transport system. The objective of the CityMobil project is to achieve a more effective organisation of urban transport, resulting in a more rational use of motorised traffic with less congestion and pollution, safer driving, a higher quality of living and an enhanced integration with spatial development.

2.2.1 Societal (people)

CityMobil will contribute by offering economic and flexible mobility solutions to businesses and individuals and by reducing the negative implications of increasing mobility. By being efficient, economic, safe and comfortable, the CityMobil solutions will contribute to a balanced society. CityMobil particular contributes to ‘people aspect’ by higher safety levels. At present most of the traffic accidents are caused by humans. Technology is only responsible for less than 10% of all accidents. By taking the human driver completely or partly out of the loop safety levels can be considerably increased.

2.2.2 Economical (profit)

CityMobil will contribute to solutions that will allow increased mobility in a well-controlled manner, with systems with low pollution, high safety levels and a much increased efficiency, using separate infrastructure or even the existing roads. Automation will enable transportation of more people and goods over the same infrastructure in a given time. This will bring congestion levels in cities down and increase the quality of the transport systems.

2.2.3 Environmental (planet)

The transport concepts to be developed and implemented in CityMobil are intended to decrease congestion by a more efficient use of the existing space, decrease pollution by the use of reduced-emission or emission free propulsion systems and decrease energy consumption by efficiency measures and demand management systems. The systems that will be introduced will have low or zero emission propulsion systems, thus lowering the impact of exhaust gases on the city environment.

A major point of attention in CityMobil is the integration of transport solutions with spatial development. Issues of land use and transport planning will be addressed by CityMobil in a total package together with technological, operational and legal issues. CityMobil will contribute to city environments where the scarce space is used as efficiently as possible and where transport solutions are not a source of safety problems and irritation, but a contribution to a better quality of life.

2.3 Advanced transport

The five definitions that are used within CityMobil are the following:

- **CyberCars (CC)**: small autonomous vehicles for individual or collective transportation of people and goods, for specific areas such as city centres with little or no interaction with other (manual) vehicles.
- **High-Tech Buses (HTB)**: buses on rubber wheels, operating like a tram on lanes with a light infrastructure using electronic guidance either for automation or for driver assistance.
- **Personal Rapid Transit (PRT)**: small fully automatic vehicles operating on guide ways to segregate them from pedestrians and other traffic.

- **Advanced City Vehicles (ACV)**: new city vehicles integrating zero or ultra-low pollution mode and driver assistance such as ISA (Intelligent Speed Adaptation), parking assistance, collision avoidance, stop&go, etc. These vehicles should also incorporate access control coupled with advanced communications in order to integrate them easily into car-sharing services.
- **Dual-mode vehicles (DMV)**: developed from traditional cars but able to support both fully automatic and manual driving. The first applications of automatic driving will be for relocation of shared cars using platooning techniques but these vehicles could become full CyberCars in specific areas or infrastructures. Dual-mode Vehicles represent the migration path from traditional cars to automatic driving.

2.3.1 Dual mode vehicle & Advanced city car

Advanced City Vehicles always have the following characteristics in common:

- Advanced City Vehicles are small vehicles, developed for use in urban areas
- Advanced City Vehicles are equipped with advanced electronic systems for driver assistance or for fully automatic operation

Advanced City vehicles can have the following characteristics in each possible combination:

- Zero or ultra-low pollution mode
- Driver assistance such as ISA (Intelligent Speed Adaptation), parking assistance, collision avoidance, stop&go, etc.
- Access control coupled with advanced communications in order to integrate them easily into car-sharing services
- Technology to enable both fully automatic and manual driving. In fully automatic mode Advanced City Vehicles operate as CyberCars
- Advanced City Vehicles can be either part of the public transport system or private vehicles

2.3.2 High tech bus

High Tech Buses are buses on rubber wheels, operating more like trams than like traditional buses.

High Tech Buses have the following main characteristics:

- High Tech Buses are vehicles for mass transport [>20 persons]
- High Tech Buses use an infrastructure, which can be either exclusive for the buses or shared with other road users
- High Tech Buses can use various types of automated systems, either for guidance or for driver assistance or for other purposes
- High Tech Buses always have a driver, who can take over control of the vehicle at any time, allowing the vehicles to use the public road

2.3.3 Cyber car

CyberCars are small automated vehicles for individual or collective transportation of people or goods. CyberCars have the following main characteristics:

- CyberCars are fully automated, meaning that under normal operating conditions no human interaction is needed
- CyberCars can either be fully autonomous, or make use of information from a traffic control centre, information from the infrastructure or from other road users

- CyberCars are small vehicles with a capacity of maximum [20] persons or a
- CyberCars can either use a separated infrastructure of a shared space. In theory there can be interaction with other road users, but the present state of the art limits the use to specific areas such as city centres with little or no interaction with other road users

2.3.4 Personal Rapid Transit

Personal Rapid Transit (PRT) is a transport system featuring small fully automatic vehicles for the transport of people.

- PRT has the following main characteristics:
- PRT operates on its own exclusive infrastructure. There is no interaction with other traffic.
- PRT is fully automated, meaning that under normal operating conditions no human interaction is needed
- PRT vehicles are small with a capacity usually limited to [4-6] persons per vehicle
- PRT offers an on-demand service, where people are transported from station to station without changing vehicles or without waiting time.

2.4 CityMobil: Towards advanced transport for the urban environment

2.4.1 General project approach

The objective of the project has been defined as follows:

CityMobil will achieve a more effective organisation of urban transport. This will result in a more rational use of motorised traffic resulting in:

- *less congestion and pollution;*
- *safer driving;*
- *higher quality of living*
- *enhanced integration with spatial development.*

The problems of mobility in cities are clear. However, the possible solutions are still in their infancy. A shift from the private automobile to a multi-modal approach is the preferred trend. Here we can think about buses, trains, metros and other individual transport modes or a combination of these. We must recognise the need for both high speed scheduled mass transport as well as individualised on-demand short distance transport. This is why we have to test and evaluate new solutions based on advanced city vehicles. At the end of the project, we will have a better understanding of the capabilities of new technologies and what the expected gains can be. There will be proposals for certification of advanced transport systems on a European level. Tools will have been created to disseminate the project results.

The CityMobil approach has been broke down into demonstration, research and evaluation projects. For the division in subprojects the set-up as given in figure 2-3 is used. The vertical columns contain the demonstrations that form separate sub-projects. The general requirements are represented by a number of horizontal lines that represent the horizontal sub-projects. The demonstrations generate a number of questions that together with the general issues are input for these horizontal sub-projects.

General issues	Sub-project		Heathrow Demon-stration	Rome Demon-stration	Castellón Demon-stration
	1	Demonstrations			
	2	Future scenarios			
	3	Technological issues			
	4	Operational issues			
	5	Evaluation			

Figure 2-3: Relation sub-projects in CityMobil project

2.4.2 Evaluation framework

The overall framework for evaluation is broken down by a series of evaluation categories. The evaluation categories are steered by both the objectives of transport policy as a whole and the objectives of stakeholders wishing to understand the success of actual implementations. The evaluation framework has been used to setup ex-ante and ex-post evaluations of the demonstrations, showcases and city studies. The results of evaluation studies are being presented in chapter 6.

“The objectives, or goals, to be pursued form a key dimension of transport policy. When those responsible for transport policy state a set of objectives, they define the direction to be taken by transport policy, which includes imposing constraints with regard to what transport policy should avoid, and they provide a benchmark against which to measure the success of transport policy, both in terms of appraisal and monitoring” (Kallionen et al., 2004, 11).

The TIPP project recently compared policy objectives at a local, national and European level concluding that the following set of objectives capture those most commonly applied within the EU for transport policy making:

- Efficiency
- Environment
- Safety
- Equity
- Economic development
- Future generations

Other objectives such as regional development, urban development, accessibility, health, integration and explicit objectives for freight were either only used sporadically, inconsistently applied or considered by inference through other objectives” (May et al., 2005, 14).

This overarching set of objectives is consistent with the sustainability goals of the project. However, these broad policy objectives do not serve to directly evaluate the acceptance, operational performance and implementation impacts that are required for CityMobil evaluation and recommended in MAESTRO and CONVERGE. The full list of evaluation categories is therefore:

- Acceptance
- Quality of service
- Transport patterns
- Social Impacts
- Environment
- Financial Impacts
- Economic
- Legal impacts
- Technological success

A set of 64 Indicators was defined in the evaluation framework (D5.1.1) in order to help interpreting in a quantitative way the behaviour and the benefits of the several systems and scenarios implemented or modelled in the CityMobil project. These indicators are hierarchically grouped into 30 Impact Categories and, at an upper level, in 9 Evaluation Categories.

Indicators were selected first based on their importance to understanding their importance to the evaluation and secondly to their likely practicability from either a measurement or modelling perspective. Further indicators were then reviewed and added in consultation with project partners to ensure a full and balanced coverage. The indicators are listed in below in Table 2-1. There are 64 indicators in the list. This can be viewed as the complete envelope of overarching indicators which could form part of the evaluation of each of the different elements of CityMobil.

Table 2-1: Passenger evaluation categories, impacts, and indicators

Evaluation Category	Impact	Indicator
Acceptance	User acceptance	Usefulness
		Ease of use
		Reliability
		User satisfaction for the on demand service
		Integration with other systems
	Willingness to pay	User willingness
		Authorities willingness
Quality of service	Information	Availability
		Comprehensibility
	Ticketing	User satisfaction
	Cleanliness	Perceived cleanliness
	Comfort	Perceived comfort
	Privacy	Perceived level of privacy
	Perception of safety and security	Perception of safety
		Fear of attack
Transport patterns	Modal change	Induced mode changes in the other segments of the journey
		System modal share

Evaluation Category	Impact	Indicator
	System use	Total passenger·km travelled
		Total N° of trips
		Vehicle occupancy
	System performances	Average Journey time per OD pair
		Journey time variability
		Total delay per/trip
		Average Waiting time
		Waiting time variability
		Interchange time
		Effective system capacity
Social Impacts	Spatial Accessibility	Change in range of key activities accessible within time thresholds
		Distribution of accessibility changes by social group
	Service Accessibility	Access times for mobility impaired users
	Safety	Accident levels
		Incidents
		Driver workload
Environment	Energy	Daily consumption (KWh)
		Energy Efficiency (KWh/pkm)
	Toxic emissions	NO_x
		PM_{10} and/or $PM_{2.5}$
		CO
	Climate Change	CO_2
	Noise	L_{DEN} and L_{night}
	Land take	Loss of green space from construction
		Total land use change
Financial impacts	Start up costs	Track construction and civil works
		Vehicle acquisition/construction
		Control systems and apparatus
	Operating costs	Personnel
		Vehicle maintenance
		Track and civil infrastructures maintenance
		Control system maintenance
	Revenues	Operating revenues
	Subsidies	Perceived public subsidies
Economic	Temporary job provided by installation and demonstration	Jobs provided at the demonstration site
		Jobs increase induced at the manufacturers
	Long terms effects on jobs	Local effects on employment

Evaluation Category	Impact	Indicator
		Non local effects on employment
	Vitality	Footfall within defined area
		Vitality index
	Efficiency	Net Present Value
		Internal Rate of Return
Legal impacts	Impacts on legal and regulatory framework	Induced regulation procedure changes
Technological success	Performance	Response time
		Accuracy
		Data updating delay
	Reliability	Failure rate

We do not anticipate that all indicators will be measured at all sites neither that it will be feasible for the modelling tools to necessarily produce all of the indicators. A sub-set list of core indicators that each demonstration site and citywide simulation should report on is given below in Table 2-2.

Table 2-2: Core indicators

Evaluation category	Indicator
Acceptance	User willingness to pay
Quality of service	Perceived level of safety
	Perceived performance
Transport Patterns	Mode Share
	Delay per passenger trip
	Journey time variability
Social Impacts	Access times for mobility impaired users
	Accident levels
Environment	Energy Use
	Toxic Emissions[1]
	Total CO_2
	Total Land-Use Change
Economic	Net Present Value
	Internal Rate of Return

[1] The most relevant toxic emissions for the local circumstances should be selected. It is expected that NO_x and PM_{10} will be the most common problem emissions.

3 Results of SP1: demonstrations, showcases and city studies

3.1 Introduction

In the first sub-project of CityMobil (SP1) the advanced concepts and tools are validated and demonstrated in a number of different European cities under different circumstances.

Therefore three large-scale demonstrators have been chosen which represent real implementations of innovative new concepts. These three innovative concepts will be implemented in the city of **Heathrow, Rome** and **Castellón**. The three cities were selected in the preparation phase of the project based on the assessment of technical feasibility, political support with Letters of Intent, a commitment to invest financially in the project and an availability of a local consortium consisting of public and private organisations, which had expressed commitment to the plans. Furthermore showcases and city studies are conducted in various cities of different European countries.

3.2 Demonstrations

Within the CityMobil project the aim was to develop three demonstrations of Automated Transport Systems. These were:

- PRT-system in London Heathrow, connecting terminal 5 with a business car park by means of a PRT system.
- High-Tech Bus system in Castellon, connecting the city centre with the campus by means of an automated steering bus.
- A CyberCar system on the parking lot of the newly built convention centre in Rome.

For evaluation both ad ex-ante and an ex-post measurement is necessary. Since the Rome demonstrator will not be finished in the duration of the project the results of the evaluation of Rome cannot be used in this documentation.

Due to a number of delays in the development of the Heathrow system, the ex-post measurement has been performed, but still needs to be translated into the evaluation framework. Therefore only the Castellon demonstrator will be used in this deliverable in our measurement to identify the contribution to urban sustainability.

3.2.1 Castellón

Eight different stretches are operating or going to operate in Castellòn. For each purposes, the Castellón demonstration is operating in two of the stretches since mid 2008. Three hybrid buses are operating in the first stretch, from the University to the city centre (UJI-parc Ribalta), while one electric mini-bus is operating in the second stretch, called calle Colón stretch.

The ex-post data collection was done for the stretch 1, reported in Figure 3-1**Fout! Verwijzingsbron niet gevonden.**.

Figure 3-1:Stretch 1 (UJI - Parc Ribalta) of the Castellón demonstration

The stretch is composed of five stops: University Jaume I (UJI), Sos Baynat, Riu Sec, Paseo Morella, Parc Ribalta. The total length of the stretch is 2 km per direction in two directions, meaning 4 km as total network length, and the distances between the stops are the following:

- UJI - Sos Baynat: 200 m;
- Sos Baynat - Riu Sec: 750 m;
- Riu Sec - Paseo Morella: 700 m;
- Paseo Morella - Parc Ribalta: 350 m.

The service along the stretch 1 is provided with 3 Civic Cristalis hybrid buses, operating from 7:30 a.m. to 10:30 p.m. during the weekdays, and from 7:30 a.m. to 10 p.m. on Saturdays, Sundays and holidays.

Data Collection

As reported in D1.4.5.1 the ex-post data of the Castellon demonstration have been collected through interviews to people who used the new high-tech bus system in the operating stretch 1 between the University Juame I and the Parc Ribalta (reported in Figure 3-1**Fout! Verwijzingsbron niet gevonden.**), interviews to the drivers of the high-tech buses, phone interviews to people travelling in Castellon, measurement on-field of the system parameters, and experts' opinions mainly about financial and economic impacts of the new system.

The users', drivers' and phone interviews have been collected in 2010 between February 16th and February 26th, including the weekend, while the measurements on-field were done in the period between June 26th, 2008 (date of start of the new system operations) and April 2009, and the experts' opinions were collected in the same period.

Concerning the users' interviews, 91 system users were interviewed after they used the system.

The indicators calculated through the results of such interviews were twelve of the Acceptance and Quality of service indicators (usefulness, ease of use, reliability, integration with other systems, information availability, information comprehensibility, user satisfaction, perceived cleanliness, perceived comfort, perceived level of privacy, perception of safety, fear of attack) and three of the Transport Patterns indicators (average journey time per OD pair, journey time variability, interchange time). For two of them (average journey time per OD pair, journey time variability) both the ex-ante and the ex-post values were calculated on the basis of the users' answers to the interviews.

Three drivers' interviews were collected, due to the fact that there were only 4 drivers working at the demonstration and only 6 drivers were been trained to drive the high-tech buses.

The indicators obtained through driver interviews are two Transport patterns indicators (incidents and driver workload) and all the Technological success ones (docking accuracy, failure rate, mean time between failures, mean time to repairs).

300 phone interviews were made, providing one Transport patterns indicator, the system modal share (the ex-ante value was collected in analyses reported in D1.4.5.2 and regarded the whole Castellon area).

Through the measurements on-field seven Transport patterns indicators (total passenger·km travelled, total number of trips, vehicle occupancy, total delay per trip, average waiting time, waiting time variability, effective system capacity), and seven Environment indicators (daily consumption, energy efficiency, NO_x, PM_{10} and/or $PM_{2.5}$, CO, CO_2, L_{den} and L_{night}) were calculated. Total passenger·km travelled were calculated using both the data of the measurements on-field and of the users' interviews. The ex-ante values of total passenger·km travelled and total number of trips were also calculated from the users' interviews results in accordance with the measurements on-field.

Eight financial impacts indicators (track construction and civil works, vehicle acquisition/construction, control system and apparatus start-up costs, personnel, vehicle maintenance, track and civil infrastructures maintenance, control system maintenance operating costs, operating revenues) and two economic indicators (net present value and internal rate of return) were obtained through measurements on-field and experts' opinion.

Indicator measurements and results

The indicators collected in the ex-post phase of the Castellon demonstration and their values are reported in the following Annex I.

For five transport patterns indicators (system modal share, total passenger·km travelled, total number of trips, average journey time per OD pair, journey time variability) the ex-ante values were also calculated and are reported in Annex I.

The ex-ante value of system modal share is the one reported in the deliverable 1.4.5.2, coming from the analyses of the “Transport Plan for Castellon and its surroundings” made by the Generalitat Valenciana in 2002. It is therefore referred to the whole Castellon area analysed in that transport plan.

The other four ex-ante values were obtained through the 91 users' interviews in accordance with the measurements on-field, thus they refers to the area interested by the system.

The ex-post values of the acceptance and quality of service indicators were obtained as the average values of the user satisfaction performances, in a ranking from 1 (worst performance) to 5 (best performance), as reported in the questionnaire used for the user interviews reported in the Annex A of D1.4.5.1.

Concerning the four user acceptance indicators collected, **usefulness** and **ease of use** are the best rated indicators, with 3.7 as performance rating. The service was also perceived as reliable and good integrated with the other systems, with both of the corresponding indicators (**reliability** and **integration with other systems**) rated 3.6.

With regards to the eight quality of service indicators measured, the information to use the system is available and comprehensible, with the corresponding indicators (**information availability** and **information comprehensibility**) both rated 3.8. The system was perceived as comfortable, safe, secure and with a high level of privacy, and the ticketing was quite good (the corresponding indicators **perceived comfort**, **perception of safety**, **fear of attack**, **perceived level of privacy**, **ticketing user satisfaction** being all rated 3.7), and the **perceived cleanliness** of the system was also satisfactory (3.6).

Concerning the transport patterns modal change indicators, **system modal share** ex-ante value is referred to the whole Castellon area, whereas the ex-post value, obtained through phone interviews, refers to the stretch 1 of the Castellon demonstration reported in Figure 3-1. Both ex-ante and ex-post values are 15%, meaning that the new system designed is able to attract the same amount of people within its potential users as the old public transport system was able on the whole Castellon area.

The system use indicators were calculated directly from the data collected on the field. Starting from the end of June 2008, when the stretch 1 of the Castellon demonstration was operating, until April 2009 the monthly passengers, vehicle trips and kilometres travelled were collected. About 467 000 passengers travelled in the period between the end of June 2008 and April 2009, meaning that the ex-post **total number of trips** were 1530 passengers/day. On the basis of the users' interviews, the ex-ante value was calculated by considering people using the old bus system in the same area, replaced by the new Castellon system. Such value is 1310 daily passengers, meaning that 220 new passengers have been attracted by the new system. 100 of them used the car before the system introduction, whereas the remaining 120 made their travels on foot.

The **total passenger·km travelled** were calculated on the basis of the modal split obtained through the users' interviews. In the survey of 91 users, 57% of them went from UJI to Parc Ribalta, 24% from UJI to Paseo Morella, 18% from Paseo Morella to Parc Ribalta, and only 1% from UJI to Sos Baynat. Considering the distances between the stops, the total number of daily passenger·km travelled obtained is 2210. The new system was built on a dedicated lane, specifically made for it. The bridge on the Riu Sec was built to allow the system to have a straight lane. It reduced the length of the old system route, which was 2.6 km long from Parc Ribalta to the University and vice-versa (the new system is 2 km per direction long). The ex-ante passenger·km value was calculated starting from the ex-ante value of the total number of trips, and considering the bus stops on the old route. The calculated value is 2370, meaning that further 160 passenger·km were travelled before the new system installation. It is due only to the fact that the distance covered by the old bus system was larger than the new system, and although the old system produced more passenger·km travelled, it attracted 220 daily passengers less than the new one.

The high-tech buses used to provide the service are three Civis Cristalis hybrid buses, each one with 80-place capacity. The 467 000 passengers were served with about 58 000 vehicle trips, meaning an average **vehicle occupancy** of 467 000/58 000 = 8 passengers/vehicle, 10% of the vehicle capacity.

Concerning the system performances, the **average journey time per OD pair** and the **journey time variability** were calculated directly from the users' interviews. The survey answers allowed to calculate such two indicators for four arcs of the network: UJI - Sos Baynat, where the time required for the journey was 2 minutes and no variability was available, UJI - Paseo Morella, with 8 minutes journey time and 2 minutes and 25 seconds variability, UJI - Parc Ribalta, with 12 minutes journey time and 5 minutes variability, and Paseo Morella - Parc Ribalta, with 4 minutes journey time and 3 minutes variability. All such values are valid for both the directions. They showed an improvement to the ex-ante values (calculated on the basis of the interviews too), where the average journey times per OD pair were twice the ex-post values and the journey time variability was always higher than the ex-post ones.

Interchange time was also calculated from the users' interviews and was 2 minutes and 40 seconds.

Total delay per trip is 0 because the system works on dedicated lanes, thus travel time is always near the minimum time required to cover the single OD pairs.

The **average waiting time** was provided in the same period of the measurements on-field (June 2008 - April 2009), and taken directly from the scheduled service hours. It changed according to the different days. In the school days the waiting time was 5 minutes from 7:30 a.m. to 9:30 a.m. and 8 minutes from 9:30 a.m. to 10:30 p.m.. In the no-school days the waiting time was 8 minutes for the whole service, from 7:30 a.m. to 10:30 p.m.. On Saturday the waiting time was 15 minutes for the whole service (from 7:30 a.m. to 10 p.m.), and on Sunday and holidays 30 minutes for the whole service (from 7:30 a.m. to 10 p.m.).

The **waiting time variability** was 0 as for the total delay per trip.

The **effective system capacity** was calculated directly from the average waiting time: 960 passengers/hour on school days from 7:30 a.m. to 9:30 a.m., 600 passengers/hour on school days from 9:30 a.m. to 10:30 p.m. and on no-school days, 320 passengers/hour on Saturday and 160 passengers/hour on Sunday and holidays.

The two safety transport patterns indicators measured, **incidents** and **driver workload**, were obtained through the drivers' interviews. Concerning the incidents, the interviewed drivers reported that the vehicles seldom had incidents from the start of the operations of the system. The driver workload required was the same required for a conventional system.

The seven environment indicators measured were calculated through measurements on-field. The Civis Cristalis hybrid bus energy consumption is 2.65 kWh/km; in the measurement period the buses travelled about 123 000 km, meaning 372 km/day. Therefore the **daily consumption** was 2.65·372 = 986 kWh.

