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CityMobil

Towards advanced transport for the urban environment

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Preface

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 December 2011 the CityMobil project will be finished. CityMobil has during its duration 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 has gathered inputs from all the other CityMobil sub-projects and work packages and concludes the CityMobil project by stating whether and under which conditions the advanced transport systems investigated will contribute to reaching urban sustainability. These conclusions are complimented with 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. The report is relevant and useful for:

- Policy makers or private companies: When planning or considering to implement a transport solution by means of the set-up of a large scale demonstration or implementation of an ATS. The practical instruments for implementation developed in CityMobil and evaluation results are of particular interest. They provide useful figures (costs, benefits, contribution to sustainability, etc.) on different technologies (PRT, High Tech Buses, Cyber Cars, etc), different applications (feeder service, city centre to city centre, suburb to suburb, etc) and the context (city characteristics, extra policy measures) that are helpful in the decision making and implementation process.
- The research community: That focuses on the next step in research on automated transport. Within CityMobil a broad spectrum of relevant aspects has been researched. Besides technical aspects other aspects (operational, psychological, legal) provide starting points for further research in order to bring the deployment of automated systems a step further.
- Manufactures: That develop and produce automated transport systems. The report provides a perspective for further development of techniques on the one hand and the policy or deployment context on the other.
- Groups or organisations that represent the end users of ATS: These groups can use the results to raise and increase awareness on the development of innovative transport systems.

Structure

This report is separated into 4 parts:

Part I summarises the results of CityMobil following the objectives of the project.

Part II describes a vision on automated transport in a future urban setting to set the scene and understand conditions where automation of transport could work in the urban environment.

Part III describes a roadmap with steps to take to reach the vision as described in part II. Here the vision is used as a point on the horizon for which several issues need to be solved.

Part IV (in a separate Annex) describes the results of CityMobil and forms the basis for part I II and III. The results are reported according to the sub-projects that have been defined within CityMobil:

- SP1 Demonstrations, demonstrators and city studies
- SP2 Scenarios
- SP3 Technical

- SP4 Operational
- SP5 Evaluation results

The most important aspects that were used as input are repeated at the end of each chapter.

Both the Vision and the roadmap have been constructed during a workshop organised in February 2011 in Delft at TNO's premises. During this workshop all participants were challenged to both define the point on the horizon and what this would look like and define necessary actions that are needed to reach this point. The Vision and the Roadmap are the integrated result of the various aspects mentioned here. A list of participants can be found in the Annex of Part IV.

Within the document also information has been used of two interviews with two related, but not connected to, CityMobil examples of implemented Automated Transport Systems:

the ParkShuttle run by Connexxion in Rivium (Rotterdam, the Netherlands) and

the Phileas bus developed by APTS (Eindhoven, the Netherlands).

Lessons learnt also in these implementations are used as input for the discussion.

Part I: Results of CityMobil

1 Purpose

The Primary objective of this report 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?

To answer the question as posed above first a flavour of the results of CityMobil needs to be given to identify the relevant work that has been done so far. After the results the contribution to urban sustainability and necessary conditions is discussed. In Part III the time scale is presented in the form of a roadmap (including some more in depth discussion on necessary conditions). This all needs to be related to the general objective of CityMobil:

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.*

2 Results from CityMobil

The particular focus of CityMobil lies on the *urban* transport system. To assess the contribution towards urban sustainability in the broadest sense of the word a list of indicators and evaluation categories has been designed and put into an evaluation framework.

To be able to assess the contribution towards sustainability a number of activities was deployed:

- three large scale demonstrations (London Heathrow (PRT), Castellon (High-Tech Bus), Rome (CyberCar) where technology will be implemented and be part of the existing transportation system.[1]
- five showcases (Daventry, Trondheim, Vantaa, La Rochelle and Orta San Giulio)
- four city studies (Madrid, Trondheim, Vienna and Gateshead)

From the showcases and demonstrations that were organized the general conclusions is that 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 changes 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 be willing to pay to use the new services proposed.

[1] The Rome demonstration has experienced different delays and therefore was not finished before the end of the project. This makes it difficult to take the evaluation results into account (valuable lessons were learnt however for the necessary conditions).

These activities have all been mapped into the Passenger Application Matrix (PAM) where various origin and destinations have been matched. For every Origin Destination pair it was estimated which potential technologies would fit best into this category (see the Annex for the latest version of the PAM).

This PAM was used combined with the above described framework to evaluate the various activities and the potential contribution towards a large number of aspects (categorised into Acceptance, Quality of Service, Transport Patterns, Societal impacts, Environmental impacts and Economic impact).

In these detailed evaluations the specific links between relevant origin and destination pairs were further scrutinized taking cities as an example. The evaluation of the performances of ATS implemented in four European cities, characterised by different sizes, geography, economy and existing transport systems for different urban transport application scenarios was performed.

The main outcomes of the analysis and assessment of the performances of ATSs across cities can be summarized in the following points:

- the (simulated) implementation of ATSs provides appreciable impacts in all relevant Urban Passenger Transportation Applications (UPTA);
- PRT and Public Transport Feeder Cyber Cars (PTFCC) are in general most successful in small-medium sized cities, while HT bus and PTFCC are more successful in larger cities;
- the (simulated) implementation of complementary measures, in general, the (simulated) introduction of complementary measures, consisting in a road user charging cordon and a 20% PT fare reduction, appears to generate more appreciable impacts than ATSs in terms of improved non-car modal share;
- some synergetic effects could only be identified at the local level.

3 Conditions to contribute to urban sustainability

As shown in the above paragraph on an evaluation level positive and negative examples were identified for the implementation of ATS within the urban area. Besides the evaluation and demonstration that were part of the large project, also other activities were performed. These activities focused on:

- Future scenarios where ATS will fit into the future transportation plans but also looking into the certification process of these new kind of systems.
- Vehicle and technological issues focused on technological and HMI aspects that are a barrier for deployment
- Operational issues which focused on all the aspects that come into play when implementing such a system from an operators point of view.

The conditions that have been identified by these three sub-projects are shortly presented in the paragraphs below.

