CITYMOBIL

ADVANCED TRANSPORT FOR THE URBAN ENVIRONMENT

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SIXTH FRAMEWORK PROGRAMME

CityMobil_brochure2011xy_druckmontage.indd 2-3
21.11.2011 15:35:15

Notes

Foreword

The first thoughts about the CityMobil project started in May 2004. In that month we were informed that a new call in the EU's 6th Framework Programme for Research and Technological Development would be issued in a few months time. Part of this call was to be about „Automated Road Transport for the Urban Environment", a topic that we, at TNO had been enthusiastically working on for many years. After consultation with some colleagues abroad, whom we knew to be interested in the same topic, my colleague Marten Janse and I decided to issue a proposal. From that moment on 7.5 years of inspired and hard work by many people led to the document that lies before you.

The official start of the CityMobil project was in May 2006, after almost 2 years of preparation. The project ends in December 2011 with the publication of this document that contains an overview of the results that we obtained in the project and some directions for the future. The 29 partners from 11 European countries that were involved in the project are convinced that we met our general goal: „To bring the implementation of automated transport systems in urban areas a major step forwards." In the next years we expect to see a steady increase in the number of automated transport systems in operation in Europe. I am proud to have been a part of that development.

Jan van Dijke
CityMobil Coordinator

CityMobil_brochure2011xy_druckmontage.indd 6-7 21.11.2011 15:35:15

Del. Number	Deliverable title
D.1.7.3.4	Final La Rochelle Small demo evaluation report
D.2.1.1	State of the art report
D.2.2.1	Common methodology definition
D.2.2.2	Scenarios for urban mobility
D.2.2.3	Passengers and goods application scenarios
D.2.2.4c	City Application manual
D2.2.5	Scenarios for automated road transport
D.2.2.6	Passenger demand (patronage) estimator
D.2.3.1.b	A set of city-specific predictive models
D.2.3.2	Results of the sets of model tests in the four cities
D.2.4.1.b	Analysis Tool for Business Cases
D.2.4.2	Application of the Business Case Model
D.2.5.1	Certification guidelines for advanced transport systems
D.2.5.2	Overview of legal and administrative barriers and strategies to remove them
D.2.5.3	Guidelines for safety, security and privacy
D.3.2.1	Human Factors' aspects
D.3.3.1	Analysis of the needs for obstacle detection
D.3.4.1	Navigation specification in urban environments
D.3.4.2	Analysis of wireless communication technologies
D.4.1.1	Solutions for operational management
D.4.1.2	New Traffic Management strategies required
D.5.1.1	Evaluation Plan
D.5.1.2	Weightings for use in Multi-Criteria Analysis
D.5.2.1a	Field trial ex-ante evaluation report
D.5.2.1b	Other field trial evaluation report
D.5.2.2	First ex-post report
D.5.2.3	Second ex-post report
D.5.2.4	Final ex-post report
D.5.3.1a	Evaluation report of the A ex-ante study
D.5.3.1b	Evaluation report of the ex-ante studies
D.5.3.2	First update on the evaluation report of the ex-ante study
D.5.3.3	Second update on the evaluation report of the ex-ante study
D.5.4.1	How to reach transport sustainability with automated road transport

CityMobil_brochure2011xy_druckmontage.indd 8-9
21.11.2011 15:35:15

Appendix C. List of deliverables

This list of deliverables does not contain all the formal deliverables of the project. Some deliverables have been issued in versions and in those cases only the final complete version has been included in the list. Other deliverables consisted of hardware delivered at a certain time, or in a few cases deliverables were just deadlines that had to be met. This list only shows those deliverables that consist of reports. As far as these reports are public, they are available for download from the CityMobil website (www.citymobil-project.eu).

Del. Number	Deliverable title
D.0.2.6	Exploitation plan
D.1.2.2.1	Summary specification for the Heathrow pilot scheme
D.1.2.2.2	Outline description of the Heathrow Pilot Scheme
D.1.2.3.1	Identification of the key parameters affecting user satisfaction
D.1.2.3.2	Simulation of representative version of the existing PRT system
D.1.2.4.1.	Evaluation of the passenger and operator satisfaction levels
D.1.2.4.2	Evaluation of the passenger and operator satisfaction using similar metrics
D.1.2.4.3	Comparison of the ULTRA PRT system with the existing bus service
D.1.2.6.1	Specification of a communication based collision avoidance system
D.1.2.6.2	Test and report of CBCAS using the ULTRA vehicles at Cardiff
D.1.3.1.5	Certification of the Rome CTS
D.1.3.1.6	Results of the vehicle tests in the Rome Magliana depot
D.1.3.1.7	Training procedure for Rome management and maintenance personnel
D.1.3.1.8	A study on the effect of user transport demand
D.1.4.2.1	Specification of vehicles
D.1.5.1.3	First cybercar showcase report (Daventry)
D.1.5.1.4	Second cybercar showcase report (Vantaa)
D.1.5.1.5	Third cybercar showcase report (Trondheim)
D.1.5.1.6	First Advanced City Cars Showcase report (La Rochelle)
D.1.5.1.7	Second Advanced City Cars Showcase report (Orta San Giulio)
D.1.5.2.3	Daventry showcase: Recomm. for the operation incl. safety issues
D.1.5.2.4	Vantaa showcase: Recomm. for the operation incl. safety issues
D.1.5.2.5	Trondheim showcase: Recomm. for the operation. incl. safety issues
D.1.5.3.2	La Rochelle showcase: Recomm. for the operation incl. safety issues
D.1.5.3.4	Orta san Giulio showcase: Recomm. for the oper. incl. safety issues
D.1.5.5.1	First Cybercars showcase execution (Daventry)
D.1.5.5.2	Second Cybercars showcase execution (Vantaa)
D.1.5.5.3	Third Cybercars showcase execution (Trondheim)
D.1.5.5.4	First Advanced City Cars Showcase execution (La Rochelle)
D.1.5.5.5	Second Advanced City Cars Showcase exec. (Orta san Giulio)
D.1.5.6.2	Report on the Uppsala Bolaenderna Feasibility study
D.1.5.7.1	Sophia Antipolis city study phase 1 report
D.1.5.7.2	Sophia Antipolis city study phase 2 and final report
D.1.7.1.2	Operating instructions manual
D.1.7.1.3	Small demo final management report
D.1.7.2.1	La Rochelle Small demo system design
D.1.7.2.2.	Perception, Planning and control subsystem
D.1.7.2.3	Communications integration and evaluation
D.1.7.3.1	Data collection requirement list for the software developments
D.1.7.3.2	Ex-ante data collection of La Rochelle Small demo
D.1.7.3.3	Data collection and consultation subsystem

Contents

CityMobil_brochure2011xy_druckmontage.indd 10-11 21.11.2011 15:35:15

1.1 History

In 1975 the Morgantown Personal Rapid Transit system was the worlds first automated transport system to transport people in a public transport scheme outside attraction parks. The Morgantown People Mover runs on rubber tires in a U-shaped concrete guideway. Vehicles carrying maximum 20 people move over a 14 km system between 5 stations with a maximum speed of 50 km/h. Although the Morgantown system is called a PRT (personal rapid transit) system, in terms of today it should be rather called a Group Rapid Transit (GRT) system. Other GRT systems followed, mostly of a train-like type, like the Vancouver Skytrain and Morgantown PRT system and the Lille VAL.

Lille VAL

Vancouver Skytrain

These systems were followed by many comparable systems, generally based on rail or monorail mechanical guiding and usually operating as metros in dense urban areas or as people movers in airports. The first automated transport system without mechanical guiding to carry people in a public transport operation was the ParkShuttle, transporting people from a metro station to an office area in Capelle aan de IJssel in the Netherlands. After a testing period between 1999 and 2002 the system entered into operation in 2007. 6 vehicles, each carrying a maximum of about 20 people, move between 4 stations over a trajectory of 1.8 km. The ParkShuttle uses a normal asphalt road surface with magnets in the road and odometry to find its way.

Parkshuttle

The first systems for PRT, personal rapid transit entered into operation in 2010; one at Heathrow airport in the UK (the ULTra PRT system) and another one, the Masdar PRT system in Masdar City in Abu Dhabi. Both systems use their own separated infrastructure and transport 4 - 6 people in their own private cabin between a number of stations on the trajectories.

