EUROPEAN PARLIAMENT

Science and Technology Options Assessment

S T O A

URBAN TRANSPORT

Description of technologies, challenges and paradigms in urban transport

Phase II

IP/A/STOA/FWC/2008-096/LOT2/C1/SC3

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SCIENCE AND TECHNOLOGY OPTIONS ASSESSMENT

URBAN TRANSPORT

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Abstract

This deliverable gives an overview on alternative fuels (biofuels, battery electric vehicles, hybrids, natural gas, autogas, and hydrogen with fuel cell) and touches upon the controversies related to the different systems. It further highlights the most important developments enabled by ICT applications. So far, the penetration of ICT applications into the transport sector is the main trigger for changes in transport technologies and services. For nearly all applications ICT is being considered as an enabling technology that brings together demand and supply in an efficient way. They are important for the attractiveness, better organisation and for an easy access to almost all transport modes. In addition to the technological developments, the deliverable takes a look at new business concepts, such as car- or bike-sharing. Those concepts are becoming increasingly popular in urban areas and offer new mobility services to the users. Some car manufacturers have adopted the car-sharing concept and are trying out new forms of providing mobility instead of only selling end-products. Also more visionary concepts are being described, e.g. cargo caps, aerial ropeways or personal air vehicles.

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Executive Summary

Technological progress has shaped and permanently changed the transport system over the last decades. This progress has caused negative effects but also provided solutions for the mitigation of many of these effects. Still, transport is related to a wide range of unsolved problems and challenges that need to be tackled in order to guarantee a high level of quality of life in European cities and to make the transport system an even more efficient pillar of the European economies. Over the past decades, the steady increase in transport volumes has caused serious challenges, such as the strong dependence on oil-based fuels and the greenhouse gas emissions induced by transport. In particular, the growing urban agglomerations suffer from the emission of pollutants and noise as well as from congestion and, thus, from reduced accessibility. Technological progress is a necessary (but not sufficient) requirement for coping with these challenges. For example, the targets of many European Countries for a reduction in greenhouse gas emission can hardly be reached without a successful implementation of technological and also organisational innovations. More information is needed, especially on the potential of future or emerging technological developments and organisational innovations. To aid understanding and to ensure that such potential is reached, it is important to get a better understanding, not only of technologies, but also of the relationship between these technologies and concepts and the different actors that are important for their successful development and implementation.

Against this background, this STOA project on urban transport considers technologies from an innovation-oriented angle. It provides an inventory of both, existing and future technology options in urban transport, as well as an overview of the scientific knowledge concerning their (potential) impacts on health and/or environment. Taking this as a basis, the project will also look at the socio-economic context in which these technologies are, or will be, implemented. The overall aim will be to highlight promising innovation pathways to a more sustainable urban transport system.

This report is the deliverable two of the project. It describes technology options and mobility services, which are, or might become, relevant for urban transport systems and, thus, will become relevant for a transition to more sustainable urban transport. The report also looks at impacts, challenges and visions related to these technologies and concepts. In doing so, it is putting the focus on the supply side of the transport system. Relevant framework conditions, as well as the role of the demand side for sustainable innovations in urban transport, will be discussed in the following phases of the project.

A wide range of technical options are highlighted in this report. Some of them are already available, some are emerging others are of a more visionary character. In the report it is argued that recently, with respect to technologies, major contributors to changes that are anticipated or already observable, are developments in two fields of technology:

- Information and communication technologies that are penetrating all areas of daily life and are also becoming increasingly indispensable in the transport sector;
- Alternative fuels and propulsion technologies that are expected to substitute fossil fuels in future.

The report is giving an overview on alternative fuels (biofuels, battery electric vehicles, hybrids, natural gas, autogas and hydrogen with fuels cells). It touches upon the controversies related to availability and efficiency of the different fuel-propulsion systems and it will try to contribute to transparency in this field.

Since most EU member states and Europe's' leading car manufacturers have launched pilot projects and set up incentives for reaching a broader market share of electric vehicles, the assumed environmental impact and influencing parameters of a wider market penetration will be considered in this report. Barriers for electric vehicles include in particular the limited range, the relatively expensive purchase price and the long charging process. In order to overcome these barriers, new business models appear to better bring together the technological settings of electric vehicles and demand structures on the user side. Elaborating more on the potentials of these business models will be an issue in the following phases of this project.

Information and Communication (ICT) infrastructure, namely the network that connects electronic devices, such as phones and computers, to the Internet and each other has become of utmost importance for design of transport systems. ICT affects urban transport in many respects. Already today, modern transport systems are based on sophisticated ICT solutions and a wide range of new applications are emerging. For example, personalised information is available for travel time or multimodal route planning, and also ICT is related to better control and guidance of the transport network. In contrast to alternative fuels and propulsion technologies, the application of ICT is not, in most cases, "sustainable" in itself, but it might enable changes in behaviour and logistics that contribute to a more sustainable transport system. Some of the applications even have the potential to substitute transport by, for example, video conferences or tele-working. In logistics, ICT is a key-enabler for increasing efficiency. New concepts such as the "smart truck" illustrate that there still is room for new ideas and approaches.

In addition to these technological developments, new business concepts are emerging that are both enabled by new technologies and are themselves enablers for technological advancement. In particular, the development of ICT technologies supports new concepts and business models for "individualised collective" forms of transport, such as car sharing, car-pooling or bike-sharing. The public transport system also profits strongly from ICT applications since they enable easier access to vehicles by handy ticketing, or easy access to information by mobile internet – at least for those societal groups that are familiar with mobile phones and the Internet. On the other hand, new business models, such as car-sharing, are supposed to support the market penetration of new fuels and propulsion technologies. This is because they are intended to allow users to select, from the car-sharing fleet, vehicles appropriate for specific, though varying purposes. For example, a battery electric car could be chosen for trips in the city and a conventional vehicle, or a vehicle with range extender, could be chosen for longer distances. It is documented in this report that car-sharing organisations are continuously growing and are becoming more and more professional in Europe. Recently, with Car2go run by Daimler and Mu by Peugeot, well-established car manufactures have begun to enter the scene with ambitious concepts - based on advanced ICT applications.

In the mid to long-term, it can be expected that technologies, which challenge established technology-infrastructure systems will become increasingly relevant. It surely cannot be predicted which technologies these might be; however a couple of approaches that are discussed in more visionary contexts are also described in the report at hand. Examples are the cargo caps, the aerial ropeway and personal air vehicles. For the latter, in particular, it is not at all clear if they can make a contribution to sustainable urban transport. The example of the personal air vehicles illustrates that, for governing a transition to sustainable transport, it is crucial to have a profound assessment of the potential impacts of the technologies on society, the economy and the environment. Undoubtedly, such an assessment should be carried out at an early stage of technology development, before the technology is established. For most of the "visionary" more unconventional approaches, only limited technology assessment is currently available.

Visions, paradigms (or “Leitbilder”) are a central element of transport planning and play a significant role for the improvement of urban transport systems. They present the strategic direction for future developments by providing principles and guidelines. The report at hand will illustrate some examples on how European cities anticipate and plan future developments in transport. Even though the outlined visions cannot be seen as representative, they illustrate the emergence of new planning goals – related to sustainable development. Achieving sustainable mobility, liveability, and high quality in cities while ensuring economic growth is given high priority in most European cities. A wide range of instruments for achieving these goals have been developed over the last decades. More knowledge is needed about which instruments work best in which urban context.

In the following phase three of the project, barriers and success factors for innovation pathways to sustainable urban transport will be analysed. The idea is to elaborate on how the paradigm of sustainable urban transport could materialise in different urban contexts. In doing so, the work will be closely connected to the present report. But it will put a stronger focus on the framework conditions for a successful implementation of approaches supporting a transition to more sustainable urban transport systems. Furthermore, in the following phase, a strong focus will be put on the demand side. This will be done by analysing literature in relation to the role of the users. On this basis, an analytical framework will be developed for the empirical research to be carried out in phase 4 of the project where perceptions and attitudes of specific user groups in relation to selected innovation pathways will be analysed. The project closes with the final report in December 2011.

In December 2010 a workshop on Urban Transport will be held in the European Parliament. Main objective of the workshop is to discuss the potentials of technological and organisational innovations to support a transition to sustainable urban transport systems in Europe as well as to reflect on further research questions to be tackled in this project (and beyond).

Contents

General Information

Urban transport is related to a wide range of unsolved problems and challenges that need to be tackled in order to guarantee a high level of quality of life in European cities and to make the transport system an even more efficient pillar of the European economies. More information is needed, especially on the potential of future or emerging technological developments and organisational innovations. To aid understanding and ensure such potential is reached, it is important to get a better understanding, not only of technologies, but also of the relationship between these technologies and concepts and the different actors that are important for their successful development and implementation.[1]

Against this background, this STOA project on urban transport considers technologies from an innovation-oriented angle. It provides an inventory of both existing and future technology options in urban transport, as well as an overview of the scientific knowledge concerning their (potential) impacts on health and/or environment. Taking this as a basis, the project will also look at the socio-economic context in which these technologies are, or will be, implemented. It will analyse perceptions, motivations and the changeability of behavioural patterns of the actors, in particular users, which are relevant for the successful implementation of technological and organisational innovations in urban transport. The overall aim will be to highlight promising innovation pathways to a more sustainable urban transport system.

This report is deliverable two of the project. It describes technology options and mobility services, which are, or might become, relevant for urban transport systems and, thus, will become relevant to a transition to more sustainable urban transport.

The report also looks at impacts, challenges and visions related to these technologies and concepts. In doing so, it is putting the focus on the supply side of the transport system. Relevant framework conditions, as well as the role of the demand side for sustainable innovations in urban transport, will be discussed in the following phases of the project.

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A number of people have contributed to this interim report. First of all, we would like to thank Mr Malcolm Harbour (MEP, 2nd Vice-Chairman of the STOA Panel), Mrs Siliva-Adrianan Ticau (MEP, Member of STOA Panel and of the Committee on Transport and Tourism) and Mr Brian Simpson (Chair of Committee on Transport and Tourism) very much for their valuable contributions to the project.

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[1] See Halbritter et al. (2008).

1. Introduction

As a result of the economic expansion of modern societies over the past years and the commensurate improvements in general standards of living, there has been a substantial increase in the demand for transport of people and goods. An efficient transport system plays a key role for economic growth and social wealth in modern societies. Moreover, it has become obvious that economic growth and the inherent growth in traffic volume have a trade-off relationship with the efficiency of the transport system. At the same time, the increased amount of traffic has led to a strong reduction in the quality of life because of the associated significant environmental consequences, including emissions of air pollutants and noise, as well as reduced spaces for living and the segregation effects caused by the expanding transport infrastructure. So, paradoxically one of the basic pillars of today's quality of life, at the same time reduces that quality. The driving force for the problems mentioned above is not only the growing amount of the general traffic volume, but especially the rapid growth in motorised traffic. Due to the increasing concentration of the population in cities and their suburbs and the connected process of urbanisation and urban sprawl, urban areas are suffering from the negative consequences of modern mobility patterns. 80% of European citizens live in an urban environment. Urban transport, therefore, accounts for a significant portion of total mobility and for an even greater proportion of its negative environmental and health effects.[2]

A lot of progress has been made in recent decades in European cities. For example, cleaner technologies have been introduced, cycling and walking have been promoted and public transport has become more attractive in many urban areas. In spite of this, however, the problems in European cities have not been solved. Urban mobility is of growing concern to citizens. Nine out of ten EU citizens believe that the traffic situation in their area still should be improved.[3]

A wide range of different technical options for transport are available, especially in urban areas, such as busses, trams, cycling, walking, taxis, private cars or car-sharing systems. They all have specific requirements and implications for infrastructure. It can be observed that these requirements and implications are changing over time, stimulated by technological progress in different areas. It is obvious, for example, that information and communication technologies (ICT) are gaining importance and having growing influence on the design of urban transport systems (public transport priority at intersections, public transport information, mobile phone ticketing, Car2Car communication is discussed, etc.).[4] Another central category of transport technologies comprises fuels and propulsion systems. For several reasons (climate change, peak oil) the need for alternatives to oil-based propulsion in the next decades is being discussed.[5] Consequently, the development of urban transport systems strongly reflects the development of technological progress. The transport systems and their underlying technologies are changing and are changeable.[6]

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[2] See CEC (2006).

[3] CEC (2009).

[4] See STOA (2009)

[5] See STOA (2007).

[6] See STOA (2008).

The crucial challenge is to use technology options as well as organisational innovations in a way that makes the transport system more sustainable. They need to enable efficient, environmental friendly and affordable transport in European agglomerations. It is widely acknowledged that technologies are a necessary condition, but not sufficient in isolation, to facilitate a transition to a more sustainable urban transport system. Not only do technologies have the power to change urban transport, technological change and socioeconomic trends co-evolve and interact. The use of existing and past technologies plays a significant role in the acceptance of new developments, as they are jointly responsible for today's preferences, tastes and lifestyles.[7] To induce a shift towards more sustainable transport, changes in the organisation of transport are needed. In this respect, Kemp states: "technology needs to be incorporated into a larger technical and socio-economic system".[8]

All this implicates that consumer' preferences, tastes and habits need to be considered when aiming to provide alternatives to established transport behaviour. Commensurate with this, it seems obvious that a purely technical approach to change today's travel behaviour is very limited; rather, user-centred approaches are needed, taking human behaviour adequately into account. Both the demand side, represented here by the users and the supply side, with the technological developments and organisational innovations, require consideration if pathways to a more sustainable urban transport system are to be understood. Against this background, the idea of this STOA project on urban transport is to analyse technologies for an innovation-oriented approach. This means looking at the entire urban transport system in its socio-economic context, taking the existing and emerging technologies into account and considering - as far as it is possible - users and stakeholders; their motivations, perceptions and behavioural patterns.

So, the supply side as well as the demand side of the transport systems will be analysed, together with relevant framework conditions. Deliverable two, the document at hand, is the product of phase two of the project. It principally considers the supply side, whereas the demand and the framework conditions will be covered in phases three and four. Deliverable two focuses on technologies and concepts that are already relevant, or are likely to become relevant, for sustainable urban transport in future. The deliverable starts with an analysis of perceived problems with the transport system. It is these challenges and trends that innovative technologies and concepts are expected to find answers for. The analysis highlights impacts of transport on health and the environment, requirements of transport demand and problems related to traffic flow and congestion. Furthermore, it mentions relevant societal trends, such as ageing and urbanisation. Existing and emerging technologies are described in chapter two and three. It is obvious that at least two crucial technological strands can be observed, which are having considerable influence on the transport systems and entail potential for various radical innovations:

1. Alternative fuels and propulsion technologies (Chapter two)
2. Information and communication technologies (Chapter three)

In chapter four it is highlighted that new mobility concepts and business models are emerging which are strongly interwoven with the technical developments described in chapters two and three. These innovative mobility services enhance established options as well as new approaches for transport supply. Chapter five gives an overview of some more visionary approaches that might become relevant in the mid or long-term.

[7] See Kemp, R. (1994).

[8] Kemp, R. (1994).

If the development of technologies and concepts should support sustainable transport, the key question, also for further work in this project, is how this is going to happen. City development plans and urban transport plans can provide interesting indicators regarding which technologies and concepts are expected to contribute to sustainable urban transport systems in the future, and in which way. Therefore, chapter six briefly looks at published documents from a couple of European cities. These analyses will be continued in the following phases of the project. The main intention of the following phases of the project will be to go beyond the supply-side oriented analysis of technologies and concepts provided in the deliverable at hand. The focus will then be on framework conditions, the demand side, the development of mobility patterns and the preferences and attitudes of the users of the transport system.

2. Trends and Challenges in urban transport

Transport is an integral part of our society. People rely on safe and rapid transport on their way to work, to school or to buy their daily purchases. The transport system is linked to a variety of factors, including technology, land-use planning, consumption and the availability of infrastructure. Even though, at least from a global perspective, the European transport system is doing rather well in terms of efficiency and effectiveness; congestion, environmental damages and negative social impacts such as health hazards incur high costs and are increasingly the subject of public concern and policy actions. With regard to environmental impacts of transport, a variety of measures have been implemented and improvements have been achieved. Air quality in European cities has improved, but still more needs to be done. The large proportion of motorised traffic did not change significantly since 1995, which means that transport is heavily dependent on fossil-fuelled modes. In 2007, 72% of all passenger kilometres in the EU-27 (excluding Cyprus and Malta) were still car journeys.[9] However, a number of cities have shown that it is possible to increase the percentage of cycling and walking journeys (e.g. 59% of all trips in Copenhagen are done by cycling or walking).

Evidently, transport is influenced by external trends and challenges, which are responsible for the way the transportation systems are being used and organised. Notwithstanding this, however, the current transportation system itself exerts influence on the environment as well as social and economic development. In the following passage, crucial drivers and challenges will be described.