3.1 Future scenarios

As with all policies that need implementation a positive business case is needed in order to be able to implement any new transportation system. The selection of the most appropriate transportation system needs to be embedded in the regular transportation planning cycle. To assist policy makers with the implementation of ATS a City Application Manual has been put together. In this manual different tools are presented which all are needed to reach successful implementation from a policy point of view. Aspects that are of crucial importance here are the Patronage Estimator, the modelling background (simulation and scenarios) and the business case tool. But also the overview which technology could fit best where, this has been done in the Passenger Application Matrix, stating which technology could fit best on

which Origin-Destination pair, using a general city description for developing this origins and destinations. Also certification procedures and guidelines are part of this process.

Following from the modelling work that has been done in this sub-project the financial impact is crucial: Necessary investments are high and they 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.

Due to the fact that within small distances (2-3 km) the smaller vehicles (PRT and CyberCars) can do a lot of feeder transport, allowing for transportation patterns that can not be made without automated vehicles. This results in a higher level of service and in turn to a more positive BCR if considered.

3.2 Operational issues

An analysis was performed for obstacle detection systems looking in more depth into the requirements for such systems. This was followed by the design of a certification process how to reach certification of a CyberCar system. A similar study was done to find coherence with cooperative systems and the potential these systems bring for ATS. Furthermore it was duly noted that the integration of navigation technologies both with the end-user but also with traffic management will contribute to a larger fleet scale creating better services and reliability.

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. What was found in the studies gives 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. 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 subject to further research.

3.3 Operational integration conditions

A complete guideline to support the design of an Advanced Transport Architecture has been developed within CityMobil. 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. Part of this analysis is also the creation and studying of the functional architecture & the design of the information flow process to get a better understanding where the difficulties lay when implementing such a system.

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. Different technologies are available to realise these two important points.

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 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.

Furthermore not only operational integration has been deemed as important, but also other preconditions for integration have been defined in the course of the project. This integration starts with the proper integration of ATS into the existing urban planning methods that are used, where ATS will serve as one of the policy options to reach policy goals. When the policy decision has been positive to implement ATS the next steps are to ensure the physical integration of the ATS into the urban environment. Making the ATS part of the urban environment will create a more attractive system that is properly connected to other public transport modes (if necessary). As already pointed out the ease of service is important, defined here as the integration of information services, this includes the ticketing aspect, but also route guidance and information which should all be easily available. Last but not least is the necessary proper organisational integration of the ATS into the existing organisational structures that are available.

4 General conclusions CityMobil

ATS can definitely contribute to urban sustainability but is not the holy grail for solving all urban transport and sustainability problems. The technologies that are available need to be adapted to the specific location, time and space to be successfully implemented.

Conditions that are necessary for successful implementation lay in a wide-variety of aspects:

- ➔ Political
- ➔ Technical
- ➔ Institutional
- ➔ Psychological
- ➔ Market
- ➔ Information

These steps towards successful implementation are scrutinized in more detail in Part III of this deliverable, which describes the roadmap for ATS towards the future.

The political aspect appears to be the most important factor when looking at a number of developments. Both for the Phileas in Eindhoven and the Parkshuttle in Rivium Rotterdam the political setting created the successful implementation, but at this stage endangers the further development and continuation of services (Phileas has already stopped and Parkshuttle is on the verge of stopping (Connexxion is currently deciding if they want to continue with the Parkshuttle, since the concession currently offered by the regional authority is financially not viable)). Political will was an important push for the Rome demonstrator to reach actual certification of the system. The difficulty on the implementation here was on the institutional level with respect to the public works that had to be performed. As already identified in the future scenarios work ATS should only be used when solving an actual policy problem. This will create the support that is necessary for successful implementation including political support but also proper market conditions where the competition between modes is based on a healthy business case.

In general it can be said that the Technical aspect is not the limiting factor anymore at this point. This is also proven by the implementation in both Castellon and Heathrow where the systems run rather smoothly.

The institutional aspect is shown in the Rome demonstrator were the certification of the ATS was something new and a whole process needed to be drawn up in order to allow this system on the road.

As already shown user acceptance of the demonstrated ATS has been very good for the systems. However in the vehicles where a driver is still present the HMI-issues as discussed above still need proper attention.

Also for Market and Information various aspects already have been identified in the above section. All these aspects will be discussed in Part III in more detail.

Contribution towards urban sustainability

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. For the CityMobil technologies their contribution towards urban sustainability is scrutinized. Also the category of Mobility has been added since most significant effects can be seen in this category.

Mobility

In general feeder systems had 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 and if anything detrimental to the environment and against other local objectives. Moreover, the new technologies will extract patronage from conventional public transport and from walking and cycling as well as from the car, and this needs to be borne in mind in considering their contribution to sustainability.

Environment

Automated vehicles will reduce the high pressure on the environment that currently exists within the urban area. The basic conclusions in the scenarios and in the models are right on this point. Specially where electric vehicles are expected to get a break through because of the much improving batteries in the coming years. When electric cars will start to become a more regular part of our environment, automated vehicles will benefit from this development in the years to come. These electric vehicles of course have strong relation with CO_2-emissions which are expected to lower as well. Although this strongly depends on how the used electricity has been generated. These aspects haven’t been taking into account within the CityMobil project.

Economic

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. This all has to be put into the perspective of the healthy business case (or a proper Benefit Cost Ratio when looking from a governmental point of view). In the studies performed it can be found that the business case generally is positive, but only very positive in limited

situations, therefore the contribution of CityMobil solutions towards the profit side of sustainability is not directly a higher improvement compared to existing systems.

Overall, the city centre PRT system and the CyberCar feeder system performed best in terms of impacts on car use and financial return. The success of PRT can be attributed to its high operating speed and the avoidance of waiting time. The success of the feeder systems arises from the improved access time to high speed modes, and improvements in their patronage. As mentioned previously this is partly because access time carries with it a higher value of time than in-vehicle time and so any scheme which reduces access time is expected to perform well. It may well be that a PRT system applied to these feeder services would have proved even more effective. The principal messages from this study are that new technologies do have a role to play in an urban transport strategy, both because they can attract users from the car and because they offer a much lower cost means of operating public transport services. However, they are clearly not a panacea. Rather, they will have a role to play in certain niche markets in a city, and those niches will differ from city to city.