ULTra PRT system

Masdar PRT system

Appendix B. Sub Projects and Work Packages

Sub-Project 0: General management:

Work Packages:
- WP 0.1: IP management
- WP 0.2: Dissemination and Exploitation

Sub-Project 1: Demonstrations

Work Packages:
- WP 1.1: Coordination
- WP 1.2: Heathrow demonstrator
- WP 1.3: Rome demonstrator
- WP 1.4: Castellón demonstrator
- WP 1.5: Showcases and city studies
- WP 1.6: Lausanne demonstration
- WP 1.7: La Rochelle demonstration

Sub-Project 2: Future scenarios

Work Packages:
- WP 2.1: State of the art
- WP 2.2: Scenario building
- WP 2.3: Analysis tools
- WP 2.4: Business cases
- WP 2.5: Legal and administrative issues

Sub-Project 3: Vehicles and technological issues

Work Packages:
- WP 3.1: Cybercars and advanced city car design
- WP 3.2: Human Factors
- WP 3.3: Obstacle detection and avoidance
- WP 3.4: Cooperative Vehicles and navigation

Sub-Project 4: Operational issues

Work Packages:
- WP 4.1: Operational management
- WP 4.2: Architecture and information flow
- WP 4.3: Service customisation
- WP 4.4: Traffic management strategies
- WP 4.5: Integrating advanced transport in an existing structure

Sub-Project5: Evaluation

Work Packages:
- WP 5.1: Definition of the evaluative framework
- WP 5.2: Demonstration evaluation
- WP 5.3: Ex-ante evaluation of other case-studies
- WP 5.4: Evaluation of advanced transport contribution to sustainability

CityMobil_brochure2011xy_druckmontage.indd 12-13
21.11.2011 15:35:15

Appendix A. Partner list

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- Dipartimento di Idraulica Trasporti e Strade Università di Roma "La Sapienza"	DITS	IT	adriano.alessandrini@uniroma1.it
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- Promotion of Operational Links with Integrated Services aisbl	POLIS	BE	shoadley@polis-online.org
- Rups Consultants (Advisors) for Innovation	Rups	NL	jan@rups.nl
- Frog Navigation Systems B.V. Note: In 2007 Frog Navigation Systems filed for bankruptcy	Frog	NL	
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- Institute of Studies for the Integration of Systems	ISIS	IT	sgaggi@isis-it.com
- Technion (IIT) Research & Development Foundation	Technion	IL	zvirin@techunix.technion.ac.il
- Régie Autonome des Transports Parisiens Note : Withdrawn from project per July 2007	RATP	FR	
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- Agenzia per i Trasporti Autoferrotramviari e la Mobilità del Comune di Roma S.p.A.	ATAC	IT	mario.dimassa@atac.roma.it
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- Swiss Federal Institute of Technology EPFL	EPFL	CH	philippe.vollichard@epfl.ch

1. 2 Status Quo before the start of the project

Transport systems in the present-day European city are almost exclusively of a traditional nature. There are automobiles for passenger and goods transport and bicycles and motorcycles. There are buses for transport of larger groups of people and there are systems for mass transport, like trams and metros and trains. With some notable exceptions these systems are driven by people and their behaviour on the road or track is controlled by people. More and more these people are assisted by safety and control systems that help them to make the right decisions or prevent them from making the wrong ones. These systems possess an increasing level of intelligence, but the progress of introduction is slow. The potential of these systems to solve mobility problems of the future, however, is high.

With the exception of some automatically operated metro systems (Paris, London, Lille) and some recently introduced automated buses and people movers (Clermont-Ferrand, Eindhoven, Capelle aan de IJssel) most progress can be seen in the private automobile, where the introduction of so-called ADA-systems (Advanced Driver Assistance systems) already has made the tasks of drivers lighter and increased their comfort and safety. Examples of such systems are Adaptive Cruise Control and Lane Departure Warning, but navigation systems that help people to find their way in an unfamiliar city environment can also be seen as ADA systems. Although ADA systems can certainly contribute to safer and more efficient transport, they have the disadvantage that the most uncertain factor for safety and efficiency, the human driver, is still in control of the vehicle. Present laws and regulations (the Vienna Convention) prohibit the introduction of systems on public roads that, by taking the driver out of the loop and replacing him or her with an automated control system, could lead to a next huge step forward towards realisation of safe, efficient and sustainable transport.

In future mobility scenarios such new transport systems will be part of the urban environment. These new transport systems will respond to the new mobility demands of the future society. In our vision the urban mobility will be greatly supported by new transport system concepts which are able to improve the efficiency of road transport in densely populated areas while at the same time help to reach the zero accident targets and minimise nuisances.

Knowledge of the mobility problems in urban areas and of the contribution that automated transport systems can provide to solutions have been the subject of many recent research projects funded by the European Union. A short overview of two of the most notable projects follows here:
The NETMOBIL cluster of projects brought together 4 projects in the fields of automated vehicles, personal rapid transit, advanced driver assistance systems, and automated vehicle guidance systems and their underlying technologies. The objective was to explore and promote the potential of developments in automatic vehicle technologies for future sustainable personal urban transportation systems, and provide advice and guidance on the options for decision makers.

The LUTR cluster linked several different projects in the area of sustainable urban mobility, including land use, transportation, and the environment. The common objective was to develop strategic approaches and methodologies in urban planning that would contribute to the promotion of sustainable urban development. This included issues of transportation demands and related land use planning, the design and provision of efficient and innovative transportation services including alternative means of transportation, and the minimisation of negative environmental and socio-economic impacts.

CityMobil_brochure2011xy_druckmontage.indd 14-15
21.11.2011 15:35:15

2. Project description

Already in the first discussions with the EU officials it became clear that CityMobil was not going to be an exclusive research and development project. A very important part of the project had to be aimed at demonstrations; showing stakeholders and the general public what automated transport is and how it can contribute to more sustainable future cities. Very soon it was decided that these demonstration activities should not be just temporary demonstrations, but rather implementations of automated systems; systems that would survive the lifetime of the project and that would continue to be operating and expanding long after the project had ended. During these first discussions the general goal of the project took shape: „To bring the implementation of automated transport systems in urban areas a major step forward". This very general goal was described more specifically as: 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.

This still general description was eventually translated in concrete project objectives as follows: The demonstration part would aim at three large scale implementations of advanced transport systems in cities. The main goal of these three implementations was to demonstrate that the technology was in such a state that implementations would be feasible. In addition there would be a number of smaller events of a temporary nature like showcases, where automated vehicles are brought to a city to allow the public and the authorities to ride them and get a feeling for the possibilities of automated systems. The research and development part would also have a strong practical component. The main focus was on identifying barriers that were still in the way of large scale implementations of automated systems, and subsequently take them away or devise strategies for overcoming them in the future. The barriers could be of a technological nature, but also of other natures like political or societal. In short: anything that could disrupt or delay the advance of automated transport.

There are many different automated transport solutions thinkable for urban areas. In order to give focus to the project and avoid a too wide spread of systems and technologies it was decided to focus on four concrete and very promising automated transport systems: Cybercars; Advanced city vehicles; High tech buses and PRT. For all of these systems there were examples that had already been implemented or were in the first stages of implementation. In this way, by making connections with developments that were already on their way, the idea that automated solutions are something for today and not something for a far away future was strengthened.

The above objectives and decisions finally led to the following concrete project components:

Demonstration components:

3 large scale implementations:

- A cybercars implementation in Rome (Italy)
- A high tech bus implementation in Castellón (Spain)
- A PRT implementation in Heathrow (UK)

Showcases and temporary demonstration activities:

- Showcases in 5 European cities: Daventry (UK) Trondheim (Norway); Vantaa (Finland) La Rochelle (France) and Orta San Giulio (Italy)
- A 3-months demonstration in La Rochelle (France)

Research and development components:

5 Sub projects

- Future scenarios; focusing on the outlook for the future and on legal and administrative barriers.
- Technological issues; focusing on vehicles and technological subsystems.
- Operational issues; focusing on the operational requirements when implementing automated systems in new and existing areas.
- Evaluation; addressing the questions whether or not automated transport can contribute to sustainable cities and whether or not the pro ject goals are met.

Acknowledgements

CityMobil would not have been possible without the support of the Directorate for Research and Development of the European Union. The project also greatly benefitted from the contributions of the Reference Group Cities, a group of cities interested in automated transport solutions.
The group met regularly to discuss there problems, possible solutions and ideas. The Reference Group cities that contributed in various stages of the project were: Almere; Limeil-Brévannes; Cardiff; Milano; Almelo; Clermont-Ferrand; Orvieto; Daventry; Santa Margherita Ligure; Gateshead; Trondheim; Genova; Uppsala; Vantää; Valencia; La Rochelle; Vienna and Lausanne, Sophia-Antipolis, Montbeliard, Helmond, The Hague, Genova.

CityMobil_brochure2011xy_druckmontage.indd 16-17 21.11.2011 15:35:16

5. Next steps

On the basis of the results of CityMobil it is possible to draw some lines for the immediate future. The lessons learned, as presented above make clear that in order to make a significant next step forward the following is needed:

- More demonstration projects to convince stakeholders that automated transport solutions are a viable option.
- A further development of the CityMobil City Application Manual and other tools that can help decision makers to overcome hesitations and draw balanced conclusions on the pros and cons of automated transport systems.
- An increased effort to come to generally accepted certification guidelines. This should take place on a European level and should result in clear and harmonized legislation that will define the precise conditions that will allow automated solutions in urban traffic.

Up until now the main efforts of European projects have been concentrated on technological research in order to assure the technical feasibility of advanced transportation systems. It is now time to step ahead and address other topics in order to achieve the aimed goal: implementation and operation of urban automated transport vehicles. Recommendations with a wider scope of action must be fostered, in particular to establish a clear and solid framework focusing on the legal and homologation aspects of operation of automated vehicles in urban areas. As long as these points stay neglected, it will remain difficult to complete the implementation and operation of a full working scheme.

An answer to the raised issues is a key target to complete a more in-depth study of the conditions for integration and exploitation of a large-scale operational system. This is of foremost importance for the achievement of one of the main and most ambitious goals of the European projects in this field: to demonstrate that the integration of advanced transportation systems in urban areas is possible and useful. In this vision, CityMobil was intended as the first step of this implementation phase of advanced transport systems in European urban areas. Future projects must further pursue this goal and, in order to fulfil it, effort should be put in funding demonstrations schemes which attest to be: coherent, dimensioned to meet an operational capacity, integrated in the urban context and which incorporate both the needs and expectations of the potential users.