2.1. Environmental and economic challenges

The growing urgency for the transport sector to mitigate its negative impact on the environment is illustrated by several studies. The International Energy Agency (IEA), for example, states that transport accounts for about 19% of global energy use and for 23% of energy-related carbon dioxide (CO_2) emissions. While CO_2 emissions from oil consumption in most sectors have remained steady in absolute numbers since 1971, those of transport more than doubled in the same period of time. The share of transport in global oil emissions was 59% in 2007, whereas it was 39% in 1971.[10]

Transport correlates closely with economic growth. In order to ameliorate the negative effects of transport without a deceleration of growth rates it is necessary to decouple economic growth from transport demand. This was already a key-objective in the 2001 Commission's White Paper on Transport.[11] However, in some of the EU-15 countries, passenger transport volumes decreased in 2007, including Austria, Belgium, France, the Netherlands, Spain and the United Kingdom.[12] The demand for freight transport on the other hand is still strongly linked to economic growth. In particular, freight transport on roads is projected to further grow heavily in the next decades, especially in central European countries.

[9] See EEA (2010).

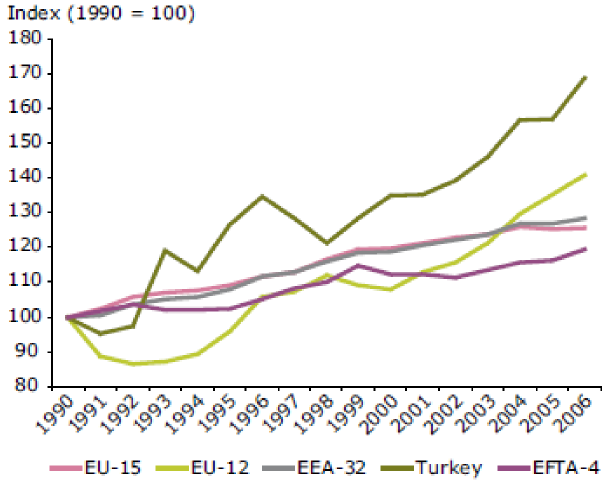
[10] See IEA (2009).

[11] See CEC (2001).

[12] See EEA (2010).

While the transportation sector is achieving fuel efficiency improvements in vehicles and a wide shift to diesel vehicles (due to high fuel prices in Europe), more and more passengers and goods are travelling longer distances. Between 1990 and 2007 in the EU-27, transport related CO_2 emissions rose by 29%, largely dominated by road transport, with 93%. Transport is the only sector in which the negative emission drivers most outgrew the positive emission drivers.[13] The transport-related emission per capita in the EU-27 was 1,941 kg of CO_2 in 2007. Further, demand for transport is likely to increase in the future.[14]

Figure 2-1: Transport sector greenhouse gas emissions 1990 – 2006.



Source: EEA (2009a)

Road transport emits mainly carbon dioxide (CO_2), nitrogen oxides (NOx), carbon monoxide (CO) and non-methane volatile organic compounds (NMVOC). CO_2 emissions, as well as the emissions of the remaining gases, are directly linked to the amount of fuel used, but they are also affected by the way the vehicle is driven (e.g. speed, acceleration and vehicle load), the vehicle type, the fuel used and technology used to control emissions (e.g. catalysts). Urban transport accounts for 40% of CO_2 emissions and 70% of emissions of other pollutants from road transport.[15]

Transport is a crucial economic sector. It provides about 7% of Europe's wealth (in terms of GDP) and accounts for over 5% of total employment in the EU.[16] However, some factors influence these numbers negatively.

2.1.1. Congestion

Congestion is a major challenge in the transport sector. Mostly, congestion occurs along urban ring roads and the Trans-European Transport Network (TEN-T), inducing high costs in terms of time-losses and higher fuel consumption. Nearly 100 billion Euros (1% of the EU's GDP) are lost annually due to congestion.[17] Among non-monetary costs there are stress and health hazards.

[13] See EEA (2009a).

[14] See IEA (2009).

[15] See CEC (2009).

[16] See CEC (2009).

[17] See CEC (2007).

Since most passenger and freight transport starts or ends in urban areas, cities are most affected by the negative impacts of congestion. Traditionally, bottlenecks in transport infrastructure have been tackled by building new roads, which in many cases have induced even more traffic. Moreover, in many urban areas there is no possibility for further expansion, since space and money are scarce. Congestion can be seen as a result of the high car-dependency of urban residents. Not only commuting but also many "non-work activities" of car owning households rely on the car.[18] To offer adequate alternatives is therefore a major challenge for the organisation of transport. Usually, dense inner cities are served quite well by public transport; though a great challenge will be to offer collective transportation coming into urban areas and to provide solution for peri-urban transport to connect directly suburban areas.

2.1.2. Land use

Space is scarce in European cities. There is a paucity of up-to-date and historical land coverage data, which impedes the accurate assessment of land consumption by transport. Despite this, the increasing length of roads, particularly motorways, and the development of other roads, shows that more and more land is being used for transport in the EU. In urban areas, land is under continuous pressure from new transport infrastructure, including parking space, roads and petrol stations etc.

When reducing car-based traffic, released land could be transformed for other use requirements. Cycling paths, for example, only need between a fifth and a tenth of the space needed for motorways.[19] Affected areas would experience an upgrade of urban life quality and thus attract investors to modernise and reuse buildings. In a study of Wilhelmsson (2000), the impact of traffic noise on the value of single-family houses in Sweden has been empirically analysed. He concludes that houses near noisy roads would sell for a discount of 30% compared to houses in quite locations.[20]

2.1.3. Scarcity of fossil fuels

Transport today relies almost entirely on oil (in 2007, 94% of the energy used globally for transport came from oil). Dominated by road transport, the transport sector is the strongest driver of world's dependence on oil.[21] It is widely assumed that oil and fossil fuels are becoming more expensive in the coming decades as low-cost sources dry up.

According to the peak oil theory, the worldwide production of oil will initially increase steadily, and then decline irreversibly as soon as half of the oil has been produced. Peak oil models have the objective to predict the future course of the worldwide oil production, including that of peak oil, at an early time. Those calculations are based on the production up to then and the finding history of the oil fields by adapting type curves. However, peak oil models are not uniform, resulting in different findings, which are usually a result of taking unconventional oil into account. Examples for predicted production courses with peak oil, as shown in Figure 2-2, point at peak oil between 2007 and 2070.[22]

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[18] See Salomon, I. et al (1997).

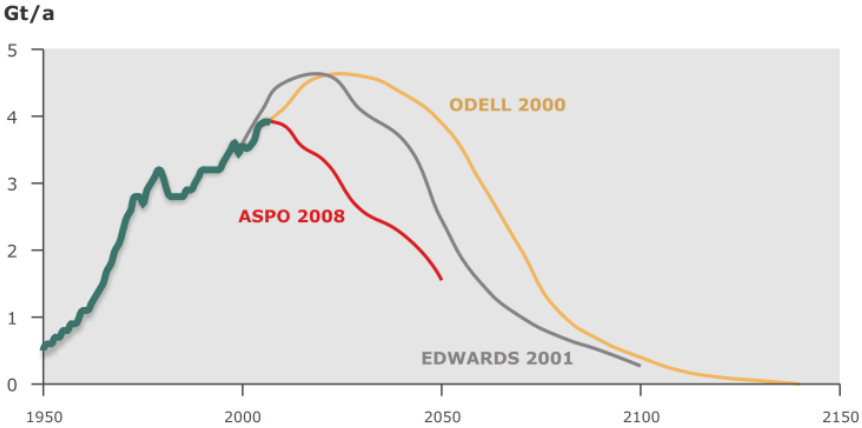
[19] See BMVBW (2002).

[20] See Wilhelmsson, M. (2000).

[21] See IEA (2009).

[22] See Federal Institute for Geosciences and Natural Resources (BGR) (2009).

Figure 2-2: Examples for predicted production courses with peak oil



Source: Federal Institute for Geosciences and Natural Resources *(*BGR) (2009)

The oil catastrophe in the Gulf of Mexico underscores possible negative impacts of drilling in ever-deeper locations. In its Communication "A sustainable future for transport: Towards an integrated, technology-led and user friendly system" the European Commission states that "the shift in relative [oil] prices will make investments in alternative energy sources more attractive [...]. The immediate consequence of such transformation will be the reduction in the need to transport fossil fuels, which currently represent around half of the volume of international shipping."[23]

2.2. Societal challenges and trends

2.2.1. Ageing

The ageing of society is one of the biggest challenges Europe is facing today, since the population is projected to become older in almost all regions in Europe. The imminent retirement of the so-called "baby boom" generation, combined with increased expectancy of life and declining birth rates will transform Europe's demographic patterns. By 2050, the proportion of the population aged over 80 years old is likely to triple from 4% in 2005 to 11% in 2050; the share of persons aged 60 years and older is likely to rise from 22% to 36% in the same period of time.[24] It is more likely that this trend will not result in less demand for transport; instead, older people who used to drive will prefer to continue doing so, as the aforementioned group is what can be called the "car-driver generation" It is assumed that this generation will tend to travel more than their parents did, since they will have improved health, more travelling options and better language skills. In this sense, a challenge will be to bring this generation to sustainable modes of transport. Design and performance of new travel modes and options which enable older people to handle these naturally will be a crucial point in making alternative modes of transport more attractive.

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[23] CEC (2009).

[24] See CEC (2005).

2.2.2. Urbanisation

Around 75% of Europeans live in urban areas. One of the major drivers of urbanisation in Europe is the growth of (smaller) households, due to ageing and individualisation. Since net incomes have increased over recent decades, people have been able to afford larger places in greener environments to live in. Urban areas expanded more and more into suburban areas with low density. But not only private households are moving outside urban areas; investors also tend to prefer Greenfield sites, as extensive land is significantly cheaper and more available in suburbia than in city centres. The realisation of this possibility has been enabled by high rates of car-ownership. Even though people are living outside urban areas, they are maintaining an urban lifestyle, often facilitated by car-based mobility. In the last 30 years the length of motorways has tripled in the European Union, which has substantially enhanced the accessibility and attractiveness of suburban areas. [25] Urban sprawl is one major challenge for urban transport as it leads to larger distances and thus the need for individual transport modes. Moreover, urban sprawl tends to increase costs for public services, such as police, emergency and school buses, as well as water and sewage. Therefore, it is essential to integrate transportation planning and spatial planning. Newly designated areas should be planned in a compact and mixed-use way, giving residents the possibility to live, work and shop within short distances. Access to public transport should be part of planning decisions, in addition to measures to increase cycling and walking.

2.2.3. Ecological awareness

In a study of the European Commission, 27,000 Europeans of the EU-27 were asked about their attitudes toward the environment.[26] 96% answered that environmental protection is very or fairly important to them. When asked who they think is primarily responsible for responding to environmental challenges (individuals or biggest industries), 90% answered that the primary responsibility should be taken by the industry, in parallel 86% agree to play individually an important role in protecting the environment. Further, respondents were presented a list of nine actions and asked which of them they had done in the past month; 28% answered to have chosen an environmentally friendly way of travelling, such as by foot, cycle or public transport. This suggests that between attitude and action there is still a stark difference. Indeed, changing behaviour implies raising consciousness, but social standards (high car ownership and usage) and habits play an important role. Driving a car becomes an unquestioned matter of course.

[25] See EEA (2009b).

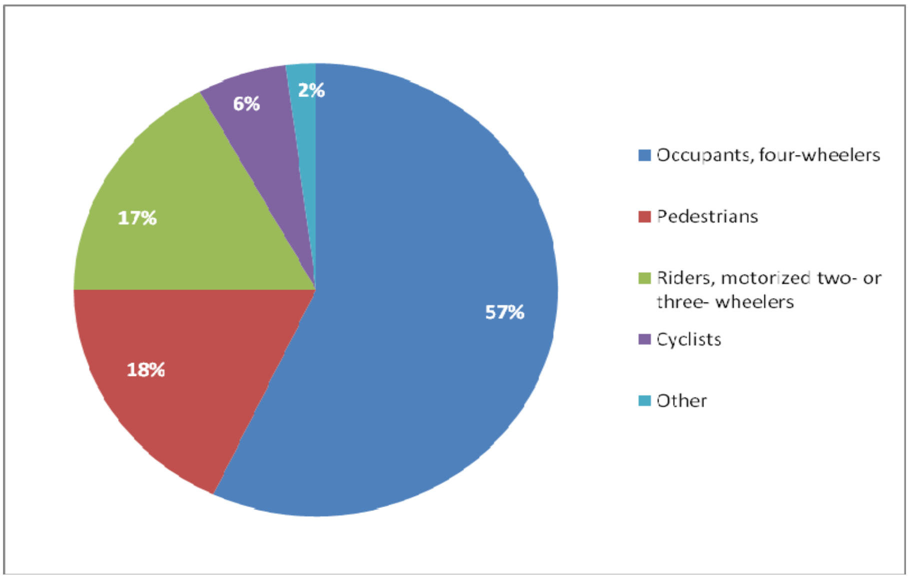
[26] See EC (2008).

2.2.4. Health

Motorised transport has notably adverse health effects, mainly resulting from road traffic crashes, physical inactivity, urban air pollution and noise.

Road transport is one of the most complex and dangerous systems people have to deal with every day. In 2009, 34,500 people were killed in the EU27. Even though numbers are declining, road traffic injuries remain a major public health problem. In the WHO European Regions, road traffic injuries are the major cause of death for five to 29 year olds. For 30 to 44 years old it represents the second most common cause of death. There are regional inequalities, however, with the Nordic countries (Denmark, Finland, Iceland, Norway and Sweden) having lower death rates than the Baltic countries (Estonia, Latvia and Lithuania) and southern Europe. Additionally to fatalities, many people are injured (in the WHO European regions about 20 people are injured per fatality).[27] Little is known about temporary and permanent mental health consequences accompanying those injuries, such as post-traumatic stress disorder. Further, road injuries have a vast cost. The WHO estimates the economic costs of road injuries to range between 0.4% and 3.1% of a country's GDP, being usually higher in countries with higher income.[28] In the EU, the highest proportion of death is among car-drivers. However, vulnerable road users, such as pedestrians, cyclist or riders of two or three-wheelers, are also a great risk (see Figure 2-3). In general, though, cycling and walking become safer when they get more widespread; an increase in active travel can consequently improve safety.[29] Vulnerable road users should therefore be prioritised by limiting speed and volume of traffic in order to organise urban traffic more safely.

Figure 2-3: Distribution of road traffic injury death by road users in the EU.



Source: Author's design based on WHO (2009).

[27] See WHO (2009).

[28] See WHO (2009).

[29] See for example: Woodstock, J. et al (2007); see Jacobsen (2003).

Another serious problem to human health is caused by ground-level urban concentrations of air pollutants, which is mainly a consequence of motorised traffic volumes being greater near major roads. In addition to CO_2, tail pipe emissions such as nitrogen oxide; hydrocarbons, ozone, benzene, lead and particulate matter also present a major health hazard. Children are more vulnerable to air pollutants than adults, because of higher per-minute ventilation and higher levels of physical activity. Tail pipe emissions are seen as responsible for respiratory morbidity, allergic illness and symptoms, cardio-pulmonary mortality, non-allergic respiratory disease and myocardial infarction. There is also a possible relation to lung cancer and an increase in total mortality. Furthermore, childhood cancer is considered by several investigators to be linked to proximity to traffic.[30] In many communities, school buses run on diesel, which is carcinogenic. A study in the United States found that children inside school buses may be exposed four-times more to diesel exhaust compared to someone riding in a car.[31] Similarly, a project of the WHO regional office for Europe (2006), demonstrated that in Leicester UK, exposure to traffic exhausts was four to 10-times higher for children walking or cycling to school than for those being driven by car following the same route.[32] This underscores the need for low pollution cycling routes and for cleaner fuels and propulsion systems in public transport.

Whilst progress has been made concerning several air pollutants in Europe, one of the most striking problems is the emissions of particulate matter. Particulate matter (particles that are less than 10 millionth of a metre), are small enough to get into the lungs. They are particularly emitted by vehicles, especially those with diesel engines as well as by road dust and wear of tyres and are therefore a growing problem in urban areas (though they are also emitted by combustion processes in industrial plants and agriculture). It is estimated that particulate matter levels in cities today lead to hundreds of extra deaths per million inhabitants,[33] as well as to increased admissions to hospital for respiratory and cardio-vascular diseases, increased frequency of respiratory symptoms and use of medication by people with asthma, and reduced lung function.[34] Even though particulate matters have decreased in most EU cities, it has increased in some very polluted cities in Central and Eastern Europe. Moreover, Ozone has been independently associated with impairments of lung function and bronchial reactivity.[35] Adverse effects of climate change on human health, e.g. caused by floods, droughts or heat waves, will become evident within a decade and others will take longer to appear. However, “the levels and composition of pollutants in the air depend not only on the number of vehicles but also on their age, engine type and condition, and the type of fuels used, as well as on meteorology, the shape of the urban environment and the way traffic is organised”.[36]

Transportation is the main source of noise pollution in Europe, and in urban areas the major cause of human exposure to noise is road traffic. Noise pollution causes difficulty to fall asleep, reductions in deep resting sleep, increased awakenings during sleep and thus interfere with mental activities requiring attention, memory and the ability to deal with complex analytical problems.