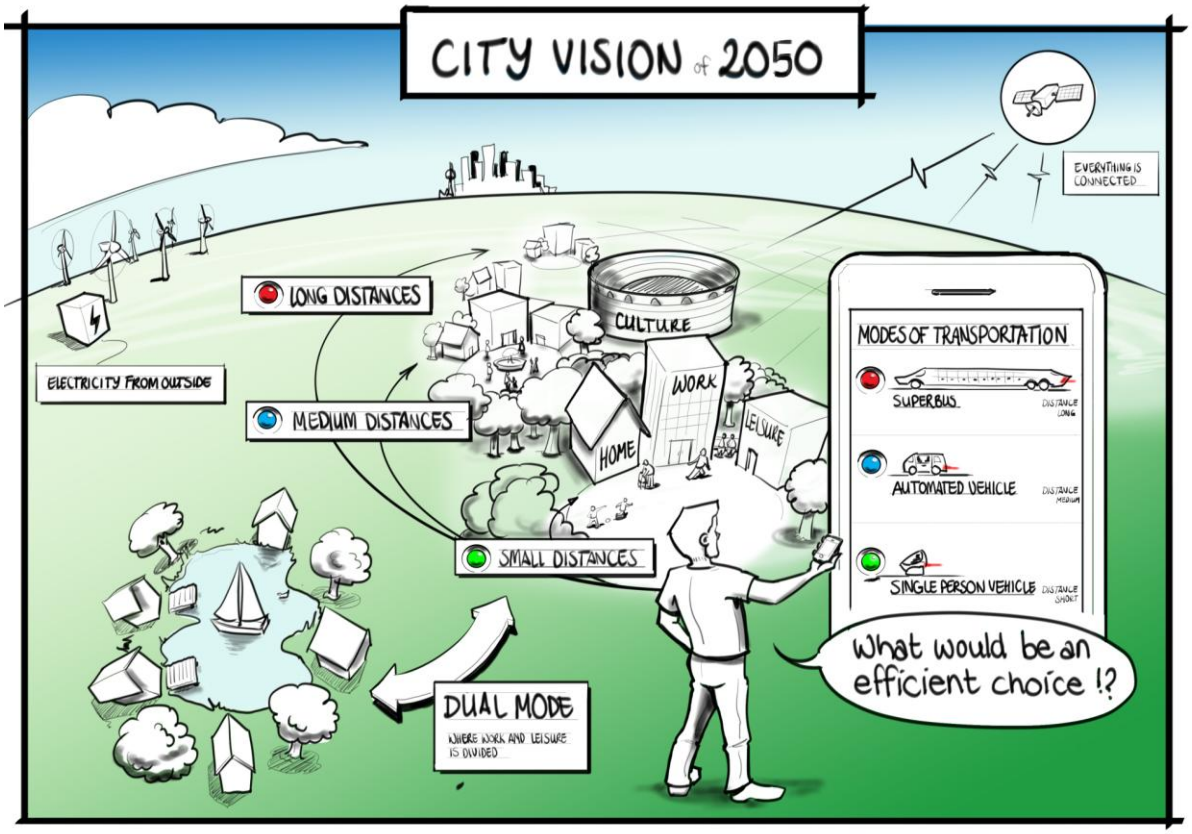
People

CityMobil solutions contribute by offering economic and flexible mobility to businesses and individuals and by reducing the negative implications of increasing mobility. By being efficient, economic, safe and comfortable, the CityMobil solutions 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 will considerably increase.

In the next sections of this report the Vision what the future with Automated Transportation Systems may look like is described. Various aspects that have been mentioned in the text above will find a place (and a possible solution) in this vision. The near-future steps that need to be taken are described in the roadmap part where specific actions are connected the categories that are described above.

Part II: Vision: Contribution ATS to urban sustainability 2050

1 Happyville 2050



Imagine yourself living in the city of 2050, let's call it Happyville, what will the city look like and more specifically how is transportation organised? We would like to take you to Happyville and let you experience this fantastic city of the future.

It is 7 am in the morning and Luisa's alarm rings, when she wakes up she looks outside and sees the sun coming up. It is going to be a beautiful day (especially in the morning). Flipping through the screen on the kitchen table her digital agenda pops up informing her she has an appointment at 9:00 with a co-worker, Filipe, but the location hasn't been set yet. Since it is quite some time she has physically met Filipe, she decides to meet him in person.

Looking at the nice weather the open office park near her house might be a good location. That shouldn't be too much hassle for Filipe to reach, since he is living close to a connecting automated subway line that has just been added to the already extensive portfolio of automated transportation services of the thriving Happytransport ltd.. For the last section he can either decide to walk or talk the small CyberCar that will drive him there automatically. The most handy thing of this digital agenda is that it keeps you up to date about the traffic states so nobody is ever late at any appointment. Furthermore it will give you all the available options for transportation taking into account your personal preferences and integrating all the advantages of virtual reality.

At 7:15 am Luisa's daughter wakes up and because it is a participative school day today she has to go to school. On a regular school day she can stay at home and follow her classes via the screen in her room. During lunch and after school all children in the area where Luisa lives come together to play, do sports and enjoy other cultural activities. Since there is no real traffic in the neighbourhood (only a couple of automated CyberCars and a subway stop at the

end of the block) it is rather safe for families to live in this area (as are actually all areas in Happyville). Reliability and safety rates have been further improved from chances of millions to tens of millions

Luisa's husband is out on a business trip, but according to his travelling schedule he will be back with dinner tonight and since delays on the Hispeed Rail Network are part of the past due to automation of the trains, travelling to other cities has become a real pleasure (especially since there are special office sections on board where they provide people with hispeed internet connections, meeting rooms and of course a good cup of coffee).

While getting her daughter ready for school and providing her the lunchbox, Filipe responds that a meeting in the parkoffice is fine and he will be there in time. In the early days when people would still run around with blackberries in their hands people would constantly be looking at their phones if anything new had happened, the next generation of 'phones' has added functionality knowing when to alert you when a message arrives and when to keep quiet. This has made life a lot easier and brought back the work – private balance in Luisa's life.