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**			

The CityMobil matrix shows the links between the demonstration components and the R&D components

The project consortium consisted of 29 partners from a large variety of European organisations. Whereas in past projects the technological angle often was prevalent, in CityMobil the wide spread of interests among the partners guaranteed an open and varied look on the project objectives. There were partners from large and small industries; from universities and research institutes; among which there were partners with technological backgrounds as well as traffic management backgrounds; from consultancies and public transport operators. For a complete list of partners see appendix A.

The results of the project are described in section 3. The detailed results are laid down in a large number of reports and deliverables. Most of these are public and can be found on the CityMobil website: www.citymobil-project.eu. A list of reports is included as appendix C.

CityMobil_brochure2011xy_druckmontage.indd 18-19 21.11.2011 15:35:16

3. 1 General

One of the main goals of the CityMobil project was to evaluate which contribution automated transport systems could provide to sustainable urban transport, in terms of advantages for the users and improvement of transport scenarios. In order to be able to evaluate the effects of the introduction of new urban transport systems an evaluation framework was conceived, capable of capturing the social, environmental, economic, legal and technological impacts of advanced transportation systems. The framework had to be suitable to evaluate a variety of different systems, ranging from computer models, laboratory and test-track installations, to real-world implementations on a large scale. For the evaluation of passenger transport systems a list of 64 indicators was generated, subdivided in 9 evaluation categories: acceptance, quality of service, transport patterns, social impacts, environment, financial impacts, economic impacts, legal impacts and technological success. To present the results of the evaluation of the various activities in CityMobil a bi-dimensional matrix called “Passenger Application Matrix” was developed. In this matrix the results have been grouped according to 10 various trip origins and trip destinations: city centres, inner suburbs, outer suburbs, sub-urban centres, major transport nodes (e.g. airports, central stations), major parking lots, major educational or service facilities (e.g. university campuses, hospitals), major shopping facilities, major leisure facilities (e.g. amusement parks) and corridors.

The cells of the matrix represent all the possible origin-destination pairs and the main results obtained by the different CityMobil activities have been grouped in the cells. Not all cells have been filled and not all automated transport systems have been evaluated in each cell.

Cybercars

The general result emerging from the analysed cells is that for short trips in low to medium density areas Personal Rapid Transit is the best suited solution, while for longer trips high tech buses seem to be the best option. Cybercars as dual mode vehicles give their best as public transport feeders in low population density areas.

The most interesting results for connections between the various origins and destinations are listed below.

City centre to city centre:
Users were generally satisfied with the dualmode vehicles tested in the showcases, considering such advanced transport systems easy to use, useful and safe.

People were willing to pay more than for conventional public transport to use the service and seemed well disposed to substitute the private car with such new technology.

Personal Rapid Transit appeared to be more suitable than other advanced transport solutions in terms of performance and emissions reduction, even if cybercars are less expensive. However, the advantages of PRT are only evident for small to medium size cities while conventional mass transit systems appear to be the best option for the centres of large cities.

Personal Rapid Transit

It is essential that these are designed to complement, reinforce other strategy elements.

- The public appears to be generally interested in these novel forms of transport which could bring an alternative to the use of the private automobile. Still the effect of major or minor accidents with automated transport systems on public acceptance is unknown.

- One of the greatest challenges during the project was the realisation of the implementations and demonstrations. It appears that a lot of hurdles must be taken from the moment a city has decided that they want to introduce a new transport system or a demonstration until the vehicles really transport people through the city streets. The period of 5, 5 years that CityMobil lasted was not in all cases enough to realize the plans. Especially in the cases of the implementation in Rome and a potential demonstration in Lausanne the difficulties were such that the plans could not be realized within the timeframe of the project. A period of 5 - 10 years seems to be a realistic time span that is needed from the time the decision is made until the system is operational.

- It became very clear that the presence of operational automated systems in other cities is a great stimulus for decision makers. To be the first one to implement a new and unknown transport solution requires a lot of courage and enthusiasm from the decision makers, especially when there are no examples that can be used to overcome hesitations from colleagues, authorities and the public.

CityMobil_brochure2011xy_druckmontage.indd 20-21 21.11.2011 15:35:16

4. Conclusions; lessons learned

After almost 6 years of working in a large project like CityMobil it can be expected that there are a large number of lessons learned. Some are of a general nature and are interesting to everybody who is interested in automated transport; some are of a specific nature and are mainly interesting for experts with expertise in the related topic. A lot of these specific results are referred to in chapter 3 and can be found in more detail in the CityMobil deliverables. Here we present a number of general conclusions. Some are unexpected and were unknown before we started the project. Some are obvious and are only confirmed by the findings of the project. But all of the general conclusions below should be imprinted in the minds of those who think of implementing advanced transport systems, because ignoring these lessons can drastically reduce the chances of success of any implementation attempt.

The most important barriers to large-scale introduction of automated transport systems are not of a technological nature.

Although there are still plenty of technological improvements necessary, technology is developed so far that within certain limitations the implementation of automated systems is feasible. The most stringent barriers are of a different nature. Perhaps the most important barrier is safety, and more specifically certification.
Until a set of generally accepted certification guidelines exist, it will be difficult for system developers to convince authorities and operators that automated systems are safe. One of the results of the CityMobil project is a set of certification procedures, but there is a long way to go before these will be widely accepted by all relevant parties.

Other barriers, that need to be addressed and that are deemed more significant than technological barriers are mainly problems related to financing projects and procuring automated systems and winning the acceptance of (city) politicians.

There is no best automated transport solution for all cities and not even one for certain types of cities. Whether or not automated transport is a viable option for any city depends on a large number of factors. Each case therefore should be looked at individually. Still there are a number of rules of thumb, that can be used to give guidance to decision makers:

- It is unlikely that one of the presently known automated transport systems can be a single solution for the transport problems of a city. Almost always the solution will be in a combination of different advanced (automated) and traditional solutions

- Individual modes are best suited for small to medium (up to 200,000 inhabitants) mono-centric cities while in poly-centric and larger cities the best performing option is a combination of collective services, with small road vehicles on demand in periphery for the last mile toward the mass transit stops and with advanced busses on reserved corridors for longer trips.

- New technologies can contribute effectively to urban transport strategies, given relatively low capital and operating costs. But they need to find appropriate niche markets in different cities:
  - Suburban PRT or Cybercar Feeders to public transport in larger cities.

  - High-Tech Buses on major medium density corridors.

  - PRT distribution within centres of smaller cities.

  - And probably services for major activity hubs.

Inner suburbs to city centre:

The best performing advanced transport system in small and medium sized cities is PRT, which has a positive benefit cost ratio, while the best performing system in larger cities is the high tech bus, although these have negative business cases. These advantages increase when the systems are combined with cybercars as public transport feeder.

High tech buses are successful in serving densely populated areas.
The best performing advanced transport systems also generate positive impacts in terms of reduction of emissions and number of accidents.


Advanced city vehicles


Advanced buses

Inner suburbs to inner suburbs:
Users were fairly satisfied with the PRT-like system tested in the showcases, considering such systems easy to use and useful.

The only indicator scoring under the threshold was the perceived security.

Extended inner suburban areas of larger cities are better served by systems like high tech buses, which permit users to save in-vehicle time and by cybercars only as public transport feeders to lower access time to public transport systems.

Advanced transport systems generate the most positive impacts in the accessibility of low income zones and accessibility to key services (PRT shows an increase of more than 6%, while cybercars and high tech buses show an increase of more than 3%).

The best performing advanced transport systems also generate positive impacts in terms of reduction of emissions and number of accidents.

Outer suburbs to city centre and outer suburb to inner suburb:
Users were generally satisfied with the high-tech buses demonstrated in Castellón, considering it as useful and reliable and providing a high quality of service.

The system showed 15% modal share for the area in which it operates (4.0 km network length) with more than 1,500 daily trips and more than 2,200 daily passenger km travelled, thus attracting more users than the previous conventional bus system.

The new capabilities of the system were well accepted by the bus drivers, who were not required to do manual corrections to automatic driving

PRT has positive impacts in small mono-centric cities.

High tech buses generate the most positive impacts in terms of accessibility by increasing low income zone accessibility by about 10% and accessibility to key services by about 4%.

High tech buses also generate positive impacts in terms of reduction of emissions and number of accidents.

The high investment costs required for the construction of high tech bus systems lead to a negative business case. This is in accordance with the cost-benefit analyses made for the Castellón demonstration. Despite a financial net present value of minus € 21,000,000 with a 20 year time horizon, the correspondent socio-economic net present value calculated is € 12,000,000, meaning that the new system is socio-economically viable and that the installation of the system is convenient for the local and regional community.

Major parking lots to major transport nodes (Heathrow demonstration with PRT):
The user evaluation of the PRT system is very good; the ease of use was said to be the best feature of the system; the perception of safety and reliability were also considered as very good.

Major parking lot to suburban centre (Rome demonstration with cybercars):
The usefulness of the system was evaluated as very high.

62% of the interviewed showed a tendency to illegal parking; half of them stated they would park legally when the system became operational.

The new system would have a net present value of minus € 7,000,000 with a 10 year time horizon.