[30] See Salvi, S. (2007).

[31] See Solomon G. et al (2001).

[32] WHO (2006).

[33] See Fenger, J. (2009).

[34] See WHO (2009).

[35] See WHO (2009).

[36] WHO (2009).

Those adverse affects could be avoided, if noise levels would be lower than 30 dB L continuous noise or 45 dB L indoors.[37] However, 55% of the European population living in agglomerations of more than 250,000 inhabitants are exposed daily to road noise levels exceeding 55 dB L. Moreover, 17% of the population living in agglomerations of more than 250,000 inhabitants live in areas where night-time road noise levels have adverse effects on health.[38]

Over the past century, occupational and domestic physical activity has decreased. At the same time, calorie intake has not decreased; consequently many western countries are increasingly facing obesity-related challenges. Physical inactivity is a major cause for back complaints, cardiovascular diseases and also psychosomatic illnesses. Today, physical inactivity is more prevalent than tobacco smoking. Together, these risks are causing the greatest number of deaths and years of life lost in developed countries.[39] Physical fitness could be promoted through a replacement of short trips by cycling and walking and would enable most car-drivers to achieve some physical activity. Moreover, physical activity supports serenity and thus is a crucial factor for physical and psychological health.

Health also includes wellbeing; to be in a good temper and to have social support. In many situations car driving can cause stress, often induced by congestion, stop-and-go-traffic, confusing construction sites and signage, but also by bad weather conditions or time pressure. To be under stress impairs psychological health, can increase blood pressure and frustration tolerance. This can reduce wellbeing and lead to aggressive behaviour and increase the likelihood of being involved in an accident.[40] Moreover, growth of car use has reduced access for those not being motorised. This is particularly hard for elder or disabled people as well as for children, since they only have limited access to services, employment or social support networks.[41]

2.3. Conclusions

From a global perspective, the urban transport systems in Europe are on a relative high level in terms of accessibility, reliability, safety and environmental impacts. However, the chapter illustrates that considerable challenges remain and new trends might become relevant in future. In addition, the situation differs significantly between different European agglomerations. It is therefore widely acknowledged that action is needed to maintain a functioning transport system in growing as well as in shrinking European agglomerations.

Technological progress effectively has a double role in this context; it can be considered as a cause and as a solution for the challenges. On the one hand, transport technologies enabled the modern mobility patterns, leading to positive but also negative impacts and challenges. On the other hand, technological as well as organisational innovations are considered as being a solution for the challenges and trends described in this chapter. In the next chapters, such innovations will be discussed in more detail.

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[37] See WHO (2000).

[38] See EEA (2009b).

[39] See WHO (2000).

[40] See WHO (2009).

[41] See Woodstock, J. et al (2007).

3. Fuels and propulsion systems

The transport sector, in particular the automobile industry, is currently facing significant changes. Several key drivers for innovations in motorised road transport are mentioned in chapter 2.; amongst them are negative impacts of the car on environment, traffic accidents, economic and social cost of road traffic congestion or the car's current reliance on oil.

A major contributor to both the environmental impacts and the oil dependency of road transport is the conventional internal combustion engine (ICE), which usually burns oil-based fossil fuels (petrol and diesel) to power a car or Lorries. Over the last one hundred years, extensive optimisations of ICE technology have been achieved in terms of emissions and efficiency. New technologies such as cleaner burning processes in engines, catalytic converters or soot filters, direct fuel injection or disconnectable cylinders have been developed and commercialised. At the same time, improvements in the quality of oil-based fuels (unleaded and sulphur-free gasoline) have been realised. Further optimisations include the reductions of vehicle weight and air resistance.

The key driver in accelerating these developments is the fact that emission standards have steadily been tightened over the last two decades. The EU has outlined several guidelines and proposals in order to decrease emissions and reduce fuel consumption. The binding legislation for car manufacturers to reduce the average CO_2 emissions of new cars to 130 grams per kilometre (g/km) by 2012 as a measure to combat climate change, as well as other standards such as EURO norm, make technical improvements and innovations necessary, since new models introduced must meet such standards.

Apart from the possibility to optimise conventional ICE vehicles, two overlapping approaches are emerging to tackle oil dependency, as well as ecological impacts of road transport. This is, on the one hand, the increased usage of alternative fuels and, on the other hand, the development of new propulsion systems.

3.1. Alternative fuels

3.1.1. Biofuels

A wide range of liquid biofuels can be blended with, or used instead of, diesel and petrol. Biofuels are often divided into two main categories: traditional biofuels and second-generation biofuels. Traditional biofuels only use parts of the plant, generally the crop, whereas second generation biofuels are produced by synthesis and use the whole plant.[42]

Traditional biofuels are:

- Biodiesel (made from vegetable oil or animal fat. Typically made by chemically reacting lipids with alcohol);
- Vegetable oil fuel;
- Bioethanol (made from sugar cane, corn or wheat);
- Biogas (which can replace natural gas either in its compressed (CNG) or liquefied (LNG) form)

[42] See STOA (2006).

Second generation biofuels are:

- Bioethanol made from cellulosic feedstock refers to straw, wood, animal and agriculture residues and waste;
- Synthetic biodiesel (so called Biomass to liquid or BTL diesel);
- Biohydrogen (hydrogen produced biologically);
- Gas-to-Liquid (GTL) from natural gas and Coal-to-Liquid (CTL);
- Synthetic natural gas (biogas);
- Ethers (such as ETBE, bio-MTBE);

In 2006, the consumption of biofuels in Europe was around 5.4 million tons, which corresponds to around 2% of road transport in Europe, whereby biodiesel is dominating over ethanol. Around 80% of all biodiesels are produced in the US and Brazil.[43] Rough estimations indicate that, in principle, in 2030 between 20% and 30% of the EU27 road transport fuels could be covered by biofuels derived from European biomass.[44] Compared to other alternative fuels, such as wind or solar power, biogenic fuels have the advantage of being capable of energy storage. Moreover, they can be used in existing ICEs although, in some cases, engines need slight modifications; particularly with a higher blend or the use of pure biofuels. Several car manufacturers are building flexi-fuel vehicles that are able to drive on a mix of petrol and ethanol.

Basically determined by the EU Biofuels Directive 2003/ 30/ EC, biofuels are becoming more widespread, but still on a small-scale basis. In 2008, EU leaders reached an agreement on a new renewable energy directive. This requires all member states to reach the mandatory target of a 10% share of biofuels in transport petrol and diesel consumption by 2020, in order to achieve GHG savings, reduce dependency on oil and thus increase security of supply. The directive includes environmental sustainability criteria, which obliges that, compared to fossil fuels, at least 35% carbon emission savings have to be reached. The criteria include restrictions on the type of land that may be converted.

However, concerns about potential negative impacts of biofuels on global agricultural markets, especially on trade-offs between food and fuels, were growing continuously in the last decade. Furthermore, concerns about unintended consequences of indirect land use change increased because massive deforestation is expected to release carbon emissions. As a consequence, the Commission compiled a report to review the impact of these indirect land use changes. The report concludes that a share of biofuels in transport beyond 5.6% could harm the environment, since land use changes "can rapidly increase and erode the environmental sustainability of biofuels."[45] Further, the report points out that negative the effects of biofuel-policies on food prices will remain limited.

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[43] See Nylund et al (2008).

[44] See STOA (2006).

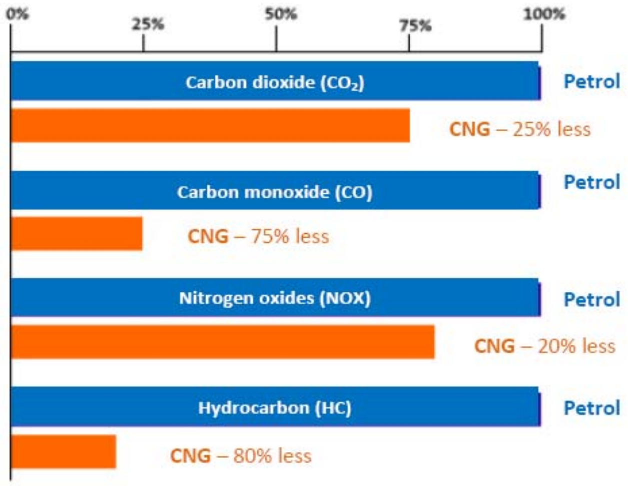
[45] Al-Riffai et al (2010).

3.1.2. Natural Gas (CNG, LNG) and Autogas (LPG)

Natural Gas and Liquefied Petroleum Gas (LPG) are both based on fossil feedstock; Natural Gas can be found in nature, whereas LPG is an artificial by-product, generated automatically from refining processes or during the extraction of natural gas.

- LPG is a mixture of butane, propane and some other gases and is primarily used in Otto engines, but can also be used in diesel engines. Only small modifications of the engine are needed for running a vehicle on LPG. A decisive advantage in terms of feasibility is that it does not need processing; LPG can be compressed to a liquid at very low pressures.
- Natural gas consists of over 80% methane (CH_4) and is characterised by a relatively clean and soot-free combustion. It is typically found beneath oil basins. Compressed natural gas (CNG) has a low volumetric energy density and is stored on-board (200-240 bar) under high pressure. Liquefied natural gas (LNG) is also stored on-board at a pressure of 2-6 bar and at -161 °C. CNG and LNG can both be used in Otto or diesel engines.

Figure 3-1: Comparison of Natural Gas and Petrol vehicles



Source: www.badenova.de

The market share of Natural Gas and LPG is still limited to certain niches and varies significantly by region, which is particularly due to the existence or non-existence of adequate infrastructure; namely filling stations. The environmental benefits decreased since EURO 5 standards came into force. In addition, CNG is a fossil fuel, which makes its role for energy security very limited, since it is not endlessly available. As CNG and LPG are imported on a large-scale basis, an increased use for automotive purposes would at the same time increase imports. Lastly, there are only small improvements in terms of GHG efficiency compared to corresponding gasoline engines (see Figure 3-1); compared to diesel engines there are hardly any. In several countries, however, the market penetration of CNG is pushed by governmental regulations because of its low emissions of particulate matter and NOx. It is an interesting alternative for taxis and public transport fleets in city centres. In cities suffering from heavy air pollution stemming from older diesel engines a change to CNG can improve air quality significantly. In the Indian capital Delhi, for example, taxis are mainly running on CNG.

3.1.3. Hydrogen and fuel cells

Hydrogen (H_2) is the world's most abundant element, though it does not exist as gas in a natural form. Therefore, it has to be produced in an energy-intensive process. Hydrogen can principally be produced from nearly all energy sources, which offers the potential for reducing dependence on imported energy. Additionally, it is an environmentally clean technology in itself. But which energy source has been used for the production process is crucial for determining the CO_2 balance. The most common method to produce hydrogen today is to employ steam to separate it from carbon found in petroleum and natural gas.

The fact that hydrogen is low in volume energy density presents significant challenges for a cost effective and environmentally friendly transport, delivery and storage of hydrogen. It may be centrally produced and then delivered to end-use destinations or at decentralised locations close to the point of usage. Currently, hydrogen is delivered via pipelines or by road, which causes considerable demands for tanks and material. Consequently, costs are higher compared to conventional fuels. Breakthroughs in material science are therefore necessary to lower the cost of transport, especially over longer distances.

Hydrogen may be used in combination with fuel cells or can be burned directly in slightly modified Otto engines. The exhaust is, in both cases, pure water and there is no need for a fuel processor. Compared to direct combustion of hydrogen in traditional ICEs, fuel cells are significantly more energy efficient. Fuel cells convert chemical energy directly into electrical energy without combustion. A fuel cell functions similarly to ordinary batteries, having an anode and a cathode, although they do not store energy (and do not need to be recharged). The hydrogen is fed into the anode and oxygen is fed into the cathode. An electrolyte, the substance between the positive and the negative pole, serves as a bridge for ion exchange. Different types of fuel cells exist, they differ in terms of size, temperature and fuel source at which they operate and pressure at which the gases/ fuels are supplied to the cell. For the transport sector, mainly Polymer Electrolyte Membrane (PEM) Fuel Cells are used.[46]

However, fuel cells are still cost intensive and as such not competitive with conventional technologies. Moreover the durability needs to be improved, to be in the same range as current automotive engines. Up until now there is no adequate infrastructure for production, supply and storage of hydrogen. Currently there are around 80 hydrogen filling stations operating for end users in Europe.[47] Further, there is only limited on-board hydrogen storage density and no global standardisation of rules and regulation. Apart from these disadvantages, there are essential advantages compared to conventional ICEs. Fuel cells have a relatively high electrical efficiency, they do not entail tailpipe emissions and they have an uncomplicated mechanical system, which makes the fuel cell relatively noiseless.[48]

Several car manufactures are working on prototypes for fuel cell cars. A few years ago, many observers considered the combination of hydrogen and fuel cell technology as a highly promising future alternative to conventional ICE technology[49].

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[46] See STOA (2006).

[47] See LBS information portal for hydrogen filling stations (n.s.).

[48] See STOA (2006).

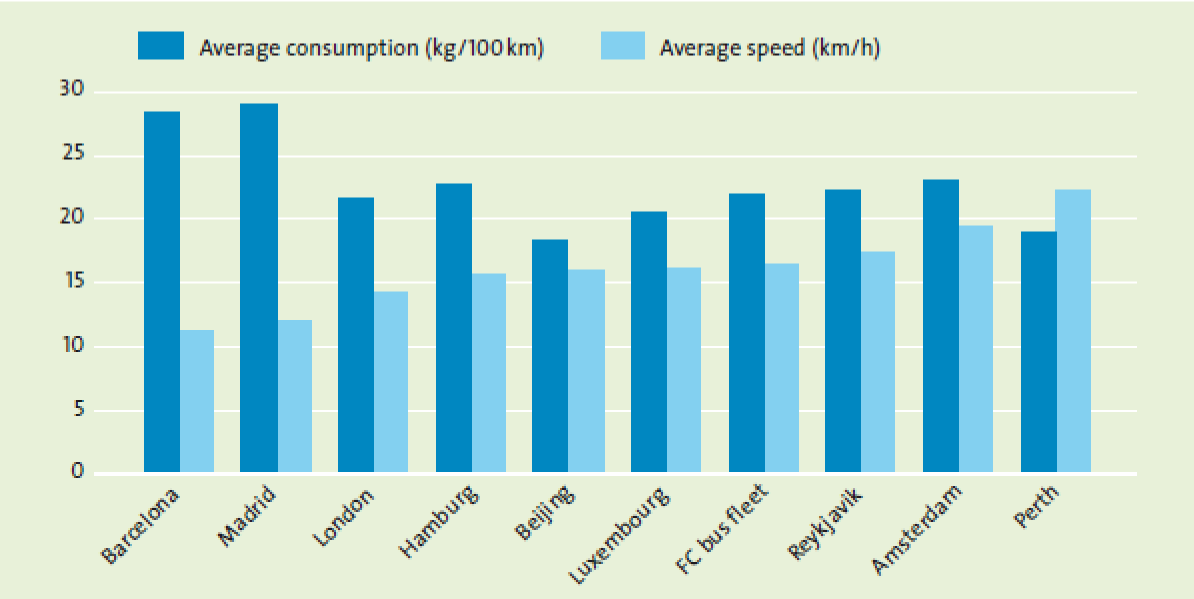
[49] See STOA (2006).

In the meantime, induced by progress in battery technology, the chance for purely electric vehicles is assessed as much more positive by many observers. As a consequence, the very positive attitude towards hydrogen as a possible fuel of the future has changed. However, many car manufactures are still working on hydrogen and fuel cell-driven vehicles. For example, Daimler expects a commercialisation of fuel cell cars in the next year.[50]

Hydrogen Buses

The introduction of hydrogen-powered buses is taking place in selected demonstration sites worldwide. Due to support of the European Commission and its hydrogen bus demonstration projects CUTE and HyFLEET:CUTE the development of hydrogen in public transport in Europe has made major advances in proving the reliability of fuel cell technology. HyFLEET:CUTE (2006-2009) was co-funded by the European Commission and 31 industry partners. The project has involved 47 hydrogen-powered buses (33 fuel cell buses and 14 ICE buses) as regular public transport in ten cities on three continents.[51] All buses accumulated 2.5 million kilometres and carried more than 8.5 million passengers. The average daily operation was seven hours. Since the design of the buses was optimised for achieving a high degree of reliability, energy-efficiency was not a primary goal. Nevertheless, the average fuel consumption of 21.9 kg of hydrogen per 100 kilometres driven was lower than expected (see Figure 3-2).