The **energy efficiency** was obtained directly as the ratio between daily consumption and total passenger·km travelled, and was about 0.44 kWh/p·km. Such value is half the value of the U.S. conventional buses, 0.88 kWh/p·km (according to *Transportation Energy Data Book: Edition 29*), but however higher than the value of the U.K. conventional buses, 0.33 kWh/p·km (according to Lowson, 2003). It is mainly due to the low occupancy of the vehicles in Castellon, 10% in average. For example, if the average occupancy was three times larger than the actual one (meaning 30%), the energy efficiency of the high-tech buses would become about 0.15 kWh/p·km. To improve the system energy efficiency is another goal of the system, and it can be obtained by attracting more people to the system use.

The Civis Cristalis did not produce noxious emissions in loco, thus **NO_x**, **PM_{10} and/or $PM_{2.5}$**, **CO**, **CO_2** were calculated according to MEET project, *Methodology for calculating transport emissions and energy consumption*. The emissions from the production of electricity in Spain in 2010 are: NO_x =0.75 g/kWh, PM_{10} and/or $PM_{2.5}$=0.1 g/kWh, CO=0.06 g/kWh, CO_2=390 g/kWh (according also to http://epi.yale.edu/). Starting from these values, the daily production of noxious emissions of the system are NO_x =740 g, PM_{10} and/or $PM_{2.5}$=99 g, CO=59 g, CO_2=385 kg. According to the data collected during the first ten months of the system operations from the end of June 2008 to April 2009, about 400 daily km were travelled by the buses, meaning that the daily noxious emissions per km were: NO_x =1.84 g/km, PM_{10} and/or $PM_{2.5}$=0.25 g/km, CO=0.15 g/km, CO_2=960 g/km. Comparing such values with those reported in Alessandrini and Persia (2001), the best improvement due to the high tech buses is that concerning NO_x, which are about ten times lower than the value of 11.55 g/km measured for such hybrid buses. CO is half the value of 0.30 g/km of those hybrid buses, whereas for the CO_2 the decrease is about 10% (960 g/km against 1082 g/km).

With regards to the noise, **L_{den} and L_{night}** were referred to the 96/20 EC limit for acoustic emissions. The maximum allowed value is 80 dB, and the Civis Cristalis noise emissions were 74 dB.

Concerning the financial impacts, obtained through the measurements on-field and the experts' opinions, **the track construction and civil works** start-up cost was about 19 000 000€. Such cost includes about 185 000€ for the design realization, about 740 000€ for the construction management and 4 000 000€ for the construction of the bridge on the Riu Sec river. The **vehicle acquisition/construction** start-up cost for the 3 Civis Cristalis buses used was about 2 600 000€ (7-9 further buses are foreseen to be used in the future development of the system, with a cost of about 7 000 000€), and the **control systems and apparatus** start-up cost for the optical guide was about 1 250 000€.

The operating costs were estimated on the basis of the correspondent start-up costs. Both **vehicle maintenance** and **control system maintenance** costs were calculated as 6% of the correspondent start-up costs, 158 000 €/year and 75 000 €/year respectively. Considering the scheduled service of the new system, 4 bus drivers were required, together with an operator for the system control, meaning a personnel of 5 employees. Considering a cost of 35 000 €/year per employee, a total **personnel cost** of 175 000 €/year was calculated. For the **track and civil infrastructures maintenance**, a cost of 30 000 €/year was included to consider the network management (bus stops, road signals, etc.).

The **operating revenues** of the system were calculated considering two terms, the first made of the user ticket revenues, and the second due to the mileage cost of the old bus system, which can considered as a benefit due to the correspondent money saved.

Different kinds of ticket are available for the Castellon public transport, including the new high-tech bus system: one-trip ticket (0.9€), 10-trip young ticket (5€), 10-trip ticket (6€), 30-day ticket (22€). Retired people and social workers do not pay to use the public transport. According to the data on the different tickets used to travel with the new system (18% of users with one-trip ticket, 53% with 10-trip young, 9% with 10-trip, 9% with 30-day, 7% retired people, 4% social workers), provided by the measurements on-field, about 290 000 €/year have been estimated as user ticket revenues.

The second term of the operating revenues was calculated by assuming 2.64 €/veh·km as mileage cost for a conventional bus. This cost has been obtained considering: 450 000 € bus investment cost, 0.5 €/km depreciation with 10 years as time horizon, 5 km/l bus consumption, 0.4 €/km fuel cost, 1 €/km driver cost, and 20% as overheads. The mileage of the old bus system was 237 veh·km/day (obtained by the ex-ante value of 2370 daily passenger·km travelled, with an average of 10 passenger per vehicle, as reported in the "Transport Plan for Castellon and its surroundings" for the old line replaced by the new system). With such figures, the annual revenues due to the money saved by using the new system instead of the old one are about 230 000 €.

The total annual operating revenues were therefore 520 000 €.

With such financial figures, the financial Cost-Benefit Analysis (CBA) of the new system was done. The cash-flows are:

- Start-up costs, spent one year before the service starting , 22 850 000 €;
- Operating costs, spent each year to run the system, 438 000 € growing each year according to an inflation rate set to 2.3% a year;
- Revenues, deriving from the user tickets and the deleted costs of running a conventional bus service, 520 000 € growing with the inflation rate each year as the operating costs.

The time horizon has been set to 20 years and the discount factor set to 2.0%.

The calculated **financial Net Present Value** (NPV) is about -21 000 000 € meaning that the municipality has to pay nearly 21 000 000 € to operate the new system during the 20-year time horizon. The correspondent **financial Internal Rate of Return** (IRR) calculated is -16%.

Together with the financial CBA, the socio-economic CBA of the new system has been done, in order to give a monetary value to the safety effects and to the environmental benefits due to the introduction of the new high-tech bus system, and to include such benefits for the community in the analysis of the system.

Concerning the safety monetization, considering the high-tech buses accident free (because they work on dedicated lanes) the benefits to account for in the socio-economic CBA are those due to the reduction of mileage of cars and conventional buses. According to the *Handbook on estimation of external costs in the transport sector*, the accident costs on the urban roads in Spain are 5.24 €/veh·km for passengers cars and 13.35 €/veh·km for heavy duty vehicles, in which the buses are included. The car mileage reduction was 113 veh·km/day, and the bus mileage reduction was 237 veh·km/day. With such figures a benefit of about 1 360 000 €/year has been calculated.

Two kinds of environmental benefits have been considered here: the reduction of noxious emissions due to the reduction of circulating polluting vehicles and the benefits due to a better use of the resources.

The pollutant emissions are produced by cars and conventional buses. According to the *Handbook on estimation of external costs in the transport sector*, the costs associated to passenger cars with displacement between 1.4 and 2 litres on urban roads are 0.1 €/veh·km for petrol cars and 0.4 €/veh·km for diesel cars in EURO5 class, whereas the cost associated to heavy duty vehicles with mass between 16 and 32 tons in EURO5 class is 2.7 €/veh·km. Considering the mileage reductions used in safety monetization and the car mileage reduction equally divided among petrol and diesel cars, a noxious emission reduction benefit of 241 000 €/year has been calculated.

The external costs associated to resource consumption are, according once again to the *Handbook on estimation of external costs in the transport sector*, 0.7 €/veh·km for a car, 0.2 €/veh·km for a bus and 0.01 €/veh·km for an high-tech bus. Applying these values to the mileage reduction for cars and buses and to the mileage of the new high-tech buses (276 veh·km/day), a 45 000 €/year energy assessment benefit has been obtained.

No direct benefits on the users were considered, because to calculate the time and costs saved by the users by shifting from the conventional bus to the high-tech bus was not possible.

The socio-economic CBA was therefore made following the same procedure of the financial one adding the safety, energy and environmental benefits to the calculation as if they were a real cash-flow. Considering these benefits in the NPV calculation as any other benefit, increasing them each year with the inflation rate, the **socio-economic Net Present Value** obtained is about 12 000 000 € with 20 year time horizon. Such value means that the new system is socio-economically viable and that that the community would benefit in its installation. The break-even point of the system is before the end of the fourteenth year of operations, when the socio-economic NPV become positive. The correspondent **socio-economic Internal Rate of Return** calculated is 6.5%.

The technological success indicators were all calculated through the driver interviews. The **docking accuracy** was measured by using a ranking from 1 to 5 as for the acceptance and quality of service indicators, and the value obtained is 3, meaning that it was considered as sufficient by the drivers.

The **failure rate** was calculated considering each correction of the automatic driving as a failure. It means that the system had not real failures, only needs sometimes a manual correction of the automatic driving. One correction was needed each 2-3 travels, meaning a **mean time between failures** (corrections) of one hour and half. Repairs were not needed, thus no **mean time to repairs** was required.

3.3 Showcases

The showcases that were organised had the goal to show for a relatively short period of time in a city the effects of running around with CyberCars on the public roads showing the capability of the technique.

3.3.1 Daventry

For the Daventry showcase the ex-post User Acceptance survey was performed by investigating the opinion of users that physically experienced the innovative transport system. The users' impressions were collected by following an Acceptance Questionnaire drafted according to the instructions provided by the CityMobil Evaluation Framework (D5.1.1). All these indicators were surveyed in terms of both **weight** and **performance rating**. This approach allowed a more complete analysis of the system User Acceptance.

The situation of the indicators is reported in **Fout! Verwijzingsbron niet gevonden.**. The surveyed indicators are marked with a "✓". For the weight-related questions the interviewed people were asked to order the indicators according to their importance (1= highest weight). For the performance-related questions the opinion was given in terms of level of satisfaction (1=completely dissatisfied, 2= somewhat dissatisfied, 3= fairly satisfied, 4= very satisfied, 5= completely satisfied). In order to quantify the "User willingness to pay" indicator, the question about the perceived level of performance was done asking the precise range of money the user would be available to pay for one run.

Table 3-1: Daventry surveyed indicators

Evaluation Category	Impact	Indicator	Weight	Ex-post performance rating
Acceptance	User acceptance	Usefulness	✓	✓
		Ease of use	✓	✓
		Reliability	✓	✓
	Willingness to pay	User willingness	✓	✓
Quality of service	Comfort	Perceived comfort	✓	✓
	Perception of safety and security	Perception of safety	✓	✓
		Fear of attack	✓	✓

A total of 63 interviews were performed. In the following pictures the distribution of the sample is shown, according the different available characteristics of the interviewed people.

The following **Fout! Verwijzingsbron niet gevonden.** reports ranking and ratings averaged on the whole interviewed population. The numbers reported on the table have the following meaning:

- As for the **Ranking** values obtained for the different indicators, the average value was provided as a scale of importance, from the most important (1) to the less important. The values from 1 to the maximum were obtained by classifying the averaged values of the collected ratings.
- The weight is derived from the Ranking; it is the complement to 4, for the acceptance indicators, and to 3, for the quality of service indicators, of the average indicator ranking.
- As for the indicators **performance rating**, the value is the average of the single ratings given by the users (1 to 5 out of 5). Also the user willingness to pay was reported as the average range.

Table 3-2: Weights and performance ratings for the Daventry indicators

Evaluation Category	Impact	Indicator	Ranking	Weight	Ex-post performance rating
Acceptance	User acceptance	Usefulness	2	2.905	3.5/5
		Ease of use	1 (most important indicator within this Ev.Category)	2.937	3.1/5
		Reliability	3	2.429	3.5/5
	Willingness to pay	User willingness	4 (less important)	1.730	Between 1 and 2 €
Quality of service	Comfort	Perceived comfort	2	2.048	3.0/5
	Perception of safety and security	Perception of safety	1 (most important)	2.286	3.2/5
		Fear of attack	3 (less important)	1.667	2.9/5

This survey, though carried out on a small number of indicators and with a relatively small number of interviews, is of high value because includes the users opinion both in terms of ranking and performance of the system. This allows to have a complete picture of the actual perception of the potential users and therefore to address the corrective actions in order to enhance the system acceptance.

Regarding the results averaged on the whole interviews, the following comments can be made:

- within the “Acceptance” evaluation category, the “Usefulness” and “Ease of use” resulted as the most important, while a lower rating was assigned to the “Reliability” indicator. Although the performance ratings are very close (all within 3.1 and 3.5), it is interesting that the most important indicator is rated as the lowest performing; this can be interpreted as a request for improvements on this aspect.
- as for the “quality of service” indicators, the perception of safety is rated as the most important. Differently form the previous category, it is also the best

performing, but again all the indicators have performance values very close to each other (2.9 to 3.2 out of 5) . The “Fear of attack indicator” is weighted as the less important but is also the one with the lowest performance.

3.3.2 Trondheim - Norway

As an illustration of the method a safety analysis of the Trondheim Showcase has been executed. In principle a safety analysis using the Risk Reduction Method will be carried out on all of the CityMobil showcases and small demonstrations. The Trondheim showcase will be executed in August 2009. The site was visited and assessed on the 25th of March 2009.

The Risk Reduction Method analyses risk factors following various angles of view of the showcase setting such as the built-up area, the potential users and trespassers, objects in the neighbourhood, specific conditions of the environment and the used vehicles and hardware. Per aspect a number of general indicators are listed in tables. By a simple expert assessment as to whether or not a certain risk factor is relevant, the seriousness of the risk can be estimated and measures to mitigate the risk can be proposed. The risk is expressed in likelihood of occurrence of an event and the severity of the effect. Where appropriate a further technical analysis will be carried out, for instance to establish the effectiveness of braking systems or obstacle detection systems.

3.3.3 Vantaa – Finland

The Risk Reduction Method as described in the previous section appeared to be useful and practical when applying on the Vantaa showcase. The recommendations below are partly the results of the analysis as presented in the risk indicator tables, but also on the discussion with the various stakeholders that was the basis for completing the tables.

Recommendations:

1. In order to avoid contact between vehicles and the public, one of the following two situations should be valid at all times:
    a. All vehicles should be provided with an adequate obstacle detection system that stops the vehicle before an impact can take place.
    b. There should be someone monitoring each vehicle at all times, with a remote control to stop the system.
2. The responsible operator should stop the system if the area is too crowded to control the system. Regular users of the area should be warned one week in advance that the event is taking place (by means of signs).
3. There are events in the last week of the showcase. One event in the church and one event with music at the city hall. The responsible operator should monitor the situation and stop the system if the area is too crowded to control the system at those times.
4. The effect of the buildings etc. in the area on the GPS navigation system and the communication system must be checked carefully
5. An additional fence and signs are needed to prevent cyclists from entering the track at Vehkapolku crossing.
6. Stickers with the text ‘Automated Vehicle’ in Finnish will be put on the vehicles.
7. To avoid people crossing the track unnecessarily, it is advisable to have signs directing people which way to take for their different destinations.
8. When trucks have to cross the track the system should be stopped temporarily.
9. Users of the parking area near the Kindergarten (Kinka Asema) will be advised to use other parking places.

10. In the case of heavy rain, poor visibility or fog the system will be stopped
11. Some additional concrete barriers should be placed behind the tent.
12. It is advisable to move the pedestrian crossing about 10 meters towards the railroad station, in order to emphasize that the situation is not as usual.

3.3.4 Orta San Giulio - Ex-post

In the Orta San Giulio showcase five of the Acceptance indicators (usefulness, ease of use, user satisfaction for the on demand service, integration with other systems, user willingness to pay) and four of the Quality of Service indicators (perceived comfort, perceived level of privacy, perception of safety, fear of attack) were measured in the ex-post survey through specific questions. One indicator belonging to the Transport Patterns, system modal share, was also measured through the survey.

For all of them the ex-post evaluation was obtained through the questionnaire answers.

155 people answered the questionnaire after that they used the new system during the showcase.

The interviewed people were submitted to a set of 12 questions, subdivided in the following categories:

- The first 2 questions were related to the evaluation of the system in terms of acceptance and quality of service, and allowed to calculate the 9 acceptance and quality of service indicators. For each indicator the performance was measured by assigning a value from 1 to 5, in order to quantify the level of user satisfaction (where 1 means completely dissatisfied, 2 somewhat dissatisfied, 3 fairly satisfied, 4 very satisfied, and 5 completely satisfied), with the exception of the user willingness to pay, which is quantified through money rankings.
- The next 4 questions were about the transport habits and the reaction to the introduction of a system based on the Dual-Mode Vehicles, and allowed to calculate the system modal share indicator, by calculating the percentage of people willing to use the Dual-Mode Vehicles if they were available;
- One further question was free and concerning suggestions to facilitate the use of the Dual-Mode Vehicles;
- The last 5 questions were related to the users' main characteristics (age, gender, education, occupation, income).

10 indicators were therefore totally quantified in terms of ex-post evaluation, all belonging to the reference set provided in the evaluation framework of the CityMobil project. The ex-post evaluations of the 10 indicators measured through the Orta questionnaire are reported in **Fout! Verwijzingsbron niet gevonden.**.

For eight of the indicators (usefulness, ease of use, user satisfaction for the on demand system, integration with other systems, perceived comfort, perceived level of privacy, perception of safety, fear of attack) the evaluation was obtained as the average value of the user satisfaction performances, in a ranking from 1 to 5, as explained in the previous section 3.2.1.

As reported in **Fout! Verwijzingsbron niet gevonden.**, both the four acceptance and the four quality of service indicators showed similar values.

For all of them the values were reported including the second decimal place, thus allowing to show the best performing ones.

Concerning the acceptance indicators, three of them (usefulness, ease of use and integration with other systems) were evaluated about 3.7, whereas integration with other systems value was about 3.6.

Table 3-3 shows their values. Usefulness and integration with other systems are the best indicators, with 3.73 as performance rate. Ease of use is little less performing, with a rate of 3.70.

Table 3-3: Indicator evaluations in user acceptance survey of the Orta showcase

Evaluation Category	Impact	Indicator	Ex-post evaluation
Acceptance	User acceptance	Usefulness	3.73
		Ease of use	3.70
		User satisfaction for the on demand service	3.57
		Integration with other systems	3.73
	Willingness to pay	User willingness	2.20€
Quality of service	Comfort	Perceived comfort	3.60
	Privacy	Perceived level of privacy	3.55
	Perception of safety and security	Perception of safety	3.62
		Fear of attack	3.57
Transport patterns	Modal change	System modal share	82%*

* result obtained soon after people of the interviewed survey tested the dual-mode vehicles

User satisfaction for the on demand service is the less rated indicator, with 3.57 as performance rate. It has however a 0.16 gap from the two best rated indicators, meaning that the users were well-disposed to accept the new system in all of its characteristics, considering it as useful, easy to use and well integrated with the other systems and being at the same time satisfied by the on demand service.

With regards to the quality of service indicators, all of them were rated about 3.6, as reported in Table 3-3.

Perception of safety was the best performing, with 3.62. The system was also perceived as comfortable, with the rate of 3.60. The last two rated indicators, fear of attack and perceived level of privacy, was rated 3.57 and 3.55 respectively.

The quality of service was therefore evaluated as homogeneously satisfactory, with the average rate of 3.6 for the four indicators, and 0.07 as the difference between the evaluations of the best rated indicator and of the less rated one.

The fifth acceptance indicator, user willingness to pay, was evaluated by quantifying the money users would be willing to pay to use the public transport service.

Seven different answers were proposed in the questionnaire to quantify such money: 1) Nothing, 2) Less than 0.5€, 3) Between 0.5€ and 1€, 4) Between 1€ and 2€, 5) Between 2€ and 3€, 6) Between 3€ and 4€, 7) More than 4€.

More than 80% of the interviewed people were willing to pay more than 1€ to use the service: 32% would pay between 1€ and 2€, 24% between 2€ and 3€, 14% between 3€ and 4€, and 12% more than 4€.

People willing to pay less than 1€ was subdivided in: 10% between 0.5€ and 1€, 4% less than 0.5€ and 4% not willing to pay to use the system.

From the interviews' responses, people were generally willing to pay to use the service. To quantify the average value they would pay, the weighted average of the answers were done. For each one of the possible answers, the intermediate value of the range considered was assumed as the value to be paid (for example 1.5€ for the answer "Between 1€ and 2€", 3.5€ for the answer "Between 3€ and 4€"), with exceptions of the answers "Nothing", where the value 0 was considered, and more than 4€, where the value considered was 4.5€.

With such assumptions, the average value people would pay to use the service is 2.20€, as reported in **Fout! Verwijzingsbron niet gevonden.**.

The transport patterns indicator evaluated, system modal share, was calculated directly from the fourth and the fifth question of the questionnaire, regarding the mode of transport used at the moment by the interviewed people and the possibility to use the Dual-Mode Vehicle if they were available respectively.

The value obtained through the survey analysis was 82%, meaning that eight out of ten people would use a Dual-Mode Vehicle to his/her travels if they were available in Orta.

This outstanding value is due to the fact that people were interviewed soon after they had "touched" and "tasted" the new concept of vehicles presented in the showcase. They showed therefore to be completely well-disposed to accept the use of such new vehicles; even if the value obtained is larger than the real feeling of people, it is however a valid index of the good feelings of Orta people for the use of dual-mode vehicles instead of the conventional vehicles, thus providing a very good result for the future developments.

3.4 City studies

This section presents a brief description of the five case-study cities that were chosen for the analysis (Gateshead - United Kingdom, Trondheim - Norway, Vienna - Austria, Madrid – Spain, Uppsala - Finland), including some information about the cities and the schemes for the proposed new PT lines. Dual Mode Vehicles are assumed to be privately owned and not part of a public transport system and are modeled as being integrated into the existing fleet.

These cities have been selected to represent the types of variation in size, geography, economy and existing transport systems and problems, found in cities across Europe.

Concerning the first four cities mentioned (Gateshead, Trondheim, Vienna and Madrid), each of them was modeled within WP2.3 by using the MARS methodology according to the different scenarios contained in the evaluation matrix, in order to estimate the values for the set of indicators established in the evaluation framework (WP5.1). These scenarios include the combination of the four technologies (CyberCar – in the two environments “PT feeder” and “Inner city service”, Public Rapid Transit, High Tech Bus, Dual Mode Vehicles); two different grow rates (high growth, medium growth); under the implementation of some complementary measures or not. The schemes were modeled over a total of 30 years, with 2005 as the base year. In all cases the new technologies are introduced in 2010.

The same cities were submitted to the Business Case modeling within WP2.4 by applying the specific tool for the assessment of the Economic and Financial impacts.

Finally, these cities are the object of the VOLTair methodology application, which provides further useful information for the case-studies evaluation.

A consultation with the cities administrations completes the input to the evaluation activities of this work package.

A complete and more exhaustive description of the sites can be found in D2.3.1.

With regards to Uppsala, a PRT system is going to be made and will be analyzed. In this case only one scenario will be provided because it will not be modeled with MARS nor submitted to the business case modeling and to the VOLTair methodology application.

Trondheim (Norway)

Trondheim is a 150.000 inhabitants town, 30.000 of which are students. The city hosts the regional public administration, and is also a centre for commerce, though the number of industrial companies is limited. Most offices are located in the city centre. The topography of the city creates challenges for transport, making it difficult to connect the east and west parts of the city.

In 2006 the city closed down the toll ring after 15 years of operation. Public transport in Trondheim is served by a bus system with local and regional routes. There is also a tram line connecting the city centre, Byåsen, to a recreational area on the western side of the city. The map of bus routes also includes the tramline as line 1. The bus system has 42 lines that serve 1100 stops. On average there are 70.000 bus passengers daily. The bus system length is 787km in one direction. The modal share in Trondheim is 57.6% car, 10.8% public transport and 31.6% walking and cycling.

The schemes for **High tech bus** include services on major routes into the city centre, and a route linking the city centre to a key facility. The proposed routes for the high-tech bus schemes will make use of the existing public transport priority network. Currently there are intersections within this network where public transport is given priority over general traffic, either towards the city centre or away from it. Most of the buses towards the city centre will be aided by this priority system at the final stage towards the city centre, meaning a reduced travel time in the peak. The proposed high-tech bus routes will run for 3.3km from the west, 5.3km from the east, and 4.3km from the south. All the routes except for the University loop are main arterials towards the city centre.