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3. 2 Demonstrations

As an integral part of the CityMobil project the first phase of the implementation of advanced transport systems was taking place in three cities, Heathrow, Rome and Castellón. The 3 cities were selected in the beginning of the project because of already existing local consortia consisting of public and private organisations that had expressed commitment to the plans and therefore supported the activities.
During the project a demonstration in the City of La Rochelle was decided upon and conducted.

Heathrow PRT four-seater battery-electric vehicles

3.2.1 Heathrow demonstration

The objective of the Heathrow demonstration was the implementation of a PRT system at Heathrow Airport connecting a Business Car Park with the new Terminal 5 to demonstrate the practicality of PRT, with a view to potentially extending it to a wider network. The system used is ULTra, developed and produced by Advanced Transport Systems Ltd of Bristol, UK . The Heathrow PRT service consists of four-seater battery-electric vehicles, which navigate automatically and autonomously along 2-metre wide guideways, carrying passengers at 35 km/h directly from a Business Car Park to Terminal 5. There are 3.8 km of guideway, mostly elevated, two 2-berth stations in the car park and one 4-berth station in the short-term multi-storey car park alongside Terminal 5, and 21 vehicles. It carries around 800 passengers per day. Passengers travel individually or in their own small group and there are no intermediate stops on the journey, since stations are off-line. Passengers rarely have to wait for a vehicle since empty vehicles are normally already waiting at stations, and empty vehicles will be called up automatically to a station as they are required. The system has been operating for car park users since April 2011. The system is fully described in CityMobil Deliverable D1.2.2.2.

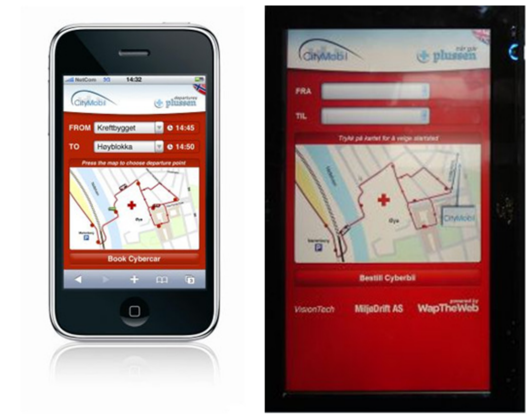
CityMobil has included the Heathrow PRT system as one of its demonstration projects to ensure that its performance is properly evaluated, and to extrapolate the results to wider applications of PRT in general.

Operating statistics of the PRT service show that:

- Mean passenger waiting time is 19 seconds (see chart).
- About 70% of passengers do not wait at all, since a vehicle is waiting for them.
- 94% of passengers wait for less than one minute.
- mean travel time delay was 24 seconds beyond the scheduled minimum run time
- Service reliability was 98.7% (99.7% if one long break in service is omitted).
- PRT emits only about half the CO2 per passenger-km emitted by the previous transfer buses.

Heathrow PRT station

The transfer passengers using the bus from the Business Car Park to Terminal 5 were surveyed in March 2009, and 304 completed questionnaires were collected. PRT passengers were surveyed in May 2011, and 314 questionnaires were collected. Both questionnaires asked exactly the same questions. Passengers were asked to score 17 aspects of the services on a 5-point scale, with 1= very poor to 5 = excellent. On all except one aspect PRT outscored the bus service by substantial margins. The PRT service gained a very low mark for “ease of finding the T5 station” because at the time of the survey direction signs to the station had not yet been fixed in the T5 arrivals hall, and passengers had difficulty finding it on level 2 of the adjoining multi-storey short-term car park.



Service customization: Real time information to the user

Main results traffic management strategies

The management strategies for automated transport systems have also been studied in the context of the CityMobil project. Specifically, work has been directed towards the investigation of five scenarios previously defined. For each of these scenarios the following issues have been addressed:

- Physical integration.
- Identification of the traffic management requirements.
- The different issues and opportunities for which traffic management strategies have been considered.
- Several simulation studies have been undertaken to investigate the different strategies.

The overarching objective of transport schemes is 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 will 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. The consequences and opportunities have been investigated using micro-simulation models.

Main results Integration issues

Advanced urban transport systems should not act as stand-alone systems, but be an integral part of the total transport system, therefore integration issues are important aspects that need to be taken into account in order to ensure an efficient operation of an automated transport system in the existing urban environment.

Three main operational issues have been identified as necessary preconditions to integrate advanced urban transport systems in existing transport systems:

- Physical integration.
- Integration of information services.
- Organisational integration.

Once these preconditions are fulfilled (mostly fulfilment depends on the easiness to solve technical or organizational issues), several issues have been identified as being the real integration issues to deal with when facing a real implementation of an advanced urban transport systems. These are the barriers identified and addressed earlier: legal, organizational and political barriers.

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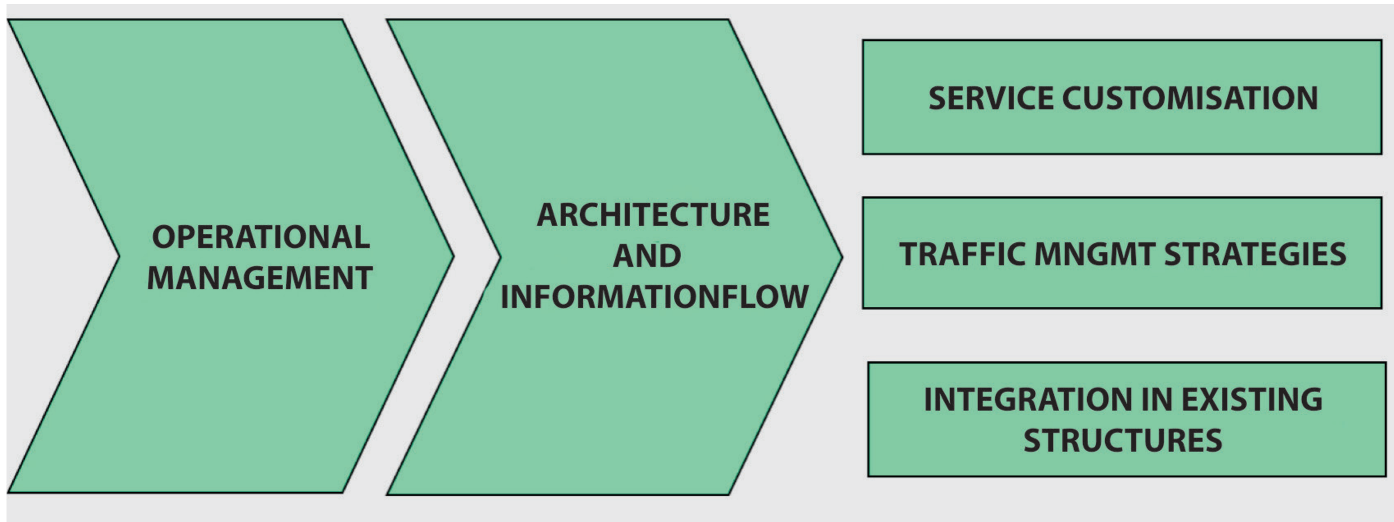
3. 5 Operational issues

The work on operational issues focused on the analysis of the new opportunities and services arising from the new means of transport proposed in CityMobil. Attention was also given to the defining the management and operational aspects required to support the new services and their integration in the present transport structures and systems.
The work has been structured in 5 different areas, as shown in the figure below.

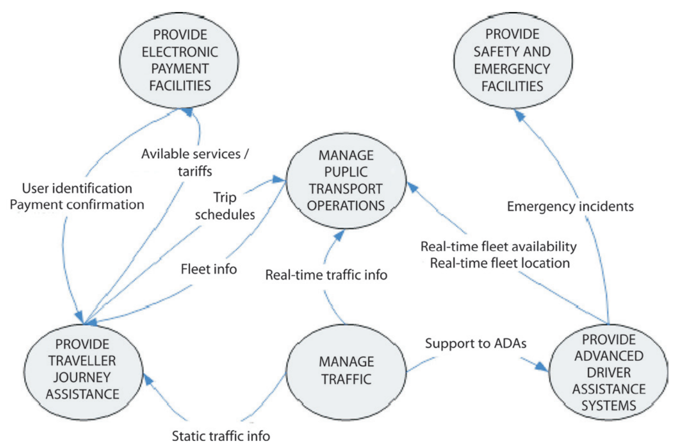
sed architectures. The results, therefore, complement, complete and detail the description of the five scenarios while also providing five different examples of how an operational architecture can be designed to include the new functional areas that are implied by the new transport systems proposed in the CityMobil project.



Operational issues workflow

Main results Operational Management
This part of the work concentrated on the requirements of advanced transport systems, defining all the functional areas and the functionalities of such systems. The functional areas chosen have been based on previous research done in European Projects, especially in the IST, KAREN and FRAME projects, which define the necessary elements and processes required to achieve a global interoperating European Transport Architecture. The work done in the CityMobil project completes the former work, adding new functionalities that the previous projects did not cover. The main results form a complete guideline to support the design of an advanced transport architecture.