Figure 3-2: Average speed and fuel consumption of fuel cell buses in selected demonstration sites



Source: HyFLEET:CUTE (2009)

[50]See Daimler (2010)

[51] Europe: Amsterdam, Barcelona, Berlin, Hamburg, London, Luxembourg, Madrid, and Reykjavik. China: Beijing. Australia: Perth.

In future, prototypes will further be tested in order to improve the overall system. To bring the technology to commercialisation it is planned to operate a small fleet in several European cities. Nonetheless, for a wider market penetration the total cost of ownership has to be reduced. Further, users' perceptions should be taken into account in order to establish hydrogen technology and for marketing purposes. In 2006 a survey was conducted, indicating that user perceptions in relation to hydrogen buses are very positive.[52]

3.2. Electric Vehicles

Electric vehicles (EVs) are widely considered as being locally emission free, relatively energy efficient and noiseless. However, electric vehicles in road transport are still a niche product and they have not been tested on a large-scale basis. It is therefore controversially discussed under which circumstances and to what extent positive impacts on environment and society will occur. Further it is important to clarify which parameters have an influence on a wider roll-out of electric vehicles; there are still many technical barriers to overcome but also users' perceptions and other socioeconomic parameters need to be examined.

Different technical approaches for the integration of the electric engine into the fuel-propulsion system do exist. In this report, the following terminology is used:

Hybrid electric vehicle (HEV) represents the first technological milestone for electric powertrains. It offers the possibility to save energy and emissions by using established technologies and infrastructures. HEVs incorporate both an electric and a combustion engine and are designed to operate in charge-sustaining mode, in which the battery is discharged by only several percent. Electric machines are used to provide power to the wheels and to charge battery packs.

Plug-In hybrid electric vehicle (PHEV) is a new generation of HEVs and refers to vehicles that can use conventional fuel or electricity, both rechargeable from external sources. For recharging the battery, the car simply is plugged into a normal power grid. PHEVs either operate by depleting or sustaining the battery. In case that the battery is exhausted, vehicles use the ICE for driving.

HEVs and PHEVs can either be designed as series-hybrids, parallel-hybrids or as combined series/parallel-hybrids:[53]

- In a *series-hybrid*, only the electric motor provides power to the wheels. Energy comes either from the battery pack or a generator powered by a thermal engine (ICE).
- In a *parallel-hybrid* an electric motor and a thermal engine can both provide power to the wheels.
- In a *series/parallel-hybrid* the advantages of the aforementioned systems are combined. This allows the car to use the electric motor only, or both the ICE and the electric motor together.

[52] See HyFLEET:CUTE (2009).

[53] See Nemry, F. et al (2009).

It is conceivable that battery-powered vehicles will be equipped with a range extender to overcome the limited range and performance of EVs. The range extender could be a small conventional ICE that is producing electrical power or fuel cells powered by hydrogen, since they produce electrical power as well. It is worth considering the possibility of having a modular and hence flexible range extender, which can be carried and used in the car only when needed. When only short distances are travelled the extender could be left at home.

Battery electric vehicle (BEV) refers to vehicles drivable solely through electric motors, without the need for an internal combustion engine. However, the disadvantage of most BEV is that their driving range is limited to about 200 km[54] between charges and thus still far more limited compared to that of a HEV or PHEV.[55]

Even though many car manufacturers today are involved in research and development of EVs, individual electric mobility is still a niche product on the European market. And indeed, many companies around the world have recently announced plans to launch vehicles, which drive electrically (at least in part) in the near and mid-term future. Currently, however, not a single BEV is commercially mass produced and marketed; only a few HEVs are built in series, although none of them are from a European car manufacturer. Nobody knows exactly how long it will take until BEVs will dominate the market. Toyota expects a time span of about 20 years[56], which most car manufacturers will probably agree with.

Most EU member states and Europe's' leading car manufacturers have already launched pilots, setting up incentives or formulating objectives to target a broader market share. Moreover, energy and environment agencies are involved in promoting electric mobility, while research institutes and universities are continually examining EVs. Apart from well-known car manufacturers, new players are entering the market; among these are automobile subcontractors, battery manufacturers and energy suppliers. All aim to enhance a wider commercialisation of EVs in order to benefit their business.

3.2.1. Environmental impact

The potential to reduce the environmental impact of motorised transport is one of the main arguments in favour of supporting the introduction of EVs. The general assumption that electric vehicles are totally emission free refers to the fact that no CO_2 is emitted at the vehicle's tail pipe. Regarding the entire life cycle of a car, encompassing its production, including the operation phase and the disposal, it becomes obvious that environmental impacts depend on several factors. How much emissions an EV produces depends strongly on the way the energy is generated, for example it makes a huge difference if the electric energy used for operation is generated in an older coal fired plant or in a modern wind turbine.[57]

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[54] Mitsubishi's iMIEV for example has a range of 130 km, whereas the high-prized Tesla Roadster can travel around 400 km.

[55] See BCG (2010).

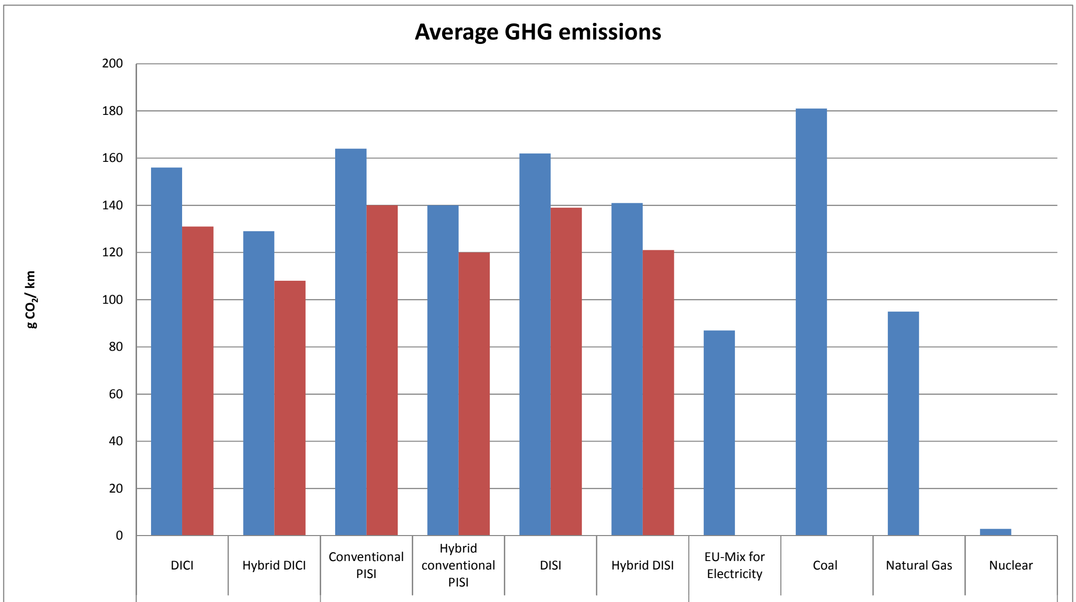
[56] See Toyota Motor Corporation (2008).

[57] See Blesl, M. et al (2009)

However, the assumption that electric vehicles produce less CO_2 than conventional ICE vehicles is controversially discussed. Opinions differ on how large the potential for “clean driving” actually is. The University of Stuttgart for example argues that already today electric vehicles produce less CO_2 emissions than comparable vehicles with a conventional Otto engine. The study comprises a “Well-to-Tank”- (emissions in fuel production and processing) as well as a “Tank-to-Wheel”-analysis (emissions in fuel consumption).[58] This view is challenged by others, who contend that reductions are insignificant as long as the electricity is produced from carbon-intensive fuels. A study of VCÖ states that additional demand for electricity would only reduce CO_2 emissions in Austria by a small margin if power were generated by coal, whereas 100% “green” electricity would reduce emissions significantly.[59] Pehnt et al. (2007) argue for Germany that using e-Mobility based on the recent energy mix is not an aggravation in terms of GHG emissions. But using electricity brings the advantage that various renewable energy sources can be used in the transport sector. However, the authors also point at the difficulties in providing accurate calculations for the GHG-balance of electric vehicles.

Figure 3-3 shows current CO_2 emissions of different propulsion systems (for compact-class vehicles). The model used for comparing was developed by Concawe, Eucar and the Joint Research Centre (JCR) and is based on the “Well-to-Wheels” Report version 2.[60] The red bar indicates the CO_2 emissions of the vehicle tank to the wheel (tank-to-wheel); the blue bar indicates the result of the complete chain, respectively from well to the powered wheel (well-to-wheel). The expected greenhouse gas emissions for Diesel engine vehicles, Otto engine vehicles and Li-Ion full electric vehicles are as follows:

Figure 3-3: Average CO2 emissions of different types of cars



	DICI	Hybrid DICI	Conventional PISI	Hybrid conventional PISI	DISI	Hybrid DISI	EU-Mix for Electricity	Coal	Natural Gas	Nuclear
	Diesel-Motor		Otto-Motor				Electric vehicle Li-Ion Battery			
Complete chain	156	129	164	140	162	141	87	181	95	2,9
Vehicle only	131	108	140	120	139	121	0	0	0	0

Source: Author’s calculation by OPTIRESOURCE tool, based on the “Well-to-Wheels Analysis of future automotive fuels and powertrains in the European context, version 2a” (2005). The term “Vehicle only” covers the tank-to-wheel analysis; the “Complete Chain” covers the well-to-wheel analysis.

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[58] See Blesl, M. et al (2009).

[59] See VCÖ (2009).

[60] The OPTIRESOURCE simulation tool, based on the “Well-to-Wheels” Analysis 2002 is available at: http://www.daimler.com/dccom/0-5-920736-1-932626-1-0-0-925197-0-0-8-876574-0-0-0-0-0-0-0.html

According to the calculations illustrated in figure 2-2, CO_2 savings are only to be realised when electricity is provided by low-emission power plants. Electric vehicles powered by electricity from coal would even exceed emissions of a conventional PISI gasoline vehicle.

In March 2007, European leaders signed the binding target that the EU will reach a 20% share of energy from renewable sources by 2020 and a 10% share of renewable energy specifically in the transport sector. The directive requires each member state to increase its share of renewable energy by 5.5% from 2005 levels. A study by PricewaterhouseCoopers of 507 car drivers between 18 and 70 years old in Germany showed that 80% of the respondents could imagine buying an electric vehicle, if electricity for the car would be from renewable sources.[61]

Many experts argue that BEVs might support the integration of renewable but fluctuating energy sources, mainly wind and photovoltaic, into the system of power supply – into a so called smart power grid. Most EVs are expected to be recharged during night and the fact that wind power can be highly variable at different times (high performance during night), could lead to a better balance of supply and demand of (green) electricity. It could help to provide a new demand for electricity, most likely at parts of the day when demand is usually low. The vision is that a vehicle capable of “vehicle-to-grid” (V2G) interaction is able to temporarily store excess output of wind turbines and to communicate between the electricity grid and the vehicle to sell excess electricity to the grid when the demand and prices are higher. This allows V2G vehicle owners to earn money by selling power to the grid. Three elements are needed to operate as a V2G vehicle: it needs a power connection to the grid, a communication device which allows grid operators to have access to the battery and precision metering on board to track energy flows.[62] However, the automobile industry points out that such a concept still has considerable technological hurdles to overcome before it is ready for its breakthrough. Batteries are not ready yet to sustain additional charge and recharge cycles. On top of that, a critical mass of EV market penetration is needed to make decentralised storing of extra electricity worthwhile.[63] Further, it is unclear if there are enough incentives (earned money) for the users to integrate their battery into the system of energy supply.

3.2.2. Influencing parameters

A study of Deutsche Bank FITT Research from November 2009 estimates that by 2020 the global market penetration of hybrid, plug-in-hybrid and electric vehicles could reach about 17%.[64] Roland Berger Strategy Consultants goes even further, estimating that in 2020 approximately 9% to 12% of global market share will be electric vehicles without plug-in functionality and, additionally, 15% to 17% will be plug-in hybrids and another 5% will be BEVs.[65] Indeed, several factors indicate that the automotive market could change rapidly towards a wide diffusion of electric-powered vehicles:

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[61] See PwC (2010).

[62] See Sovacool, B.K. et al (2009).

[63] See PricewaterhoseCoopers (2010).

[64] See Deutsche Bank FITT Research (2009).

[65] See Roland Berger Strategy Consultants (2009a).

- There is active government support for vehicle electrification in nearly all major European countries and beyond, mostly in the form of financial incentives. These can either be subsidies in the form of tax reductions for the purchase of electric vehicles up to full tax exemption or grants for buying electric-powered vehicles. Yet other governments give a tax reduction for investments in electric charging facilities outside a private person's home or on a company compound. Moreover, pilot projects have been set up to test the interplay of car manufacturers, electricity providers, consumers and the authorities. Consequently, many governments have set themselves targets in the timeframe 2020 to have a certain percentage of electric vehicles on the roads by then.[66]
- China is becoming the biggest sales market for automobiles worldwide. At the same time the country is ambitious in becoming market leader in electric vehicles since it aims for cleaner urban agglomerations, at a reduced oil dependency and, last but not least, with a better position on the international car markets. The Chinese government massively supports the development of advanced materials and production technologies;[67] against this background it is more likely that customers in China will adopt electric vehicles.
- Several new players entering the market, which often bring along significant competitive advantages. This could either be their low-cost structure (e.g. BYD, Tata) or their relatively long experience with electric cars (e.g. Th!nk, Tesla). These new ventures challenge established manufacturers, as they have the ability to apply an ecological approach in their business model and are able to focus on alternative drive technologies.[68]
- Although the battery is still the most expensive component in an electric vehicle, it is more likely that costs will decline. High costs are not only due to materials used, but also due to capital investment in battery manufacturing, which depends mainly on production volume, on economy of scales, and less on the material itself. Once batteries are a mass product, costs are more likely to decline.[69] Moreover, there are increasingly research efforts that explore new electrochemical mechanisms. Patent fillings in the field of energy storage increased 17% per year since 1999 up to 2008; in Japan, China, USA and Western Europe 62% of these patent fillings comprised lithium-ion technologies.[70]
- Changes in customers' perceptions and preferences can be observed; there is increased societal concern regarding environmental risks. The average engine size of new-sold cars fell from 1,740cc in 2008 to 1,706cc in 2009. Moreover, the market penetration rate of small vehicles was the highest ever.[71] Research carried out by Roland Berger Strategy Consultants has shown that 68% of car buyers are interested in alternative drive technologies.[72]

[66] See ACEA (2010).

[67] See Roland Berger Strategy Consultant (2009b).

[68] See Roland Berger Strategy Consultant (2009a).

[69] See Cheah, L. et al. (2010).

[70] See BCG (2010).

[71] See ACEA (2009).

[72] See Roland Berger Strategy Consultants (2009a).

- New business models appear to change the way consumers handle mobility. On the one hand, there are business models such as car-sharing (see chapter 5.2.2) and similar offers of established car manufacturers, testing approaches for selling mobility services instead of just a car (e.g. Mu by Peugeot, chapter 5.1.3). On the other hand, there are new players entering the market, giving their products a completely different setting. Such models are structured to accelerate the penetration of BEVs by offering customers attractive prices for the initial purchase (e.g. Better Place, see chapter 5.2.1).

However, in spite of this rather positive expectation, there are still considerable technical and economical hurdles that need to be overcome, before the projected market penetrations of electric vehicles will be realised.

Technical barriers

Batteries used for HEVs, PHEVs and BEVs (and generally most portable electronic devices) are, to date, primarily Lithium-Ion batteries (Li-Ion batteries). The advantages of Li-Ion batteries are that they are small in weight and high in energy density. To produce these batteries, the metal lithium is needed. Up until now a replacement of lithium seems very unlikely.[73] Most car manufacturers expect Li-Ion batteries to have a life span of ten years at 3,000 charge/ discharge cycles for HEVs and 2,500 for EVs.[74] Some manufacturers design extra margin in batteries, which in turn influences battery size, weight and cost. However, lithium is only available in limited amounts; values for lithium reserves differ significantly between four and 30 million tons, though more recent data tend to show higher numbers of lithium resources.[75] About 70% of worldwide lithium is found in South America, in the triangle between Chile, Argentina and Bolivia. It is said that Bolivia accounts for 50% of the worldwide Lithium metal reserves (around 5.4 million tons), which are currently still unexploited.[76] It is been expected that large-scale battery recycling will be developed in order to ameliorate possible shortages. It needs to be discussed, however, whether electrifying mobility just means to run from oil dependency into the dependency on other scarce raw materials.