As for the **PRT**, the schemes include a city centre network linking key facilities. The 18.5 PRT network includes a west-east line linking the two sides of the river and the city centre to the university campuses, and a north-south line linking the harbor to the city centre.

Two sets of schemes are to be designed for **Cybercar** – a city centre network, and feeder services in suburban zones linking to the existing public transport. The feeder system in the suburban zones will allow the bus routes to be simplified as the buses will not have to take detours to cover the whole area (most users will use the feeder to get to and from the bus stops) and will therefore reach the city centre more quickly.

Integrated ticketing between the bus and the feeder system is foreseen, as well as a coordination with their operational times.

Gateshead - Tyne and Wear (UK)

The Tyne and Wear region comprises five local authority districts – Newcastle-upon-Tyne, Gateshead, Sunderland, North Tyneside and South Tyneside. The urban conurbation of Newcastle and Gateshead will be the focus for the modelling work, with the other areas featuring in the external zones. Newcastle and Gateshead have populations of 259000 and 186000 respectively, of which around 66% and 64% are of working age.

Newcastle and Gateshead are adjacent with Newcastle located in the north of the River Tyne and Gateshead located in the south. The two cities are highly interdependent with intense commuting flows between the urban centres supported by an interconnected transport infrastructure. The majority of this is the Metro underground system, though the lines running

from just north of Gateshead town centre to the west and south are heavy rail track mostly used for regional services. The River Tyne acts as a geographical barrier between the two cities; several bridges serve various modes, however they tend to act as bottle necks.

The Tyne and Wear Metro system largely covers the central and eastern areas of Gateshead and Newcastle, but also links to Newcastle Airport located to the northwest of the city centre. The Metro is 74.5km long and has 59 stations.

The modal split in Tyne and Wear is approximately 6.5% rail, 16.7% bus, 64.5% car and 12.3% walking and cycling. On average each household in Tyne and Wear owns 0.78 cars, compared to the English average of 1.11 cars.

Three schemes for the **High tech bus** are planned, covering different zones. The route length range is 14 to 19 km each, with 5 to 7 stops 3 km distant to each other approximately. The first high-tech bus route runs from south-east to north-west along the A1 key route, a dual carriageway that experiences a large amount of congestion around the Metro shopping centre. The scheme includes a dedicated bus lane along both sides of the road. The second proposed high-tech bus route runs from Gateshead town centre, along the northern side of the River Tyne, up to Newcastle Airport. Although it is currently possible to travel by Metro from Gateshead to Newcastle Airport, the communities in the west of Newcastle are not served and the proposed schemes would address this. An additional bus lane would be added to the most congested sections on the route. The third proposed high-tech bus route runs from Rowlands Gill, along the south side of the River Tyne, to Gateshead town centre. This route would also link the Metro Centre and Teams, which is an area with a large amount of industrial activity.

The proposed **PRT** system includes one scheme, linking a number of key facilities, including the Metro Centre, Newcastle and Gateshead centres and the Newcastle Business Park. There is currently no river crossing to the north of the Metro Centre and it is proposed that this would be created for this scheme. The other crossings would make use of existing bridges. It is currently problematic to travel between the north and east of the cities, and this scheme would aim to in part address this.

As for the **Cybercar** system, the inner city scheme is the same as the PRT city centre network to enable direct comparison between the two modes. The three proposed suburban CyberCar schemes link to the existing public transport network (the Metro in this case). These schemes were all selected for locations where the existing public transport coverage is fairly sparse.

Vienna (Austria)

The city of Vienna has a population of 1.500.000 approximately, and steep increase in population is foreseen for the next decades. The city has a well developed and efficient public transport system consisting of LRT, metro, tramway and bus lines. The density of public transport stops is about 33 stops per km² built up land. Due to the good public transport system Vienna has a high share of public transport.

All the three proposed **High-tech bus** routes run on existing corridors of bus lines: the first one is positioned along the 48A bus line. The second route running on the same corridor as the existing 57A bus route. The third proposal for a high-tech bus scheme parallels the existing 59A bus line.

For the **PRT** schemes there are two proposals. The first is within a new development on the outskirts of the city, and the second is a city centre network.

The city of Vienna is currently in the process of developing a new high quality mixed use city district on the area of the former airfield “Flugfeld Aspern”. The master plan developed by Tovatt Architects & Planners has recently been approved by the city council. The “Flugfeld Aspern” will involve the 23 Viennese administrative districts and will be connected to the Viennese PT system by an extension of the metro line U2 and an extension of the tramway lines 25 and 26. The metro and tramway stations will be linked to several bus lines (the distance between the bus stops on the circular part of the bus lines is about 300 to 500 meters). The circular part of the bus would be replaced by the PRT system, with an average distance between the stops of about 200 meters and a total line length of about 3.5 kilometres.

The second line is planned to serve the city centre, also named Central Business District (CBD). In 2001 the Viennese central business district was home to 17056 residents and 101668 workplaces. More or less the whole district is a protected cultural heritage site and covers about 3 km². The city centre is well connected by public transport: within or very near to its boundaries there are 39 bus stops, 23 tramway stops and 14 metro stations. This gives a density of about 25 public transport stops per km². From nearly every location in the CBD it is possible to get to the next PT stop within 3 minutes walking. Within 5-6 minutes walking a metro station can be reached from more or less any point of the CBD.

The proposal for the case study of Vienna includes the following measures:

- make the whole CBD car free except on the ring roads “Ringstraße”, “Kai” and “frühere 2er Linie” and on the access roads to public garages,
- replace the existing feeder bus lines by a new PRT system.

The suggested PRT system has 49 stops. The total length of the network is about 11 km.

The city centre **Cybercar** network will mirror the proposed city centre PRT network to enable comparison between the modes.

Madrid (Spain)

Madrid currently has 6 million inhabitants, in an area of some 8030 km^2. Its population is distributed unevenly among the city and the outskirts.

The main problems related to traffic and air pollution are concentrated in the central city and its suburbs with high density of populations and activities.

Regarding mobility patterns, nearly 15 mill trips are made every working day in Madrid Region. One third of them are no-mechanized trips. The rest, 54.7 % are made on Public Transport, and rest on private vehicles. This means that 11 mill trips are motorised trips every working day.

Public Transport maintains a high modal share mainly on those trips linked to the CBD or the Inner City of Madrid. But those regarding relation between the outer parts of the region are mainly dominated by car.

Private transport is predominant in metropolitan trips. Also, motorcycles and taxis are the lowest demand, metro and urban bus are predominant in Madrid City and suburban bus and rail in metropolitan and regional trips.

Current PT scheme is mainly a radial scheme. There is a high density of public transport supply on the City, and good connections between the suburbs and the City Centre (radial Scheme). On remarkable issue is the current display of Metro Network that has been enlarged last year to new areas in the outskirts of the city, and also, incorporating some LRT systems on its network (more than 300 km).

The three public transport technologies have been modelled with the following schemes.

High-tech bus: this system is modelled as an enhancement of the existing bus system. It is assumed that new HTB services will substitute existing services through the defined corridors. Thus, trips made on HTB are included on those made by bus.

PRT: it is assumed that PRT systems will be used as a sole mode for those inner trips made on the area where the system is implemented or as a access or egress mean connected with the rail services. PRT system is operationally suitable for the inner city of Madrid as it is an area where car is being restricted more and more, and its street design does not permit to supply with a good surface transport system based on standard buses. If infrastructure scheme is not a limitation, a PRT system is propound to be included on the city centre linking main key facilities and public transport hubs as an extension of the current system.

Cybercar: in the inner city scheme this system has been modeled as an extension of the rail existing system. The same scheme as PRT is propound in order to compare same geographical schemes of transport systems. In the public transport feeder scheme the CyberCar is modeled as an enlargement of existing rail system. Four different schemes have been planned: the first in District Number 18 – Villa de

Vallecas, the second in the corridor of the highway A3 in the south-east of the city, the third in the Municipality of Boadilla del Monte and the fourth in the Municipalities of San Sebastian de los Reyes and Alcobendas.

Uppsala (Finland)

Uppsala is the capital of Uppsala County and the fourth largest city of Sweden with about 128000 inhabitants.

A PRT system is going to made in the Bolaenderna District, with the aim to reduce use of private cars and to enhance the use of the public transport in such area. Such system will also improve the service provided through the buses, which will be substituted by PRT.

The network proposed is 9.4 km long and single-track, with 16 stops and 130 circulating 4-place vehicles.

3.5 General Findings/Syntheses SP1

User Acceptance and Quality of Service

The user acceptance of the new systems proposed and tested through the CityMobil project can be showed by comparing the results of the sites in which the ex-post evaluation has been done.

Six surveys have been provided, of which five showcases (Trondheim, Vantaa, La Rochelle, Daventry, Orta San Giulio) and one demonstration (Castellon). Four of them (Trondheim, Vantaa, La Rochelle, Daventry) have been analyzed and compared in the previous deliverables D5.2.1a and D5.2.1b. However a global comparison with the two further ex-post evaluations reported in this document has been done, including a demonstration together with the showcases.

In **Fout! Verwijzingsbron niet gevonden.** all the indicators measured are reported, together with the performance ratings obtained by the surveys.

Four indicators have been collected for all the sites surveyed: usefulness, ease of use, perceived level of privacy, and perception of safety.

Three indicators have been collected in five of the six sites: user willingness to pay (not measured in Castellon), reliability and perceived cleanliness (these two not measured in Orta).

Integration with other systems and perceived comfort have not been measured in La Rochelle and Daventry, whereas user satisfaction for the on demand service has not been measured in La Rochelle, Daventry and Castellon (where the services are not on demand).

Fear of attack has been measured in Orta and Castellon, whereas information availability, information comprehensibility and ticketing user satisfaction have been measured only in Castellon.

Considering the average values of those indicators measured at least in four of the six sites, ease of use is the best perceived with an average value little less than 3.7. Good satisfaction value was obtained by usefulness, with more than 3.5 as average performance rating. Reliability, integration with other systems, perception of safety, perceived level of privacy obtained quite sufficient average values (little more than 3.4), even if in Daventry and Vantaa the systems were not considered as safe and with a good level of privacy. Perceived cleanliness and comfort close the ranking, with average values respectively 3.35 and 3.3.

The interviewed people were also well-disposed to pay to use the new systems in the five sites in which user willingness to pay has been measured. Considering a user willingness value in the middle of the ranges provided as answers (1.5€ for Trondheim, Vantaa and Daventry, where people answered between 1€ and 2€, and 2.5€ for La Rochelle where people answered between 2€ and 3€), the average value people would pay to use the services is little less than 2€.

As general conclusions, people were satisfied by the new ATS proposed. They evaluated them as useful, easy to use and reliable. The safety, the cleanliness and the level of comfort on the vehicles change on the basis of the system tested, and may be influenced not only by the kind of service (with or without a driver), but also by the kind of vehicles used to provide the service. In all the sites people would pay to use the new services proposed.

Table 3-4: Cross-comparison for the user acceptance indicators for the six ex-post evaluations (five showcases and one demonstration)

Evaluation Category	Impact	Indicator	Ex-post performance rating					
			Trondheim	Vantaa	La Rochelle	Daventry	Orta San Giulio	Castellon
Acceptance	User acceptance	Usefulness	3.1/5	3.3/5	3.8/5	3.5/5	3.7/5	3.7/5
		Ease of use	3.5/5	4.0/5	4.0/5	3.1/5	3.7/5	3.7/5
		Reliability	3.2/5	3.3/5	3.6/5	3.5/5		3.6/5
		User satisfaction for the on demand service	3.5/5	3.3/5			3.7/5	
		Integration with other systems	3.1/5	3.3/5			3.7/5	3.6/5
	Willingness to pay	User willingness	1 to 2€	1 to 2€	2 to 3€	1 to 2 €	2.20€	
Quality of service	Information	Information availability						3.8/5
		Information comprehensibility						3.8/5
	Ticketing	User satisfaction						3.7/5
	Cleanliness	Perceived cleanliness	3.7/5	2.9/5	3.6/5	3.0/5		3.6/5
	Comfort	Perceived comfort	3.1/5	2.8/5			3.6/5	3.7/5
	Privacy	Perceived level of privacy	3.5/5	2.7/5	3.8/5	3.2/5	3.6/5	3.7/5
	Perception of safety and security	Perception of safety	3.7/5	3.0/5	3.7/5	2.9/5	3.6/5	3.7/5
		Fear of attack					3.6/5	3.7/5

Transport patterns

The site of Castellon is the only one in which a lot of transport patterns indicators have been measured after the ex-post survey. As reported in section 3.1 of the present document, also five ex-ante indicators were available: system modal share, total passenger·km travelled, total number of trips, average journey time per OD pair, and journey time variability.

According to the indicators provided in the deliverables (D5.2.1a and D5.2.1b), comparisons were possible between Rome and Castellon for two indicators (total passenger·km travelled and total number of trips), and between Castellon and Orta San Giulio for one indicator (system modal share).

The total number of daily trips in the Rome demonstration is little more than 14000, whereas in Castellon it was more than 1300 with the conventional bus (ex-ante phase) and more than 1500 with the new high-tech bus system (ex-post phase). The large difference between Rome and Castellon values is due to the different services provided. In Rome the 20-place CyberCars serve the P1 car-park (containing about 3000 cars) during the exhibition days, taking people from the slots in which they parked their cars and from the train station and keeping them to the exhibition building entrance (and vice-versa). It is a parkshuttle service. In Castellon both the 80-place old buses previously used and the actual 80-place new high-tech buses make a public transport service between the University campus Juame I and the zone of Parc Ribalta.

Even if the network lengths are similar at the moment (2.2 km per direction in Rome, 2 km per direction in Castellon), the different kinds of service generate such large difference in the total number of trips.

However, the difference between the total number of daily passenger·km travelled is less evident: about 3300 passenger·km have been calculated ex-ante for the Rome demonstration, whereas for the Castellon demonstration they were little less than 2400 before the new system and more than 2200 with the new system. Such difference is due to the fact that the average passenger journey in Rome demonstration is 0.2 km for people coming to the exhibition building by car and 0.4 km for people coming by train, whereas in Castellon it was about 1.8 km before the new system introduction and it is about 1.4 km with the new system.

Concerning the system modal share, the value obtained in the Orta showcase (82%) was very different from the value obtained for the Castellon demonstration (15%). As reported in section 3.2, the high percentage of people willing to use the new system in Orta indicates the good feeling of people for the innovative concept, but it is also due to the fact that they were interviewed soon after testing and "touching" the system. The value obtained in Castellon indicates that the new system produces good results, because the 15% percentage measured is about the same value measured in the ex-ante analysis (reported in the deliverables 5.2.1b and 1.4.5.2) for the whole Castellon area with the conventional bus systems, meaning that the new system is well accepted by people and the new concept of bus does not keep users away from the public transport.

Financial and socio-economic impacts

The financial and socio-economic impacts cross-comparison can be done for the demonstration of Rome and Castellon, on the basis of the costs and revenues estimated and collected, and the consequent cost-benefit analyses.

The main cost differences were those concerning the start-up costs: the works to install the new CyberCar system in the P1 car-park in Rome requires about 3,3 million Euro , whereas the works to build the new high-tech bus system in Castellon required an investment of about 23 million Euro. The difference in such costs is mainly due to the track construction costs, about 19 million Euro in Castellon, where all the system infrastructures were built ex-novo (including the construction of the new bridge on the Riu Sec river), and 1,5 million Euro in Rome, required to change the car-park structure in order to include the dedicated CyberCar lanes.

The operating and maintenance costs were similar: 455 000 Euro /year for the Rome demonstration and 438 000 Euro/year for the Castellon demonstration. More personnel is required in Castellon, because the vehicles have the driver whereas in Rome

CyberCars are fully automated, and more annual system costs are required, while in Rome the track and civil infrastructure costs are higher than in Castellon.

The revenues calculated in Castellon (520 000 Euro/year), due to tickets to use the buses, are more than twenty times larger than those considered in Rome (25 000 Euro/year) and due to the car-park hourly fees.

The Net Present Value of the financial cost-benefit analysis with 10 year time horizon of the Rome demonstration, about -7 million Euro, is significantly different from that calculated for Castellon with the same time horizon, about -22 million Euro. However, the Castellon demonstration has been proved to be socially viable through the socio-economic cost-benefit analysis, which provided 12 million Euro as net present value with 20 year time horizon, meaning that the new system produces a benefit for the community. Once the data about social benefits will be available for Rome, the same socio-economic cost-benefit analysis will be done.

Passenger application matrix on the basis of demonstration and showcase evaluation

A dedicated table was built by the evaluation team, named Passenger Application Matrix. The purpose of this tool is to move the focus from the researcher perspective to the decision maker's one, typically more practical, trying to think in terms of what system is best to be implemented in order to improve the mobility in a certain specific situation.

In this matrix the case studies, the demonstrations and the showcases are grouped according to the type of areas linked by the single scheme. Being the possible OD pairs the same (rows and columns), the matrix results to be a two-dimension symmetrical one. The information for each OD pair, expressed in terms of the available indicator values, can be considered as the third dimension.

The use of this general view should be ideally focused on each cell of the matrix, and help evaluate pro and cons of the implementation of the different technologies in each particular environment. Nevertheless a strict "single cell based" analysis will not be always feasible, in particular when the city-study modeling are involved; in fact in the modeled scenarios, due to the different dimensions of the cities, the area types may not be consistent with the categorization of the matrix, or the same area type of cities that are very different in dimension may lead to non proper comparisons; on the other hand, the indicator values resulting from the models may refer to single zones of the modeled area and not to the entire city, and this may avoid the cross comparisons as well. Such cases do not however represent a problem to the matrix filling, because in these cases it will be possible to provide valid results to the decision makers by changing the level of the geographical scale and evaluating the information on a more aggregate geographical level, i.e. grouping more cells.

In Figure 3-2 the fourth release of the passenger application matrix is represented.

It represents the fourth step of the matrix evolution: after the first release presented in D5.3.1a, it has been filled with case studies results, reported in D5.3.1b, and with the results of demonstrations and showcases obtained in this deliverable, in D5.2.1a and in D5.2.1b.

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	ICCC (Gateshead. Madrid. Trondheim. Vienna) **PRT** (**Gateshead. Madrid. Trondheim. Vienna**) DMV (La Rochelle, Orta)								
Inner suburbs	ICCC (Gateshead. Trondheim) **PRT** (**Gateshead. Trondheim**) HT-bus (Gateshead. **Madrid**. Trondheim. **Vienna**) DMV	ICCC (Gateshead. Trondheim) PTFCC (**Gateshead**. Madrid. Trondheim. Vienna 1) **PRT** (Gateshead. **Trondheim**) HT-Bus (Gateshead. **Madrid**. Trondheim. **Vienna**) DMV PRT (Daventry)							
Outer suburbs	PTFCC (Trondheim) PRT (Trondheim) **HT-bus** (**Madrid**. Trondheim, Castellon) DMV (Madrid. **Trondheim**)	PTFCC (Trondheim) PRT (Trondheim) **HT-bus** (**Madrid**. Trondheim, Castellon) DMV (Madrid. **Trondheim**)	PTFCC (Trondheim) **PRT** (Trondheim) HT-bus (Trondheim) DMV						
Suburban centre (within an intermediate distance range)	HT-bus (Gateshead)	HT-bus (Gateshead)							
Major transport node (e.g. airport, central station)	HT-bus (Gateshead) CC (Vantaa)	HT-bus (Gateshead)			PRT (Heathrow)				
Major parking lot				CC (Rome)	CC (Rome)				
Major educational or service facility (e.g. University campus, hospital)	PRT (Trondheim) HT-bus (Castellon)	PRT (Trondheim)	PRT (Trondheim)				CC (Trondheim showcase)		
Major shopping facility	ICCC (Gateshead) **PRT** (Gateshead) HT-bus (Gateshead)	ICCC (Gateshead) **PRT** (Gateshead) HT-bus (Gateshead)		HT-bus (Gateshead)					
Major leisure facility (e.g. amusement parks)	HT-bus (Castellon)								
Corridor	**HT-bus** (**Gateshead. Madrid. Trondheim. Vienna**) DMV	**HT-bus** (**Gateshead. Madrid. Trondheim. Vienna**) DMV	HT-bus (Trondheim) DMV	HT-bus (Gateshead) DMV					

Figure 3-2: Fourth release of the Passenger Application Matrix

4 Results of SP2: Future scenarios

4.1 Introduction

The aim of SP2 "Future scenarios" is to investigate how automated road transport systems fit into expected scenarios for advanced urban transport in the future, and in particular how they will contribute to sustainability. Tools for cities and operators have been developed to analyse transport requirements and potential impacts and to assess the transport and land-use implications of innovative transport technologies if applied now or over the next 30 years.

The concepts, methods and tools developed in SP2 have been validated and demonstrated in the showcases and demonstrations of City Mobil in a number of different European cities under different circumstances.

A number of tools for cities and operators have been developed to analyse transport requirements and potential impacts. These include:

Scenarios

- A starting point for the scenario development is the "State of the art review with a preview for the scenarios" (D 2.1.1)
- A series of context scenarios over the period to 2050 in "Scenarios for urban mobility and innovative automated road transport systems" (D 2.2.2).
- 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, (D 2.2.3).

Modelling

- The city application manual is a general guidance to consider new technologies
- The alternative patronage estimator for travel demand prediction
- The modelling background report to analysis tools to assess the implications of new transport technologies.
- Generic economic analysis tool for business cases
- A business model for assessing the financial viability of technology projects,

Certification procedures and guidelines

- Certification procedures, their evaluation in CityMobil and a number of guidelines and barriers of automated transport systems.

4.2 Scenarios

The state of the art (in 2007)

We have been working on automated transport systems for 50 years now. In the "State of the art deliverable" the development a general review is made of the results of European research projects including the conclusions and recommendations of the Netmobil project. The state of the art has illustrated the promising technologies and their potential impact. A comparison of automated transport with regular transport modes have been included as well. From there the need for automated transit has been described. The state of the art deliverable finalises with recommendations on how to implement system changes.

Scenarios for Automated Road Transport (Visioning of the future)

The deliverable on “scenarios for automated transport” illustrate the first ideas of the future of urban transport. Its aim is to provide scenarios for urban mobility and innovative automated road transport systems at long-term horizons (2015, 2030, 2050). The document outlines the specific approach taken to envision the diffusion of road automated technologies and the issues of:

- expected long-term evolution of demographic, economic and societal context variables;
- the different city typologies to be considered for the application scenarios developed in a subsequent task of the sub-project;
- complementary land use and transport policies which can facilitate the introduction of the advanced technologies in the different city contexts.

Subsequently, an online DELPHI Survey has been performed in two rounds between mid-December 2006 and mid-January 2007, involving all CityMobil partners. The aim of the survey was to elicit the experts opinions about the scenarios for urban mobility and specify the expected consequences for the large scale introduction of advanced transport systems. The first round was to distinguish the most predictable elements from the more uncertain elements. The second round was to establish consensus on the most important elements. An overall analysis of these results have lead to the identification of the macro-elements the likelihood of the realisation of the elements, their expected outcome, time horizon, linkages with application scenarios and linkages with the CityMobil evaluation framework

Finally, in order to support the case studies, D 2.2.2 has been completed providing a classification of different city typologies using indicators such as city size, urban topography, transport infrastructure pattern and economic structure.