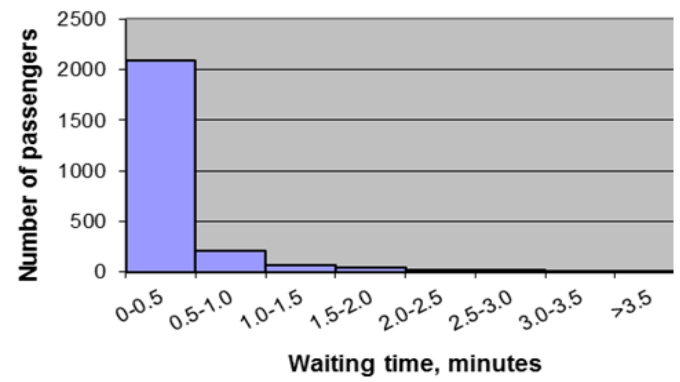
Main results Architecture and Information flow
The work done on architecture and information flow describes the proposed operational architectures for each of the five scenarios defined previously. The design of these architectures has been based on previous work in the European Converge and FRAME projects, and has followed the design guidelines recommended by these projects. The use of these guidelines provides confidence on the completeness and quality of the propo-



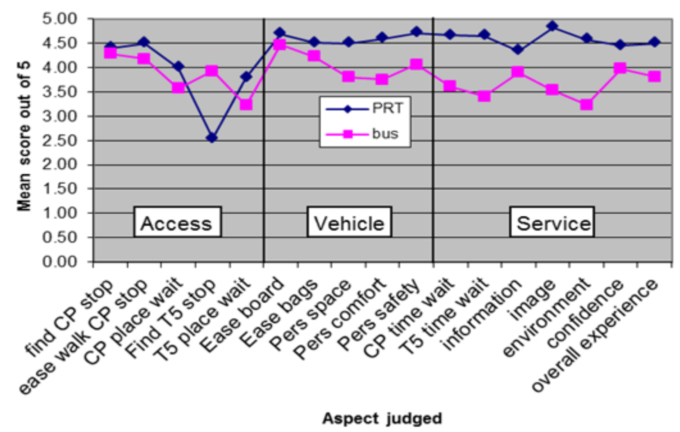
Architecture and information flow: Functional architecture example

Main results Services Customization

As new technologies are applied in transport systems, new services and opportunities must be investigated. Two important points to focus on are the ease of use of the services offered and the enhancement of the quality and comfort. The services customization work was focused on e-IDentification and e-Ticketing, two technologies with great possibilities in the area of public transport, since their advantages directly influence the quality of the services offered. On-board surveillance, incident management and on-demand information services were other areas of interest.



Distribution of waiting time for the Heathrow PRT system



Summary of passenger scores for the PRT system in Heathrow

The first five aspects in the chart below are aspects of access to the service, and are not intrinsic to PRT itself. For the 12 aspects of the PRT vehicle and the service PRT provides, the mean score was 4.58 ± 0.04, compared with 3.82 ± 0.05 for the transfer buses. The gap in scores between PRT and bus are highly statistically significant. As would be expected the highest score was for the image of the PRT service, at 4.83 ± 0.03, but it is extremely encouraging that the second highest score was for "personal safety", at 4.71 ± 0.03 compared with 4.06 ± 0.05 for bus.

This is for a totally new mode of transport, without a driver, and on a track which is elevated by several metres over most of its length. PRT also scores high, at 4.57 ± 0.04 compared with 3.23 ± 0.06 for bus, for being an "environmentally friendly" mode of transport. Especially high scores were also given for the very low waiting times, whether in the car park or at T5. Average waiting times of less than a third of a minute. It is also remarkable that passengers posted a large number of spontaneous and enthusiastic remarks about the service on "Twitter" (e.g. "this makes Heathrow fun again!").

CityMobil provides a wider and more general assessment of PRT than can be obtained from the Heathrow system alone. The Heathrow system is intended to prove the concept as a practical transport system. It is a very small network, and acts as a shuttle. A wider PRT network would provide anywhere-to-anywhere transport, non-stop and with little waiting and no interchange. Within the airport, it would be possible to bring the stations inside the buildings to maximise access, since PRT has no vehicle emissions, there is very little noise, and the floor loadings required are minimal. The Heathrow project shows that PRT works well and reliably, that passengers are very pleased with it, and that it provides a level of service which cannot be matched by conventional urban public transport. However, it is too small to demonstrate the full benefits of PRT, and offers only a few minutes' reduction in journey time over the previous transfer buses. These benefits were never intended to justify its costs, since this system was built to prove its practicality.

Several case studies have illustrated the economic justification for PRT. Although some of the costs of Heathrow are declared confidential by BAA, the owner of the system and a detailed costing of the ULTra system is confidential for commercial reasons, the experience has enabled ULTra PRT Ltd to update its costing system and make it fully realistic, and CityMobil is able to provide a costing formula which can estimate the overall costs of an ULTra network to within 10%. Case studies based on ULTra have been updated for CityMobil to provide cost-benefit assessments using the Heathrow experience. The box below summarises the socio-economic and financial cases for four such studies, and it can be seen that in all cases PRT shows an excellent socio-economic return, and a financial case which easily covers operating costs, and seems capable of covering capital costs at a public 6% discount rate.

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Case study	Size of network kms of one-way guideway	Cost per passenger +	Reduction in journey generalised cost	Revenue "surplus"	Benefit / cost ratio* 30-year NPV	First year rate of return†
Heathrow	7.6	€1.38	65%	NA (*no fare*)	223%	332%
Cardiff	7.7	€1.30	53%	-€0.07M	248%	254%
Corby	30	€1.50	23%	+€6.9M	184%	430%
Bath	45	€1.48	30%	+€4.3M	Not calc.	271%

+defined as (annual operating cost + 6% of capital investment)/annual passengers. Costs in euros are converted from £ sterling at 1.12 €/£

defined as (annual revenue - operating cost - 6% of capital cost)

**defined as NPV of (value of total passenger time savings relative to transfer bus + saving in bus operating cost)/(capital costs including vehicle replacement + operating cost)*

†defined as (first year passenger benefit + saving in bus operating cost)/(first year PRT operating cost + 6% of capital investment)

Summary of the socio-economic and financial cases for four PRT studies

In these studies PRT has a journey time much less than for the alternative bus journey, and it attracts substantial transfer from car use. Modelling predicted that 8% of current car users in Cardiff Bay would transfer to the existing rail services plus PRT, despite the fact that PRT covers only the last 2 km of the journey at the city end. In Corby 18% of car users were predicted to transfer to PRT, and in Bath 17%. The Corby study compared PRT with Light Rail Transport (LRT), and suggested that PRT would attract 19% of all trips in the area served, compared with 11% by LRT, while LRT would reduce car trips by 9% compared to 18% with PRT. Both modes would cover operating costs, but LRT could make only a small contribution to capital costs, whereas with a slight increase over the existing bus fare PRT would cover investment at 6%. PRT guideway is substantially cheaper than LRT track, though the fleet of vehicles may be more expensive.

The practicalities of installing PRT are also considered in CityMobil, in particular the requirement for segregated routes, with much of the guideway elevated to avoid severance. The potential for PRT in Park & Ride sites is noted, the safety case, environmental aspects and energy use and the steps involved in the decision to install PRT were discussed in the project as well.

The Heathrow demonstration has shown that PRT can be made to work reliably, offer a high level of service, and that passengers prefer it, so its adoption in airports and other campus environments seems assured. But PRT was originally developed for urban public transport. It has clear and substantial advantages in improving and integrating passenger transport in towns and cities. But the public sector is generally risk-averse, and is unlikely to take the initiative in the same way as the private sector. Individual urban authorities cannot be expected to take the risk of becoming first adopters. Unless we are prepared to wait decades for these next steps, it seems likely that national governments, or supra-national organisations like the European Union, will have to provide support and funding to offset the risk.

3. 4 Technological issues

Automated urban transport requires addressing and solving a wide-range of technological and human-machine 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 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. To make it practicable a few reference scenarios were developed:

- Historical town centres with lanes reserved for new transport systems.
- Principal urban roads open to normal traffic, with specially equipped „e-lanes“ reserved for vehicles operating in highly assisted / automatic drive mode.

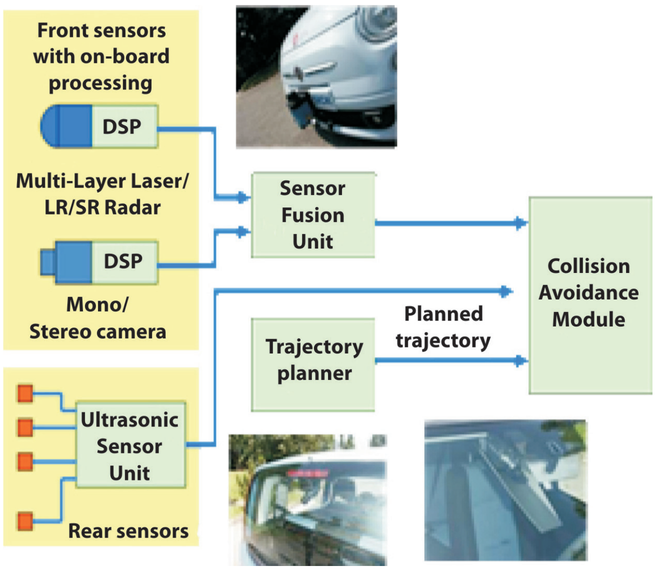
Safety was the main challenge to be addressed to introduce automated transport, in particular if mixed with normal "human driven" traffic. Sustainable solutions will be possible only if an integrated approach will be followed, with contribution from both vehicles, collision avoidance, and from infrastructure,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

Results:
An integrated approach is needed and vehicle concepts for personal mobility and goods transportation were developed, to evaluate, validate and demonstrate issues like obstacle detection and human machine interfaces.