Another technical challenge and crucial commercial barrier is the long charging time. The majority of BEVs already on the market or those close to market introduction are smaller vehicles with a capacity of 15 to 30kWh. The specific energy requirement for small cars is about 9 to 15 kWh/ 100 km.[77] An available standard wall socket usually allows a maximum output of 3,6 kW. Consequently, to recharge a 30-kWh battery will take up to around eight and a half hours, so for a 15 kWh battery charging time is around three to four hours. On average, BEVs which have been introduced to the market today can drive around 200 km until they need to be recharged again (see chapter 3.2). Against this background, charging at home during the night seems to be more than sufficient for the majority of journeys made in one day. However, rapid charging is much more comfortable and in line with customers habits. Several scientists are working on possibilities for reducing charging time.

[73] See Weil, M. et al.

[74] See BCG (2010).

[75] See Weil, M. et al (2009).

[76] See Tahil, W. (2006).

[77] See Brauner, G. (2008)

However, vehicles capable of being recharged rapidly need two separate charging outlets and enhanced cooling systems on board the vehicle, which means additional cost and weight. Moreover the effects of rapid charging for the battery and the electricity grid still remain unknown.[78]

Electric vehicles need, in the same way as conventional cars, a supportive infrastructure. Refuelling habits of electric vehicle users will have to adapt to the new conditions. While refuelling conventional cars is done every two to three weeks, primarily determined by tank capacity, recharging EVs will be determined by the available infrastructure. It is expected that, in a first step, charging stations will be predominantly domestic, because charging times are still very long, making overnight charging an equitable solution. As it can be expected that battery research will continue to improve (in the past, energy density of batteries increased by 5%/ year on average)[79], it is not unlikely that recharging times will be reduced and longer distances will become available. In a second step, charging infrastructure will be extended beyond domestic settings.[80] Nonetheless, charging stations will probably be concentrated at certain main points, such as workplaces, public transport nodes or car parks. As a next step, it is conceivable that a dense network of charging stations along high frequented highways will be set up, in order to allow purely electric overland journeys.[81] A complete charging system should offer several devices for recharging batteries in different manners, in order to serve different user needs. Further different algorithms are needed for different types of batteries as well as for batteries of the same type, but of different depth of depletion.[82] Battery switch stations are another possibility to provide a full charge in less than three minutes (see Chapter 5.2).

Despite those technical barriers, EVs are already an attractive opportunity for certain niches, such as car-sharing and business fleets as well as for delivery and taxi fleets. However, besides technical barriers, there are many important social and cultural factors and business practices, which influence a large roll out of electric vehicles. The potential for a breakthrough of electric cars depends heavily on customers' perceptions and values.

[78] See Hatton C.E. et al (2009).

[79] Estrin, D. et al (2002).

[80] See Hatton, C.E. et al (2009).

[81] See VCÖ (2009).

[82] See Hatton, C.E. et al (2009).

Box 3-1: Historical Review

In September 1990, California launched the "Low Emission and Clean Fuel Programme", which required car manufacturers to have an electric vehicle sales quota of 2% by fleet by 1998, 5% by 2001 and 10% by 2003. Any manufacturer who did not fulfil the quota would be fined $5,000 for each vehicle falling short of the quota. One year later, further nine states decided to adopt the programme.

As a result, engineers of General Motors (GM) created a sleek car that operated entirely on battery power – the "IMPACT". GM started a huge marketing campaign by placing advertisements in local newspapers, inviting interested individuals for a test drive. Close to half a million applied. From the responses several hundreds were selected in each city, those who were seen as "car nuts". The marketing campaign sparked enthusiasm for the electric car, many of the test-drivers wanted to buy one. The fact that it was non-polluting had a unique appearance as well as the status-conferring advantage of driving an innovative car were strong consumer draws. [83] A lesson learned from the campaign was that IMPACT was an inappropriate name for the car, so it was renamed the "EV-1". In response to GMs work on the EV-1 vehicle also in Europe first pilot projects were launched. Especially France, Germany and Switzerland followed up; for example, on the German island of Rügen, 60 EVs of different manufacturers were tested.[84]

However, the American Automobile Manufacturers Association (AAMA) put up resistance against the programme and as a consequence the electric vehicle programme was postponed in 1996, even though the programme originated the first successful prototypes, such as General Motors EV-1. Consumers' and manufacturers' interest in electric vehicles faded until 2000, when several manufacturers began marketing HEVs.

The efforts were bound to fail as they "relied exclusively on technological improvement [...] and have not favoured the application of land-use planning, demand travel management and fuel tax policies as means to reduce automobile emissions."[85] Though, in no country or region have electric cars ever reached the critical mass. Main reasons for failure were, from a users' point of view, the limited range of the cars and elaborate battery management as well as poor quality and density of service.[86] This implies that common incentives and strategies are not sufficient to serve users' wishes. Strategies are needed, which compensate adequately existing technical barriers to today's electric cars. The exemplary following measures could be implemented: strategic promotion of promising business models, restrictions to specific areas for ICE vehicles, priority handling of EVs, and promotion of alternative modes of transport in order to reduce dependency on cars etc.

[83] See Rogers, E. (2003).

[84] See PwC (2010).

[85] Calef, R. et al (2007).

[86] See Knie, A. et al (1999).

Social and cultural factors

Several studies emphasise that high costs compared to conventional ICE vehicles are the most relevant obstacles for consumers to buy an EV. PricewaterhouseCoopers, for example, found out that 89% out of 500 respondents would only buy an EV if purchase prices decrease.[87] In a similar way Potoglou et al. (2007) state that individuals "consider cost and performance characteristics of vehicles as important".[88]

A study by Turrentine et al (2007) contradicts this opinion. In a research on how US consumers think about fuel economy, almost two-thirds of the respondents answered that "fuel saving is not part of the vehicle purchase decision-making".[89] Even though these statements were made before the increase in oil prizes in 2008, the study implies that the economic factor might not be the only crucial factor for purchasing decisions. According to the following cost-benefit calculation (see Table 3-1) modern Petrol or Diesel vehicles (Blue Motion Series of VW) amortise within 5.6 years, whereas the new Toyota Auris, as an example of a hybrid car, reaches its pay-back after seven years. Since the average car in Europe is 8.2 years old,[90] it would still be an economic reason to buy a HEV.

Table 3-1: Cost-benefit calculation of modern ICE cars compared to a Hybrid car

	VW Golf	VW Golf	VW Golf	VW Golf	Toyota Auris
Model	Trendline 1.2 TSI (105 PS); 5 Door	BlueMotion 1.6 TDI (105 PS); 5 Door	BlueMotion 1.6 TDI (105 PS) 5 Door	Trendline 1.6 TDI (105 PS); 5 Door	Hybrid Synergy Drive (99 PS), 5 Door
Fuel	Petrol	Petrol	Diesel	Diesel	Hybrid
Price	€17,800	€22,200	€22,825	€21,800	€22,950
Fuel consumption *(combined)*	6.4 l/ 100 km	5.2 l/ 100 km	3.8l/100 km	4.5 l/ 100 km	3.8 l/ 100 km
Additional price *(compared to VW Golf Petrol)*	-	€4,200	€5.025	€4.000	€5.150
Amortisation after	-	12.3 years	5.6 years	5.6 years	7 years

Source: Author's calculation based on recommended retail prices (by German manufacturers) and petrol price of €1.42 and diesel price of €1.22 (according to Europe's Energy Portal: Fuel prices in Germany in 05/2010). Calculation based on assumed annual mileage of 20,000 km.

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[87] See PwC (2010).

[88] Potoglou, D. et al (2007).

[89] Turrentine, T. et al (2007).

[90] See ACEA (2008).

Moreover, even in the last years, despite a phase of a general downturn in the automobile industry, sales for HEVs remained strong. Sales figures for the Toyota full hybrid Prius have doubled to the 200,000 mark within two years (between 2008 and 2010).[91] Globally, Toyota has sold two million hybrids by August 2009, accelerating their sales performance spectacularly.

Figure 3-4: Toyota Global Hybrid Sales

Source: http://www.hybridsynergydrive.com/en/sales.html

Consequently there must also be other reasons for individuals, in addition to so-called "rational" ones, to buy an HEV. It is widely acknowledged that automobiles symbolise more than only mobility; for many people they express an idea of self-identity. Through their car, people communicate what interests, beliefs, values and social status they have, in other words, who they are. Labelling owners of an EV simply as environmentalists and technology enthusiasts would "oversimplify the factors involved in their buying decisions".[92] In a study of Heffner et al (2007), different motivations for purchasing a HEV were analysed. Intentions such as preserving the environment, opposing war, managing personal finances, or reducing support for oil producers as well as embracing new technologies were the superficial reasons, and as those widely recognised. But the underlying – and maybe unconscious - motivations linked to these intentions are of different nature. By revealing these attitudes towards a product, HEVs become a product of distinction. They were bought to communicate that they are (for example) mature and sensible persons, that they have strong ethical principles, such as caring for others or that they are aware and more intelligent than others. Further, the study emphasises that sending an effective message to car manufacturers was another strong argument for owners to buy a HEV. Individuality was also a particularly strong argument for young owners.

In this sense, an interactive Stated Preference analysis,[93] conducted by Sammer, G. et al showed that information visualisation, public relations and marketing have a significant impact on willingness to buy and use electric cars.[94]

[91] See Toyota Motor Corporation (2010).

[92] Heffner, R. et al (2007).

[93] Stated Preference method has become an important research tool within the field of transportation. Stated Preference methods are used to evaluate measures not yet implemented.

[94] See Sammer, G. et al (2008).

Nevertheless, promoting EVs solely as novel and revolutionary might involve the risk of deterring those who do not want to make a statement and thus will impede the chance to win a wide market share.[95] However, a sort of peer group might be reached by such activities. Consumer preferences are one of the most significant obstacles to achieve a wide market penetration of electric vehicles. If consumers keep asking for luxurious and heavy cars, industry will more likely attend to these desires. More recently, Europeans tend to purchase smaller vehicles, which is at least partly due to rising fuel prices and the difficult economic situation.

The decision to buy an electric vehicle evidently depends on different sets of variables. The first set of variables is certainly driven by technical factors, such as extension range, power or driving performance. The second set depends on subjective experiences and habits, as well as on customers' specific life situation. Further crucial factors are service density, reliability, purchase and maintenance costs, road safety, availability and design.

Consequently, a holistic strategy is needed to promote electric mobility that takes economic and technological factors into account, but also comprises a political strategy that considers the social aspects of electric mobility (see therefore a short view into the historic political strategy of California in Box 3-1)

3.2.3. The relevance of Business Models

Business models describe how a firm organises itself to create and distribute value in a profitable manner. Chesbrough (2010) states that: "the economic value of a technology remains latent until it is commercialised in some way via a business model [...]."[96] Further he concludes that: "Unless a suitable model is found, these technologies will yield less value to the firm than they otherwise might – and if others, outside the firm, uncover a business model more suited for a given technology, they may realise far more value from it than the firm that originally discovered the technology." [97]

It was illustrated above that many activities related to electric mobility, as well as to other alternative propulsion systems, have so far been focused on the advancement of technology and less on the demand side, on mobility patterns or the users' wishes and perceptions. There are several examples indicating that innovative business models have the potential to better bring together the technological settings of electric vehicles and demand structures on the user side. We will only briefly touch upon this issue here and have more detailed look on business models in an additional chapter (see chapter 5.2).

Since the battery is the most crucial part of the electric vehicle, quite a few business models aim to overcome the restrictions of high cost and the limited range of the battery. A prominent example that is trying to overcome some of the technical and economic hurdles for electric mobility is Better Place (see chapter 5.2.1). The company's idea is that the battery remains the property of the company, while people buy only the electric car. By setting up a dense network of battery switch stations and charging spots the company wants to optimise the usage of BEVs. Another interesting option to promote electric mobility is car-sharing. Car-sharing is a model of car rental where people rent cars for short periods of time, often by the hour (see chapter 5.2.2).

[95] See Sovacool, B. et al (2009).

[96] Chesbrough (2010).

[97] Chesbrough (2010).

More recently, schemes have been established, where users can drop off the car wherever they like. If travelling for longer distances it might be possible to change the vehicle on midway to a fully charged vehicle. Paris is starting the first of such initiatives with electric vehicles.

3.2.4. Alternative modes of electric transport

Ongoing debates about electric vehicles create the impression that electric powertrains are a new phenomenon. Electric vehicles are new, in sense of mass implementation of electrified individual transport, but not for collective modes of transport. Electrification is most advanced in public transport. Metro trains, trams and trolley buses are well proven and widespread, and electrified two-wheelers are also becoming increasingly popular.

Public transport

Rail-based public transport, like trams, metros or suburban trains are running since decades on electric powertrains. Railroad systems have the advantage of combining high capacity with little personal resources, the ability for energy recuperation and a high level of automation. They do need relatively high investment costs and long and complex planning and decision processes, while long implementation times disturb urban life. However, in many European countries a revival of the tram can be observed. For example, nearly all larger cities in France have recently (re-) implemented tram systems. This development was seen as exemplary, with many, mostly South European cities, following.

Picture 3-1: Strasbourg tramway (right) and Lyon trolley bus (left)

Sources: www.strasbourg-tramway.fr/ www.trolleymotion.com

The same advantages can be realised by trolley buses, which also run on electric powertrains. In recent years the number of trolley buses has continued to increase. Around 350 cities worldwide have more than 40,000 trolleybuses in use. Between 2000 and 2008 5,300 new buses were ordered or put into operation. In several European cities trolley buses have revitalised formerly shut down systems (e.g. Rome) or are developing Bus Rapid Transport (BRT) systems (e.g. Castellón, Spain or Lyon, France) with trolley buses. In total, 156 European cities are having at least one operating trolley bus, most of them in Switzerland.

The electric propulsion system is especially advantageous in cities with steep topography. To avoid obstacles, the buses are additionally equipped with a diesel engine or a battery-supplied engine. Purchase prices of trolley buses are higher than conventional diesel buses, though they do have a longer durability.[98]

Light electric vehicles

Light electric vehicles (LEV) are two or three wheel vehicles with a battery or fuel cell, or are hybrid-powered and usually weigh less than 100 kg. Electric bicycles (e-bikes or pedelecs) are the most common LEVs and a promising solution for individual urban mobility. In 2009, one in seven bicycles sold were battery-assisted. An e-bike is a bicycle with an electric motor, the battery is usually detachable in order to be able to recharge at home. A pedelec is a bicycle, which requires the user to pedal in order to activate electrical assistance. Steep topographies can easily be tackled or luggage be transported. The range of a Li-ion pedelec is about 30 to 70 km.

China is indisputably the dominant market for electric bicycles; more than 90% of the world's e-bikes are sold there, though it is expected that they will plateau at around 22 million units in 2010. Sales in Europe will grow by 33% in 2010 from 750,000 units to one million units per year. The Netherlands and Germany account for almost 50% of all EU sales in 2009.[99]

A further prominent example of a Light Electric Vehicle is the "Segway Personal Transporter", a two-wheeled, self-balancing electric vehicle, which was unveiled to the public in 2001 for the first time. The high-tech scooter is extremely manoeuvrable, as it can turn on the spot.[100] By leaning forward the scooter moves forward, by leaning backwards, the scooter moves backwards. A handlebar or steer is used to move left or right. Maximum speed of a Segway is 20km/h and it has a range of 38 km (related to weight of the driver, topography, surface, as well as wind and tyre pressure). Up until now, Segways are only being used in niche markets, such as for guided city tours or as transportation for police.[101]

Particularly for commuter travel there is a large potential for LEVs in Europe, since electric bicycles or even Segways provide for short distance journeys an attractive alternative to the car. Moreover, it is conceivable that electric bicycles are being used in a fleet, which operate in designated geographical locations, e.g. postal services, nursing services, delivery services as well as bicycle tour operators or fleets of public authorities.

3.3. Conclusions

Whatever fuel and propulsion technology will be dominant in 20-30 years, it seems to be likely that hybrid technology will be part of the propulsion system. The potential of hybrid systems can be best tapped in urban areas because the driving cycle is characterised by many stop and go situations. Today, HEVs are sold primarily in the U.S. and Japan, since in Europe HEVs have to compete with the diesel engine. As "hybridisation" implies an "electrification" of the drive train technology, it thus supports a more dominant role of the electric engine in general. But, as analysis clearly shows, GHG reductions are only possible if additional electricity is generated by renewable sources.

[98] See VCÖ (2009).

[99] See Extraenergy (2010).

[100] See Segway.inc (2010).

[101] See Fischer, G. (2008).

Generally it needs to be discussed, whether vehicles with alternative fuels of propulsion technologies should simply substitute existing ICE vehicles, or whether alternative usage concepts should be promoted. Application concepts adjusted to the propulsion system seem promising in this context. Young urban dwellers are increasingly multimodal and used to handle different mobility concepts, such as car sharing or e-ticketing;[102] this development could stimulate the adoption of concepts such as Project Better Place or Autolíb. A wide diffusion of electric mobility could, on the other hand, cut off these tendencies.