Considering all these factors, it is concluded that in order to envision the future for the application of the transport automated technologies it is important to identify not one “ideal” urban configuration which could represent the optimal context for the large scale introduction of the new technology, but a number of them, which will represent as many city typologies to be considered in the CityMobil application scenarios. The suggested city typologies are:

- Small to medium size homocentric city
- Large size monocentric city
- Medium to large size car oriented polycentric city

As it concerns the introduction of automated transport systems for passenger transport, City Mobil may envisage:

For **monocentric cities**: the diffusion of small CyberCars in the inner cities and historic centres, for short to intermediate distance travel in car-restricted areas. The small to medium size monocentric city typology will be a suitable environment also for the introduction of high-tech buses on radial connections. The large size monocentric city experiencing urban sprawl becomes a suitable environment to introduce also PRT between important origin-destination pairs (for instance an airport and a local rail or metro node) and dedicated lanes for dual mode vehicles on road axes penetrating the central city.

For **polycentric cities**: the diffusion of small city CyberCars for slow speed travel in the inner areas of the central city and of high-tech buses and dual mode vehicles for the higher speed travel between the different towns and nodes (e.g. airports) of the polycentric city. Car-oriented polycentric cities can benefit from dual-mode cars, especially when the same system is implemented in a number of cities and people can still travel between these cities on their own. In the polycentric alternative transport oriented city we envisage also the diffusion of PRT shuttle services to supply feeder transport, enlarging the catchment areas around public transport stops.

For **network city regions**: the diffusion of dual mode vehicles, high-tech buses and PRT providing more sustainable solutions for the traffic between the towns of network city regions, as compared to the today mostly car dependent traffic. In a network city with a proper functioning existing public transport infrastructure, new expansions with not enough density for a conventional mobility concept (e.g. public transport) can be unlocked with automated public transport. This will benefit both the new city expansion and the existing public transport infrastructure, because of the efficiency level that still can be reached.

Passengers and freight application scenarios

In contrary to the focus of the abovementioned D2.2.2, D2.2.3 illustrates the most promising passengers and freight "*application scenarios*". The basis lies in an analysis of both the transport demand and supply in urban area. An application scenario is defined here as a combination of a transport service (based on a CityMobil technology), a type of urban area and specific transport demand characteristics. The application scenarios are divided into two principal sections: 1) passenger transport and 2) freight transport.

For **passenger transport** there is a section devoted to possible application scenarios, in different types urban contexts. After a description of different basic road-based mobility concepts, this section analyses the role of automation and introduces new innovative mobility concepts enabled by the CityMobil technologies. Through a supply-oriented approach, the benefits of these CityMobil concepts/technologies are subsequently analysed for the passenger, the transport operator and society and the contribution that they give for a more sustainable urban transport system is underlined.

After that the viewpoint is from the transport demand side: by creating an origin-destination matrix with a number of typical urban contexts the usefulness of mobility concepts as a service between this origin and destination is established. The combination of the transport supply and demand, finally gives rise to a set of passenger application scenarios.

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

For freight there are possible freight application scenarios and corresponding innovative logistics schemes. The main development trends behind the transformation of the city, of the structures of commerce and the demand for freight transport generated by these is identified through an analysis of 30 European urban areas where innovative city logistics projects have been implemented. A set of 5 scenarios, which are sets of possible scenarios defined in terms of transport demand features, logistic schemes and types of urban context (no specific automated transport technology is indicated here), are identified, as a combination of skeletal scenarios with City Mobil technologies. They analyse where these technologies maximize the benefits for the driver, the freight transport operator and the society. All the scenarios are based on loading/unloading operations done manually. Finally a potential step forward in the automation process is described were additional specific technological components are shortly introduced.

The benefits of the City Mobil technologies in the freight case could make the application scenarios win-win solutions:

- on one side the transport operator could increase the transport productivity and possibly reduce the transport costs, which are the main factor of competition in the urban freight transport sector;

- on the other side, the public authorities could obtain less pollution and an increased level of safety of the road transport.

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

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

4.3 Modelling

City application manual

The City Application Manual is designed to help cities make good use of the tools developed in CityMobil, 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.

Deciding whether to invest in a whole 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.
The 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
- identifying the most appropriate applications
- considering the wider range of policies within which the new technology might fit
- appreciating the barriers and ways in which they might be overcome
- predicting performance and patronage
- assessing the business case
- conducting a wider appraisal of the options
- an alternative urban planning approach to the assessment of city applications
- microsimulation of detailed designs.

Alternative Patronage estimator

The 'Alternative Patronage Estimator' concerns a model for travel demand prediction. The objective of this model is to be able make quick rough estimates of travel demand for a particular public transport service. This tool allows for a first analysis and quick comparison of several schemes for a new automated public transport service. It is particularly useful in the design process of a new system. The tool is a GIS-based application that predicts the use of an automated public transport system. The demand for the system is calculated based on socioeconomic data (number of inhabitants, jobs, schools, etc.) in the GIS-map of your region and the properties of the service.

The developed demand predictor is applied on a case study. Three High-Tech bus routes are considered in the Tyne and Wear region. Trip amounts predicted by the Alternative Patronage Estimator are compared to those predicted by the MARS model. Results of both models have the same order of magnitude.

Modelling background report (MARS, micro simulation, cities and scenarios)

The main objective of the modelling work is to develop analysis tools to assess the transport and land-use implications of innovative transport technologies if applied now or over the next 30 years. Four representative case study cities: Gateshead in the Tyne and Wear region in the UK, Madrid in Spain, Trondheim in Norway; and Vienna in Austria have been selected.
A total of 22 scenarios have been modelled, including 5 passenger applications (inner city CyberCar, public transport CyberCar feeder, PRT, high tech bus and dual mode vehicles). Both with and without a set of complementary measures, under medium and high growth scenarios.
MARS, a Land Use and Transport Integrated (LUTI) model has been used to model the 22 scenarios for the 4 case study cities.

In modelling new technologies, no previous information existed about the supply characteristics such as access and egress times, headway and changing times. The tipping point tool, which is based on a simplified version of the MARS model has been used to create estimates for the supply characteristics for the new modes. Findings include a threshold of 6.5 minutes walking to a public transport stop, and a public transport headway of below 15 minutes to make a CyberCar feeder system viable.
Microsimulation models were used to provide MARS with quantitative information about the impact of the new automated modes.
The VOLTair methodology is based on a "top-down" process of urban transport planning and integration. It is used to improve the understanding of how the proposed new technology schemes in the 4 case study cities can contribute to a new sustainable mobility and under which conditions.

A stated preference survey was conducted in Leeds (UK) to establish how the new technologies are valued relative to traditional public transport modes. Outputs from the survey will be used in the MARS model.

Predictive tests using a fixed set of context and passenger application scenarios have been conducted in MARS for each city. The following passenger application scenarios have been modelled in all four case studies:

- *Inner city CyberCar*: this system is modelled as an enhancement to the local public transport system.
- *CyberCar public transport feeder*: this system is modelled as an enhancement to the existing rail/Metro/bus system.
- *PRT*: In general the PRT network covers the same route and zones as the city centre CyberCar.
- *High tech bus*: this system is modelled as an enhancement to the existing bus system.
- *Dual mode vehicle*: these vehicles are modelled as being integrated into the existing fleet and are assumed to be privately owned and not part of a public transport system.

A medium and high growth context scenario is modelled for all cities, and tests are conducted both with and without complementary measures.

Despite the differences in schemes across cities, some general conclusions can be drawn:

- In general feeder systems will have a significant impact when implemented in zones with initially poor access/egress to main line public transport.
- PRT will out-perform the use of CyberCars in central areas due to lower access and wait times but these systems will no doubt have higher barriers both financially and culturally to overcome compared to CyberCars which will be cheaper and less intrusive.
- High tech bus systems rely on quality/comfort and segregation from other traffic to increase patronage and have been seen to be successful when implemented along corridors with previously lower levels of service from public transport.
- In all case studies the impact of Dual Mode Vehicles was seen to be minimal

Generic Economic Analysis Tool for Business Cases (Analysis Procedure + User Guideline)

Work-package WP2.4 ‘Business Cases’ aimed at assessing the economic viability of a range of specific applications and solutions to develop a generic economic analysis tool, to aid the site selection process through economic analysis, and to contribute to the evaluation framework for the CityMobil project. The objectives and planned activities were: “a generic analysis tool will be developed to evaluate the transport and business case of implementing new systems. This will show the methodology required to confirm economic viability of systems and can be used after the project”.

The analysis tool developed and described in this report is applicable to be used by planners and decision-makers for the evaluation of potential future applications. D2.4.1 and D2.4.2. provide a detailed outline of the business case analysis tool, including the main processes and calculations carried out by the spreadsheet model, the main inputs required and the outputs given by it, and the user interface used as part of the model.

The BCT (Business Case Tool) has been used to assess the business cases for the cities and schemes analysed using the MARS model in CityMobil WP2.3. The results of this exercise are presented.

The BCT has performed as expected, and any variations due to known and accountable factors appear to be encompassed by a simple sensitivity analysis involving a worst case scenario made up from assuming a 20% reduction in demand and a 20% increase in costs.

For best results however, the exercise has shown that modifications are required to the BCT, in particular:

- to take account of a build period
- to allow for a vehicles, and perhaps an infrastructure refurbishment/replacement programme
- to recognise the effects of a growth in demand on the growth in numbers of
- vehicles required

These changes will be implemented in the final version of the BCT which will be a public deliverable available at the end of the project

With regard to the results for the particular cities:

- *Gateshead*: the results look to be reasonable. The PRT scheme has the highest BCR, most probably because it attracts the highest demand and hence revenue. Both of the CTS schemes produce respectable BCRs suggesting they would not need subsidising. Only the HTB shows a negative BCR, but a relatively small increase in the fare from €3.15 to €3.75 would appear to be sufficient to achieve break even.
- *Trondheim*: the results look reasonable in parts. The PRT and HTB schemes both have positive BCRs, with the PRT having a substantially higher figure. However, note the off-peak demand for PRT appears to be greater than the peak. There is insufficient demand to make an analysis of the IC CTS scheme worthwhile. The demand for the CTS Feeder is also very low and requires only 2 vehicles. It produces a negative BCR and is unlikely to be a viable scheme.
- *Vienna*: very low fares (€0.3) for all schemes, relative to the other cities, mean relatively very low revenues which tend to be swamped in all cases by the costs so that the BCR = (B-C)/C tends to -C/C = -1. Break even, or better, looks to be possible with fares comparable with the other cities' schemes ie around 2€ for all but the HTB scheme. For the IC CTS scheme the demand is satisfied using only 5 vehicles, it may not be viable. The network length for the CTS Feeder looks high compared with the other schemes. For the HTB scheme, the off peak demand is greater than the peak
- *Madrid*: the results look sensible. All except the HTB scheme produce positive BCRs. The demands for all schemes are relatively very high compared with the other cities, and require correspondingly larger numbers of vehicles. For the PRT, a 21.4m vehicle separation, at 30 kph, implies a 2.5 sec headway. This is unlikely to be viable. Generally, the reason the HTB schemes perform badly, relatively, is very probably because of the high staff costs involved in providing drivers. The PRT and CTS schemes are driverless. They need operations and maintenance staff, but not drivers, and so save very substantially on operating costs.

The PRT schemes seem to perform better than the CTS schemes in Gateshead and Trondheim. They are more expensive than the CTS, but it seems the higher demand, and consequently revenues, they attract is more than enough to outweigh the additional cost

4.4 Certification procedures and guidelines

Certification procedures and legal and administrative issues for automated transport systems

Work package 2.5 "*Legal and administrative issues*" aims at identifying legal and administrative barriers that are in the way of large scale introduction of advanced transport systems, to take them away where possible and to define strategies for the removal of the remaining barriers. WP 2.5 consists of three parts.

In the first part certification procedures and guidelines for safety, security and privacy have been developed. For the purpose of a good understanding the following definitions are used:

- Safety: The level of protection in case of malfunctions of the system.
- Security: The protection against unfriendly actions of other people
- Privacy: The level of protection of personal information

A considerable part of the work done in this work package is dealing with certification. The goal was to develop and evaluate a certification procedure for automated transport systems and to develop guidelines for safety, security and privacy.

The work consisted of three phases:

1. A review phase, in which an overview was made of existing procedures and guidelines related to automated guided transport systems and barriers that are in the way of large scale implementation of these systems.
2. A definition phase in which actions were defined to develop or modify procedures and to remove or at least lower the severity of existing barriers.
3. A production phase in which these actions were carried out, resulting in certification procedures for automated systems and a first text on guidelines for safety, security and privacy.

This deliverable concerns the certification procedures for automated systems and specifies a number of requirements that guidelines for security and privacy should meet. The deliverable describes the requirements of certification procedures, the past work that the procedures are based on and the relevant developments in recent years in the field of Advanced Driver Assistant Systems (ADAS). As a final result the deliverable presents the first version of the certification procedures and a flow diagram that will allow experts to carry out safety analyses in accordance with the procedures.

In the second part the results of the first part is used for the demonstrations and showcases from SP 1. The resulting in updating the procedures and guidelines. A full evaluation was carried out on the people mover for the CityMobil Rome demonstration. The result of the evaluation was that the Rome people mover met the requirements set out at the beginning of the analysis process. It gave a number of learning points, which have been included in the final procedure.

In the third part the guidelines for safety, security and privacy have worked out, as well the barriers to implementation. They are the results of the work on safety, security, privacy and barriers to implementation for CityMobil. The main result is a number of guidelines and strategies:

1 The definition of a number of guidelines for safety security and privacy in automated transport systems and

2 An overview of barriers that are still in the way of the large scale introduction of automated transport systems and strategies to remove these barriers.

The deliverable is meant to be used as a tool to assist stakeholders in making their decisions concerning the implementation of an advanced transport system.

4.5 Results

The result are a list of references, starting points, models and guidelines to be prepared for the difficult decisions to start projects of new innovated transport systems.

Acceptance

Scenarios do not give doubt that automated transport systems will have a future development. The only interesting factor is about the time they need to break through. In all experiences and first projects there is a great acceptance of the users for these systems.

Quality of service

The important factor the automated vehicles can become small and therefore can run on a frequent frequency will give a high quality. It is for this reason that PRT and CyberCars give high performances.

Transport patters

Due to the fact that within small distances (2-3 km) the smaller vehicles (PRT and CyberCars) can do a lot of feeder transport patters can be made that can not me done without automated vehicles

Social Impacts

Certification procedures and guidelines for safety, security and privacy give a lot of attention on social impacts. Nevertheless the conclusion is that much work has to be done to take can that all kind of social impacts have worked out as it should be done.

Environment

Automated vehicles will reduce the press in the environment. The basic conclusions in the scenarios and in the models are right on this point. Specially where electric vehicles are expected to get a wreak through because of the much improving batteries in the coming years. When electric cars will be the future in the years to come automated vehicles will benefit from this.

Financial Impacts

In both scenarios as models it is clear the financial impacts on innovative systems will be a problem. Investments a big and the have to be done by governments with a higher price just because it is more difficult to get the big amounts that are needed to start the new projects.

Economic

The models underline the there are some economic benefits from automated vehicles but they are small and there is a risk that do not appear in a number of projects

Legal impacts

The same conclusions as the social impacts can be made for the legal impacts: much work has to be done to take can that all kind of legal impacts have worked out as it should be done. Practice and experience wit running projects are needed next to the desk research.

Technological success

In this work packages there was little to no attention to technological success. One of the important factors from the scenarios and the experience with running projects is that reliability of technical items (including IT) is of great influence on the appreciation of the clients. In that may technical success is more important that many people do want to know.

5 Conditions

5.1 Introduction

Automated urban transport requires to address and solve a wide-range of technological and human-interaction issues before large-scale introduction of these transportation systems can become a reality. The main focus points were to identify and address those issues. It became clear that the status of the technology strongly depends on the environment in which automated systems are planned to be used. The present technology already allows the introduction of systems that use their own infrastructure and do not mix with other modes of traffic. If, however, systems must share the infrastructure with other modes, a number of issues need to be addressed.

Besides the study of new advanced modes of transport for urban environments is focused in achieving higher quality services in the future, but his quality can not only be measured in the traditional terms of reliability, low congestion, low travel times, etc. CityMobil project also considers the reduced pollution emission, enhanced safety, higher quality of life and integration as quality factors of an urban transport system, some of these factors are included in the so called operational issues.

In the following subsections the work performed within CityMobil regarding both technology and operational issues, and the main results on this issues are presented.

5.2 Technology

In sub-project 3 of CityMobil the technological issues of advanced urban transport systems have been addressed. The main objective of this sub-project is to remove technological barriers in order to introduce advanced urban transport systems on a large-scale. Advanced vehicle architectures have been developed and the basic subsystems for CyberCars and advanced city cars have been defined to achieve this objective. A dual-mode platform is developed within SP3 and an optimum solutions for human-machine interfaces and information systems are proposed. Furthermore specific obstacle detection systems and navigation techniques, focusing on wireless communication for high throughput are evaluated.

In order to study the described technological issues, 4 different scenarios have been described, which represent different transport areas in modern city life and provide possible solutions for future deployment of innovative transport systems. The selected scenarios are as follows:

- Historical town centre with lanes reserved for new transport systems
- Principal urban roads with specially equipped "e-lanes"
- Inner city centre scenario with CyberCars
- Shared traffic space with automated buses and dual mode vehicles

The scenarios offer a good level of generality and potentiality for the CityMobil sub-project. Functions, such as automatically moving in dedicated lanes, entering and exiting a parking area automatically and joining and leaving a formation of Cybercars, have to be considered within those scenarios.

Main scenario requirements

The first scenario “Town centre” deals with partly automated dual mode vehicles/advanced city cars in a historical town centre. The second scenario is a combination of CyberCars and dual mode vehicles (mixed traffic) “Principal urban roads with an equipped lane (called „e-lane)”. In third scenario, “Inner city centre”, CyberCars are operated within a city area. The last scenario ("Shared traffic space with automated buses and dual mode vehicles") describes automated high-tech buses on dedicated lanes, which are shared with dual mode vehicles and CyberCars.

The main identified challenges for the town centre scenario are on one side the complex environment (road users, safety, speed) and dual mode operation respectively mixed control of the vehicles. On the other side modifications of the infrastructure should be minimised to obtain the historical town centre. The e-lane scenario is characterised by dual mode operation on dedicated lanes, where interaction with ordinary traffic at high speed has to be considered. In the inner city centre scenario the application of CyberCars is extended. Pedestrians and other slow-moving traffic participants have to be taken into account. The last scenario "shared traffic space" the main challenge is represented by the mixed control of the vehicles on one side and on the other side by the mixed traffic participants (buses, dual mode vehicles, CyberCars).

Generally the main requirements for these scenarios can be classified into three groups:

- Detection of obstacles: As the vehicles in the four scenarios do not move in a protected environment only, other traffic participants and obstacles have to be detected. Therefore environmental sensors like radar, lidar and camera-based technologies have to be utilised and adapted to the detailed needs of each of the scenarios. Depending on the level of interaction with other traffic participants partly the state of the art sensing technology is sufficient.
- Vehicles guidance: For autonomous or assisted longitudinal and lateral guidance information about the surrounding environment is needed. Especially in complex areas, as given in the town centre scenario, the acquisition of this information by sensing technologies is difficult. A solution for this challenge is presented by GNSS and detailed digital maps with the necessary information about the attributes of the surrounding road sections.
- Communication with other traffic participants and infrastructure is an essential aspect for all four scenarios. The communication has to be secure, reliable and allow high data rates. State of the art communication technologies fulfil already many of these requirements. However modifications of these technologies are necessary.

The requirements on actuators (except for CyberCars for higher speed), ECUs and HMIs can be fulfilled by the technologies, which are already available.

5.2.1 Obstacle detection and avoidance

Obstacle detection is a key issue for the deployment of automated vehicles in the urban environment. Work package 3.3 deals specifically with the technologies and the requirements for obstacle avoidance. Its objective is to give to the developers of the systems recommendations for the introduction of sensors and software in accordance with the sites selected.

In order to provide these recommendations the following issues have been tackled and addressed.

- An assessment of the state of the art in sensor technologies suited for the different CityMobil scenarios in controlled laboratory conditions using specific CityMobil scenarios.
- Guidelines on the selection of the most suitable sensor technology specifically for each CityMobil scenario.
- Future work regarding obstacle detection technology.
- Certification issues with respect to obstacle detection systems.

In order to assess the performance of the current state of the art obstacle detection systems several evaluation tests have been performed on the different market available options. To have evaluation results most suitable for the objectives of the CityMobil project, it was decided to perform measurements aimed at evaluating obstacle detection systems suited for the four identified CityMobil scenarios

The evaluation tests of obstacle detection sensors for these scenarios were distributed among the participating partners. Each partner focused on one of the scenarios.

The subproject.

One of the outcomes of this subproject is a generic procedure to obtain a uniform approach in evaluating different kind of ADA systems. Although the work is on obstacle detection systems which are a part of an ADA system, the generic procedure is usable in the definition of the evaluation tests for CityMobil work package 3.3.

So the evaluation template developed within Preval was slightly changed and is used as a base to compose the evaluation measurement plans for all partners.

In order to perform a uniform evaluation process and consistent evaluation results, a properly modified generic procedure defined by Preval, the subproject of the EU project Prevent has focussed on the evaluation of ADA (Advanced Driver Assistance) systems. This generic procedure was defined in order to obtain a uniform approach in evaluating different kind of ADA systems. Therefore, the different partners used this modified procedure thereby explicitly defining the following:

- The use case description that is to be evaluated (the CityMobil scenarios)
- Choice and specification of the evaluated sensor set
- A measurement plan with
    - Definition of key indicators. The concept of a key indicator is a quantification of the measurement result towards the objective of the measurement. E.g. the percentage of measurements in which a false obstacle location is detected.
    - Description of the measurement location
    - Detailed description of the performed manoeuvres of both the vehicle with the sensor and the objects.
    - Type of objects
    - Environmental conditions
    - Reference measurements

After performing the obstacle detection sensor assessment, the specific guidelines for the selection of the most suitable technologies for the investigated CityMobil scenario and future work regarding these technologies were formulated.

Parallel to the assessments of obstacle detection systems, certification issues with respect to obstacle detection systems were also investigated. First an overview was given of the different steps needed to reach certification of a CyberCar system, describing, afterwards, a generic test procedure that incorporates all identified key factors that should be evaluated during the certification procedures.

5.2.2 Cooperative vehicles – communication technologies for CyberCars

Communication between vehicles and between vehicles and infrastructure is a key issue for the deployment of a cooperative system of automated vehicles in the urban environment. The work performed in SP3 regarding communication technoloogyes aims at providing useful information to the developpers of such systems. It introduces the state of the art of the various techniques now in the market and those which might soon be trying to match the different available technologies with the requirements of the different scenaris which have been considered in CityMobil.

The different technologies available on the market and analysed within SP3 can be summarised as follows:

- Communication technologies:
  - Wireless communication technologies (WPAN, WLAN, WMAN, WRAN)
  - Radio communication technologies (GSM, CDMA, GPRS, WCDMA, UMTS, etc.)
- Vehicular message propagation
- Vehicular ad-hoc network protocols
  - Topology based routing protocols
  - Geocast routing protocols
  - Network clustering protocols
  - Broadcast protocols
- Vehicle to infrastructure communications
  - IP unified networks
  - Mobile IPv6
  - Mobile network protocols
  - CALM
  - Vehicle connection to internet

The impact of these communication technologies on the vehicle throughput have also been studied, and finally, test procedures for the certification of the comunication techniques of the vehicles were proposed.

5.2.3 Navigation technologies

Navigation technologies provide a wide range of sensors and actuators that fit the needs of the four deployment scenarios addressed in CityMobil. Many prototypes integrate them in full control autonomous control architectures, yet certifications procedures are to be defined in order to demonstrate the liable navigation capability of advanced city cars.