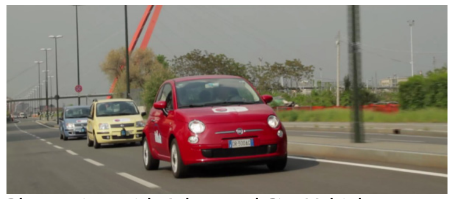
Some of the questions answered were:

- How does the driver interact with Advanced City Cars and Dual Mode Vehicles?
- What should the interface design for these vehicles look like?
- How do drivers react to unusual and critical events when driving highly automated on an eLane (electronic lane where vehicles could run autonomously)?
- Which systems for obstacle detection exist and which system offer the best solutions in the relevant scenarios

Human factors testing in a simulator



Obstacle detection system



Platooning with Advanced City Vehicles

A CityMobil vehicle in Orta San Giulio (IT)

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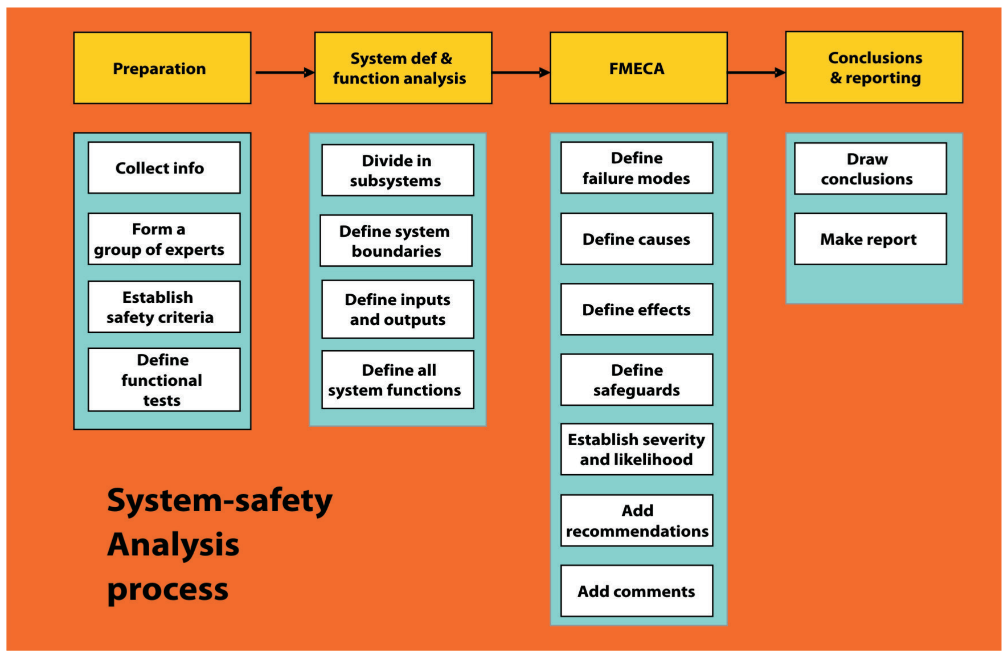
Under the heading „future scenarios“ the legal and administrative barriers that must be addressed prior to the large scale introduction of emerging advanced transport systems were addressed. The three main deliverables cover Certification Procedures, Legal Barriers along with Guidelines for Safety (the level of protection in case of malfunctioning of the system), Security (protection against acts of sabotage) and Privacy (the level of protection of personal information).

Towards the end of the project, the accuracy of the assumptions were re-evaluated given the experiences gained in the various parts of the project, resulting in a number of project deliverables that most accurately articulate our current understanding of the constraints and demands of transport systems in future cities.

CityMobil - Business Case Analysis Tool

Result Summary				CityMobil System	Conventional Transport System
Transport mode/ vehicle	*From list*	⇨	*n/a*	PRT	Bus
Number of vehicles	*#*	⇨	*n/a*	20	10
Type of guideway	*From list*	⇨	*n/a*	Separate Lane/Guideway	Existing Road
Length of guideway	*[m]*	⇨	*n/a*	4,881	5,000
Number of stations/stops	*#*	⇨	*n/a*	5	25
Average vehicle speed	*[km/hr]*	⇨	*n/a*	27.7	10.0
Average trip times	*[min]*	⇨	*n/a*	3.7	15.0
Average waiting times	*[min]*	⇨	*n/a*	0.3	5.0
Vehicle.kms / hour	[veh*km/hr]	⇨	*n/a*	310.2	
Trip production / hour	[pax*km/hr]	⇨	*n/a*	204.4	
Average vehicle spacing	*[m]*	⇨	*n/a*	244.1	
Business BCR Value	-	⇨	*n/a*	-0.61	-0.89
Total BCR value	-	⇨	*n/a*	1.87	0.70
TOAST rating	*7-point-scale*	⇨	*n/a*	2.49	1.80

Technology Options Appraisal Summary Table (TOAST) from the Business Case model



Certification process Advanced Transport Systems

3. 2. 2 Castellón demonstration

The main objective of the Castellón large scale demonstration is to implement a hybrid public transport system. This system is segregated from normal traffic by the use of a reserved infrastructure. The system uses electrical trolley bus vehicles with optical guidance systems circulating on this reserved platform. This system has been selected to combine the loading capacity, accessibility, speed and regularity of a railway based solution with the flexibility, adaptability and smaller costs of a road based system.

The Castellón demonstrator forms part of a transport plan that in the future will connect several cities – such as Benicàssim, in the seaside, Almassora or Vila-real - with the city of Castellón. This transport plan will be performed by the Valencia regional government (GVA). The Castellón demonstrator in CityMobil is the stretch connecting the university and the city centre in Castellón –the main city in one of the most touristic areas on the east coast of Spain.

The vehicles used in Castellón are high-tech hybrid buses powered by a tramway-like overhead catenary system for electric power supply when running on the reserved infrastructure and powered by an internal combustion engine when driving outside this infrastructure. This provides the system with considerable flexibility in operations, especially useful in areas where a catenary system cannot be constructed or in the way to the vehicles depot. This type of system provides a lower cost alternative to light rail while having the advantages of dedicated rights of way.

Furthermore, the optical guidance used in the system allows the vehicle to follow automatically an identified path signalled with dashed lines painted on the road (see figure below), while the driver is controlling the vehicle and watching the itinerary.

The reading of the marks is done by a camera located on the front-top of the vehicle. The readings are analysed instantly by the system to establish the difference between the real trajectory and the reference one. A servo-control device includes a motor that acts on the steering of the vehicle with the aim to cancel this difference. The inclusion of a guidance system involves taking the steering of the bus away from the bus driver for all or, as in the case of Castellón, part of the route. By doing so, the need to allow for any lateral movement of the bus within a lane of traffic is dramatically reduced and, therefore, it is possible to implement dedicated bus lanes where road space is in short supply and, hence, where conventional bus lanes could be impractical. Furthermore, it also enables, by means of precise automated docking, improved physical access to the bus by minimising the vertical and horizontal gaps between the bus stop and the vehicles.

The optical guidance needs a high level of contrast between the white line and the pavement to operate properly. It has been found that at some places, mostly at curves, the pavement gets dirty with the rubber of the tires. This is solved easily by cleaning these parts of the lane regularly so that the optical guidance can work properly.

The next figure shows an example of the structure of the dedicated lane and how it makes use of the space available. The optical guidance marks depicted on the platform can also be observed in the figure.

Heathrow PRT station

Example of a stretch of the dedicated lane segregated from the normal traffic

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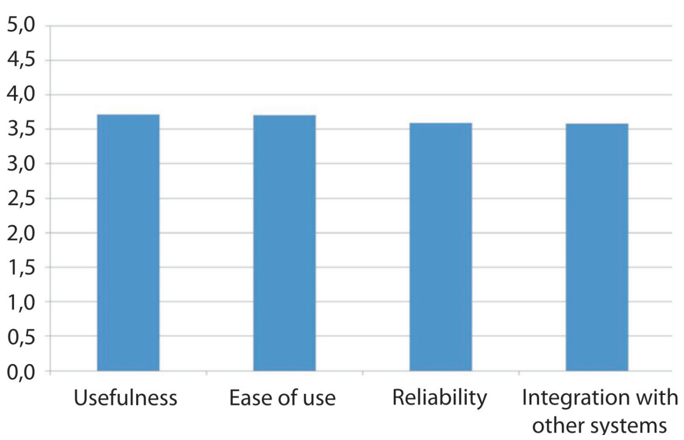
21.11.2011 15:35:19

The Castellón demonstrator has been in operation since June 2008 with good operational results and only minor day to day issues which are solved efficiently during operation such as the cleaning of the tire's rubber marks on the lane.

The total length of the stretch is 2 km per direction, meaning 4 km as total network length, divided into 5 sections with the following stops: University Jaume I (UJI), Sos Baynat, Riu Sec, Paseo Morella, Parc Ribalta, with a service along the stretch provided by 3 Civic Cristalis hybrid buses, operating from 7:30 hrs. to 22:30 hrs. during the weekdays, and from 7:30 hrs. to 22.00 hrs. on Saturdays, Sundays and holidays.

The performance and the user acceptance of the system has been analysed within the CityMobil project by means of measuring several indicators such as, usefulness, ease of use, reliability or integration with other systems, among others. The necessary data for the analysis of the Castellón demonstration have been collected through interviews with passengers who used the new high-tech bus system on the operating stretch between the University Jaume I and the Parc Ribalta, interviews with the drivers of the high-tech buses, phone interviews with people travelling in Castellón, measurement of the system parameters, and experts' opinions mainly about financial and economic impacts of the new system.