Luisa's daughter is picked up by the school's CyberCar bringing all children from the neighbourhood to school. Although Luisa isn't very fond of the 'automated' bus driver, she enjoys this more than the stress her mother experienced when getting her to school (and back). Getting back to the living room, she notices her boss is looking for her, maybe she has to come to the office after all (that would be a pity, since the weather is so nice). But when getting back to her boss, he only wants to ask her if she would like to help organising the company weekend for the end of the year. Luisa is happy to do so and already has a couple of great ideas like going out and camping in the new Nature reserve or maybe enjoy an automated safari in the local zoo.

When coming outside her house she notices she is a bit late for her meeting with Filipe and decides to grab a Segway to get to her destination a bit quicker. Every block of buildings has a number of transportation modes available and they are for common use. Since all movements from people are made criss-cross at various points within the area a number of modes of transport are available, also if you need to go a bit further you can call a CyberCar to come to your house and take you to the outside located parking where all automated electric vehicles are located. The different means of transportation are automatically redistributed according to the needs of travellers, so you never have to wait long before getting on your way.

Cruising to the park office on her Segway Luisa suddenly remembers that she still has to order special food, since her mom is coming over this weekend. She puts the Segway into automation mode and tells her home-computer to order the foods for her mom. Her selection is quickly confirmed and she gets the message

the food will be there within 24 hours, they must have had it still on stock Luisa thinks. Well she'll find it in her fridge tomorrow.

In the park office Filipe has also just arrived and together they go and find a spot for their meeting. They have a rather interesting project that focuses making the company more sustainable, although every car is electric now The company has set itself the goal to contribute heavily to the set policy goals and needs to improve improve societal impact even further. Cradle to cradle has been the basis for this trend, but now also the customer is more heavily involved. The transportation of employees is still quite energy consuming although everyone (like Filipe and Luisa) works in different offices all over town and work from home regularly. The production process of their company is already Cradle to Cradle 2.0 certified, but to get the next sustainability certificate employees and customers need to be tackled as well. The main question for their project is how to get these aspects operational within the company itself.

After the meeting Filipe and Luisa talk about the plans for the weekend, the new city which has focused areas on work and living has allowed the government to establish nature areas outside the city parameter. Not only does this allow for efficient intra urban transport, recreative traffic can also be organised in a more efficient way and even here the first automation efforts are emerging. These nature areas serve as some kind of secondary hubs where all other activities take place with respect to nature. Filipe is planning to spend a long weekend with two friends to go fishing. Filipe is thinking about taking the new HiSpeedBus connection which is only two stops away from his house by the metro. At the transport center the bus takes you to your selected recreation area. These buses are fast on the medium to long distances (and since flying has become unreasonable expensive due to fuel taxes) this is one of the good and efficient means to have transportation over larger distances. Driving yourself has become rather obsolete and a new theme park has recently been opened where children can experience and see how transportation was organised in the old days (including the faking of emissions and fuelling with gas of vehicles).

2 The setting of automated transport

The story about Filipe and Luisa can continue about the city of the future and more specifically the role that Automated Transport plays within this city. In this section the focus on ATS will be further scrutinized in combination with important social and economic trends that have been identified. Happyville outlines a possible scenario in a period around 2050 that can be termed 'sustainable', in a setting that can be described as follows:

- **Environment** Compared to the situation now there is a very significant decrease in (net) CO2 emissions. Other polluting emissions are dramatically reduced, noise from traffic and transport is reduced and the compartmentalization / barrier effect has not increased any further ('planet'). Energy supply is being delivered by sustainable energy sources such as wind, water and solar power. The breakthrough of sustainable energy sources have enabled the steady growth of electric powered vehicles including transport systems. With the electrification and cleaner vehicles Automated Transport Systems have contributed to the accessibility of economically important concentrations of activities in cities ('profit') ;
- **Public transport** ATS delivers a contribution to the public transport system (in combination with the use of space) that provides for the efficient, reliable and affordable accommodation of the need for mobility whereby the transport system is

accessible to everyone (no social exclusion) – ('people'). Furthermore the focus has changed from owning a vehicle towards using a vehicle. In other words car-sharing has become a common denominator within urban areas. New business models provide for the healthy exploitation of ATS in urban settings. This means that also the (strategic) dependence on non-renewable fuels is substantially reduced and in a number of fully electric cities totally absent.

- **Fully electric vehicles** have a very high penetration rate (85-90%). The transition towards electromobility has almost been reached. This transition process had evolved parallel with developments in ICT, necessary for smart grid charging infrastructures.
- **ICT** ATS has been fully integrated into the ICT infrastructure that has been further advanced under the flag of European innovation programmes on ICT, Intelligent Transport Systems and Future of Internet. The connection between your agenda, the location and the selection of the means of transport is just what is shown on the outside. These services are being offered by service providers that can use public and private open data sources. Public authorities, supervising these organisations, are still able to monitor traffic and influence traffic behaviour. Predicting traffic behaviour and demand has become one of the cores of this backoffice allowing for public authorities to identify and solve problems in advance.
- **Regular congestion** appears to be a problem of the past, not only because the regular home-work trips have been dispersed all over the network, the peak also has spread due to flexible working times. Economically and socially important concentrations of activities in cities are accessible for all passengers ('prosperity /profit'). Besides the infrastructure has more and more capacity since people use the 'right means of transportation' for the specific trips that they make. Furthermore vehicle to vehicle and vehicle communications enable the 'right means of transportation' to efficiently adapt to the local traffic situation and make optimal use of infrastructure capacity.
- **Big events** such as the Olympic games have given a great boost to the development of Automated Transport Systems. Starting at the 2016 Rio Games with Bus Rapid Transit still on wheels this has progressed into very prosperous outcomes in 2040 where a full PRT system is integrated in the Olympic games site allowing for quick and easy transportation of all athletes, spectators and related personnel. In contrast with the early days when such an event would cause a complete area and transport system to become obsolete, the plans now include re-use of items and areas and full integration into the existing transportation system (cradle to cradle).
- **Cities** will continue to grow. The majority of the people will live, work and leisure in urban environments. Sophisticated integral urban planning, started and dispersed from densly populated countries to other countries in the early decades of the second millennium have led to efficient urban structures. Functions and design of the urban structure and transport system have been synchronised, leading to efficient usage for working, living and leisure. It is common to have several other home bases beside a primary home base in a home city. People will basically live in a their own hub and spoke networks**.**
- **Showing technical feasibility** of ATS as shown in the current demonstrators performed in CityMobil have created the trust of users in such systems. User acceptance has increased significantly and at a certain point citizens started to ask for these systems. Especially in conjunction with the ageing of society the need for more automation has become eminent and this partially has caused the breakthrough for such systems.