However, some urgent problems related to individual motorisation are still not going to be solved, even though a wide market penetration of EVs and alternative fuels would be tangible. Since road is the biggest land consumer in the EU, the spatial impact of transport infrastructure would not be solved by simply switching from ICE vehicles to electric vehicles or vehicles with alternative fuels, nor would it be an adequate measure to target congestion. The advantage of EVs having comparatively low noise emissions could have the unintended effect that it could endanger sight-impaired and distracted passengers. Though, most car-based noise in urban areas is caused by glide- and roll speed and less from the engine itself.

[102] See PwC (2010).

4. Information and Communication Technologies (ICT)

Information and communication technologies (ICT) are a heterogeneous set of technologies that allow electronic communication and exchange of information, data collection and processing in distributed networks. ICT infrastructure, namely the network that connects electronic devices, such as phones and computers, to the Internet and each other is growing rapidly. In this sense, the sector of information and communication technologies has become of utmost importance for future design of transport systems. ICT is a crucial enabling technology in nearly all areas of daily life and it also affects urban transport in many respects. Already today, modern transport systems are based on sophisticated ICT solutions, and a wide range of new applications is emerging.

Many experts point to the great potential of ICT applications for supporting sustainable urban transport. A better organisation and management of the transport system is supposed to lead to improved traffic flows, less congestion, more efficiency through better load factors and the use of less energy consuming modes of transport.[103] The relevant IT applications are usually subsumed under the terms "Telematics" or "Intelligent Transport Systems" (ITS). ICT concepts are often related to control and guidance, road pricing, parking, assistance, freight and fleet control and management.[104] A central aspect of ICT concerns a better supply of information to both the private and the commercial users of transport services. ICT applications collect, create and supply real time data to the users; individual travellers as well as freight distributers. Due to user-friendly interfaces, better information on travel options, possible delays or congested networks ICT applications help to better plan and execute a trip in an effective and comfortable way. Offering personalised information may help to reduce waiting times and encourage multimodality, reduce travel time and develop more advanced applications for reservation services. At the same time data can be used for establishing policies that have influence on the way transport is organised.[105]

Since the 1980's, fundamental developments in ICT have had a remarkable impact on the way transportation is organised. At EU-level, however, adoption has been relatively slow and in an uncoordinated manner. Therefore, an action plan at EU-level has been developed in order to provide a pan-European coordination framework, which will facilitate geographical continuity, interoperability of services and standardisations. The action plan aims to mobilise industry, EU Member states, infrastructure and service providers and other stakeholders. Priority is given to the use of road and traffic data and to improving road traffic management on European transport corridors and in cities.[106]

However, nearly all transportation modes have applied ICT solutions; highly important technical systems are:

- Global System for Mobile Communications (GSM) and other relevant technologies for mobile communications and positioning;
- Broadband communications;
- Internet services for handheld devices;
- General Packet Radio Services (GPRS);
- Radio Frequency Identification (RFID) and Near Field Communication (NFC);
- Global Positioning Satellite technologies.

[103] See CEC (2001), CEC (2006); Hummels (2006).

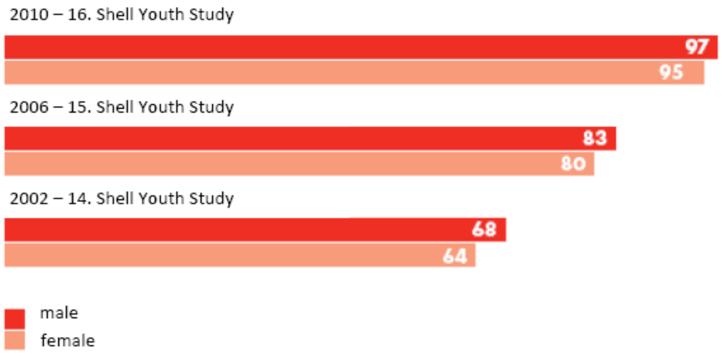
[104] See Erdmann et al. (2004).

[105] See Giannopoulos, G. (2004).

This list of technologies is definitely not exhausted, but is of particular relevance to this paper. As emphasised, computers, satellites and sensors are playing an increasingly important role for the whole transport system. Of particular importance is the upcoming European Global Positioning Satellite system “Galileo”. Satellite navigation technology allows any person with a receiver to determine their position precisely by picking up signals emitted by several satellites. This is especially interesting for motorists using it for private purposes as well as for companies using it for managing their vehicle fleets. The Galileo system is meant to ensure Europe’s competitiveness in a global market in satellite navigation products and services. Currently this technology is dominated by the US and Russia,[107] both financed and controlled by the military. Galileo is planned to be interoperable with the existing global satellite navigation system GPS but will, however, be under civilian control and will provide a high level of accuracy, integrity and authentication of signals.[108] Galileo will be launched by approximately 2013. In the context of urban transport, satellite navigation systems are not only used for navigation of private cars, but also for tracing and tracking of shared vehicles, such as bicycles or cars (see chapter 5.1), for fleet management or for monitoring the road network as well as for tolling purposes.

Other important initiatives to create new options for the transport sector are related to innovative internet services that provide individuals with various types of information, according to their specific preferences (e.g. speed vs. environmental compatibility). For example, personalised information is available for travel time, weather or multimodal route planning. Real-time information can make public transport more attractive and enable car drivers to avoid congestion. Internet services can minimise the need to travel, as things can be done online. The number of individuals using the Internet regularly has been constantly growing; in 2009 60% of the Europeans in the EU27 used the Internet at least regularly.[109] According to Shell, in Germany more than 95% of the 12-15 year old teenagers have access to the Internet. It can be expected that the generations growing up now will be familiar with the Internet; it is not unlikely that they will be used to being online almost permanently. This would, on the one hand, mean that they would have access to transport-related information any time and everywhere. On the other hand, that they would have fully internalised the habit to use this information, to contact friends, colleagues and services (maybe doctors), as well as to sell and purchase commodities.

Figure 4-1: Internet access in Germany – youths between 12 – 25 years (in %).



Source: 16. Shell Jugendstudie (2010).

[106] See CEC (2008).

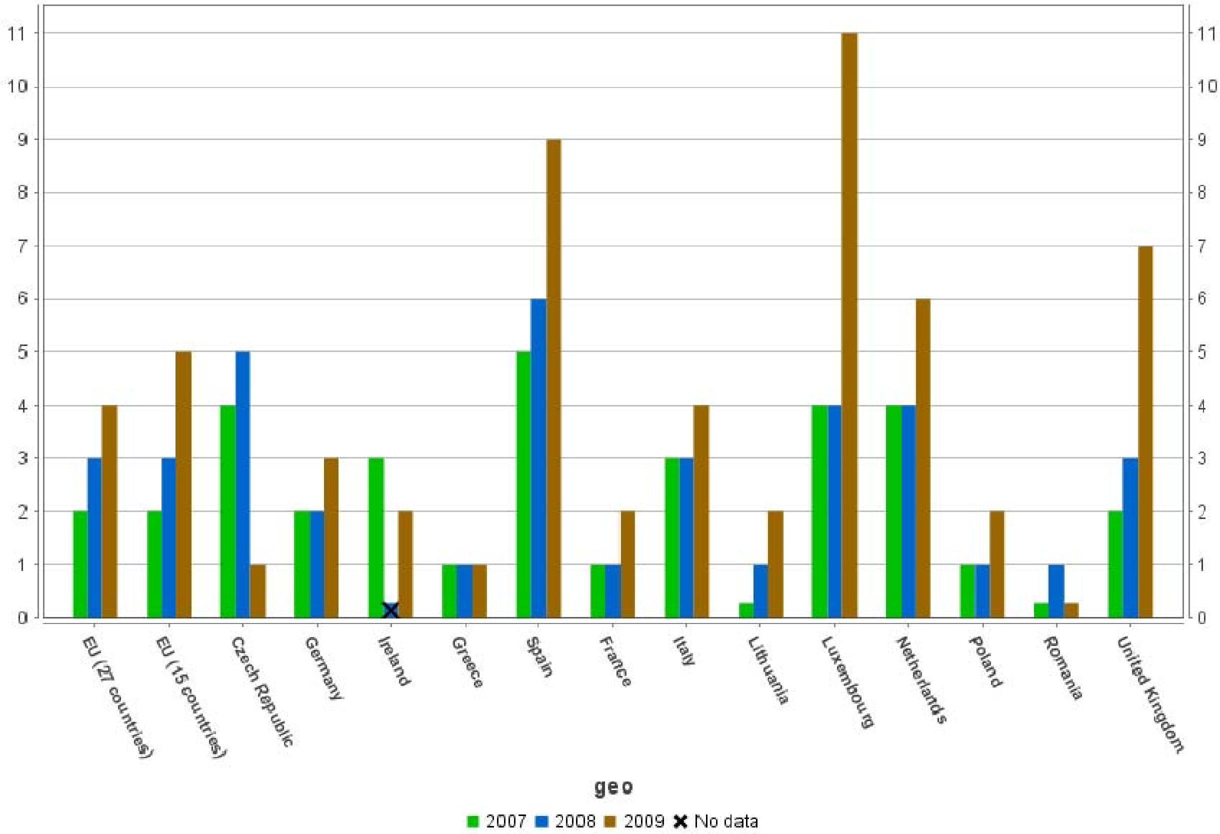
[107] United States with its Global Positioning System (GPS) and Russia with its GLONASS.

[108] See STOA (2006).

[109] See Eurostat (2009a).

Furthermore, the use of so-called Smart phones is of special interest. A Smart phone offers more advanced computing ability and connectivity than conventional mobile phones. Smart phones run complete operating system software to provide a platform for application developers, thus allowing transport operators to extend their service to mobile devices. In this, handheld devices are converted to vending machines and service counters. Most of these phones are able to run specific applications, which are installed by the users and their particular needs. Users of Apple's iPod for example can choose from a range of applications in 20 categories, including "business", "going out" and "travel". In less than 18 months, three billion applications have been downloaded worldwide,[110] within three days more than 1.7 million of the new iPhone 4 have been sold.[111] In other words, smart phones have found their way into daily use. Globally, as well as within the EU27, internet access via mobile phones is increasing, though with huge regional differences (see Figure 4-2).

Figure 4-2: Individuals using a mobile phone to access the Internet.
(Percentage of individuals in selected European countries)



Source: Eurostat (2009b)

Further developments include technical concepts to substitute contact-based technologies, such as magnetic-stripe cards, by contactless technologies in order to alleviate multimodal transportation for individuals as well as for freight transport. Promising technology in this field is Radio Frequency Identification (RFID) or Near-Field-Communication (NFC). The function of RFID systems is primarily the same that barcodes perform today: to store and provide information or data about products.

[110] See Apple (2010a)

[111] See Apple (2010b)

They are, however, far superior to barcodes, as they can also process data or communicate with other RFID tags and are thereby compatible with existing contactless infrastructure.[112] RFID systems consist of a reader that can wirelessly read and write data, in real-time, to a RFID tag using radio waves. Real-time indication of processes and flow of goods is fundamental for freight transport and a basis for process improvement.[113] A move towards embedding RFID technology into a mobile device is NFC, which is a composite technology of RFID and contactless infrastructure. NFC technology comprises two elements; a tag inside a mobile phone, which can store data and transmit it wirelessly, and a reader, which can access the data stored on the tags. An NFC chip can either be attached to the hardware shell of a mobile device or can be integrated to the SIM card of a mobile phone. As such it is of relevance for use and payment of diverse modes of transport using only one device.

In the following chapters, a variety of applications for the transport sector will be introduced; their applications are clustered by their field of implementation, namely private car transport, public transport and freight transport.

4.1. ICT for Car Transport

Road traffic management systems to better control traffic flows have been operating for many decades. They have emerged from individual single control systems to highly integrated network systems. Usually implemented to improve road safety, further motivations, such as efficiency or environmental objectives, have followed. [114] Nowadays, innovative ICT applications focus on a better organisation of transport by steering traffic flows, and optimise the use of infrastructure capacities.[115] The underlying idea is that the availability of real-time information for users through a variety of mediums, such as navigation systems, internet or mobile phones, helps to avoid congestion and to improve traffic flows. For example, real-time information about full or free parking facilities can help to reduce travel time, and thus emissions; knowledge about accidents allows urgent aid and data on construction sites can divert traffic flows. ICT applications do not only target increased efficiency but are also seen as a means for reducing traffic volumes by avoiding trips.

Intelligent cooperative systems enable vehicles to communicate wirelessly with one another (vehicle-to-vehicle communication - V2V) or with roadside infrastructure (V2I). It is seen as the next crucial step in automotive electronics and an important component of the envisioned Intelligent Transport Systems (ITS).[116] Cooperative Systems enable the driver of one vehicle to communicate with other drivers (or their vehicles) even if they are out of sight. It is expected that the gathered qualitative and quantitative real-time data can be used to improve traffic management and road safety.[117] For example, it would be possible to send warnings on environmental hazards (e.g. aquaplaning on the asphalt), traffic and road conditions (e.g. congestion, accidents, construction sites), and it might even be possible to book a parking lot in advance, as well as to receive information on local points of interest.[118]

[112] See International Organization for Standardization (2004).

[113] See Baranek et al. (2010).

[114] See Giannopoulos, G. (2004).

[115] See Rothengatter (2008).

[116] See Kompfner et al. (2008).

[117] See Luo, J. et al. (2004).

[118] See Papadimitratos et al. (2008).

Also in this area, the potential benefits and effects on the transport system are difficult to predict. Whilst Polis[119] comes to the conclusion that benefits will only be vital when enough vehicles are equipped with on-board devices[120], Kompfner et al. state that even "an equipment rate of only 20% could lead to fewer traffic jams on selected highways [...]".[121] Indeed, for full market penetration there are still some barriers to overcome. For instance, it is fundamental for local authorities to clear legal and liability issues, such as questions about responsibilities in case something happens. Another barrier relates to data privacy, as transfer of data is a security, as well as a user acceptance, issue.

Virtual mobility

The substitution of transport by virtual mobility is made possible due to various opportunities for e-activities. Key words in this context are e-working or e-commuting, video conferences, e-commerce or e-learning, but also e-medicine, e-banking and e-entertainment. Each case has potential to replace travel demand by handling tasks online. E-commerce, for example, is experiencing robust growth in the EU27; in 2009 37% of Europeans made a purchase online, whereas 26% did so in 2006.[122] It is expected that in 2013 nearly half of all Europeans will make use of e-commerce.[123] The advantage of e-commerce on transportation derives from the fact that delivery of goods directly from the warehouse is more efficient than having everyone using their own cars (given that deliveries are not done by plane). A study in the city of Stockholm extrapolated that an increase of online shopping to 50% of daily household goods could reduce emissions by 34%.[124] Besides e-commerce, e-commuting is probably the most investigated ICT application in terms of substitution of transport. WWF (2008) provided an overview of existing research in this field and comes to the conclusion that e-commuting "can potentially enable millions of tons in GHG emissions reductions."[125]

Figure -4-3: Emissions reductions by telecommuting (only direct emissions considered).

	2005 emissions LDV MtCO2e	2030 baseline emissions LDV MtCO2e	% emissions from commuting	% of commuting emissions saved by individual telecommuters	Telecommuting take up			Emission reductions from telecommuting MtC02		
					low	medium	high	low	medium	High
OECD North America	1,282	1,623	30%	75%	5%	10%	30%	18	37	110
OECD Europe	516	535	30%	75%	5%	10%	30%	6	12	36
OECD Pacific	219	219	30%	75%	5%	10%	30%	2.5	5	15

Source: WWF (2008)

[119] Polis is the European cities and regions network for innovative transport solutions.

[120] See Polis Position Paper (2010).

[121] Kompfner et al. (2008).

[122] See Eurostat (2009c).

[123] See Staunton, C. (2008).

[124] See Persson et al. (2000).

[125] WWF (2008).

However, several authors cite a number of rebound effects that may reduce the advantages of virtual mobility. According to Banister et al (2004), ICT applications do not necessarily reduce passenger transport in general, as it is still possible that additional trips will be made instead. Liberated roads may invite other road users to do supplementary trips or former work related journeys might be substituted by leisure activities with even longer distances. A simulation study by Hilty et al. to analyse the overall impact of ICT applications on passenger transport concludes that an increase of 50% - 80% between 2000 and 2020 due to ICT applications is possible, though private car transport will decrease. [126] This implies that ICT applications would stimulate public transport use. In fact, there are several unexploited ICT applications, which have the aim to tap unused potential.