The surveys for collecting the users' data were gathered during February 2010 and allowed the evaluation of several acceptance and quality of service indicators. More concretely, four acceptance indicators (usefulness, ease of use, reliability and integration with other systems) were measured in Castellón:



Castellon ex-post user acceptance indicators

The results of the aforementioned indicators are shown in the previous figure and can be summarized as follows:

- Users were generally satisfied with the high-tech buses, with an average performance rate of 3.65;
- Usefulness and ease of use are the best rated indicators, with 3.7 as performance rating;
- The service was perceived as reliable and well integrated with the other systems, with both of the corresponding indicators rated 3.6.

On the other hand, eight quality of service indicators were also measured. The outcomes of the surveys regarding these indicators are reported in next figure.

As shown in the figure below:

- Users perceived a high quality of service for the high-tech buses, with an average performance rate of 3.7;
- The information to use the system is available and comprehensible, with the corresponding indicators 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 being all rated 3.7);
- The cleanliness of the system was also satisfactory (3.6).

The average rate of acceptance and quality of service indicators is little less than 3.7, meaning that the innovations due to the introduction of this ATS are well accepted by the users, who like the system to make trips between the city centre, inner suburbs, outer suburbs and major educational and leisure facilities.

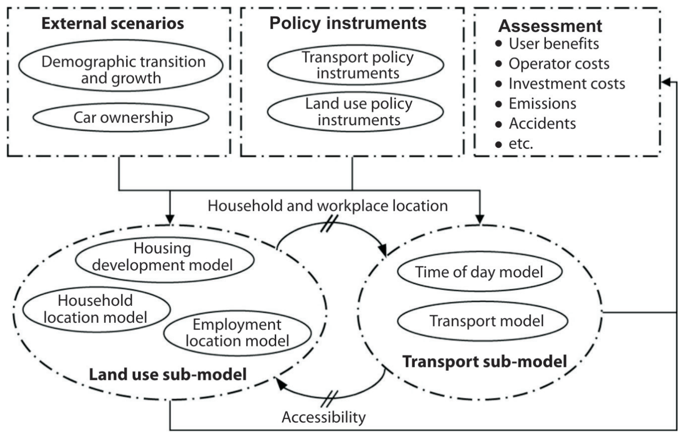
3. 3 Future scenarios

In the work on future scenarios, the contribution of emerging and innovative urban transportation technologies in terms of their contribution to transport sustainability was assessed. As a basis for the further work the state-of-the-art in various forms of advanced road transport was established. Each mode was analysed with reference to the existing literature and the consortium's current level of understanding of the contribution that each has the potential to make toward transport sustainability. Each mode was also assessed against current (deployed) applications with the help of an economic and societal cost/benefit analysis.

Then various scenarios of urban mobility for passenger and freight transport were developed, taking into account socio-economical, ecological and demographical trends. A number of tools for cities and operators were developed to analyse transport requirements and potential impacts. These include a series of context scenarios over the period to 2050, a set of passenger and freight application scenarios which indicated the contexts within which different technologies are most likely to be effective, a tool for predicting patronage for emerging technologies, a business model for assessing the financial viability of technology projects, a sketch planning model for assessing the overall impact of these technologies in cities, and guidance on how to overcome the key barriers to implementation.
The key output, the City Application Manual (CityMobil deliverable D.2.2.4), is aimed at policy makers. It provides guidance as to how individual cities may make optimum use of the tools developed in the project, and the approach which cities might adopt in deciding whether/how to adopt emerging transport technologies.

Analysis tools were developed to assess the transport and land use impacts of the emerging transport technologies. These tools were applied to four case study cities, Gateshead in the Tyne and Wear region in the UK, Madrid in Spain, Trondheim in Norway and Vienna in Austria. Using MARS, a transport land use model, predictive tests using a fixed set of context and passenger application scenarios were conducted for each city.

Scenarios involving inner-city cybercars, cybercars as public transport feeders, PRT, high-tech buses and dual-mode vehicles were modelled in all four cities for a medium and high growth context scenario in each. Despite the differences in schemes across cities, some general conclusions could be drawn. In general feeder systems will have a significant impact when implemented in zones with initially poor access/exit to main-line public transport. PRT will out-perform the use of cybercars in central areas due to lower access and waiting times. However, these systems will have higher financial and aesthetic barriers to overcome than 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 will 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 minimal.



MARS dynamic Land Use and Transport Integrated model

A generic Business Case Model was developed, intended for use by policy-makers wishing to implement advanced transport systems. The Business Case Model defines a methodology to assess the wider 'transport case' that will enable a local authority partner to not only assess various schemes against one another, but also to develop a more focussed 'business case', commonly required to satisfy funding partners. Direct comparisons of systems, performance parameters, operating characteristics, economic analysis and the qualitative assessment of other system benefits are possible. Where benefits can be quantified, they are included in the calculation of a Cost Benefit Ratio (CBR). Where benefits are not quantifiable, they can nevertheless be recognised and rated. The use of a TOAST (technology options and appraisal summary table) for comparing alternative schemes and assessing value for money is also described. The Business Case Model is extremely accessible in the form of an Excel spreadsheet presenting the various systems in terms of functionalities, structure and cost-effectiveness.

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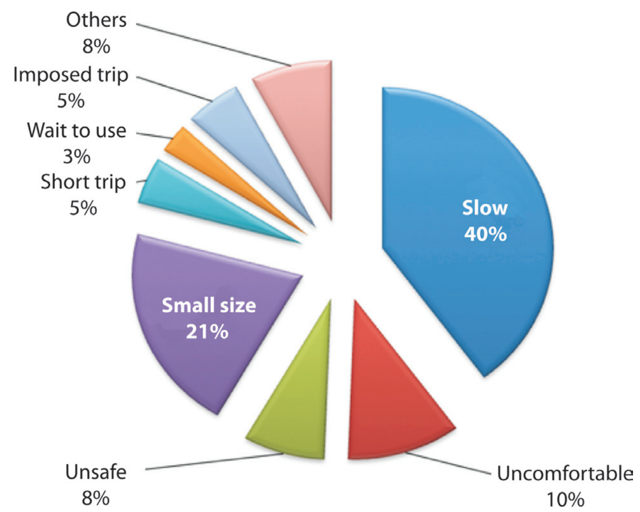
Disadvantages of cybercars according to the users



Concerning the service, the vehicles served an average of 8 passengers per hour while they operated in automated mode. However, the automated service was unavailable due to different technical problems or to weather conditions for a total of 23 days. While the automated service was unavailable, the vehicles were displayed in the Media Library, allowing the operator to explain the service concept to the visitors. Despite these problems, the users' acceptance level was quite high. Indeed, 94% of the interviewed users considered that this system was well adapted to the city, and 93% thought it could be extended to the whole city. 64% of the users stated they were willing to pay for such service, especially if it could be used with La Rochelle's public transport smart card.

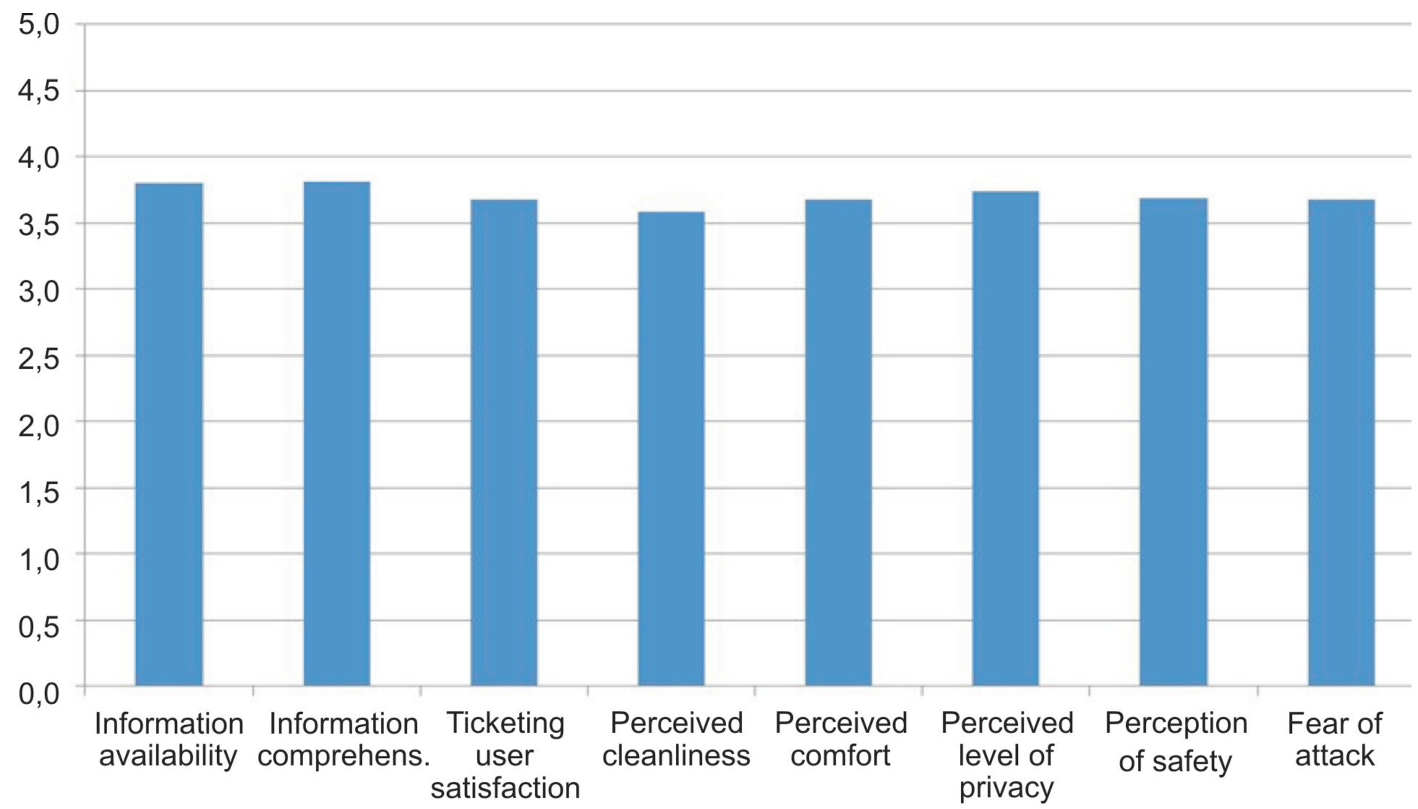
The demonstration attracted considerable interest from the media, which resulted in numerous articles and TV coverage. An international conference on automated urban transport was also organized by CityMobil in La Rochelle at the beginning of the demonstration (May 12-13, 2011).