3 Market and product: The Customer

Within Happyville both the Automotive industry as well as public transport providers have made the transition from a technical orientation on the vehicle towards a customer mobility service or product orientation.. This was caused by the change in mentality from the young generation which caused the status assigned to cars has decreased rapidly over the years. Automotive industry that missed this opportunity only nearly survived.

- The typical Happyville inhabitant is still a **busy person** who has a lot on his mind and who doesn't have time for a hassle with respect to mobility. At a certain point the younger generation were fed up with the difficulty of travelling by public transport that they happily embraced the new mobility service providers like Google which emerged at the beginning of 2020. Also the ageing of society caused a rethinking of the mobility concept as a whole. Especially since people not only tend to get older, but the pensionados are very mobile as well and request this mobility from society. The comfort issue from their retrospect is very important and large investments were made by mobiltity providers to create required standards of comfort and flexibility.
- The **quality of life** of the conscious inhabitants of Happyville is also a major push factor for automated transport. They not only want to live in an accessible area they also request that it is safe, both for themselves and their children and that the transport is clean. Parallel with the EU-regulations on EURO emissions and the goals set in the transport white paper of 2011 a big movement of EU-citizens connected with each other through social networks emerged. This has sped up legislation and market development. Legislation for cleaner vehicles to was to be approved quicker and earlier; the market for sustainable products and services further emerged. Using the right political environment (e.g. for GHG-emissions) and identifying the contribution of ATS to limits set in policy has stimulated the use of ATS.
- Another stimulating development in the beginning of Happyville has been the rise of **prices for parking**. This has highly stimulated the first set op people to use other means of transport and decide not to own a car. This rise in parking prices was also coming from the feeling that parking space was a spoilt usage of the already crowded space, especially inside cities.
- As stated above already due to the rise of **new status symbols** other than the car by the younger generations (generations Y and Z), car ownership decreased rapidly. Although people are still fond to create an 'own' car feeling in their cars (including their own outside colour, their own music, but also their own horn or 'ring tones' for greeting others) they don't need the vehicle to stand on their driveway all the time. Not only does this take up too much valuable space it is also experienced that due to the very limited of these old cars (and difficulty with keys, gasoline etc.) people fairly more appreciate using a standardised car which can be adapted to personal preferences when needed.
- The switch **from car ownership to ATS usage**, has been accelerated by the penetration of smartphones such as Apple's I-Phone serving as platform for initiatives of new mobility providers. First examples were information services and P2P car sharing initiatives. These providers cooperate in PPP-like constructions where the road authorities set the boundaries in between which these providers can operate and provide these services to their customers. This allows the public authorities to keep supervise and manage societal objectives, while the service providers can provide the best optimal solution to their customers allowing for both an individual and societal optimum.
- Furthermore, due to technological improvements information is leading and the **prediction of travel times**, usage of modes and needs for capacity has greatly

improved. Due to interactivity between travel time, agenda's, meeting times etc. the difference between actual and predicted transport supply and demand has greatly been reduced to a small difference due to individual choices not foreseen. The predictive capacity has also allowed to deliver the best travel options, route choice and transport mode for each individual traveller.

- As stated before customers are done with the hassle of mobility and therefore integral mobility services are provided, including all related aspects making ATS a full part of the mobility chain. E.g. with solving Issues like **ticketing and time schedules** important first steps were made, but seamless travel from a travellers point of view was still quite far away. As part of these mobility services payment of course needs to be arranged, since nothing is for free. But due to new stakeholders that have entered the market the business models have become rather complex. These complex business models need of course money flowing through, but e.g. by using credits a complete new payment system has been realised.

4 ATS Technology: The Vehicle and the system

Looking at Happyville it is seen that no specific technology has prevailed over the other, so many technologies exist next to each other. The different technologies are complementary. They all fit in the spectrum of mobility needs of the users: their day to day use, their occasional use and destinations varying from short, to medium and long distance travels. The CityMobil technology application matrix has contributed to this development.

- The overlap between technologies allows for a **good integration** and the most optimal choice of the most suitable mobility service in every situation. For example the developments of new areas provide a mix with a high-frequency metro stop at the edge of the building location, combined with a big parking lot for electric vehicles. In this transport hub all forms of transport come together and allow for a smooth integration. At specific points in the city a combination between short, mid and long range transport come together (like in railway stations nowadays). The technological developments also have allowed for the removal of the physical barriers that usually where placed at the first deployment sites of ATS. This has also been made possible due to road users who have better understand these automated systems.
- What can also be seen is that ATS systems haven't been deployed first in city centers but outside in **peripheral areas**, such as applications at airports, expo's or greenfield development of cities (new cities in China and Arabic Emirates). Experiences in these peripheral areas have been used to implement the system allowing for a good integration with the already planned developments. Basically ATS have started in providing the last mile into areas where regular urban transport had difficulty to provide their services in the requested high frequency.
- The distinction between urban and non-urban transport systems has strongly been emphasized making it clear for both the traveller and the operator to understand where the different modes are supposed to go. This doesn't mean that structural **different technologies** are used for the vehicles but the split has more or less been made on the operator level to allow for further specialisation of both the vehicles and the design of the stations.
- Technology developments in predictive technologies allow for a seamless match between the supply of transport with the demand regarding **complex travel patterns**. These complex patterns still exist, but from a focused hub and spoke system that is known from the integration of all forms of data. The basic focus has been to redesign cities in such a way that they can accommodate these complex patterns where ATS is just part of the solution and not covering all possibilities .

Part III: Roadmap for CityMobil technologies

The vision as described in the previous section identified trends which favour the development of ATS within urban areas.

In the roadmap it is identified how to get from today towards a future where ATV's are used..

This process is written down in a roadmap where various aspects are discussed. In the EC Action plan six barriers have been identified for the deployment of ICT related systems on the road. These are combined with the six categories that have been identified during the roadmapping session of CityMobil.