GPS technologies -now trivialised- and dense measurement technologies such as vision, radar and laser systems, coupled with increasing computational power have entered the cockpit of advanced city cars and fill the gap between successive infrastructure-based markers, the latter providing highly liable information sources for navigation.

Automotive actuators are now heavily assisted with electronics and electro-mechanics, for greater functionalities and performances -greater output and fewer emissions- although at the cost of complexity, pointing the need for advanced control architectures that use all information available on board or even from other vehicles.

These control architectures are evolving towards more complex schemes that can sensibly handle many navigation primitives, eventually reaching fleet-scale control strategy.

Certification procedures for advanced city cars need to be defined from general recommendations or derived from existing specific norms. This requires technology expertise as well as experimentation on the field to provide valuable input for iterative maturation of these procedures.

Tomorrow's challenges for navigation technologies is their ability to withstand more operational constraints such as service customisation, traffic management, integration into existing structures, and so that the global architecture eventually reaches fleet-scale for better service and liability.

5.2.4 Human Factors analysis

When talking about autonomous or semi-autonomous driving, there are several human factors concerns that need to be taken into account. Part of the work performed in SP3 deals with the Human Factors issues that come into play when introducing dual mode vehicles, e-Lanes and CyberCars.

This Human Factors study includes, not only acceptance and comfort topics, but also other important issues, such as: situational awareness (does the driver still know what goes on around him and what will the system do), loss of skill (if a driver becomes a passive monitor, will he still be able to keep up his driving skills), behavioural adaptation and risk compensation (will a driver behave differently if he knows the system will respond), workload (which may be too high or too low), transitions from normal driving to autonomous driving and vice versa, the response of the driver in case of a system breakdown and the usability and interface aspects.

These factors have been studied for the 4 different scenarios previously defined. The four studies performed focussed on investigating how highly automated driving would affect driving behaviour and how highly automated vehicles and the human machine interfaces should be designed. The studies of TNO and ITS concentrated especially on effects of automation on driving performance and on drivers' reactions in critical situations, whereas the studies of DLR and CRF focussed more on the design of human machine interfaces and the exploration of transitions of control for the eLane concept. Independent from these different perspectives of the studies, there are some general outcomes that should be summarized here.

Effects of critical events

Regarding drivers' reactions to critical events, it seems that this was very much related to the critical event itself, which governed whether drivers' response differed between manual and highly or semi-automated driving. As it is known from the literature (Endsley & Kiris, 1995), automation can lead to reduced situation awareness if the human is only monitoring the automated system, and is not adequately involved in the task itself. This reduced situation awareness can be especially problematic in situations where the driver has to take back control due to automation limits or automation failure.

CityMobil studies, therefore, give a first indication that highly automated driving has effects on situation awareness in some driving situations and that this effect should be under further research for ensuring a safe usage of this new automation technology in the vehicle domain.

Transitions of control and interface design

With respect to the safe use of highly-automated vehicles, not only the driver's reaction to critical events, but also the normal transitions of control for activation and deactivation of the system should be a subject of further research. The DLR study showed that the transitions of control can lead to mode confusion. The drivers were not always aware in which automation mode they were driving, and therefore showed risky behaviour like taking the hands away from the steering wheel although the automation was not active.

The CRF study concentrated on the design of a human machine interface and how this should be optimised to support the driver in transitions of control in an eLane. A vocal and an acoustic human machine interface were tested to determine which was best in providing information about the different transitions that occurred on an eLane. In each case, messages were also accompanied by a visual interface. The vocal interface resulted in slightly better performance and subjective acceptance. Because vocal messages sometimes become annoying, the vocal interface might be especially used for the learning phase and in case of system failures (it shortens driver's reaction times). A dedicated design that allows the deactivation of the vocal messages for expert users could be an appropriate solution.

The results highlight how important it is to take into account the effects of the interface design for highly automated vehicles to find a solution that is generally accepted by the user but that also supports the safe and comfortable handling of the vehicles by raising situation awareness and avoiding mode confusion.

Trust in highly automated vehicles

All studies performed showed that the drivers trust in the automation system was generally high.

Some of these trust effects may have been caused by the tendency of the driver to leave the automation system activated as long as possible because it was comfortable (nicknamed "lazy-leave-on effect" by the CityMobil Human Factors partners). Others could be explained by the fact that the system limits were not clearly understood or that the drivers estimated the risks of driving highly automated in a simulator as relatively low. In general, providing the drivers with the right balance of trust and mistrust regarding the automation behaviour is a challenging topic. Different approaches like designing appropriate, full proof HMI, providing specific driver training , inducing some automation failures in uncritical situations for training purposes, or designing with a system image or design metaphor that already implies the trustworthiness of the automation, are promising directions.

Acceptance of highly automated driving

With respect to the subjective evaluation of the systems presented in the four studies, most of the participants liked the systems and rated the automation positively. Most of the participants did not have any contact with highly automated vehicles before and there seemed to be a high fascination of driving a highly automated vehicle for the first time. This fascination seemed to be even higher when driving in a real vehicle as we saw in the FASCar drives of the DLR study. However, when drivers were asked if they wanted to have such a system in their vehicles, the answers were not that consistent.

The ITS study resulted in a high percentage of people who declined to have the system in their cars whereas the participants of the TNO study showed interest in having such a system. The results of the CRF study implies that highly automated systems might be desired by the driver for specific and not all driving situations.

General conclusions

In conclusion, driver human factors play an important role in automated transport to ensure that the system is properly tuned to the drivers' capabilities and limitations. When talking about highly automated vehicles and dual mode vehicles, the following is highly important from a human factors perspective. The automation should be kept as intuitively understandable as possible and the HMI and the combination of the automation levels should be properly designed. This is important to ensure that the driver understands how the system works, that he does not lose situation awareness and the skill of driving and that the transitions of control from manual driving to autonomous driving and vice versa are done in a safe way.

In the CityMobil project, various human factors aspects were studied, both in driving simulator studies and in a research vehicle on a test track. The results of the four studies give first indications of the advantages and challenges of highly automated vehicles from a human factors perspective. However, results were not conclusive so there is a need for further human factors research regarding the introduction of high automation in the vehicle domain.

5.2.5 Design of Advance city cars and CyberCars

In general, safety was the main challenge to be addressed to introduce automated transport, in particular if mixed with normal “human driven” traffic. Sustainable solutions will be possible only if an integrated approach will be followed, with contribution both from vehicles, collision avoidance, and from infrastructure, allowing a minimal and controlled interaction with normal traffic. In particular systems for obstacle detection and avoidance were given attention. Another important topic appeared to be the interaction between the vehicles and human beings.

Essentially two different types of vehicles have been designed in SP3 in CityMobil: CyberCars, which drive fully autonomously in a dedicated area, and advanced city cars, which incorporate systems to provide advanced assistance to the driver and which can include the specific case of dual-mode vehicles that are equipped so as to enable driving either autonomously (in a similar way to CyberCars) or under the control of the driver.

In relationship with the basic scenarios described above, the following aspect of vehicle design have been considered:

- The vehicle dimensions, layout and design of the vehicle architectures
- The general performance characteristics
- The need to incorporate ecological power-trains in advanced city vehicles
- Solutions to guarantee reliability, safety and comfort when driving and generally using the vehicles or the on-board services
- Cognitive design issues regarding the interaction between the driver and the vehicle, especially when the control switches from the automatic system to the human and vice versa.

In dealing with these general issues, the study has considered particular requirements and situations which could include both autonomous and conventional vehicles. A relevant aspect is the consideration of architectures and solutions also for the carriage of goods.

For certain scenarios an interaction between vehicle and infrastructure is required. This interaction can be for instance a positioning system, which is needed for guidance and navigation, a communication system to get necessary information from a traffic control centre or regulated intersections (e.g. traffic lights), but also a cooperative environment, which makes it easier for the sensors to acquire relevant information.

The activity has been divided in two phases:

- In the first phase, a preliminary design has been conducted and documented taking into account the envisaged scenarios and the base technologies, such as, HMI, obstacle detection avoidance or cooperation between vehicles and navigation.

- In the second phase, the results of the activities conducted in related activities and during the demonstration tasks have been reviewed as concerns the design of the different vehicles considered.

5.3 Operations

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

To this extent the work done within this area has been focused on:

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

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

In order to cover all these goals, the work has been structured into several different areas:

- Operational Management
- Architecture and Information flow
- Service Customisation
- Traffic management Strategies
- Integrating automated transport in an existing structure

Clear application scenarios are required in order to study the Operational Issues mentioned above. It is assumed that operational issues such as traffic management will basically remain unchanged for vehicles with drivers, such as dual mode vehicles in manual-mode and advanced city cars. The operational issues for driverless vehicles are new however, and will comprise the core part of the research to be undertaken. The scenarios defined are therefore closely related to the operations of driverless transport. Each of the operational issues areas defined above will be studied and analyzes in each of the 5 different scenarios defined.

- Scenario S1: Town Centre with Advanced City Cars
- Scenario S2: Principal urban roads with an equipped “e-Lane”
- Scenario S3: Inner City Centre with Cybercars
- Scenario S4: Shared Traffic Space with automated buses

- Scenario S5: PRT (Personal Rapid Transit)

5.3.1 Main results Operational Management

The new transport systems proposed and studied under CityMobil project do offer services whose requirements are not fulfilled by most of the systems utilised nowadays. This part of the work deeps in the requirements of those modern transport means, defining all the functional areas and the functionalities in which the Operational Issues subproject works on. The functional areas described have been based on previous researches done in European Projects, especially in IST KA3REN and FRAME projects, which define the necessary elements and processes required to achieve a global interoperating European Transport Architecture. The work done in this area under CityMobil project completes the former work, adding new functionalities that the previous projects did not cover and are important for developing the new technologies and concepts defined in CityMobil.

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

From IST KA3REN and FRAME projects, 8 main functional areas related to the operational management have been identified:

- 1. Provide Electronic Payment Facilities
- 2. Provide Safety and Emergency Facilities
- 3. Manage Traffic
- 4. Manage Public Transport5. Provide Advanced Driver Assistance
- 6. Provide Traveller Journey Assistance
- 7. Provide Support for Law Enforcement
- 8. Manage Freight and Fleet Operations

For each of the 8 general functional areas, a number of relevant functionalities, specific for the AUTS studied under the project, have been identified some of them are CityMobil innovations. As an example, the following figure shows one of these areas with the main relevant functionalities (the CityMobil innovations are highlighted in blue).

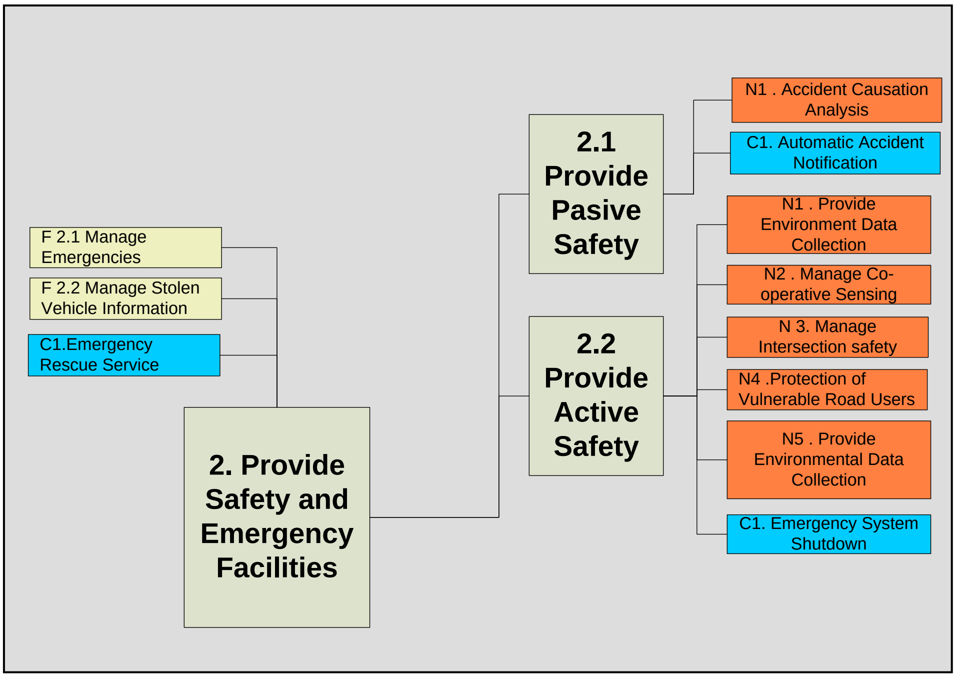

Figure 5-1: Area 2 - Provide Safety and Emergency Facilities

An overview of the functionalities identified for the 8 functional areas is shown in the following figure.

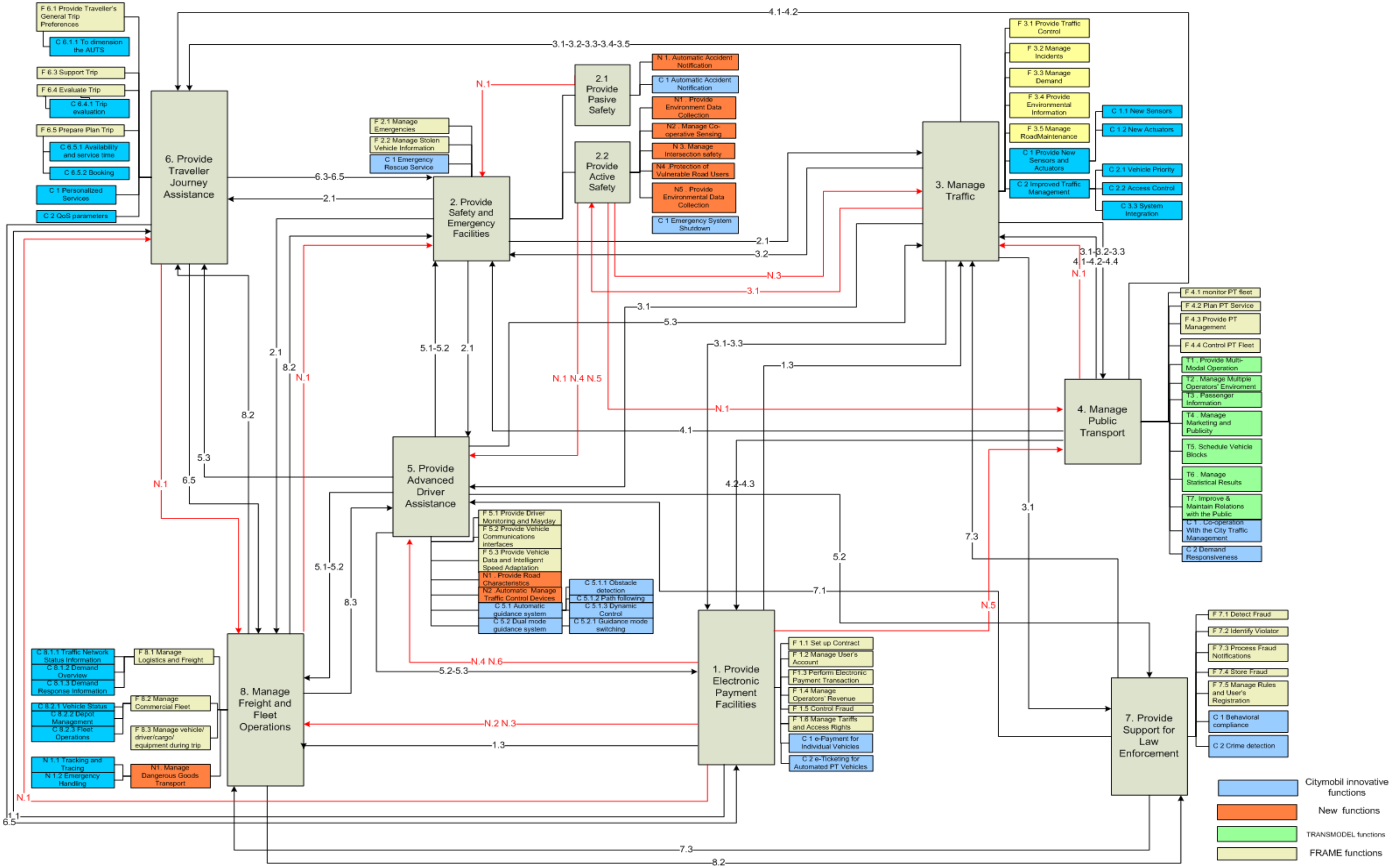

Figure 5-2: General overview of the functional Areas

5.3.2 Main results Architecture and Information flow

The work done in this area describes the proposed operational architectures for each of the five scenarios being previously defined. The design of these architectures has been based on previous work in the European Converge and FRAME projects, and has followed the design guidelines recommended by them. The use of these guidelines provides confidence on the completeness and quality of the proposed architectures. The results, therefore, complement, complete and detail the description of the five scenarios while also providing five different examples of how an operational architecture can be designed to include the new functional areas that are implied by the new transport systems proposed in the CityMobil

Four architectural angles have been identified, based on the previous work in Converge and FRAME projects:

- Functional Architecture
- Information Architecture
- Management Architecture
- Physical and communications Architecture

These aspects have been analysed for the 5 scenarios. As an example of the results obtained, the following figure shows the angles.

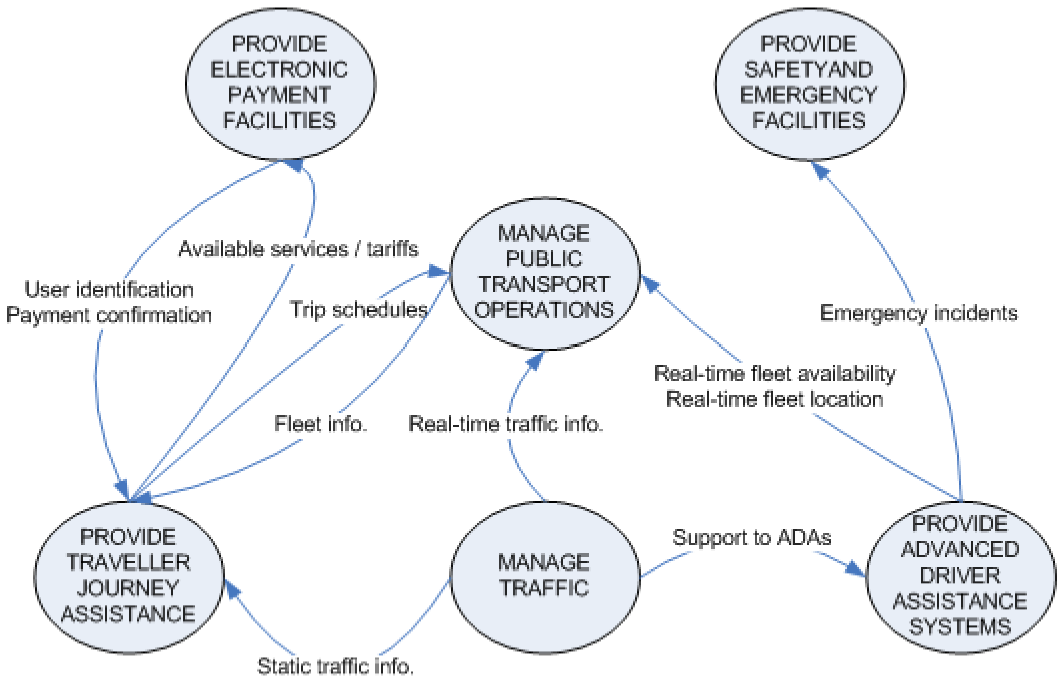

Figure 5-3: Functional architecture, Scenario 1 : Town Centre with ACCs

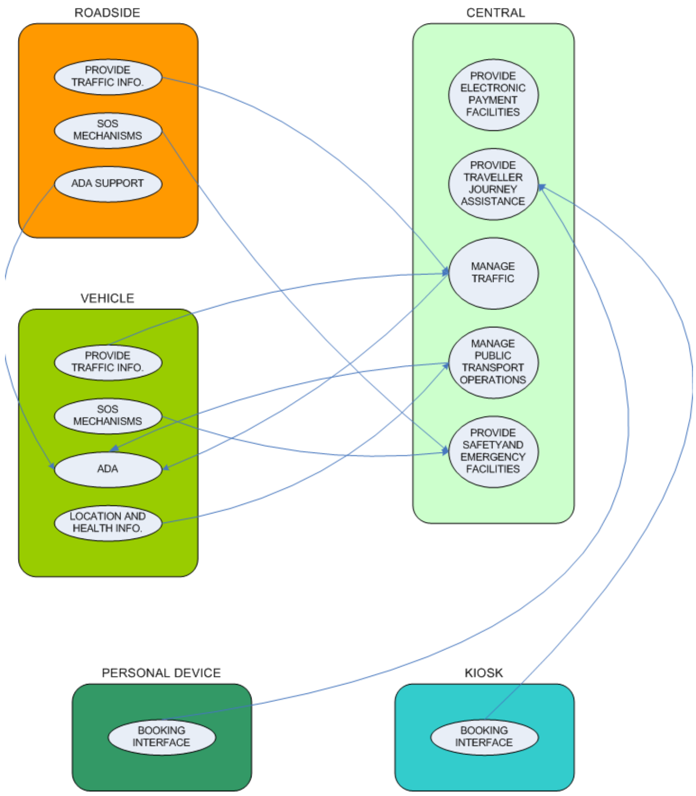

Figure 5-4: Physical architecture, Scenario 1 : Town Centre with ACCs

5.3.3 Main results Services customization

As new technologies are applied to transport systems, new services and opportunities must be investigated. New transport services must become more and more comfortable for users, and also more and more manageable for stakeholders.

On the way to transport systems improvement, two important points to focus on are the ease of use of the services offered and the enhancement of the quality and comfort. e-IDentification and e-Ticketing are two technologies with great possibilities in the area of public transport, since their advantages directly influence the quality of the services offered. As well as electronic identification and E-ticketing, the service customization work has also been focused on on-board surveillance and incident management and On demand information services.

By means of those technologies, users could receive customized information and assistance before, during and after the travel; they could be able to make use of several different services with the same ticket; or they could travel across large areas (such as the EU) without noticing changes on the ticketing system, for example. Transport services become easier to use, and information delivered to the passengers exactly fits their needs.

Nowadays, several different technologies are available to achieve the electronic identification of the passengers. Not every technology can be suitable for every situation. Each transport system (in this document studied by means of scenarios) has its own requirements, limitations, objectives, etc.) Therefore, several choices have been studied for each scenario, determining which technologies fit each of them and how the stakeholders can make use of them to increase the quality of the service.

5.3.4 Main results traffic management strategies

The management strategies for transport automated systems have also been studied in the context of the Operational Issues analysis within CityMobil project. Specifically, work has been directed at investigating the five scenarios previously defined. For each one of these scenarios the following issues have been tackled:

- Identification of the traffic management requirements
- The different issues and opportunities for, and from traffic management strategies have been considered.
- Several simulation work and studies have been undertaken to investigate the identified the different strategies

The overarching objectives of transport schemes are generally to improve mobility in a sustainable way and to reduce environmental impacts. However, the specific objectives of each scenario, and the opportunities for influencing them through traffic management strategies depend on whether the system is private or public transport in nature. Private transport schemes generally have factors such as increased capacity and efficiency as primary objectives, while public transport schemes aim more to reduce waiting times and improve accessibility. The extent to which the objectives can be influenced will in turn depend on the level of control that can be exercised to respond to changing conditions and, in particular, demand.

Scenarios 1 *Town with advanced city vehicles* and 2 are essentially private transport while 3, 4 and 5 are Public transport systems.

The main findings for each of the scenarios studied can be summarized as follows, and the overall conclusions are summarised below.