4.2. ICT for Public Transport

The less people need to be concerned about how to use public transport, the more attractive it is actually seen. Customers want to be mobile without putting too much effort in finding out about ways, tariffs or timetables, but they desire flexibility.[127] The user needs information but does not want too much; thus, individualised information would be a real benefit. The car and new media (such as mobile phones and internet) have set the standard very high. Numerous different measures have been implemented in the past regarding customer information, integration of the various modes of public transport in order to offer a seamless journey, electronic payment or more flexible demand/supply coordination. All of these measures rely on the use of information and communication technologies. Especially young and random users expect the use of technology as a standard and experience innovation as a value in itself.[128] A first and important step was the availability of real-time information on time schedules, as well as individualised online route planning. A further approach was the possibility to print online tickets, which made the purchase easy, flexible and more individual. Meanwhile, information on time schedules is constantly available via mobile phones and mobile ticketing solutions have been implemented in many places. Mobile ticketing is an approach where customers obtain, buy and validate tickets from any location and at any time using their own mobile phone. However, the fact that customers still needed certain knowledge of valid fare systems to actually choose the right ticket was an unsolved disadvantage that mobile ticketing had to overcome. In other words, mobile ticketing did not provide the greatest possible support to ticket selection. New upcoming solutions of location-based ticketing indeed offer the possibility to buy a ticket via a mobile phone, without knowledge of valid fare systems.

E-ticketing is not a new phenomenon; for the airline industry it is has been the standard for a couple of years. In 2004, only 20% of all airline tickets were electronic and even though there was uncertainty about the return on investment and scepticism about customer acceptance, the entire industry had moved to 100% electronic ticketing by 2008.[129] At present, an increasing amount of public transport agencies invest effort in developing new solutions for e-ticketing for their industry.

[126] See Hilty, L. et al. (2006).

[127] See Maertins et al. (2008).

[128] See Maertins et al. (2008).

[129] See IATA (2010).

Public transport has a different initial position to the airline industry; customers hop on and hop off whenever they need or want to do so, some people use public transport regularly and some only once in a while. Additionally, customers do not stop at borders or at tariff areas and some use several modes of transport during the same trip. Different tariff structures are therefore appropriate, but at the same time face the risk of being confusing.

The central element of the upcoming e-ticketing solution is a check-in/check-out process, whereby customers begin their trip by using a mobile phone, irrespective if one or several means of transportation are being used. Once a customer enters a bus, tram or train, he/she either uses a mobile phone or a smart card to check-in. As soon as the destination is reached he/she checks-out again (either through a phone call, or by holding a RFID smart card or NFC device against a reader). In doing so, the customer is located at origin, destination and during the trip at defined time intervals. [130] The reconstructed route is then the basis for pricing and thus a pre-selection of tickets is not applicable anymore. Once a month, customers are charged, covering all journeys undertaken. By knowing the exact route, best-price calculation is possible and it is assured that customers will always pay the best price. For example, if the fare depends on the degree of use, and public transport is used several times within a month, he/she will be charged a monthly ticket as long as it is cheaper than several one-way tickets. Travelling by public transport is then supposed to be as easy as using a mobile phone and potentially lessens the barriers to using public transport, especially for occasional users. Moreover, additional services such as information on time schedules or the integration of various modes of transport (such as car-sharing, bike-sharing or rail) can be included in the system, offering customers a wide variety of mobility services. The fact that customers are being located throughout their entire journey and that this data is being stored in order to fulfil the pricing, does raise some concerns about data privacy. A study by Maertins et al. about user acceptance of e-ticketing in Berlin found that customers do feel uneasy about the location procedure, but generally trust in the adherence of high data and safety standards.[131]

4.3. ICT for Freight transport

Efficient logistics are based on communication, organisation and co-ordination; ICT clearly is of utmost importance for such activities. Consequently, freight transport might be the area in which the impact of ICT on transport is the greatest. The developments of ICT for the freight transport industry are indeed closely related to the enormous shift in commercial and industrial practices. Production, processing and warehousing, as well as consumer behaviour, have adapted to the new technologies, in order to reduce and control costs and to plan efficiently and in a timely, reliable fashion. It also enables rapid reaction to new customer requests.[132] The key effects of ICT in freight transport consist of obtaining, processing and distributing information for a more efficient use of the existing transportation system, infrastructure and services. This is achieved either by simplifying freight management at the institutional level, or at the carrier level.

[130] See Böhm, (2008).

[131] See Maertins et al. (2008).

[132] See Banister, D. et al. (2004).

To enhance management at the institutional level, electronic vehicle and cargo identification, location and tracking is needed, which relies heavily on cargo positioning systems such as GPS or RFID. The aim of simplifying management at the carrier level in turn has the goal of controlling and coordinating operations in real-time to secure more timely and efficient allocation, for which accurate positioning devices, in-vehicle computing and communication equipment is needed.[133] In the following examples the “SmartTruck” and the “Cargohopper” are identified as innovative approaches in this field.

DHL, a division of Deutsche Post AG, is one of the largest freight forwarders in the European overland transportation business.[134] In March 2009, DHL launched a three-month pilot project in Berlin, Germany, to reduce transport capacity per kilometre and simultaneously increase the capacity load of trucks, as well as to enable rapid and reliable delivery of parcels. For the first time, advanced technology was combined with dynamic route planning. The “SmartTruck” uses RFID tags and readers to permanently screen the loading condition of the truck and to check whether the right parcels are on board. Additionally, the truck is equipped with an on-board intelligent route planning system, based on satellite-supported geo and telematic data that, turn-by-turn, sends the optimal route to the driver. The route changes dynamically according to current traffic conditions. This information, in turn, is based on the input from GPS signals of 500 taxis in Berlin and sent to DHL automatically and in real-time.[135] According to DHL, the project exceeded all expectations; the SmartTruck could significantly reduce driven kilometres, time and distances between two stops, as well as increase the number of stops per hour. The business will now be extended to other cities.[136]

The fundamental idea of a city distribution centre is to not consider every delivery, company or vehicle in isolation, but to understand it as an integrated logistic system, which can be optimised through coordination and consolidation. A City Distribution Centre is a facility, where shipments are consolidated prior to distribution and then preloaded to city freighters for allocation. Electronic Data Interchange, GPS and RFID technologies are playing a significant role in this context, as goods from several forwarders need to be consolidated and re-consolidated, when reaching their destination.[137] City freighters, which do the actual allocation in the inner city, can be relatively small with a great manoeuvrability to travel along narrow streets. The “Cargohopper” in Utrecht, Netherlands for example runs completely on solar energy and is able to tow 3 metric tons in a linear procession. The Cargohopper is able to do the work of five to eight regular (European sized) vans.[138]

[133] See Crainic, T.G. et al. (2009).

[134] See Deutsche Post AG (2010)

[135] See Deutsche Post AG (2009a).

[136] See Deutsche Post AG (2009b).

[137] See Craini, T.G. et al (2009).

[138] See Lintmeijer, F. (2010).

Picture 4-1: Cargohopper Utrecht

See: Transport Online (2009)

As transport is becoming faster, more flexible and cheaper, potential rebound-effects of improved efficiency have to be taken into account. Therefore, it may be that increasing capacities leads to an increase in demand. Hilty et al. come to the conclusion that ICT is highly relevant but not necessarily enough for organising freight transport more sustainably; it needs to be combined with other measures.[139]

4.4. Conclusions

ICT is becoming a ubiquitous technology, with the potential for penetrating and interlinking nearly all areas of daily life. Most applications are enabling in character; supporting co-ordination and providing information. In contrast to alternative fuels and propulsion technologies, the application of ICT is not, in most cases, “clean” or “sustainable” in itself, but it enables changes in behaviour and logistics that contribute to a more sustainable, cleaner and/or, efficient transport system. Some of the applications even have the potential to substitute transport by, for example, video conferences or teleworking. However, it is not clear to what extent positive effects are balanced by rebound effects in the form of additional traffic that might be induced by the new technologies or attracted by the freed capacity in the network. The next chapter of this report, which considers mobility service business models, and is thus strongly related to behavioural changes, underpins the importance of ICT application for approaches and concepts supporting a transition to a more sustainable transport system. It appears to be clear that, in future, ICT applications and in particular the Internet, will have considerable effects on the transport system, but it is not easy to predict exactly how these effects will look.

The chapter illustrates that many rather new application and concepts are emerging in this field. On the other hand, many applications do exist that are already discussed or have been available for several years but not fully applied or not fully used yet. These include real-time information in public transport and dynamic speed control highways. Although technology exists to organise urban freight transport more efficiently, it is not yet integrated enough to offer a seamless multimodal transport chain.

[139] See Hilty et al. (2006).

Uncoordinated transport operations and the fact that there are still many empty return runs are clear evidence of the existing inefficiencies.[140] In an ITS action plan, the EU Commission states that ITS solutions in road transport are being taken up more slowly than expected. Furthermore, services are deployed in a fragmented basis in Europe. Against this background, a need for action at the European level was identified. Some issues need to be addressed from a European perspective to avoid the emergence of a patchwork of ITS applications and services: geographical continuity, interoperability of services and systems and standardisation. They should facilitate pan-European applications, secure, accurate and reliable real-time data and an adequate coverage of all travelling modes. The action plan identifies the need to create adequate framework conditions to accelerate and coordinate the deployment of ITS. The description of technologies in this chapter as well as the ICT action plan emphasise that ICT is a highly relevant enabling technology. To ensure significant contribution to sustainable urban transport, however, it needs to be combined with other policy measures.

[140] See Giannopoulos, G.A. (2006).

5. Mobility services

The previous chapters illustrated that a wide range of different means of transport exist in European countries that can be used in specific situations and for different purposes. In many cases, different modes of transport are usable in combination, which is termed multimodality (when different modes are used during one week) or intermodality (when different modes are used during one trip).[141]

Amongst these different means of transport it is possible to distinguish at least between the following two categories: individual and collective modes of transport. To date, these two systems are, in general, operated separately with little integration. The difference lies predominantly in the logic of use and accessibility. Individual mobility offers the possibility to decide spontaneously where to go, when to go and – when travelling by car - what to carry. Moreover, car-based transport is supported by advanced technique-infrastructure systems and by inter-organisational relationships covering different actors or institutions. For example, cross-links exist between automobile companies and the oil industry; between garages, insurance and leasing companies and between transport departments and infrastructure services.[142] Thus, car mobility is embedded into a coherent and stable system, which is responsible for the fact that users have high demands on how transport has to be organised and what it has to offer. Conversely, public transport is regulated by timetables, fares and predetermined routes. Hence, many users consider public transport as being less flexible; consequently multimodal/ intermodal transport behaviour lacks in attractiveness.

Car usage is coined by habitualised behavioural patterns and is embedded in social and cultural systems, which support a high convenience of car transport.[143] Creating conditions that make alternatives to car usage more attractive can influence this. To facilitate access to, and changes between different modes is necessary to integrate distinctive modes of transport into one complementary system. Therefore, the supply side needs to invest effort into the integration of different infrastructures, as well as developing integrative organisational standards and marketing strategies.[144] For the demand side, it can be expected that preferences and acceptance of new modes and barriers regarding products and services vary, as user groups are different. Alternatives to car transport in urban areas need innovative and service oriented concepts for existing and upcoming transportation modes. Such visions must be successful in meeting users' preferences and must support new customers in using different means.

To offer a broad range of transport modes and to foster intermodal/ multimodal behaviour, it is fundamental to maximise mobility options and to facilitate access to public transport. For doing so, mobility services, as they are described in this chapter, are an important means. Attractive services and concepts, which are flexible, convenient and viable for the user, are able to make urban transport more sustainable. Those services could include all kinds of offers, which aim to fulfil customer needs by selling the utilisation of a product, rather than providing the hardware. This idea is the starting point for many new mobility concepts or services. It is especially a matter of accessibility and ease of use.

[141] See EC (1997).

[142] See Kemp, R. et al. (2001).

[143] See Schade, J. et al (2007).

[144] See Maertins et al. (2008).

New mobility services are more likely to be adopted, when corresponding with common habits and already existing items, such as bicycles, cars or media use.[145] When further addressing those services in a target group-based manner, a shift in modal split appears to be possible.

Typical examples are car-sharing and bike-sharing services, since they are able to combine the attractiveness of individual mobility (convenience and comfort) with advantages of public transport (low prices, area-wide services, general accessibility). Moreover, some new concepts of the automobile industry are pointing in this direction, as only recently the car manufacturers seem to have evolved from “car-sellers” to “mobility-providers”. Further, it is of great importance to alleviate access to public transport through better information supply and integrated ticketing services. Advanced technologies, such as e-ticketing solutions, are a promising option to ensure easy access and simultaneously communicate an image of a modern service provider.

5.1. Concepts for individualised collective transport

A promising form of car traffic management that promotes multimodal behaviour lies within new concepts related to ownership of vehicles. There are several motivations for using these rather new mobility services. One is that public transport does not usually offer a door-to-door service. When using public transport, the route between a destination and the next bus stop or train station often is a problem for the users – named the problem of the first mile or the problem of the last mile. Sharing-concepts are able to operate as a feeder to destinations or intermodal intersections. Shared vehicles can provide the link between existing public transportation and desired destination. Car-sharing in particular is also an alternative to private car ownership and increasingly applied in urban agglomerations; mainly in central European countries, with the highest membership numbers in Germany and Switzerland. In the following passage, several concepts for sharing cars and bicycles are introduced. It will be shown that these mobility services offer interesting additional options for mobility in urban agglomerations.

5.1.1. Bike-sharing

In recent years, bike-sharing systems have received increasing attention as they have been implemented in 125 cities around the world – though mainly in Europe. At present, a total of 139,000 shared-bikes are in use.[146] The main principal behind the system is that a person can take a bike and return it, either at the same, or at another location for the next person to use it. Generally, bike-sharing claims to promote a cycling culture, as bicycles become a visible transportation mode and thus citizens are encouraged to use a bicycle for transportation.

Public bikes differ from traditional bicycle rental services, as bike-sharing systems give users full autonomy due to the use of technology. Compared to traditional bike rental services, public bikes are not limited to certain opening hours or extensive rental procedures; they are available 24 hours, seven days a week. They provide fast and easy access by making use of applied technology, such as smart cards or mobile phones, and provide users with real-time availability information on the Internet.

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[145] See Maertins et al. (2008).

[146] See Shaheen, Guzman, Zhang (2010).

In many cases, they are designed as part of the public transport system and in a unique organisational layout. Strategically placed at regular intervals (every 300-500 m) in the city, public bicycles are accessible at crucial nodes near to public transport stations and at office and shopping areas. By far the largest system is Vélib in Paris, with 20,600 bikes available in 2008.[147]

The idea of bike-sharing isn't new; over the past 45 years, three generations have made an attempt and now the 4th generation is entering the arena. From the 1960s on, efforts were made to implement bike-sharing systems in Europe. It began in Amsterdam, when donated bikes were painted white and allocated throughout the city for use by everyone. The plan didn't work out; bikes were stolen and appropriated for private use. Due to a lack of control-mechanisms and professionalism, the programme collapsed within short time. In the 1990s the 2nd generation schemes were developed. The first large-scale system was launched in Copenhagen with many improvements compared with the previous generation. Like a shopping trolley, bikes could be picked up with a coin as deposit. Although the system was more formalised, bikes were stolen due to the anonymity of the users. In the following years, the 3rd generation of public bikes was born, but grew slowly with one or two programmes per year. In 2005 the city of Lyon (France) put Velo'v into service, a programme with 1,500 bikes by JCDecaux. By incorporating advanced technologies for reservations, pick-up, drop-off and information services, bike-sharing gained worldwide popularity and didn't go unnoticed by other communities. Two years later, Paris launched its much-admired bike-sharing programme "Vélib'" with, to date, 20,600 bikes and 1,451 stations in the city centre and suburbs.

Today, public bicycles of the 3rd generation are spreading rapidly after the success in Paris, facilitated by the use of smart technology and credit cards. In recent years, bike-sharing has expanded to four continents, though Europe remains the leading hub (see Figure 5-1). The success of the 3rd generation systems has increased the numbers of bike-sharing providers worldwide and has paved the way for diverse business models and technologies.

[147] See DeMaio (2009).

Figure 5-1: The bike-sharing world map (including bike-sharing systems of 2nd and 3rd generation).

Source: www.bike-sharing.blogspot.com

Diverse Business Models

The financial organisation is mainly defined by the institutional organisation of the system. Bike-sharing providers range from local authorities to transport agencies, from advertising companies to for-profit and not-for-profit groups. Five "models of provision" have emerged as being successful. However, the most popular funding sources for bike-sharing systems are municipalities and advertising companies. Generally, bike-sharing is funded through advertising, user-fees, subsidies from municipalities and public-private partnerships.

Government model: The local government operates the bike-sharing system and thus holds liability for the programme. Either it purchases an off-the-shelf system, or hands it over to an operator, like any other transit service. When being the operator themselves, they might have control over the system, but haven't as much experience as existing bike-sharing operators in managing such a programme.