CityMobil roadmap categories	EC Barriers
Political	
Technical	Technology
Institutional	Legal
Psychological	Mind Change
Market	Economic
Information	
Implementation	Implementation
	Diffusion

This match reveals a great overlap in subjects identified. If studied in more detail also overlap between the non-matching categories can be found, but also cross-matching can be expected. In the following sections the CityMobil roadmap categories are described, with the different events that have been linked to this specific track. During the identification of the events sometimes various categories have been assigned to a number of the crucial activities.

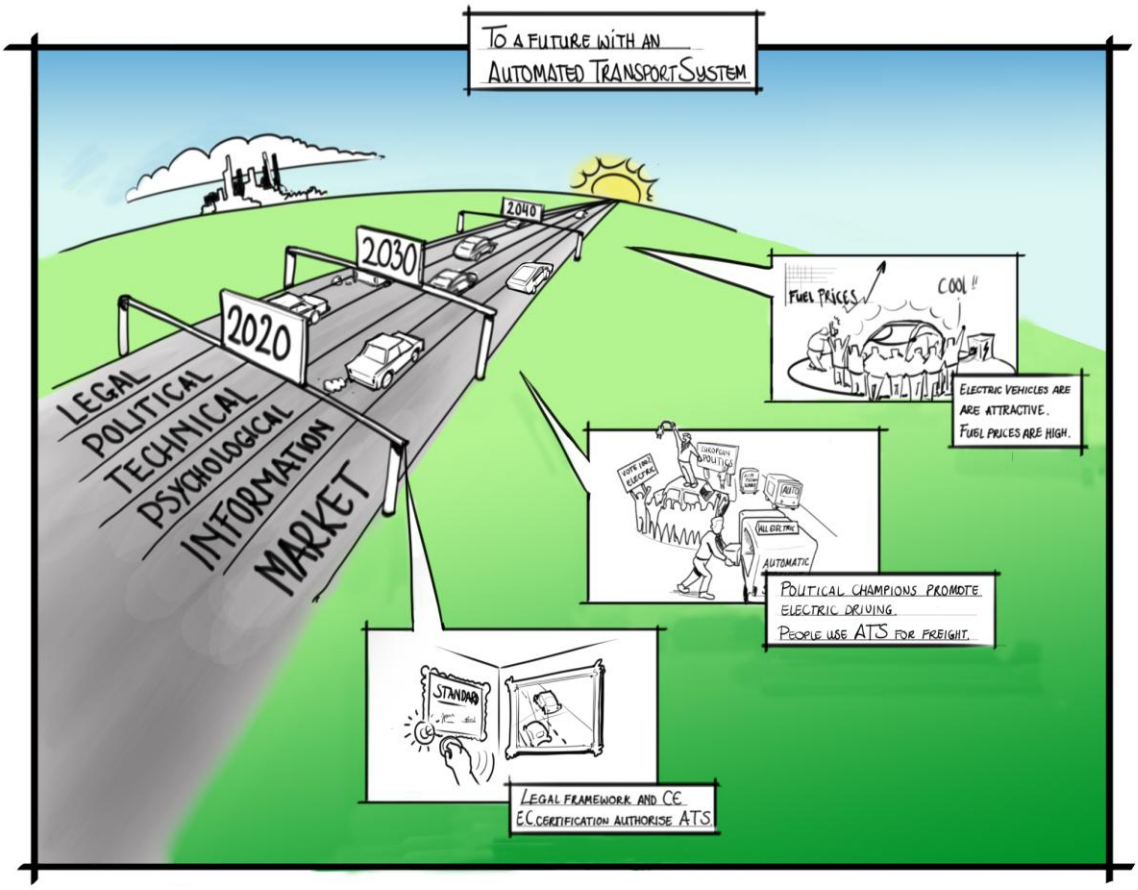
The roadmap consists of a number of results which will be realised in a certain year and will contribute to the introduction of ATS in the urban area. As can be seen in the figure above three specific aspects have been identified as very important for the three specific years 2020, 2030 and 2040.

Main milestones

2020 Legal framework and certification for Automated driving has been established by the EC. The first ATS are deployed quickly afterwards.

2030 A political champion steps up stating that within in parts of his city only electric vehicles are allowed. ATS has been widely recognised to be used for freight transport (mainly long distance).

2040 The final rise in fuel prices and parking costs and the specific incentives applied to electric vehicles (both automated and normally operated) created a significant growing penetration rate for these vehicles, causing the final EU-wide breakthrough for ATS.



On the figure also a number of categories have been identified for which specific deployment issues still need to be solved. Below all the categories that have been identified are described, including specific events that fit into the category. These events are first shortly introduced, followed by a short conclusion for each category with the most important aspects. Since the focus of the work is based on the vision described in the previous chapter the roadmap can be defined as evolutionary. The vision was used as a point on the horizon before describing the path to reach this vision.

1 Legal milestones

- Legal framework authorizing automated vehicles on (parts of) the road within a experimental or research setting (2016)
- Legal framework authorizing automated vehicles on (parts of) the road for regular use (2018)
- Uniform European Certificate for standard ATS launched. Applicable for different systems and technical frameworks (2022)
- Only electric vehicles are allowed in centres of large European cities (2037)

An important aspect is the need for a legal framework and related standardisation of Automated Transport Systems. Currently the Vienna Convention is not supporting such systems actively, although loopholes have been identified. Adapting this Vienna convention to allow for Automated Transport is therefore also an important aspect which needs to be arranged by the political leaders (also for them to show their political commitment towards

ATS). A step-by-step approach - starting from a legal framework applicable in a R&D setting, via a framework for parts of the road to a uniform standard applicable for all standards and techniques – makes it possible to develop and adjust the framework according to the results of applications. In the step-by-step approach lies a parallel with the development of cooperative systems, where the legal framework is an important issue as well. The development of the legal framework could serve both ATS as well as cooperative systems.