S1 Town with advanced city vehicles

From a traffic management perspective, the main opportunities were identified from the small size of the vehicles, which results in increased network capacity, and the potential of DRG for guiding traffic over the network in such a way that certain optimal criteria can be met. The optimal criteria can be defined in different ways depending on relevant policies and objectives. In general it should be possible to take into account a range of factors, including congestion and delays, pollution, and safety.

The simulations results show that the presence of smaller vehicles such as ACVs can lead to improved performance of the traffic network in a city, and that vehicles fitted with DRG that can improve their path because they are informed and have the opportunity of selecting better routes. Both systems give benefits not only for the equipped vehicles but for the whole traffic.

The results also show that in a traffic system, a change in one vehicle has impacts for others and it has been usefully demonstrated that improvement for some can lead to improvements for the whole.

S2a Principal urban roads with an "Open e-lane"

In the 'Open e-lane' scenario, dual mode vehicles (DMV) can run in automatic mode, but other (ie manually controlled) vehicles are also allowed. The e-lanes can be designated using buried cables or magnets to facilitate lateral guidance, or simply designated as a series of map coordinates that can be followed by an in-vehicle navigation system, and highlighted on the ground by means of road signs and road markings as required.

For this scenario, the main opportunities were considered to be through encouraging the formation of automated vehicles to form up in platoons in the e-lane, and so achieve improvements in capacity and throughput. A potential improvement in safety should also be obtained as a consequence of automated car following, and hence braking.

The simulation results show that traffic operation on an e-lane demonstrated similar phases such as free flow, near capacity and congestion as are typically found in traditional traffic operation. However, the average travel times on an open e-lane are less than in traditional traffic operation when the proportion of DMVs is low. When the proportion of DMVs reaches a critical level, e.g. capacity, travel time on the e-lane starts to increase. In this investigation, it was found that significant increases in journey time happened when traffic demand for the e-lane reached: 2600 vph at DMV headway setting of 1.2 seconds, 2700 vph at DMV headway setting of 1.0 seconds, 3100 vph at DMV headway setting of 0.8 seconds and 3500vph at DMV headway setting of 0.6 seconds. When demand for the e-lane exceeded these figures, the e-lane became congested and traffic operation was unstable.

It was also found that minimum travel time could be achieved when the proportion of DMVs using the e-lane was properly managed.

S2b Principal urban roads with a "Dedicated e-lane"

The dedicated e-lane scenario is the ultimate development of the open-lane scenario, in which manually driven vehicles are excluded from the e-lane. To achieve this, a dedicated, ie segregated e-lane is required, with controlled access. The opportunities provided by this scenario are for organised platoons of vehicles, or 'road trains', that can be formed using only automatic vehicles (eg DMV's operating in automatic mode), in order to maximise throughput and hence traffic efficiency, and at the same time maximise safety and minimise emissions through smoother traffic flow.

From a traffic management perspective, the main opportunities for traffic management were considered to be the organisation of platoons in the e-lane, and the access control strategy for metering vehicles into the road train at the entry points along the e-lane.

A hypothetical scheme involving a dedicated e-lane with 3 access/egresses at 3km intervals, and 400m long access (ie acceleration) lanes was simulated by TRG using the MATLAB simulation environment.

The simulations show that a synchronous access control strategy that controlled the number of access vehicles based on demands at all entries of the network reduced overall delays to entry traffic, especially when traffic demand is close to the capacity of the dedicated e-lane network.

It is therefore concluded that synchronised access control for the dedicated e-lane is necessary for a network wide efficient operation. Local access control based on available gaps (spare capacity) at an entrance may result in excessive delays to downstream entry traffic, which may also result in merge buffers being exceeded because of excessive number of queuing vehicles at some downstream entrances. A synchronised access control strategy is able to regulate entry traffic based on demand, thus maintain a balanced operation at all entries.

S3 Inner City Centre with Cybercars

From a traffic management perspective, 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.

The results from the simulations carried out clearly show 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.

S4 Shared Traffic Space with Automated Buses

The main opportunities for this scenario 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.

The experiments undertaken assure a small shortening of the duration of the trip due to the particular advantages advanced buses provide (ie their better docking minimises the stop times, while they are able to circulate faster on the reserved lane). On the other hand, these enhancements can only be achieved if a reserved lane is provided for part of the path driven by the public transport service. The reserved platform also provides a shortening the trip time up to a 50%, and more reliable schedules for public transport, while the negative impact on private traffic can be minimised with good network planning and a well-adjusted priorisation system.

Finally, a new demand responsive way of dealing with passenger demand was investigated, to check its feasibility and the oportunities it offers. The simulation results show this 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. In addition, several parameters (including the waiting time threshold at which the system requests a support bus, alternative routes for the support buses, combination of statistical and real-time information to design the behaviour of the system...) can be adapted in order to fulfil the specific requirements of a particular scenario. This includes setting the mean bus occupancy values near to 90% in peak hours in order to achieve a good exploitation of the transport system, while keeping the average waiting time under the scheduled time between buses and so ensuring that most passengers are able to board the first bus that arrives, even in the peak hours. Therefore, the system has been found to be efficient, but does require some measures that are highly dependent on the scenario specifics to ensure that it does not negatively affect other aspects of traffic management. For example, good route guidance and enough (and suitable) information available to forecast peaks of demand in advance helps the operator to deliver only the minimum necessary number of buses at the necessary time to the neccesary stops, thus minimising the number of support buses required by the system and their impact on private traffic.

In summary, an urban public transport system based on automated buses has been shown to significantly enhance the quality of traditional bus systems, improve accessibility for passengers and provide them greater comfort during the trip.

S5 PRT

The main opportunities for traffic management were considered to be from forecasting demand so that the distribution of vehicle in the network could be organised in advance to minimise waiting times.

The results from simulation studies show that benefits were obtained from two demand forecasting strategies:

- a local demand prediction tactic for vehicle dispatching would allow vehicles to be dispached 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.

Particular results showed savings of 15% in average waiting time across all stations in the test network as a result of using the local demand predication tactic. The effects of using the long term demand prediction strategy are significant for scenarios with both rising and falling travel demands, with reductions in average waiting time of 26% and 20% respectively. When overall network demand is stable, waiting time is not significantly different for scenarios with and without the long term demand prediction strategy. This is expected as demand and predictive demand for the network are basically identical when network demand is stable.

5.3.5 Main results Integration issues

AUTS should not act as stand-alone systems, but as an integral part of the total transport system, therefore the integration issues are important aspects that need to be taken into account in order to ensure an efficient and full integration (and therefore full usability) of an automated transport system in the existing urban environment of which the existing transport system is a part.

To study the integration of the new AUTs studied in CityMobil project, three main operational issues have been identified to be necessary preconditions to integrate AUTs in the total existent transport systems. These preconditions are the following:

- Physical integration
- Integration of information services
- Organisational integration

Once these preconditions are fulfilled (mostly these preconditions depend on technical or organizational issues easy to solve), several issues have been identified as being the real integration issues to deal with when facing a real implementation of an AUTs as the ones studied in CityMobil. These subjects to tackle with are:

As discussed in part II of this deliverable it is already shown that integration issues with respect to the CityMobil technologies mostly occur on high level and are often policy oriented.

- Legal issues
- Governmental issues
- Operational issues
- Organisational issues

These issues have already been identified to be the most important bottlenecks when trying to implement a real AUTs system.

6 SP5: Evaluation: contribution to urban sustainability

6.1 Assessment framework

The objective of the CityMobil project is to achieve a more effective organization of urban transport, resulting in a more rational use of motorized traffic with less congestion and pollution, safer driving, a higher quality of living and an enhanced integration with spatial development. This objective is brought closer by developing integrated traffic solutions: advanced concepts for innovative autonomous and automated road vehicles for passengers and goods, embedded in an advanced spatial setting. The CityMobil project therefore requires an evaluation framework capable of capturing the social, environmental, economic, legal and technological impacts of Advanced Transportation Systems. The framework is required to operate at spatial scales ranging from laboratory and test-track interventions, through computer modeling to real-world implementations on a large scale. It is an aim of the evaluation framework is to facilitate mainstreaming of the assessment of ATS within local and national evaluation processes.

A review of the state-of-art in evaluation frameworks for ATS systems and, more broadly, for integrated transport and land use strategies demonstrates the need to establish the following key evaluation elements:

- Objectives – a series of key evaluation categories relating to the achievement of sustainability goals and capable of capturing the practical implementation of new technologies;
- Framework – a specific interpretation of the evaluation categories developed from the objectives which sets out the key impacts that relate to each category and the more specific indicators that can be used to assess achievement;
- Assessment methods – a clear understanding of how the framework should be applied (for example using social cost-benefit, MCA or mixed approaches) and to which parts of the CityMobil project
- Implementation – the establishment of clear procedures for the ex-ante and ex-post evaluation of the different parts of the project.

The objectives which form the outline of the evaluation framework for CityMobil are:

- Acceptance
- Quality of service
- Transport patterns
- Social Impacts
- Environment
- Financial Impacts
- Economic
- Legal impacts
- Technological success

The results of the ex-ante and ex-post evaluation is reported in the various deliverables of SP5 in a very detailed manner per show case, city study or small demonstrator. These results are not repeated in this deliverable. What is reported is an example of the cross comparisons that where made with use of the passenger application matrix (as shown in the Annex of this report). An example is given in the next section.

6.2 Cross comparisons

Indicators were selected to allow monitoring against each of these key objectives. For the evaluation of passenger transport systems a list of 64 indicators was generated. This can be viewed as the complete envelope of overarching indicators which could form part of the evaluation of each of the different elements of CityMobil.

The cross-comparison reported was used to confirm the robustness of the implementation of ATSs across cities by assessing for each available indicator how a new ATS as PRT performs compared to the conventional systems (do nothing scenario).

The main findings of such comparison are the following:

- The number of daily trips were similar in the peak hour for Uppsala (3 800 trips in the scenario considered for the year 2020) and for the actual Trondheim scenario (4 200 trips in the scenario for the year 2010). In the future Trondheim scenario (year 2035), such value grows to 5 500. During the entire day the Uppsala PRT passengers calculated are about 36 000, whereas in Trondheim they are about 73 000 in 2010 and about 82 000 in 2035;
- The modal share foreseen for Uppsala is 20% in 2020 and for Trondheim 27% both in 2010 and in 2035. The difference between the two case studies can be considered as directly linked with the modal shares of the modes of transport different from PRT, mainly for the car modal share (55% in Uppsala and 30% in Trondheim after the PRT introduction);
- The non-car modal shares are different for the two case studies. In Uppsala its value is 45%, while in Trondheim such value is 70% in 2035. It seems to be due to the different use of car and slow modes, with Uppsala needing further measures to push people not to use their private cars;
- The capital costs were similar for the two case studies. In Uppsala the costs assumed as real were those included in the low cost scenario, 68 millions €, whereas in Trondheim the costs are little higher, 76 millions €;
- The Business Case Result (BCR) of the Uppsala case study provided a positive value, 1.29. The Trondheim value was higher, 2.30, meaning higher benefits for the system;
- A public transport PRT service would be useful in Uppsala to have the vehicle occupancies foreseen after the case study simulation, thus reducing the number of empty vehicle trips and offering a performing service to the users.

All such findings (and the corresponding indicators reported in the previous sections of this deliverable) have to be considered included in the cells of the Passenger Application Matrix containing both the Uppsala and the Trondheim case studies.

The use of this general view should be ideally focused on each cell of the matrix, and help evaluate pro and cons of the implementation of the different technologies in each particular environment. Nevertheless a strict “single cell based” analysis will not be always feasible, in particular when the city-study modeling are involved; in fact in the modeled scenarios, due to the different dimensions of the cities, the area types may not be consistent with the categorization of the matrix, or the same area type of cities that are very different in dimension may lead to non proper comparisons; on the other hand, the indicator values resulting from the models may refer to single zones of the modeled area and not to the entire city, and this may avoid the cross comparisons as well. Such cases do not however represent a problem to the matrix filling, because in these cases it will be possible to provide valid results to the decision makers by changing the level of the geographical scale and evaluating the information on a more aggregate geographical level, i.e. grouping more cells.

7 References

7.1 List of CityMobil deliverables

SP 1

Del No	Deliverable title	diss Level
D.1.1.1-I	1st 6 months progress reports demonstrations	PU
D.1.1.1-II	2nd 6 months progress reports demonstrations	PU
D.1.1.1-III	3rd 6 months progress reports demonstrations	PU
D.1.1.1-IV	4th 6 months progress reports demonstrations	PU
D.1.1.1-V	5th 6 months progress reports demonstrations	PU
D.1.1.1-VI	6th 6 months progress reports demonstrations	PU
D.1.1.1-**VII**	7th 6 months progress reports concerning the demonstrations	PU
D.1.1.1-VIII	8th 6 months progress reports concerning the demonstrations	PU
D.1.1.1-IX	9th 6 months progress reports concerning the demonstrations	PU
D.1.1.1-X	10th 6 months progress reports concerning the demonstrations	PU
D.1.1.2	User requirements: results RG consultation	PU
D.1.1.3	Plan WP 1.5: Other demos, showcases and city studies	PU
D.1.2.1.1	Annual reports and demonstration progress	PU
D.1.2.1.2	Annual reports and demonstration progress	PP
D.1.2.1.3	Annual reports and demonstration progress	PU
D.1.2.1.4	Administration and coordination of the Heathrow demonstrator	PU
~~D.1.2.1.5~~	~~Administration and coordination of the Heathrow demonstrator~~	~~PU~~
D.1.2.2.1	Summary Specification for the Heathrow demo	PU
D.1.2.2.2	Outline description of the Heathrow Pilot Scheme	PU
D.1.2.3.1	Identification of the key parameters	PU
D.1.2.3.2	Simulation of representative version existing PRT system	PU
D.1.2.4.1	Evaluation of the passenger and operator satisfaction	PU
D.1.2.4.2	Evaluation of the passenger and operator satisfaction using similar metrics	PU
D.1.2.4.3	Comparison of the ULTRA PRT system with the existing bus service	PU
D.1.2.5.1	Generalisation of the evaluation results analysis	PP
D.1.2.6.1	Specification of a communication based collision avoidance system	PP
D.1.2.6.2	Test and report of CBCAS using the ULTRA vehicles at Cardiff	PP
D.1.3.1.1	Annual progress report	PU
D.1.3.1.2	2nd Annual progress report	PU
D.1.3.1.3	3rd annual report on the demonstration progress	PU
D.1.3.1.4	Administration and coordination of the Rome demonstrator	PP
D.1.3.1.5	Administration and coordination of the Rome demonstrator	PP
D.1.3.2.1	Rome demonstration requirement	PP
D.1.3.2.2	Rome demonstration detailed design	**CO**
D.1.3.3.1	Certification of the two Vehicles CTS and opening to customers	PU
D.1.3.3.2	Preparation of the call for tender of a 6 vehicle CTS	PU
D.1.3.3.3	Certification of the CTS in an on-demand scheme	PU
D.1.3.4.1	Review of the guidelines for management	PU
D.1.3.4.2	Implementation of a 6 cybercars CTS	PU
D.1.3.4.3	Evaluation of the extension to other sites	PP
D.1.3.5.1	Data collection for the ex-ante analysis	PP
D.1.3.5.2	Data collection for first ex-post analysis (2 vehicles)	PP
D.1.3.5.3	Data collection for first ex-post analysis (6 vehicles)	PP
D.1.3.5.4	Evaluation of the extension to other sites	PP
D.1.3.6.1	Rome site acceptance	PU
D.1.3.6.2	Factory acceptance site	PU
D.1.3.6.3	Delivery of the two prototypes and start of staff training	PU
D.1.3.6.4	Definition of guidelines for Rome demo management	PU

D.1.3.7.1	Delivery of Rome Demo civil works	PU
D.1.3.7.2	Extension to the train station and the east Fiera entrance	PU
D.1.4.1.1	Adm.and Coord.of the Castellón demonstration	PU
D.1.4.1.2	Annual reports on the progress of the demonstration	PU
D.1.4.1.3	Annual reports on the progress of the demonstration	PU
D.1.4.1.4	Annual reports on the progress of the demonstration	PU
D.1.4.1.5	Annual reports on the progress of the demonstration	PU
D.1.4.2.1	Specification of vehicles	PU
D.1.4.2.2	Adapted vehicles	PU
D.1.4.3.1	High level specification	CO
D.1.4.3.2	Castellon exploitation support system including DS	CO
D.1.4.4.1	Design of dedicated lane infrastructure	PU
D.1.4.4.2	Infrastructure for the Castellon demonstrator	PP
D.1.4.5.1	Impact assessment framework	PP
D.1.4.5.2	Ex-ante impact assessment Castellon demonstration	PP
D.1.4.5.3	Ex-post impact assessment Castellon demonstration	PP
D.1.4.6.1	Operation, Service and maintenance plans	PP
D.1.4.7.1	Operation data collection for the ex-ante analysis	PP
D.1.4.7.2.	Data collection for the ex-post analysis	PP
D.1.4.8.1	Analysis of the user needs and pref.	PP
D.1.5.1.1	Adm.and Coord.of site selection/showcase prep.	PU
D.1.5.1.2	Adm. and Coord. of the showcase implementation	PU
D.1.5.1.3	First cybercar showcase report (Daventry)	PP
D.1.5.1.4	Second cybercar showcase report (Vantaa)	PU
D.1.5.1.5	Third cybercar showcase report (Trondheim)	PU
D.1.5.1.6	First Advanced City Cars showcase report (La Rochelle)	PU
D.1.5.1.7	Second Orta San Giuilio Advanced City Cars showcase report	PU
D.1.5.2.1	Three operational cybercars	PU
D.1.5.2.2	Management centre	PU
D.1.5.2.3	Recommendation for the operation incl. safety issues (Daventry)	PU
D.1.5.2.4	Recomm.report for the operation incl.safety issues (Vantaa)	PU
D.1.5.2.5	Recomm.report for the operation incl. safety issues (Trondheim)	PU
D.1.5.3.1	Two operational city vehicles	RE
D.1.5.3.2	Safety Recommendation for the operation La Rochelle SC	PU
D.1.5.4	List of selected sites for studies and demos	PU
D.1.5.5.1	First cybercar showcase execution (Daventry)	PU
D.1.5.5.2	Second cybercar showcase execution (Vantaa)	PU
D.1.5.5.3	Third cybercar showcase execution (Trondheim)	PU
D.1.5.5.4	First Advanced City Cars showcase execution (La Rochelle)	PU
D.1.5.5.5	Second Advanced City Cars showcase execution (Orta San Giuillio)	PU
D.1.5.6.1	Report on the Management of the Uppsala Study	PU
D.1.5.6.2	Report on Uppsala Bolaenderna PRT Feasibility Study	PU
D.1.5.7.1	Antipolis city study phase 1	PU
D.1.5.7.2	Antipolis city study phase 2	PU
D1.5.3.4	Safety Recommendation for the operation Orta San Giuilio	PU
D1.7.1.1.	La Rochelle - reccommendation report for the operation including safety issues	PU
D1.7.1.2	La Rochelle - Operating instructions manual	PU
D1.7.1.3	La Rochelle - Small demo final management report	PU
D1.7.2.1	La Rochelle - Small demo system design	PU
D1.7.2.2	La Rochelle - Perception, planning and control subystem	PU
D1.7.2.3	La Rochelle - Communications integration and evaluation	PU
D1.7.3.1	La Rochelle - Data collection requirement list for the softwar developments	PU
D1.7.3.2	La Rochelle - Ex ante data collection of La Rochelle Small demo	PU
D1.7.3.3	La Rochelle - Data collection and consultation subsystem	PU
D1.7.3.4	La Rochelle - Final La Rohcell Small demo evalution report	PU

SP 2

Del No	Deliverable title	diss Level
D.2.1.1	State of the art report	PU
D.2.2.1	Common methodology definition	PU
D.2.2.2	Scenarios for urban mobility	PU
D.2.2.3	Passengers and goods application scenarios	PU
D.2.2.5	Scenarios for automated road transport	PU
D.2.3.1	A set of city-specific predictive models	PU
D.2.3.2	Results of the sets of model tests in the four cities	PU
D.2.4.1	Analysis Tool for Business Cases	PU
D.2.5.1	Certification guidelines for advanced transport systems	RE
D.2.2.4	City Application manual	PU
D.2.2.4b	City Application manual	PU
D.2.2.4c	City Application manual	PU
D.2.2.6	Passenger demand (patronage) estimator	PU
D.2.3.1b	A set of city-specific predictive models	PU
D.2.4.1b	Analysis Tool for Business Cases	PU
D.2.4.2	Application of the Business Case Model	PU
D.2.5.2	Overview of legal and adm. Barriers and Strategies	PU
D.2.5.3	Guidelines for safety, security and privacy	PU

SP 3

Del No	Deliverable title	diss Level
D.3.1.1	Preliminary system definition	PP
D.3.1.2	Prelimary Design of various advanced cars for cities	RE
D.3.1.3	Report on simulation of automatic driving and validation in vehicles	RE
D.3.1.4	Final design of various advanced cars for cities	RE
D.3.2.1	Human Factors' aspects	PU
D.3.2.2	Test results of HMI in use on cars and with simulators	PP
D.3.3.1	Analysis of the needs for obstacle detection	PU
D.3.3.2b	Detailed report on existing products and future expected developments	PP
D.3.3.2a	Detailed report on existing products and future expected developments	PP
D.3.4.1	Navigation specification in urban environments	PU
D.3.4.2	Analysis of wireless communication technologies	PU
D.3.4.3	First technological demonstrator for platooning of advanced city cars	PU
D.3.4.4	Report on off-tracking management for trains of cybercars and multi-trailers	RE

SP 4

Del No	Deliverable title	diss Level
D.4.1.1	Solutions for operational management	PU
D.4.1.2	New Traffic Management strategies required	PU
D.4.2.1	Operational Architecture	RE
D.4.3.1	Electronic identification to customize services, e-ticketing	PP
D.4.3.2	Prototypes of customized services in automated transport	PP
D.4.4.1	Management strategies for transport automated systems	RE
D.4.5.1	Integration of automated transport in existing structures	RE
D4.5.1b	Integration of automated transport in existing structures (modified)	RE

SP 5

Del No	Deliverable title	diss Level
D.5.1.1	Evaluation Plan	PU

D.5.1.2	Weightings for use in Multi-Criteria Analysis	PU
D.5.2.1a	Field trial ex-ante evaluation study report	PU
D.5.2.1b	Final field trial evaluation report	PU
D.5.2.2	Field trial first year evaluation report	PU
D.5.2.3	Field trial second year evaluation report	PU
D5.2.4	Final ex post report	PU
D.5.3.1a	Evaluation report of the A ex-ante study	PU
D.5.3.1b	Evaluation report of the A ex-ante study	PU
D.5.3.2	First update of the evaluation report of the ex-ante study	PU
D.5.3.3	Second update of the evaluation report of the ex-ante studies	PU
D.5.4.1	How to reach transport sustainability with automated road transport	PU

7.2 Literature

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7.3 EU-projects

MAESTRO

CONVERGE

Preval

IST KA3REN

FRAME

CityNetMobil

8 Annex I Ex-ante and ex-post indicators Castellón indicators

Table 8-1: Ex-ante and ex-post Castellon collected indicators

Evaluation category	Impact	Indicator	Ex-ante	Ex-post
Acceptance	User acceptance	Usefulness		3.7
		Ease of use		3.7
		Reliability		3.6
		Integration with other systems		3.6
	Willingness to pay	User Willingness		
		Authority Willingness		
Quality of service	Information	Information availability		3.8
		Information comprehensibility		3.8
	Ticketing	User satisfaction		3.7
	Cleanliness	Perceived cleanliness		3.6
	Comfort	Perceived comfort		3.7
	Privacy	Perceived level of privacy		3.7
	Perception of safety and security	Perception of safety		3.7
		Fear of attack		3.7
Transport patterns	Modal change	Induced mode changes in the other segments of the journey		
		System modal share	15% (daily trips in the whole Castellon area)	15%
	System use	Total passenger·km travelled	2370/day	2210/day[2]
		Total number of trips	1310/day	1530/day
		Vehicle occupancy		10%
	System performances	Average Journey time per OD pair	Node 1→2: 5' Node 1→4: 16' 45'' Node 1→5: 24' 30'' Node 4→5: 11' 30''	Node 1→2: 2' Node 1→4: 8' Node 1→5: 12' Node 4→5: 4'
		Journey time variability	Node 1→2: N.A. Node 1→4: 4' 30''	Node 1→2: N.A. Node 1→4: 2' 25''