The major challenge, which constituted the greatest risk for the cybercar's users, was the crossing of a two-way street with an intense level of traffic. The local authorities gave the priority to the cybercars only through stop signs, since no budget was available to install traffic lights or stronger traffic measures. To cope with this, the cybercar speed was reduced at the crossing in order to allow drivers to correctly assess it and allow the vehicle to cross safely. This proved to be efficient, since no incidents occurred in this spot.

Another major challenge was the system operation, since INRIA had no prior experience and there was not a specialized partner in charge of this task. The local Engineering School carried out the day-by-day operation, while INRIA provided the technical support, with good results. The operation was also challenging for the hardware itself, since INRIA's prototypes had never operated for such longs periods. Only the laser sensors could not prove to be reliable enough to operate in a commercial system, but these will be replaced for the demonstration's extension.

3.2.5 Showcases

In addition to the demonstration activities described above a series of smaller "showcases" was organized. A showcase was meant to show the possibilities of advanced transport systems to the public and to interested city authorities. 3 cybercars and 2 advanced city vehicles were developed especially for this purpose. In total 5 showcases were organised in the cities of Daventry (UK), La Rochelle (FR), Vantaa (FI), Trondheim (NO) and Orta San Giulio (IT).



Castellon ex-post quality of service indicators

The system showed 15% modal share, with more than 1,500 daily trips and more than 2,200 daily passengerkm travelled, and 10% average vehicle occupancy. 12 minutes were required to cover the entire network in one direction, and the average interchange time required was little more than 2.5 minutes. There were no delays per trip, because the system works on dedicated lanes, therefore the average waiting time was between 5 and 8 minutes during the weekdays, and the consequent system capacity was little less than 1,000 passengers per hour.

One of the main conclusions drawn from the analysis of the Castellón demonstrator indicators and results is that, although the stretch of the system open to the public is still short, it has met its potential of delivering a reliable and flexible system and expectations are high for the time when the whole system will be completed, connecting the main cities and tourist sites in the area.

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3. 2. 3 Rome demonstration

The objective of the Rome demonstration was to demonstrate the feasibility, public acceptance and performance of innovative automated transport systems for short distance transport services using small automated vehicles, so called cybercars. The system was designed to collect people from various stops within the car park and to bring them to the entrance of the new Rome exhibition building. The exhibition building is located in the direction of Fiumicino airport on the west side of the city 3 km outside of the outer ring road and 16 km away from the city centre, along the airport highway and railway link. The building is around a 1.5 km long central corridor. In front of the building is a car-park with about 2,500 car-slots. The building can be reached not only by car, but also by train by using the railway from Fiumicino Airport to Rome (FM1). The distance between the railway station and the nearest building entrance is about 500 metres.

- Putting all technical components underneath the floor optimizes the volumes available for passengers, allowing 30% more space available than conventional vehicles;
- This is a very simple and robust mechanical design, where the steering is generated by a rotating front axle, whose rotation is generated by the difference of speed of the left and right wheel;
- This platform has a step to allow passengers to easily get on and off the vehicle.

Because of a number of political and financial reasons the civil works at the exhibition centre were delayed, which caused a major impact on the planning of the demonstration. Due to this delay the European Commission decided to stop supporting the Rome demonstration in the spring of 2011.

Cybercar vehicle "robuRIDE" for the Rome demonstration

With respect to the initial design, the car-park in front of the building was planned to be re-designed so that a cybercar network could be built inside it. It was intended to pick-up the visitors once they had parked their cars and to bring them to the building entrance. On the return trip a cybercar would drive them back to their car-slots.
The planned cybercars called "robuRIDE" are made of 2 separate parts: the flat platform, and a customized body. The platform is an evolution of a previous ROBOSOFT platform. This concept has been chosen for several main reasons:

- The platform can be generic, whatever body is put on top. Consequently, it can be used to implement many type of cybercars or goods transportation systems;

Nevertheless the activities provided valuable results for the CityMobil project. The Italian Ministry of Transport formally agreed to certify the Rome system on the basis of the certification procedure that was developed in CityMobil, on the condition that the system met its specifications. A handbook was created for the certification process that can be used as a reference for future projects.. Finally training processes on management and maintenance of automated vehicles were devised and can be applied to other automated transport systems in Europe.

3. 2. 4 La Rochelle demonstration

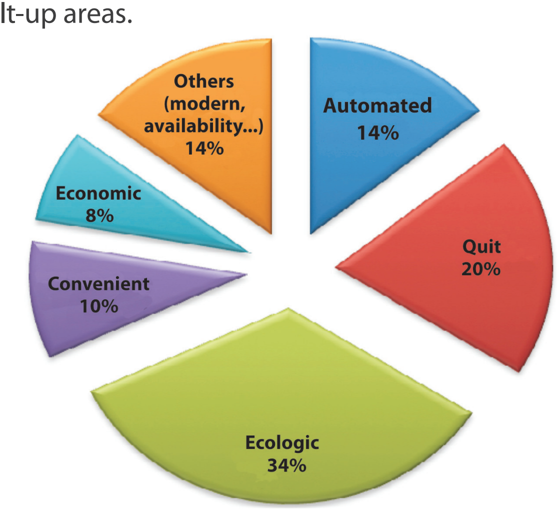
Demonstration of cvbercars in an unprotected site in La Rochelle

INRIA completely rebuilt the electronics, control and perception systems of two 5-passenger Yamaha-based electric prototype cybercars (renamed "Cybus"). The perception system is based on two 180° laser scanners, used for the localization and obstacle detection subsystems. The precision of the localization system was increased with the use of an inertial unit and the vehicle's odometers. As a backup in case of problems, only one vehicle operated at a time, everyday, from 15.00 – 18.00 hrs.

Between September 18th and 28th, 2008, La Rochelle hosted its first CityMobil showcase of fully and partly automated vehicles. The objective of this demonstration was to raise awareness among transport specialists, officials and the local population of what tomorrow's small capacity urban transport could be like. Given the success of this first showcase, CityMobil partner INRIA and a local consortium consisting of La Rochelle's authorities and research and transportation partners, agreed to carry out a three months test of fully automated vehicles, open to the public. Unlike other CityMobil demonstrations, La Rochelle's cybercars system had to operate in an unprotected site open to pedestrians, cyclists and a low-speed local traffic. During this demonstration, two automated vehicles provided an on-demand transportation service in real-life conditions, allowing the CityMobil project and the local consortium to gather significant data about user's reaction, technical difficulties and the system's performance.

The selected site was located between the quay of the electric "passeur" (a boat that crosses the channel between the Media Library area and the city centre) and the University premises. Five stations, equipped with a touch-screen where users could call the vehicles, were deployed along the 800 m. path. The stations served as relays for the full-IPv6 communication network, which allowed the Vehicle Management System (VMS) to transmit the users' requests to the vehicles. In order to reduce safety risks, the vehicles drove at a maximum speed of 10 km/h, and an operator was always on board, to overlook the vehicle's systems and to inform the users. A speed profile system controlled the speed in areas in which the risks were higher, such as crossings and building entrances.

One of the major achievements of the demonstration was the involvement of the French national authorities in the definition of a legal framework for the operation of the system on public roads, which constitutes a first step towards the legal recognition of cybercars. In fact, since the demonstrated vehicles could not be legally considered as "motor vehicles" given their maximum speed is lower than 25 km/h, a Mayor's decision provided the framework for the system operation. This decision requested, however, the presence of the operator on the vehicle.
The main technical achievement was the proof of the reliability of the laser-based guidance system. This technology proved to be the best suited for urban areas, since it is entirely infrastructure independent. It is the result of INRIA's experience in the execution of CityMobil and CityNetMobil showcases in 10 European cities, and has been replacing the use of centimetre-accurate GPS guidance, which is not completely dependable in built-up areas.



Advantages of cybercars according to the users

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