2 Political milestones

- Legal framework authorizing automated vehicles on (parts of) the road (2016)
- Robustness proven of Heahtrow's PRT system in different situations (2018)
- Mazdarcity 2 opens in Dubai (2018)
- European Certificate for standard ATS launched (2018)
- Passenger & freight Hi-tech buses operate in Castellon (2019)
- Political champion promoting ATS appointed in a major city in Europe (2020)
- Electronic certification for freight delivery allowing automatic delivery between nodal points to be fully automated (2024)
- City of the future opens where no conventional vehicles with internal combustion engine are allowed (2028)
- 1 litre of petrol costs 5 Euro and 1 hour of parking costs 10 Euro (100% more than 2011 prices) (2030)
- Only electric vehicles are allowed in centres of large European cities (2037)

One of the most important events is the political champions which are needed to make ATS happen. Somebody has to have the guts to actually go forward and to promote to install and buy ATS systems. This political champion will of course be largely influenced by the citizens who elect the officials and if they request Automated Transport Systems, these will be delivered at a certain stage. Important to take into account for the political roadmap is to take care that the ATS systems developed as a structural solution being supported for a longer period of time than the existing election periods. Having users request these systems is one the most important aspects to realise this.

3 Technical milestones

- '100% smartphone penetration' for active people (2014)
- Reliable V2V communication established and standard set (2016)
- Obstacle avoidance 99,9% reliable (2017)
- Passenger & freight Hi-tech buses operate in Castellon (2019)
- Longlife batteries (renewable and battery-to-grid) made available for lower (50%) prices (2032)

As stated already many times in different conferences, the technical part of ATS is not the limiting factor for implementation, unless integration with regular traffic is the pre-requisite that is concerned. This aspect therefore is not so much concerning the hard-core technical aspects, but other aspects like integration with mobile communication devices. The penetration rate of these devices is crucial in order for mobility service providers to be able to over full mobility services. The other challenging technically event is the integration with cooperative systems, or the so-called V2V and V2I communication.

Other challenging technical issues are the organisation and creation of reliable travel information. Currently this information is coming from various sources and is not always easily accessible. This aspect is also a key priority of the ITS Action plan (EC, 2010).

One important lesson that was learnt when implementing the Phileas bus in Eindhoven was that adding too much innovative techniques into one vehicle at once will create many difficulties. For the technicians involved in this line of work limiting themselves instead of expanding the technological possibilities would be better.

4 Institutional milestones

- The first three cities have successfully used the practical instruments (application manual & business case tool) delivered by CityMobil to set up demonstrations with ATS (2014)
- Development of an international minor 'urban development with automated transport solutions' for universities to use (2015)
- Town planning and transport planning have integrated into one discipline (2015)
- The greenzones regulation have banded polluting vehicles from in innercity area's (2022)
- Increase outer city parking development and Kiss and Ride spaces (2024)
- Electronic certification for freight delivery allowing automatic delivery to be fully automated (2024)
- ATS as evolved into a standard transport solution within town and transport planning (2026)
- Insurance of driverless vehicles is cheaper than for vehicles with a driver (2033)

The tow lines that can be identified here are the integration of town and transport planning into one discipline, allowing for "HappyVille" to be actually created by planners. Planners have access to a 'toolbox' that helps them find the suitable solution for their cities. They can now take into account the characteristics of the town, the mobility problem at hand and transport demand in order to select and implement the most suitable ATS solution. If not accessibility but mobility becomes an important part of the town planning theory, the integration of ATS in such systems cannot be far away. These can also be enhanced by new models of traffic circulation used by traffic engineers where ATS can also be seen as a solution. The second line is the legal line which needs to be institutionalised following the certification and legal framework. An specific interesting point here is the insurance of driverless vehicles, which will be another great incentive if this is properly covered.

CityMobil Tools & Instruments

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

City Application Manual

The City Application Manual is designed to help cities make good use of the tools developed within the CityMobil project, 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. Tools developed within CityMobil:

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

5 Psychological milestones

- Through a growing number of applications in niche markets such as airports and expo's people are used to the concept of PRT (2019)
- First PRT native is born (2025)
- The rising of oil prices and the breakthrough of electrical and automated transport systems have influenced the consensus of the general public with regard to mobility (2032)
- Huge system crash, 100.000 people are stuck in a PRT system for more than 24h. People have no manual driving skills anymore to be able to get home (2034)
- No individual owned cars allowed in (central) parts of cities (other than collectors) (2035)
- Only electric vehicles are allowed in different places (2037)

Being used to the concept means a significant penetration rate and spreading over places, needs to be reached, if this is realistic in 2019 is still a question. However getting used to the concept (combined with PRT natives) will give a boost to having these systems on the road much faster. Furthermore the decrease in driving possibilities (especially in city centres) of the next generations to come is a specific aspect to keep in mind when designing such systems. At a certain point the possibility to drive a vehicle will be ruled out and automation will be the standard. Managing user acceptance is a major issue when deploying such systems on a large scale. This was e.g. experienced by the ParkShuttle project in Rotterdam where due to start up difficulties the system got a 'bad' name in the media, nowadays however the system runs rather successfully and is fully integrated in the transportation patterns of users.

User acceptance of the existing systems is already quite high and this only expected to be growing further with a further integration of ATS into the existing environment. Another factor that needs time is the car driver that will loose it's skills but in the mean-time also needs to get used to automated vehicles on the road in ordinary traffic. Not only will this driver meet automated vehicles, it will be driving in semi-automatic vehicles where responsibilities are transferred at a certain point. This is still a rather new area and big steps still need to be made in order to accommodate the changes foreseen within Happyville.

6 Market milestones

- Real-time door-to-door travel information available (2013)
- '100% smartphone penetration' for active people (2014)
- Mobility service providers are a fast growing business (2014)
- Passenger & freight Hi-tech buses operate in Castellon (2019)

- Assembly line production / growing demand of PRT and CyberCar vehicles (2019)
- Insurance companies have products for the use (instead of ownership) for different modes of transport (2021)
- Insurance of driverless vehicles than for vehicles with a driver (2023)
- Main airports have PRT systems running as part of a MoU (2026)
- 1 litre of petrol costs 5 Euro and 1 hour of parking costs 10 Euro/hour (100% more than the 2011 prices) (2030)
- No individual car ownership (central) parts of cities (other than collectors) (2035)
- Only electric vehicles are allowed (2037)

Main aspect jumping into the picture is the entrance of new market players into the market of automated transport systems. Not only the mobility service providers are an example from this aspect, but also insurance companies identifying these kind of vehicles as beneficial for their business are seen as crucial. These players offer solutions that facilitate their customers. A growing amount is shifting from a consensus of 'car ownership' to 'access to a mobility solution' – through for example a subscription or pay per use solution. Options could be to use a PRT or CyberCar for short distances, High Tech buses for longer distances. The first services will be initiated in 2014. In 2035 this market is a mature market leading to the milestone where no individual car ownership in central parts of cities are allowed. In the beginning this will be combined public and private effort, changing more and more to a private effort, where the public sector defines the conditions and boundaries in which these developments can take place.