[2] To be explained by bridge

Evaluation category	Impact	Indicator	Ex-ante	Ex-post
			Node 1→5: 9' Node 4→5: 5' 30''	Node 1→5: 5' Node 4→5: 2' 30''
		Total delay per trip		0
		Average Waiting time		5' → school days (7:30 - 9:30 am) 8' → school days (9:30 am - 10:30 pm) and no school days 15' → Saturdays 30' → Sundays and holidays
		Waiting time variability		0
		Interchange time		2' 40''
		Effective system capacity		960 p/h → school days (7:30 - 9:30 am) 600 p/h → school days (9:30 am - 10:30 pm) and no school days 320 p/h → Saturdays 160 p/h → Sundays and holidays
	Spatial Accessibility	Change in range of key activities accessible within time thresholds		
	Service Accessibility	Access times for mobility impaired users		
	Safety	Incidents		The vehicles seldom had incidents from the start of the system
		Accident levels		
		Driver workload		The same required for a conventional system
Environment	Energy	Daily consumption (KWh)		986 kWh
		Energy Efficiency (KWh/p·km)		0.44 kWh/p·km
	Toxic emissions	NO_x		1.84 g/km
		PM_{10} and/or $PM_{2.5}$		0.25 g/km

Evaluation category	Impact	Indicator	Ex-ante	Ex-post
		CO		0.15 g/km
	Climate Change	CO_2		960 g/km
	Noise	L_{DEN} and L_{night}		74 dB (<80 dB, 96/20 EC limit)
	Land take	Loss of green space from construction		
		Total land use change		
Financial impacts	Start up costs	Track construction and civil works		19 000 000€
		Vehicle acquisition/construction		2 600 000€
		Control systems and apparatus		1 250 000€
	Operating costs	Personnel		175 000 €/year
		Vehicle maintenance		158 000 €/year
		Track and civil infrastructures maintenance		30 000 €/year
		Control system maintenance		75 000 €/year
	Revenues	Operating revenues		520 000 €/year
	Subsidies	Perceived public subsidies		
Economic	Temporary job provided by installation and demonstration	Jobs provided at the demonstration site		
		Jobs increase induced at the manufacturers		
	Long terms effects on jobs	Local effects on employment		
	Vitality	Vitality index		
	Efficiency	Net Present Value		Financial CBA (20 years): -21 000 000€ Socio-economic CBA (20 years): 12 000 000€
		Internal Rate of Return		Financial CBA (20 years): -16% Socio-economic CBA (20 years): 6.5%
Legal impacts	Impacts on legal and regulatory	Induced regulation procedure changes		

Evaluation category	Impact	Indicator	Ex-ante	Ex-post
	framework			
Technological success	Performance	Docking Accuracy		3
	Reliability	Failure rate		1 correction of automatic driving each 2-3 travels
		Mean time between failures		1h 30' (considering about 30' per travel)
		Mean time to repairs		Repairs not needed

9 Annex II: Showcases

Daventry – England

Evaluation of user reaction to the showcase

For the Daventry showcase the ex-post User Acceptance survey was performed by investigating the opinion of users that physically experienced the innovative transport system. The users impressions were collected by following an Acceptance Questionnaire drafted according to the instructions provided by the CityMobil Evaluation Framework (D5.1.1). All these indicators were surveyed in terms of both **weight** and **performance rating**. This approach allowed a more complete analysis of the system User Acceptance.

The situation of the indicators is reported in the following **Fout! Verwijzingsbron niet gevonden.**. The surveyed indicators are marked with a "✓". For the weight-related questions the interviewed people were asked to order the indicators according to their importance (1= highest weight). For the performance-related questions the opinion was given in terms of level of satisfaction (1=completely dissatisfied, 2= somewhat dissatisfied, 3= fairly satisfied, 4= very satisfied, 5= completely satisfied). In order to quantify the "User willingness to pay" indicator, the question about the perceived level of performance was done asking the precise range of money the user would be available to pay for one run.

Table 9-1: Daventry surveyed indicators

Evaluation Category	Impact	Indicator	Weight	Ex-post performance rating
Acceptance	User acceptance	Usefulness	✓	✓
		Ease of use	✓	✓
		Reliability	✓	✓
	Willingness to pay	User willingness	✓	✓
Quality of service	Comfort	Perceived comfort	✓	✓
	Perception of safety and security	Perception of safety	✓	✓
		Fear of attack	✓	✓

<u>*Results*</u>

A total of 63 interviews were performed. In the following pictures the distribution of the sample is shown, according the different available characteristics of the interviewed people.

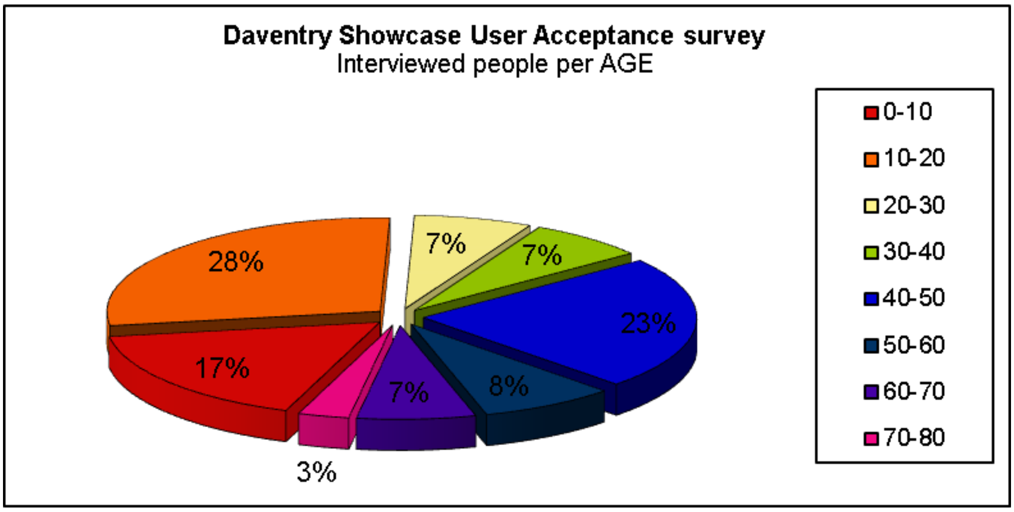

Figure 9-1: Interviewed people per age

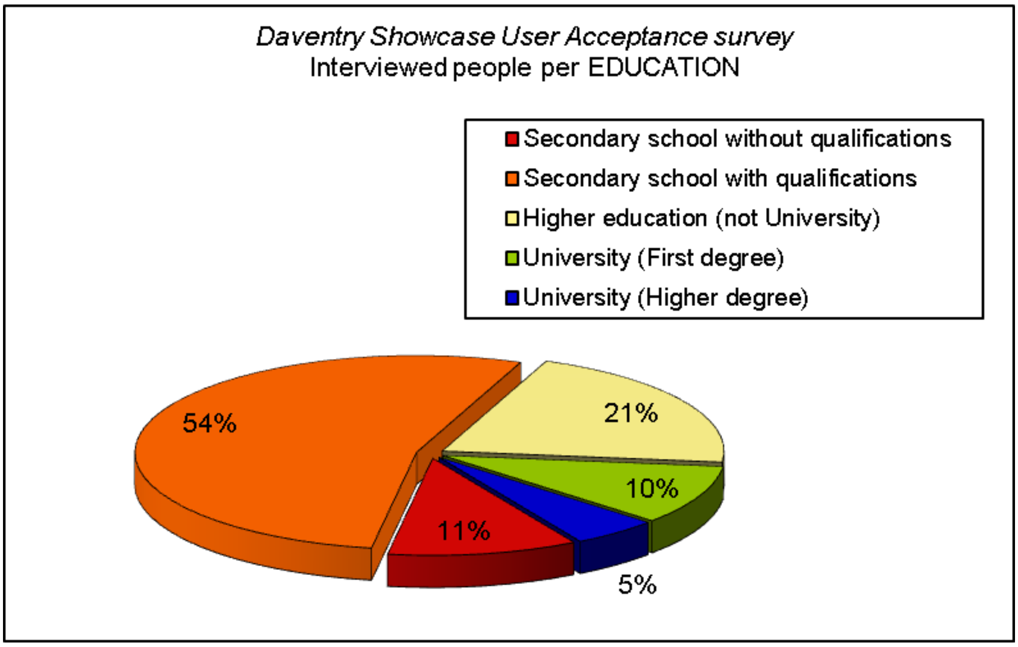

Figure 9-2: Interviewed people per education

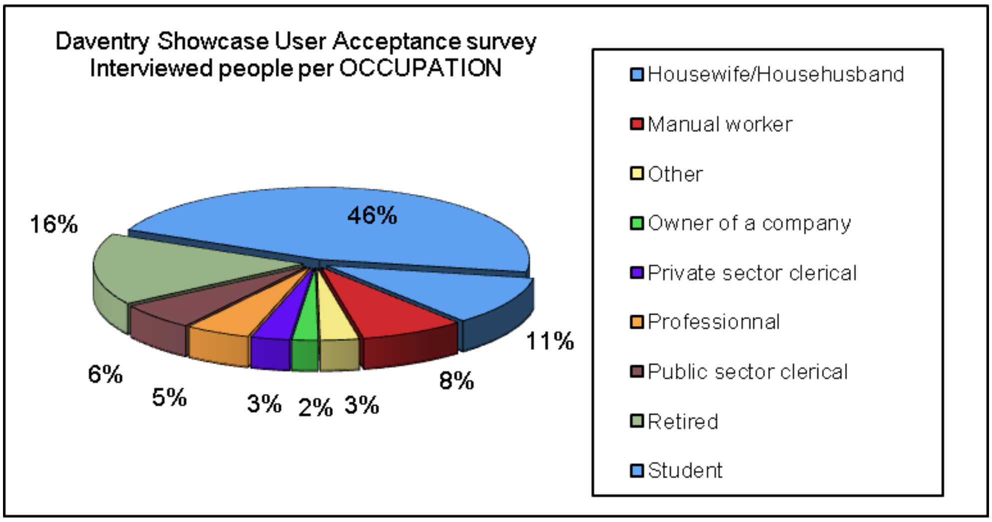

Figure 9-3: Interviewed people per occupation

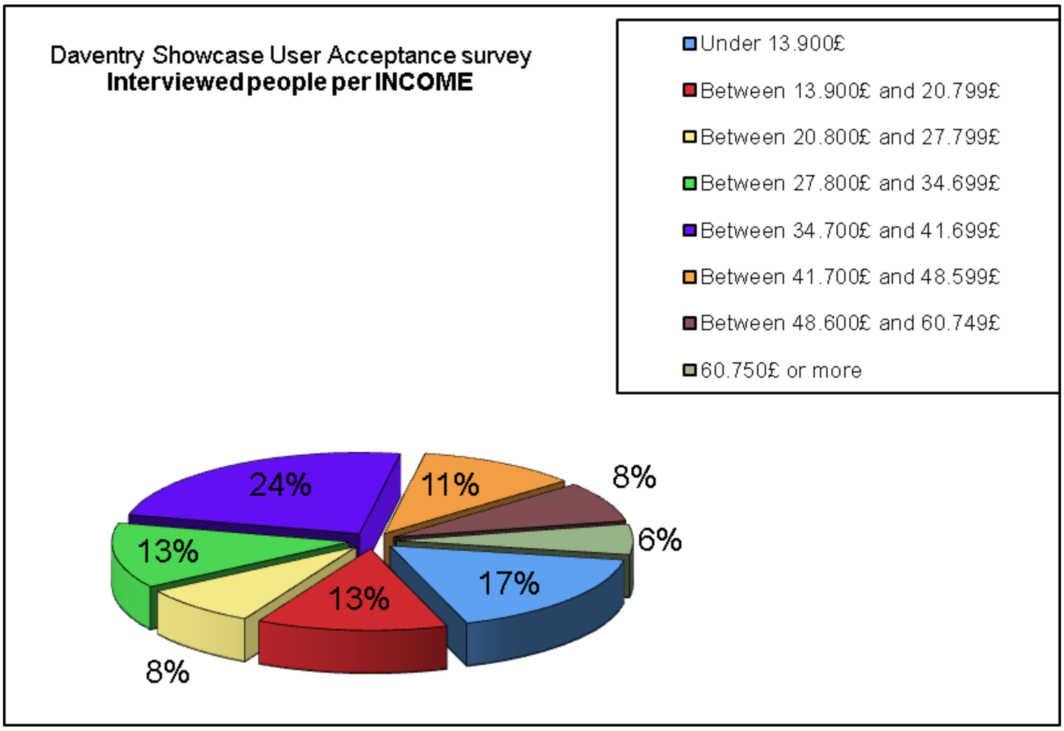

Figure 9-4: Interviewed people per income

The following Table 9-2 reports ranking and ratings averaged on the whole interviewed population. The numbers reported on the table have the following meaning:

- As for the **Ranking** values obtained for the different indicators, the average value was provided as a scale of importance, from the most important (1) to the less important. The values from 1 to the maximum were obtained by classifying the averaged values of the collected ratings.
- The weight is derived from the Ranking; it is the complement to 4, for the acceptance indicators, and to 3, for the quality of service indicators, of the average indicator ranking.
- As for the indicators **performance rating**, the value is the average of the single ratings given by the users (1 to 5 out of 5). Also the user willingness to pay was reported as the average range.

Table 9-2: Weights and performance ratings for the Daventry indicators

Evaluation Category	Impact	Indicator	Ranking	Weight	Ex-post performance rating
Acceptance	User acceptance	Usefulness	2	2.905	3.5/5
		Ease of use	1 (most important indicator within this Ev.Category)	2.937	3.1/5
		Reliability	3	2.429	3.5/5
	Willingness to pay	User willingness	4 (less important)	1.730	Between 1 and 2 €
Quality of service	Comfort	Perceived comfort	2	2.048	3.0/5
	Perception of safety and security	Perception of safety	1 (most important)	2.286	3.2/5
		Fear of attack	3 (less important)	1.667	2.9/5

This survey, though carried out on a small number of indicators and with a relatively small number of interviews, is of high value because includes the users opinion both in terms of ranking and performance of the system. This allows to have a complete picture of the actual perception of the potential users and therefore to address the corrective actions in order to enhance the system acceptance.

Regarding the results averaged on the whole interviews, the following comments can be made:

- within the "Acceptance" evaluation category, the "Usefulness" and "Ease of use" resulted as the most important, while a lower rating was assigned to the "Reliability" indicator. Although the performance ratings are very close (all within 3.1 and 3.5), it is interesting that the most important indicator is rated as the lowest performing; this can be interpreted as a request for improvements on this aspect.
- as for the "quality of service" indicators, the perception of safety is rated as the most important. Differently form the previous category, it is also the best performing, but again all the indicators have performance values very close to each other (2.9 to 3.2 out of 5) . The "Fear of attack indicator" is weighted as the less important but is also the one with the lowest performance.

Daventry results may be analysed by single user profiles. For this analysis the following categories are used:

- users with high school or university education
- users with primary-secondary school education,
- people aged up to 30,
- people over 30 years old.

In Table 9-3 the ratings for these categories are reported. The substantial differences compared to the global values are highlighted in yellow.

The difference between the opinion of the selected users profile groups compared to each other and to the average involves a limited number of aspects. The “Usefulness” indicator got a higher importance among people with a higher education; the same group gave also a performance rating which is over the average, and this suggest a higher enthusiasm on the system by this user profile. Also the over-30 gave a good rating to the usefulness of the system (4.0 out of 5). Looking at the disaggregated analysis on the “Ease of use” indicator, unexpectedly the under 30 performance rating is rather lower than the over 30s’ (2.5 versus 3.7), but the first group also considered this aspect as less important compared to the other group. The under 30 group differed from the others also for the “Reliability” aspect: they gave it the highest importance within its category and also the lowest performance rating, although higher than 3. Finally, all groups showed more or less the same willingness to pay, that is in the “1 to 2 €“ range.

Looking at the results regarding the “Quality of service” category”, the situation is more flat among the different groups: safety creates the biggest concern among all groups, however the feeling of the actual level of protection offered by the system is more than satisfactory (except for the under-30 that gave an average value slightly lower).

Table 9-3: Ranking and performance ratings divided per categories for the Daventry indicators

			All	High school or higher education	Primary/ Secondary school	Under 30	Over 30	All	High school or higher education	Primary/ Secondary school	Under 30	Over 30
Acceptance	User acceptance	Usefulness	2	1 (most important)	2	2	2	3.5/5	3.7/5	3.4/5	3.0/5	4.0/5
		Ease of use	1 (most important)	2	1 (most important)	2	1 (most important)	3.1/5	3.3/5	3.1/5	2.5/5	3.7/5
		Reliability	3 (less important)	3 (less important)	2	1 (most important)	3 (less important)	3.5/5	3.5/5	3.5/5	3.2/5	3.8/5
	Willingness to pay	User willingness	4 (less important)	4 (less important)	4 (less important)	4 (less important)	4 (less important)	Between 1 and 2€	Between 1 and 2€	Between 1 and 2€	Between 1 and 2€	Between 1 and 2€
Quality of service	Comfort	Perceived comfort	2	2	1 (most important)	2	2	3.0/5	3.0/5	2.9/5	3.0/5	3.0/5
	Perception of safety and security	Perception of safety	1 (most important)	1 (most important)	1 (most important)	1 (most important)	1 (most important)	3.2/5	3.3/5	3.2/5	2.8/5	3.6/5
		Fear of attack	3 (less important)	3 (less important)	3 (less important)	3 (less important)	3 (less important)	2.9/5	2.7/5	3.1/5	3.0/5	2.8/5

Conclusions

Daventry showcase was a great success in many respects:

1. high media coverage;
2. enthusiastic public (mostly kids);
3. Successful conference very lively with local people interested in their own town future.

Other than congratulating on the showcase success it was also important to learn some lessons from the Daventry showcase.

4. A conference addressed to the local audience and to present the local plans for upscaling from a showcase t a full system is a powerful way to motivate and interest people. From Daventry on the CityMobil consortium is requesting to the hosting cities to organise such a conference.
5. The showcase itself is normally a small journey in vehicles different from those that will be used in the full scale implementation. It is necessary to show people the vehicles and the journey to make them try it but it is also necessary to present the full concept of an automated transport systems and the local plans for such a concept. The consortium is therefore producing a video (with a common section on mobility problems one section on advanced city car transport concepts and one on CyberCars) and in the next showcases the video will be displayed, possibly alongside posters showing the local plans.

Vantaa – Finland

This sub-chapter contains the safety analysis of the Vantaa showcase. First there is a general description of the system, a general description of the site and a number of photos, drawings and maps. The following paragraph contains the Risk Indicator Tables. These tables contain a number of general indicators. During the analysis a decision is made as to whether or not these indicators are applicable and if they are, what their influence is. The final paragraph contains a number of recommendations to improve the safety of the showcase. These recommendations are the result of the analysis. They should be followed in order to be assured of an acceptable level of safety.

General description of the transport system

Table 9-4: Information about the Cycab hardware

Vehicles				
	Description			
		Height		1.60m
		Max height (incl. sensors)		1.70m
		Length		1.90m
		Max. length (incl. sensors)		1.90m
		Width		1.62m
		Max. Width (incl. sensors)		1.62m
		Turning radius		3.20m
		Nb of passengers		2+2
		Insured? (date if yes)		Yes (15/01/2010)
	Specifications			
		Mass		350 Kg
		Maximum speed		30 Km/h
		Brakes		
			Type	Electric
			Specifications	Disc brakes
		Propulsion		
			Type	Electric
			Specifications	4 electric motors, one by wheel
		Obstacle detection system		
			1. Type of sensor	Laser scanner Ibeo LD ML
			Specifications	Range: 100 mts, Frequency:
			2. Type of sensor	Stereo Camera Bumblebee
			Specifications	Detection range 15m, 80¡ using Fly algorithm
Communication system				
	Present?			Yes
	1. Type			4G Cube running Linux 2.6
	Specifications			Specifications 802.11 a/b/g WiFi, OLSR, ZeroConf. GPRS. Range: Wi-Fi: 50-150 mts.
	2. Type			GPRS
	Sp□cifications			Wavecom Fastrack 33kb. GPRS range: 2-3 kms depending on base stations around
Central control system				
	Present?			Yes
	Type			CAN, inertial unit, compass, RTK GPS, Windows PC, Linux PC, touch screen
	Specifications			
Emergency switches				
	Present?			Yes
	Type			Active radio remote controled emergency stop, on-board emergency stop button
	Specifications			Jay Electronique UR
Specific safety measures				
	Doors present			No
	Door locks present			No

Table 9-5: Information about the Yamaha hardware

Vehicles			
	Description		
		Width	1.40m
		Max. width	1.55m
		Length	3.26m
		Max. length	3.36m
		Height	1.88m
		Max. height	1.88m
		Turning radius	4.20m
		Nb of passengers	5
		Insured? (date if yes)	Yes (15/01/2010)
	Specifications		
		Mass	500kg
		Maximum speed	20km/h
		Brakes	
		Type	
		Specifications	
		Propulsion	
		Type	Electric
		Specifications	
		Obstacle detection system	
		Type	2 Front laser scanners Ibeo Alasca XT
		Specifications	Detection range 150m, 270¡
Communication system			
	Present?		Yes
	Type		4G Cube mobile router running Linux 2.6
	Specifications		Specifications 802.11 a/b/g WiFi, OLSR, ZeroConf
Central control system			
	Present?		Yes
	Type		PC + 2 * Microcontroler DSPIC 4010 (CAN Bus)
	Specifications		
Emergency switches			
	Present?		Yes
	Type		Remote active Emergency Stops + manual onboard and outside switches
	Specifications		Jay Electronique UR
Specific safety measures			
	Doors present		Yes
	Door locks present		No
Specific safety remarks			
	Risks		

Risk Indicator Tables

The risk indicator tables used in this document are directly taken from the description of the risk reduction method in reference. No changes were made for this particular application.

Table 9-6: : Built-up area

Type of build-up area	Risks for users	Applicable
Living	Number of houses/inhabitants: more inhabitants is higher likelihood of incidents	1
	Playing children are weak implies higher impact of incidents	2
	Playing children are not aware of the risks implies higher likelihood of incidents	2
	Animals are not aware of the risks implies higher likelihood of incidents	-
Home for elderly	Elderly are weak implies higher impact of incidents	-
	Elderly move slowly and therefore they may be not able to avoid a collision; implies higher likelihood of incidents	-
Recreation, Nature, Park, Tourism, Amusement park, Airport	Visitors are not familiar with the traffic situation, people aren't paying attention to the Cybernetic Transport System and people are not aware of the risks: implies higher likelihood of incidents	1
	(Playing) children are weak implies higher impact of incidents	-
	(Playing) children are not aware of the risks implies higher likelihood of incidents	-
	Animals are not aware of the risks implies higher likelihood of incidents	-
Offices	Commuters cause crowded peak hours, implies higher likelihood of incidents	1
Schools / kindergarten	(Playing) children are weak implies higher impact of incidents	2
	(Playing) children are not aware of the risks, implies higher likelihood of incidents	2
	Crowded peak hours, implies higher likelihood of incidents	3
Sport area, Events	Visitors are not familiar with the traffic situation, people aren't paying attention to the Cybernetic Transport System and they are not aware of the risks, implies higher likelihood of incidents	4
	Peak of number of visitors at the end of a match or event, implies higher likelihood of incidents	4
Hospitals	Rushing ambulances, implies higher likelihood of incidents	-
Parking	Peak of number of visitors, implies higher likelihood of incidents	5

Remarks:

1	Area is a busy shopping district with shops, houses and offices. The CTS track is separated from the other users.
2	There is a Kindergarten, but it is fenced so that children can not wander around
3	Peak hour is at 16.00. The responsible operator should stop the system if the area is too crowded too control the system. Regular users of the area should be warned one week in advance that the event is taking place (by means of signs)
4	There are events in the last week of the showcase. One event in the church and one event with music at the city hall. The responsible operator should stop the system if the area is too crowded too control the system.
5	There is a parking area next to the track. People normally using that should be asked to avoid it if at all possible during the showcase. Interference between the parking traffic and the CTS is prevented by the use of concrete barriers

Table 9-7: Potential Users, trespassers and other traffic

Risk profile	Risk subject/type of environment	Risks for users of the environment	Applicable
Potential users of the Cybernetic Transport System	Number of users	Peak intensities (high peak intensities will cause longer waiting times and a higher number of waiting people) implies higher likelihood of incidents	1
	Characteristics of the users	Are they aware or unaware (animals, playing kids) (unaware is higher likelihood of dangerous situations) Are they patient or impatient (impatient is more likelihood of dangerous situations because they may be entering the track) Are they fast or slow moving (fast moving is more difficult to avoid a collision) Are they weak or strong (weak is higher impact of incidents)	2
	Origins and destinations of the users, routes of the users	What route will they take from origin to destination? Will they cross the track of the Cybernetic Transport System? Is the straight line connection crossing the track of the Cybernetic Transport System? If the shortest route is crossing the track there is a greater likelihood that users will enter the track; implies a greater likelihood of encounters. The fewer crosswalks, the larger the detour and the greater the likelihood that people will cross the track at a place where it isn't allowed. If the distance between origin and destination is not too far, users will enter the track if they have to wait too long for the next CyberCar. Higher likelihood of incidents	3
	…		-
Trespassers	Number of trespassers	more trespassers is a higher likelihood that someone enters the track is higher likelihood of incidents	-
	Characteristics of the trespassers	Are the aware or unaware (animals, playing kids) (unaware is higher likelihood of dangerous situations) are they patient or impatient (impatient is greater likelihood of dangerous situations) are they fast or slow moving (fast moving is more difficult to avoid a collision) are they weak or strong (weak is higher impact of incidents)	-
	..		-
Other traffic on the same track	Cybernetic Transport System	See risk profile for Cybernetic Transport System	-
	Pedestrians	Slow and weak road-users implies easy to detect, but higher impact of incidents	-
	Bikes	Slow and weak road-users implies easy to detect, higher impact of incidents	-
	Cars	Fast road-users implies difficult to detect, high impact on Cybernetic Transport System, both in likelihood and severity	-
	Lorries	Fast and strong road-users implies difficult to detect, high impact on Cybernetic Transport System, both in likelihood and severity	-

Other traffic on the same track	Rail traffic	Fast and strong road-users without maneuvering capabilities	-
	…		-
Other traffic crossing the Cybernetic Transport System track	Number of crossings	The more crossings, the greater the likelihood of incidents	3
	Type of crossings	grade crossing or road over road crossing, unguarded or guarded implies influence on the likelihood of incidents (encounters)	-
	Number of CyberCars	The more CyberCars the smaller the time period between two CyberCars = smaller gap to cross	-
	Amount of traffic	The more traffic crossing on the Cybernetic Transport System track, the greater the likelihood of incidents	-
	Type of traffic	Are the aware or unaware (animals, playing kids) (unaware is higher likelihood of dangerous situations) are they patient or impatient (impatient is more likelihood of dangerous situations) are they fast or slow moving (fast moving is more difficult to avoid a collision) are they weak or strong (weak is higher impact of incidents)	4
	…	…	

Remarks:

1	There are only three vehicles. In case of peak intensities time slots can be instated. If the situation gets uncontrollable the system should be stopped
2	Stickers with the text 'Automated Vehicle' in Finnish will be put on the vehicles.
3	There are two crossings, one for pedestrians and one for trucks
4	If trucks have to cross, the system will be stopped.

Table 9-8: Objects in the neighborhood

Risk profile	Risk subject	Risks	Applicable
Objects in the neighborhood	Power pylon and power transmission line	Electric magnetic fields, danger of electric shock	1
	Industry	Processes can be dangerous	-
	Buildings	Effect on navigation, communication, and obstacle detection	2
	Tunnels	Effect on navigation and communication	-
	Flyover	Obstacle, Falling objects	-
	Ditches, canals, rivers	Water near the track, drowning danger, natural barrier	-
	Trees	Falling branches, objects on track	-
	Mountains	Falling objects, natural barrier	-

Remarks:

1	One power cable crossing over the track is necessary at the central roundabout
2	The effect of the buildings etc. in the area on the GPS navigation system and the communication system must be checked carefully.

Table 9-9: Specific conditions of the environment

Risk profile	Risk subject	Risks	Applicable
Weather conditions	Heavy wind	Extreme wind forces on vehicles → effect on stability and driving behavior of vehicles. More steering deviation of the CyberCar due to wind load. Change of behavior of other traffic.	-
	Extreme cold	Effect on components of the Cybernetic Transport System	-
	Extreme heat	Effect on components of the Cybernetic Transport System	-
	Snow	Slippery track, poor visibility. Cybernetic Transport System can not brake accurately due to slippery road.	-
	Freezing rain	Slippery track, poor visibility. Cybernetic Transport System can not brake accurately due to slippery road.	-
	Heavy rain	Slippery track, water on the track, reflection of light, poor visibility	1
	Fog	Poor visibility	1
Natural phenomena	Earthquake	Disturbance of the track, falling obstacles	-
	Flooding	Water on the track	-
	Lightning	Effect of Electric magnetic fields on the vehicle, lightning stroke	-
Lighting conditions	Dark area	People do not see the Cybernetic Transport System properly	-

Remarks:

1	In case of heavy rain or poor visibility in case of fog the system will be stopped

Table 9-10: Risk profile of the vehicles and hardware

Risk profile	Risk subject	Risk effect	Applicable
Cybercar	Speed	Higher speed means more reaction time needed, higher speed in combination with higher mass means more energy and can result in more damage by collision	1
	Deceleration Jerk	Increase in the deceleration jerk will be dangerous for passengers inside, especially if standing	-
	Acceleration	Higher acceleration means more difficult to anticipate by other users of the environment	-
	Ability to maneuver	The ability to maneuver gives the ability to prevent collisions, a lot of change in maneuvers means more difficult to anticipate by other road-users	2
	Mass	Higher speed in combination with higher mass means more energy can result in more damage by collision	-
	Obstacle detection and Collision avoidance	A good obstacle detection system and collision avoidance system will prevent collisions with obstacles and other road-users	3
	Number of passengers in vehicle	More people do not necessarily raise the likelihood of anything to happen, but surely this raises the severity of anything that occurs because of the impact it might have on more people	4
	Sitting or standing passengers	Standing passengers can fall	-
	Dimensions L, B H	Free space needed for the vehicle, bigger dimensions can make a vehicle more visible	-
	Navigation	Accurate navigation results in less room needed on the track and less steering errors	-

Remarks:

1	Vehicle speed is 6 km/h
2	There is no maneuverability
3	There will be either an obstacle detection system or permanent monitoring by an operator who can stop the system
4	The small vehicle can hold 2 people and the big one 4

Table 9-11: Risk profile of the embedded control system

Risk profile	Risk subject	Risk effect	Applicable
Control System	Communication	Loss of communication can result in a standstill -> the Cybercar becomes an obstacle. Cybernetic Transport System communication can interfere with other systems in the environment. Depending on the power and frequency of the communication system.	1; 2
	Accuracy		
	Traffic management	Slow down ability of vehicles at dangerous spots like crossings, stops and dangerous curves -> positive for safety	3; 4
	Fleet management		
	Total number of passengers a day	The number of people possibly involved in an incident with the system	-
	Type of passengers	Tourists with luggage, students, commuters	-
	Number of vehicles	More vehicles mean a more complex system	3
	Number of vehicle types	More types of vehicles mean a more complex system	2

Remarks:

1	Vehicles stop when GPS falls away
2	Measurements were made on March 24, to assess whether interference can take place
3	Vehicle speed is lowered in curves
4	Vehicle speed should be lowered at crossings

Table 9-12: Risk profile of the track

Risk profile	Risk subject	Risk effect	Applicable
Track	Type of passengers	Tourists with luggage, students, commuters	-
	Number of vehicles	More vehicles mean a more complex system	-
	Number of vehicle types	More types of vehicles mean a more complex system	-
	Stops	The design of the stop affects the safety, e.g.: The placement of a stop Free stops along the track	-
	Navigation	Accurate navigation results in less room needed on the track and fewer steering errors	-
	Communication	Loss of communication can result in a standstill of CyberCars. Cybernetic Transport System communication can interfere with other systems in the environment. Depending on the power and frequency of the communication system.	-
	Infrastructure	The dimensions of the track → maneuvering area The pavement of the track → special pavement for Cybercar to keep other road users from the track.	1
	Crossings	Design of crossings affects the safety, e.g.: Crossings with bars or only signaling	-
	Fences	Physical barriers to prevent people to enter the track	-
	Shelters		2

Remarks:

1	The pavement has to be adjusted to allow the vehicle to run up to a sidewalk
2	The controller is in the shelter

Conclusions:

The method as described appeared to be useful and practical when applying on the Vantaa showcase. The recommendations below are partly the results of the analysis as presented in the risk indicator tables, but also on the discussion with the various stakeholders that was the basis for completing the tables.

Recommendations:

1. In order to avoid contact between vehicles and the public, one of the following two situations should be valid at all times:
    1. All vehicles should be provided with an adequate obstacle detection system that stops the vehicle before an impact can take place.
    2. There should be someone monitoring each vehicle at all times, with a remote control to stop the system.
2. The responsible operator should stop the system if the area is too crowded to control the system. Regular users of the area should be warned one week in advance that the event is taking place (by means of signs).
3. There are events in the last week of the showcase. One event in the church and one event with music at the city hall. The responsible operator should monitor the situation and stop the system if the area is too crowded to control the system at those times.
4. The effect of the buildings etc. in the area on the GPS navigation system and the communication system must be checked carefully
5. An additional fence and signs are needed to prevent cyclists from entering the track at Vehkapolku crossing.
6. Stickers with the text ‘Automated Vehicle’ in Finnish will be put on the vehicles.
7. To avoid people crossing the track unnecessarily, it is advisable to have signs directing people which way to take for their different destinations.
8. When trucks have to cross the track the system should be stopped temporarily.
9. Users of the parking area near the Kindergarten (Kinka Asema) will be advised to use other parking places.
10. In the case of heavy rain, poor visibility or fog the system will be stopped
11. Some additional concrete barriers should be placed behind the tent.
12. It is advisable to move the pedestrian crossing about 10 meters towards the railroad station, in order to emphasize that the situation is not as usual.

Trondheim - Norway

As an illustration of the method a safety analysis of the Trondheim Showcase has been executed. In principle a safety analysis using the Risk Reduction Method will be carried out on all of the CityMobil showcases and small demonstrations. The Trondheim showcase will be executed in August 2009. The site was visited and assessed on the 25th of March 2009; the results are in chapter 2 of this document

The Risk Reduction method

The purpose of the Risk Reduction Method is to establish the safety risks related to the implementation of an automated transport system in an urban environment. The Risk Reduction Method is not meant to be a comprehensive safety analysis method. The intention is to have an indication of safety risks in a very early stage of the planning process. A different, much more extensive procedure exists for the complete safety and certification process needed when an automated transport system is implemented in a city.

The simplicity of the Risk Reduction Method makes it excellently suited for the analysis of the safety implications of short duration showcases and demonstrations. The method is used for the first time to establish safety implications of the showcases and small demonstrations carried out in the CityMobil project, an integrated project in the 6th framework of the EU. (www.citymobil-project.eu).

The method analyses risk factors following various angles of view of the showcase setting such as the built-up area, the potential users and trespassers, objects in the neighbourhood, specific conditions of the environment and the used vehicles and hardware. Per aspect a number of general indicators are listed in tables. By a simple expert assessment as to whether or not a certain risk factor is relevant, the seriousness of the risk can be estimated and measures to mitigate the risk can be proposed. The risk is expressed in likelihood of occurrence of an event and the severity of the effect. Where appropriate a further technical analysis will be carried out, for instance to establish the effectiveness of braking systems or obstacle detection systems.

Information about the site and the system can be found in the second chapter of this document. This chapter also contains the risk reduction tables and the results of the analysis in the shape of a list of recommendations that need attention in order to guarantee the safety of the showcase. A formal written reaction on these issues from the parties responsible for the showcase is required.

Safety Recommendations for the Trondheim Showcase

This chapter contains the safety analysis of the Trondheim showcase. First there is a general description of the system, a general description of the site and a number of photos, drawings and maps. The following paragraph contains the Risk Indicator Tables. These tables contain a number of general indicators. During the analysis a decision is made as to whether or not these indicators are applicable and if they are, what their influence is. The final paragraph contains a number of recommendations to improve the safety of the showcase. These recommendations are the result of the analysis. They should be followed in order to be assured of an acceptable level of safety.

Table 9-13 : Information about the Cycab hardware

Vehicles				
	Description			
		Height		1.60m
		Max height (incl. sensors)		1.70m
		Length		1.90m
		Max. length (incl. sensors)		1.90m
		Width		1.62m
		Max. Width (incl. sensors)		1.62m
		Turning radius		3.20m
		Nb of passengers		2+2
		Insured? (date if yes)		Yes (15/01/2010)
	Specifications			
		Mass		350 Kg
		Maximum speed		30 Km/h
		Brakes		
			Type	Electric
			Specifications	Disc brakes
		Propulsion		
			Type	Electric
			Specifications	4 electric motors, one by wheel
		Obstacle detection system		
			1. Type of sensor	Laser scanner Ibeo LD ML
			Specifications	Range: 100 mts, Frequency:
			2. Type of sensor	Stereo Camera Bumblebee
			Specifications	Detection range 15m, 80¡ using Fly algorithm
Communication system				
	Present?			Yes
	1. Type			4G Cube running Linux 2.6
	Specifications			Specifications 802.11 a/b/g WiFi, OLSR, ZeroConf. GPRS. Range: Wi-Fi: 50-150 mts.
	2. Type			GPRS
	Sp□cifications			Wavecom Fastrack 33kb. GPRS range: 2-3 kms depending on base stations around
Central control system				
	Present?			Yes
	Type			CAN, inertial unit, compass, RTK GPS, Windows PC, Linux PC, touch screen
	Specifications			
Emergency switches				
	Present?			Yes
	Type			Active radio remote controled emergency stop, on-board emergency stop button
	Specifications			Jay Electronique UR
Specific safety measures				
	Doors present			No
	Door locks present			No

Table 9-14: Information about the Yamaha hardware

Vehicles				
	Description			
		Width		1.40m
		Max. width		1.55m
		Length		3.26m
		Max. length		3.36m
		Height		1.88m
		Max. height		1.88m
		Turning radius		4.20m
		Nb of passengers		5
		Insured? (date if yes)		Yes (15/01/2010)
	Specifications			
		Mass		500kg
		Maximum speed		20km/h
		Brakes		
			Type	
			Specifications	
		Propulsion		
			Type	Electric
			Specifications	
		Obstacle detection system		
			Type	2 Front laser scanners Ibeo Alasca XT
			Specifications	Detection range 150m, 270¡
Communication system				
	Present?			Yes
	Type			4G Cube mobile router running Linux 2.6
	Specifications			Specifications 802.11 a/b/g WiFi, OLSR, ZeroConf
Central control system				
	Present?			Yes
	Type			PC + 2 * Microcontroler DSPIC 4010 (CAN Bus)
	Specifications			
Emergency switches				
	Present?			Yes
	Type			Remote active Emergency Stops + manual onboard and outside switches
	Specifications			Jay Electronique UR
Specific safety measures				
	Doors present			Yes
	Door locks present			No
Specific safety remarks				
	Risks			

10 Annex III Participants at the workshop

Name	*Organisation*
Martijn de Kievit	TNO (WP-leader)
Teije Gorris	TNO (mobility expert)
Pieter Verhagen	TNO (facilitator)
Martin van der Lindt	TNO (Transition expert)
Adriano Allessandrini	DITS (SP5-leader – policy expert)
Alma Solar Catalyd	ETRA (operational expert)
Shlomo Berkor	Technion (environmental expert)
Jan Katgerman	RUPS (technology expert)
Fast drawing expert	Jefte Bade

11 Annex IV Interview reports

11.1 Interview Connexxion – Parkshuttle Rivium

Introduction

These notes are based on an interview with the a company (Connexxion) for public transport which owns and runs the Parkshuttle between a Rotterdam metro line and a business park in Capelle in a concessions of the Regional Public Transport Board .

Park Shuttle bus is an ATS and works without driver (people mover). It drives between Metro station Kralingse Zoom with three stops in Rivium business park in ‘Capelle aan den Ijssel’. Since 1 September 2008 the park shuttle runs from Monday to Friday from 06: 00 until 21: 00, every 2.5 minutes during rush hours and beyond on demand, maximum waiting time is 6 minutes. The route is closed to other traffic (so a free bus lane) and has two lanes, so buses may pass one another except under the viaduct under the Highway (A16) and the bridge over the local road (N 210), where if necessary, wait until the bus against is over. There are some crossings with roads. They have been protected with barriers.

The Park Shuttle is no part of the CityMobil project but in is way it is a unique and innovative project of automated transport. The results are important for the evaluation of CityMobil.

Current situation

The Park shuttle is owned and run by Connexxion. The Public Transport Board in the region has decided (after consultation with the Ministry of Transport) that the concession for the operation of the Parkshuttle every 6 years will be reversed. The impression of Connexxion is that in end 2011 there is hardly any interest in other transport companies to participate. A reverse auction is seen as a threat for this ATS and later initiatives for ATS’s in the Netherlands.

The system had many technical problems in the past and has a 'image' problem. A possible solution of the problem is that the city region gives some extra money for the operation of the park shuttle.

It is given the national ticketing system for public transport difficult for Connexxion to run a profitable operation with the park shuttle Capelle without subsidies. Connexxion has in recent years a great deal of experience gained with the system in Capelle. Chances are real that the system will stop and not starts again.

The system could been sold second hand (e.g. abroad to Daventry). But is not clear if there is interest at the (international) market.

Experiences of Connexxion

The system with automatic vehicles is too much designed from the technical aspects. In the beginning there was no transport company involved in the design requirements and implementation. Later, Connexxion tried to minimize problems.

Connexxion has the impression that still new systems, as in Masdar-city, again are technically designed and are dropped where too little knowledge and experience of transport companies is used.

Since recent years Connexxion does the management and works on optimization functionality with minimization of costs. Previously, the own (financial) interests of suppliers (also Frog and 2Getthere) where too big. Repair and replace parts of Connexxion are now generally less expensive than the expensive solutions in history.

The Parkshuttle remained in the air with subsidies. It is depending on a few enthusiastic people protecting the system to be stopped. Right now when the technical problems finally seem to have disappeared the organizational problems prevail.

This ATS system clears to be optimal to a distance of ca. 5 km. For connections of business parks, attractions, large-scale parking lots etc. In particular, the high frequency (waiting times <5 min.) is leading to high quality without extreme costs. As soon as the frequency is smaller (10-15 min.) it becomes less expensive to go back to to regular busses.

Conclusions

After many years of technical problems the system works properly now. But the organization around the public transport systems stil does have a view of the unique Parkshuttle project. The system has an image of often unreliable and not proper functioning. It is clear it takes a long time get rid of this image again. A year of proper working is by far to short.

At this moment the financial crisis (November 2011) gives extra uncertainty for a political support for innovative systems. (unknown is less wished). There is still not enough information about the Parkshuttle to make people enthousiast. Projects like CityMobil give much attention for these developments but it is still difficult to reach a broader audience.

If the operation of Parkshuttle Rivium will stop it will be clear that these systems will get a delay of many years.

11.2 Interview APTS – Phileas Eindhoven

These notes are based on interview with the local authority which is responsible for public transport around Eindhoven area, Netherlands (SRE)

Introduction

Phileas is high quality public transport, since 2004 run and further developed by the Regional Government around Eindhoven (SRE, Cooperation Foundation Eindhoven), Netherlands with support of some companies. The development of the system has started around 1997 with subsidies from the Dutch national government. The goal was to develop an advanced guided bus. Intended to deliver tram-like public transport at a very low cost. In fact the infrastructure is much cheaper than a railway system because of less maintenance and there are no rails and overhead lines. The biggest feature of the bus is the recharging of the battery by means of electromagnetic induction; which means that the battery can be made much smaller, and thus less heavy. The project was created in the late 1990s; there was a wish to demonstrate the high technology level and technical knowledge in the Eindhoven area and to create jobs. The project has cost more than one billion of euros, including infrastructure changes. Many of the intentional technological plans could in the end not be fulfilled:

- no central guidance system
- and no positioning system, (original thought with transponders)
- electric hub motors

Still it has:

- a light weight body
- modern appearance
- hybrid drive, but parallel-hybrid in stead of the original serial-hybrid
- doors at both sides (but the are not used at both sides)
- as a concept: ‘tram on tires’: larger capacity, own infrastructure, low entrance, high service an frequency.

Phileas is no part of CityMobil but still a unique project with at least in the beginning the ambition to become an automated transport system.

SRE coordinates and gives concessions (10 years) to public transport companies for running the Phileas between centre of Eindhoven to the local airport. Per year 5 million people are moved.

Experiences:

Automatic guidance

- The running system does not use any automated guidance. It appeared to be to expensive to adapt the trajectory. Specially the traffic lights were a bottleneck in social security. Grade-separated crossings where financial too high.
- Now automated stopping at the busstops is an issue but fully ATM is no option.
- There were had many technical problems with too fast breaking and speed up. (less comfort).
- Electrical wheel drives did not work properly and were removed
- Batteries were not big enough and the batterymanagement did not work properly. In the end the serial hybrid system is replaced by a parallel hybrid system.
- In the beginning there was no back-up system for the management system. Risk on failures was much to high.

Design & material

- The design is good
- Seats are to hard (uncomfortable)
- The wheel arches are high (not used any more)
- Doors at both sides are not used but give less sitting places
- Axes where not strong enough and broke
- In the beginning busses had only 1 computer and no back-up
- Relative much noise

Concept

- Originally no stop buttons (metro system) was too unusual in busses
- Ticketing system was not proven for foreigners (airport connection)
- Not enough seats
- No fully separated infrastructure: traffic lights, small curves, traffic bumps etc.

Conclusions

Many years there was a line of technical problems with the vehicles. Due to these problems many innovations have been removed. Effect: the confidence in the concept came to a minimum. In recent years the resting Phileas system is working good.

After all the general conclusion is: too many innovations at once.

The idea was a political driven project with many ambition goals possible with many subsidies. The reality learns that the exploitation is too expensive because there are not enough passengers for the system (it has not the minimum 25.000 people a day).

In other countries the system is working properly (Douai, France). But is some places (for instance Istanbul) also after problems. In France they see the system as a cheaper tram, in the Netherlands too much as a expensive bus.