The second to address is the competing capacity of automated transport with existing means of transportation. This capacity is strongly influenced by the rising fuel prices and prices for parking in city centres that are skyrocketing in rather crowded urban areas.

The last important change, already starting to take place in the current decade, is a move from ownership to usage. Car manufacturers are expected to anticipate this switch and customers are expected to request usage like this. This will also involve existing stakeholders in new roles, for example the leasing companies.

If looking at the end-user the most important aspect is the affordability of the mobility solutions that are offered. These costs are expected to be lowered in the transition phase as already described. The appealing factor of these systems shouldn't be forgetting as a specific market discussion that needs to take this into account.

7 Information milestones

- Real-time door-to-door travel information available (2013)
- Wise trip multi modal, door to door, international routeplanner available in the EU (2015)
- Google launches an application integrating travel and modalities: iTravel (2015)
- People are used to the concept of People Movers (2019)

This category information has a great overlap both with psychological and with technical, but specific focus is need towards creating the availability of information. This availability of information is crucial for the next step of automated transport systems coming out of the niches and into the general transportation system.

8 Implementation milestones[2]

- The majors of Masdar city, Rotterdam and director of Heathrow fill in an ambassadorship for the deployment ATS (2012)
- The majors of three European cities have signed up for CityMobil 2 due to the help of the ATS ambassadors (2012)
- Development of a public private partnership for sharing investments and risks in the implementation of ATS (2015)
- Heathrow expanded their PRT system with a second tranche (2015)
- Masdar City PRT-2 opens in Dubai (2018)
- Assembly line production/high demand of PRT and CyberCar vehicles (2019)
- Main airports have PRT systems running as part of a MoU (2026)

With respect to the implementation of such systems a couple of steps still need to be taken before full-scale penetration can be realised. The scenario that aims at just waiting till the systems become ready for use is not preferred at this point, but currently there are still too many barriers for the big-bang scenario. Usually city centres of existing cities are well served by existing modes of public transport. Most of the times the problems lie in the PT coverage of the suburbs. CityMobil has shown that ATS 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. Suggestion here is to start with the niches as described above, and to 'wait' for the political support for these systems to grow. Good examples in e.g. Heathrow and MasdarCity can be found, including plans for further optimisation. To keep these kind of systems on the road and developments going, it is important that existing systems are nurtured and where possible expanded.

Marketing towards all stakeholders of these systems in that retrospect is crucial. The installation of ATS ambassadors can help. The majors of Masdar City, Rotterdam and the director of Heathrow all have an ATS system in their city or premises. They can have an important role in the raising of awareness among other decision makers. They can explain to other decision makers from a first hand experience what kind of problems they were facing, why they decided to choose for an ATS solutions, how they have deployed the system and what benefits they are gaining.

Another important aspect with regard to the implementation of ATS systems is the funding of the initial investments. For cities, operators or manufactures the large investments and the related risks can be an important barrier not to implemented ATS systems. A public-private partnership or public-public partnership program could help as instrument to raise funding and share risks. The EC could be an important partner in these partnerships. The further development of the business modelling tool can be used to provide insight in initial investments, operation costs, expected benefits and provide a basis for investments.

[2] During the time of the workshop this was not given as a specific chapter, therefore it is not represented in the roadmap - picture

Annexes

Abbreviations and acronyms used

ATS	Advanced Transport System
BCA	Business Case Analysis
CC	City Centre
CMs	Complementary Measures
DMV	Dual Mode Vehicle
ICCC	Inner City Cyber Car
IS	Inner Suburb
MARS	Metropolitan Activity Relocation Simulator
MCA	Multi-Criteria Analysis
OS	Outer Suburb
PAM	Passenger Application Matrix
PRT	Personal Rapid Transit
PT	Public Transport
PTFCC	Public Transport Feeder Cyber Car
SP	Sub-Project
UPTA	Urban Passenger Transport Application

Passenger Application Matrix

Destination→ **Origin** ↓	City centre	Inner suburbs	Outer suburbs	Suburban centres	Major transport node	Major parking lot	Major service facility	Major shopping facility	Major leisure facility
City centre	ICCC (Gateshead. Madrid. Trondheim. Vienna) PRT (Gateshead. Madrid. Trondheim. Vienna, Uppsala) DMV (La Rochelle, Orta, Gateshead. Madrid. Trondheim. Vienna)								
Inner suburbs	ICCC (Gateshead. Trondheim) PRT (Gateshead. Trondheim, Uppsala) HT-bus (Gateshead. Madrid. Trondheim. Vienna) DMV (Gateshead. Madrid. Trondheim. Vienna)	ICCC (Gateshead. Trondheim) PTFCC (Gateshead. Madrid. Trondheim. Vienna) PRT (Daventry, Gateshead. Trondheim, Uppsala) HT-Bus (Gateshead. Madrid. Trondheim. Vienna) DMV (Gateshead. Madrid. Trondheim. Vienna)							
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 (Sophia-Antipolis)						
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)	DMV (Sophia-Antipolis)						
Major parking lot					CC (Rome) PRT (Heathrow)	CC (Rome)			
Major educational or service facility (e.g. University campus, hospital)	PRT (Trondheim) HT-bus (Castellon)	PRT (Trondheim)	PRT (Trondheim)		CC (La Rochelle demonstration)		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 (Gateshead. Madrid. Trondheim. Vienna)	HT-bus (Gateshead. Madrid. Trondheim. Vienna) DMV (Gateshead. Madrid. Trondheim. Vienna)	HT-bus (Trondheim) DMV (Gateshead. Madrid. Trondheim. Vienna)	HT-bus (Gateshead) DMV (Gateshead. Madrid. Trondheim. Vienna)					