Advertising company model: Companies such as JCDecaux or Clear Channel Outdoor operate the system in a jurisdiction in exchange for the right to use public space to display revenue-generating advertisement on city furniture or billboards. This model has been the most popular so far.[148] It can be convenient and cost-effective for local governments, but includes some disadvantages as well. Incentives to keep the system working are low for the advertisement company, as they don't necessarily benefit from revenues.

Transport Agency model: In this case, a quasi-governmental organisation offers bike-sharing as an extension to their other transport services. The transport agency company presents itself as a well-rounded mobility provider and gains experiences in possible new trends in the business.

148 DeMaio (2009).

For-profit model: A private company provides bike-sharing with limited or no government involvement at all. The utility of this model is that service can start as an entrepreneurial activity, without relying on public sector initiatives. A prime example of this model is Nextbike, which runs several bike-sharing systems in Germany. They generate profit through user-fees and the rental of advertisement space on the bikes.

Not-for-profit model: Non-profit organisations are either created to run the systems or, alternatively, integrate the operation of the system in their existing interests. Usually, they receive funding from the jurisdiction; additionally, they collect the revenues generated by membership and user-fees. An example of a not-for-profit model is university bikes, which are usually implemented to expand intra-campus transit services.

Bike-sharing 4th generation

As mentioned above, the 4th generation bikes are under development. Anticipated improvements over the 3rd generation include more flexible docking stations, use of smartcards, which can be used for other modes of transport as well (such as car-sharing and public transport) and innovations for bicycle redistribution. Technological advances include GPS tracking, touch screen kiosks and the use of electric bikes (pedelecs).

Innovations for redistributing bikes: Experiences have shown that some stations have high demand and low supply, or vice versa. This means that staff need to redistribute bicycles several times within a day. This is time consuming, expensive and produces unnecessary emissions. Innovative programmes will create stations, which will either encourage users to pick-up or drop-off a bike through incentives such as free time, credit or even cash.

Ease of installation: So called “technical platforms” are being installed, which include the bike-sharing station’s base and houses the wires for its bike docks and pay station. Consequently, no asphalt or paving needs to be removed, nor subterranean installation of the structure and wires is necessary.

Powering Stations: Underground wiring to the nearest electrical source provides the powering of the stations. As such, relocation of stations is almost impossible due to cost. Solar panels remove this need.

Tracking: Global Positioning Systems will allow a better tracking of the bikes and facilitates data collection and recovery of stolen bikes.

Use of pedelecs: In the light of an ageing society, as well as for areas with a challenging topography, the use of pedelecs is an interesting option. A bike-sharing fleet doesn’t need to be composed entirely of pedelecs; rather, a percentage could be sufficient for such purposes.

5.1.2. Bicycle Leasing

Bicycle leasing is based on the model of car leasing (see 5.2). Customers can usually choose between different types of bikes (e.g. e-bikes, city-bike, folding-bikes) and different service packages. Generally, bicycle leasing is interesting for private companies or public authorities, in order to offer their staff an alternative mode of transport, in the same way as offering a company car. The advantages of leasing bicycles instead of buying them are favourable financing, no need to handle repair and maintenance and no need for extensive parking. Additionally, it is an attractive incentive for staff to use bicycles and, moreover, employees who regularly cycle to work are less frequently ill.

Possible customer groups for bicycle leasing are bicycle tour operators, (bicycle-) delivery services, postal services, mobile nursing services, larger organisations (especially those whose offices are distributed across cities), recreational and leisure facilities (in order to offer bicycles to their guests), universities, hospitals and schools.

5.1.3. Car-sharing

Car-sharing is a model of car rental where people generally rent cars for short periods of time, often by the hour, as an alternative to the privately owned car. The car is no longer property of a single owner, but is owned by an organisation for managing the fleet. Clients choose and book a vehicle in advance for a specific period of time; after usage they bring it back to the initial parking lot. The fleet manager is responsible for the service organisation, maintenance (including tax and insurance), repair and fuel costs. In return, customers pay the fleet manager for the allocated service, mostly by time and mileage.

When closing a contract with a car-sharing provider and after paying a membership fee and bond, customers be handed-over a smart card (in earlier days it was a key), which allows use of the car-sharing fleet. According to the organisation size, customers have access to a variety of different cars at easily accessible nodes throughout the city, e.g. at transportation intersections as well as in housing or business areas.

Such schemes are attractive to customers who make only occasional use of a vehicle, as well as to customers who would like to have occasional access to a vehicle of a different type than they use day-to-day. Car-sharing companies argue that when driving less than about 10,000-15,000 kilometres per year car-sharing is, in general, cheaper than owning a car. Apart from the costs, car-sharing is interesting for people that do not want responsibility for the maintenance of a car.

While in the early days of car-sharing, users as well as operators were primarily ecologically motivated, nowadays users tend to be much more milieu-indifferent. Most users are male, between 25 and 45 years old and well educated. In Germany, the number of car-sharing users has been growing continuously over the last two decades. Meanwhile, car-sharing operates in nearly all German cities with more than 200,000 inhabitants and also in most of the cities between 100,000 and 200,000 inhabitants. In 2009, nearly 160,000 people were users of the system in Germany.[149]

Most car-sharing programmes are on a small scale and were implemented as a bottom-up approach. More recently, pilot projects illustrate that car manufactures are getting interested in the idea and have started to implement top-down approaches (see “Car2Go”, “Mu by Peugeot”). First experience dates back to 1948 when in Zurich a cooperative established the first documented car-sharing organisation as an act of economical necessity after the 2nd World War. Various other experiments were attempted, but failed due to inefficiency in the 1970s. At the end of the 1980s, the concept of car-sharing was re-adopted in Switzerland and made its way to the wider public; the organisation is still operating today (see “Mobility”). Currently, 14 European countries have car-sharing operations, with a total of nearly 385,000 customers and 12,000 vehicles.[150]

[149] See Bundesverband CarSharing (2008).

[150] See Bundesverband CarSharing (2009).

Whereas most car-sharing organisations of the late 1980s and 1990s had a strong ecological motivation and were established as cooperatives, nowadays most car-sharing organisations are corporate entities and operate stronger profit-oriented. The operators act much more professionally than two decades ago. It must be emphasised that information and communication technologies (ICT) have considerably supported and much improved both the organisation and the appearance of car sharing. ICT allows access to cars by smart cards instead of keys, 24 hour internet booking instead of telephone booking and on-board computers instead of manually filling out vehicle logbooks.

There are different views on the potential contribution of car-sharing to sustainable urban transport. It strongly depends on whether car-sharing trips substitute trips by cars, bike, or public transport, or if car-sharing induces additional traffic. Experiences prove that many car-sharing users have a strong affinity to public transport and use car-sharing when public transport is not available. However, a wide range of patterns of usage does exist.

According to several car-sharing surveys,[151] the impacts on transport and environment are large. Effects are especially seen for:

- CO_2 – reduction. Many car-sharing providers already meet EU established standards, even though they will not be binding until 2015.
- Strengthening of modes of transport with no, or low emissions (bus, tram, bicycle, walking) as the fee structure encourages the combination of different modes.
- Diffusion of more eco-efficient vehicles, as car-sharing vehicles are on average newer than personal cars and thus benefit from improved engine technology, fuel efficiency and emission levels.

Car-sharing could be an interesting niche market for alternative fuels and propulsion technologies, since it is possible to choose between different types of vehicle according to the purpose or distance of the journey. Battery electric vehicles could be used for trips in urban areas. For longer trips a car with range extender or a conventional ICE might be chosen (see chapter 5.2).

In the following passage several modern car-sharing approaches are described:

Mobility

Mobility is a Swiss car-sharing provider and was established 1987 in Zurich as a cooperative. As such, it is an example of a classic bottom-up approach. Along with its car-sharing service, in 1998 Mobility launched a mobility service programme that combines car-sharing, public transit, car rental, taxi and other services on a single smart card for its customers.[152] In 2001, Mobility participated in the car-sharing programme of the Swiss Rail Company. Since then the numbers of car-sharing users have been growing continuously. To date, Mobility is the biggest car-sharing provider worldwide, counting 90,800 customers and 2,300 vehicles.[153]

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[151] See Carplus (2008); see Rösch (2001); see Bundesverband CarSharing (2009).

[152] See Shaheen, S. et al. (1998).

[153] See Mobility International AG (n.s.)

Car2Go

In October 2008 Daimler, in cooperation with the German Aerospace Centre, started its Car2go scheme. In a first step as a research project, around 500 employees of the Daimler Research Centre in Ulm and their family members participated. Since March 2009, the scheme has been expanded for every registered resident and tourist. The idea is similar to the above-mentioned car-sharing programmes, except that Car2go is a top-down approach. 200 “Smart fortwo” are placed in the German city of Ulm for every registered person to use and then leave for the next person. The cars can either be picked up spontaneously or with a reservation. Registered users[154] will receive a little RFID chip on their licence, which they simply need to hold up to a card reader on the windshield. User data will be stored on the chip and automatically sent to the central office. The price structure is simple; the standard price is €0.19 per minute (maximum is €9.90 per hour) including tax, insurance, fuel, parking and mileage. The service will be charged on a monthly basis. No security deposit, monthly fee or reservation deposit has to be paid. After using, the car can either be parked at any destination within the centre, or at one of 130 parking lots, which are exclusively booked for Car2go. So far, 18000 users have been registered, of which 60% are younger than 36 years old. On average, every customer used a Car2go Smart 12.7 times, with a mileage of 13 km.[155]

Picture 5-1: Car2go in Ulm, Germany.

Source: www.car2go.de

Since November 2009, another Car2go scheme has been launched in Austin, USA. In a pilot phase a defined group of users, such as city employees, participated as test drivers. Since May 2010, the programme has been expanded for the rest of the 750000 residents.[156] Recently, it was announced that Car2go will also start in the City of Hamburg with a fleet of 300 cars.[157]

The concept in Ulm has recently been extended to an online ride share service called “car2gether”. Registered drivers and passengers can send offers and requests about routes via their PC or their mobile phone. Start, end-point and time are then transmitted in real-time between suitable partners. Moreover, all offers and requests are posted every 15 seconds on a live-ticker. Data of possible drivers and passengers that are having the same direction are then transmitted mutually among both. In principle, the idea of an agency for arranging lifts is not new and is widespread since the late 1980s in Germany and other European countries.

[154] Users have to register in the city hall and online.

[155] See www.car2go.de

[156] See http://blog.car2go.com/

[157] See Pander, J. (2010)

Mu by Peugeot

The French automobile manufacturer Peugeot launched an alternative approach in 2009. Peugeot introduced the Mu mobility programme, which was developed to offer customers and non-customers an integrated mobility service from a single source. The central idea of the concept is to give people access to a variety of vehicles, according to their particular needs for given circumstances.

The offer includes two categories. On the one hand, customers can choose from the comprehensive portfolio of Peugeot dealers, including different types of cars as well as scooters, bicycles, e-bikes and diverse accessories such as roof racks, child seats or bicycle racks. On the other hand, card holders can choose from different services; therefore partner agencies attend in booking train tickets or hotel rooms as well as in arranging trips. The peer group comprises people who can't afford or simply do not want a car, but still have the demand of being mobile. But car-owners can also profit from the new service, as they do not need to own accessories anymore.

The service works in a similar way to a prepaid cell phone. Customers have to open an account for a non-recurring fee of €10. From then on, users can top up the card online and use it to pay for the rentals. Products can be identified on the website and can be booked using the telephone. Vehicles can then be picked up at a local dealer. To make the service more accessible, Mu by Peugeot recently introduced an iPhone application that allows customers to do transactions directly over the phone.

So far, Mu by Peugeot is operating in Brest, Lyon, Nantes and Rennes and in five dealerships in Paris, as well as the capital cities of Germany, Spain and Italy. Since July, Peugeot has also offered its service in London and Bristol. Until 2011, the scheme will be extended to another five European countries.

5.1.4. Car-Pooling

Another form of sharing cars is car-pooling.[158] Car-pooling refers to the organised sharing of participants' private passenger cars by carrying additional passengers. By offering available vehicle seats that would otherwise be unoccupied, car-pooling has minimal incremental costs for the car-owner and the passengers, as they divide costs. However, car-pooling is generally most suited to predictable journeys, such as commuting or special events and is especially interesting for areas that are not well served by public transport. Car-pooling is usually implemented by an individual employer, a public transport operator or another for-profit or non-for profit organisation, though without any significant impact on overall car occupancy so far. Existing programmes allow trip arrangements over the Internet. Smaller programmes sometimes simply use bulletin boards or, usually for employees, the intranet to find potential passengers. Large programmes instead use computerised matching systems that take into account each users' origin, destination, schedule and special needs. However, people are used to flexible working hours and overall availability of transportation means, meaning that trip arrangements are often not flexible enough. Notwithstanding this, as mobile computing becomes a commodity; it might enable an even larger scale of application. Modern technology could organise ridesharing as easily as using a mobile phone, once navigation, tracking, billing and authentication are combined to offer an elaborate service for car-pooling.[159] One step in this direction is the new offer Car2gether by Daimler (see Car2Go).

[158] Also called "ridesharing" or "liftsharing".

[159] See Hartwig, S. (2007).

5.2. Business concepts for electric vehicles

As mentioned in chapter 3.2.2, electric vehicles still have a variety of barriers to overcome, until they can attain significant market shares. New concepts of usage, or business models, can help to overcome those barriers by tackling insufficiencies through suitable service offers.

A well-established example of a business model is leasing. It is widespread among private persons and companies to finance the purchase of cars. Manufacturers (or external leasing companies) and customers enter into a contract, which covers the usage of a specific car. The lessee is the receiver and thus pledges to pay a monthly rate to receive the right to use the vehicle, whilst the lessor remains legal owner of the vehicle. There is usually a wide scope for negotiating parameters, such as duration or amount of the fee. Optional is a full-service leasing, which includes maintenance, repair and insurance. At the end of the term of a contract the lessee has the right to purchase the vehicle for a sum that was fixed at the beginning of the contract. Other possibilities are that the lessee receives a new car (and a new contract), or the contract expires. Leasing guarantees companies, as well as private individuals, a solid calculation basis and low administration costs.

In the case of electric cars, it is conceivable that customers purchase an electric vehicle, but enter into a leasing contract to receive the right to use the battery. Different lessors would be suitable, such as e-vehicle manufacturers, battery-manufacturers, finance companies or energy suppliers, as well as providers of infrastructure.

The Norwegian e-car manufacturer Th!nk uses this idea for its electric car, Think City. Purchase price of the vehicle is 212,500 Norwegian Kroner (about €26,800). In addition to the car the customer has to sign a "mobility agreement". For a monthly payment of 975 Kroner (about €123) the agreement allows customers to use the battery, whilst Th!nk remains owner of the battery.[160] The leasing rate includes repair and maintenance as well as exchange of the battery, when capacity decreases. Up until now the Think City is only available in Norway, Austria and the Netherlands. Pre-launch activities have begun in Denmark, Sweden, Switzerland, and Spain, although the car is primarily being sold to governmental institutions, municipal fleets and utility partners; so, they are used in specific niches, with a pilot and demonstration character.[161]

5.2.1. Project Better Place

The company "Better Place" aims to offer a comprehensive approach to governments by supporting the market penetration of Battery Electric Vehicles and, thus, reducing the global dependency on fossil resources. The overall idea of "Project Better Place" is that suppliers own the battery themselves and sell usage (miles, kilometres or KWH) to the customers at lower cost than the average gasoline price in each country. [162] This idea is adopted from the mobile phone sector: initial costs of electric vehicles are subsidised by the ongoing per-distance revenue contract, just as mobile handset purchases are subsidised by per-minute mobile service contracts. The main partner of the project is the French car manufacturer Renault, who will provide mass-market electric vehicles with switchable batteries.[163]

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[160] See Wallentowitz, H. et al (2010).

[161] See www.thinkev.com

[162] See www.betterplace.com

[163] See Renault (2010).

Concerning infrastructure, the idea of Better Place relies on two axes: a dense network of charging stations and a less dense network of battery switch stations. The latter offers the possibility to change depleted batteries for full ones in under a minute. A cohesive network will be developed of cars that are virtually connected to the main control unit, in-car software that constantly monitors the charging status and calculates the range of the battery until recharging is necessary and a navigation system that shows the closest switch or charging stations.[164] Advanced information and communication technologies are crucial for such forms of electric mobility.

Picture 5-2: Better Place switch stations.

Source: www.betterplace.com

Japan was the first country to adopt the idea. In April 2010 Better Place, together with the Japanese Ministry of Economy, Trade and Industry, launched a three-month pilot project with four taxis and a battery switch station in Tokyo.[165] In approximately 2011, the company will have their first complete systems realised in Israel. Cars will be available from the first half of 2011 in specific Better Place locations as well as at some Renault Dealers. In February, Better Place Israel signed a partnership with Dor Alons, one of Israel's leading petrol station operators to deploy switch stations at Dor Alon's facilities in Israel.[166] Moreover the company has already sold 30,000 vehicles to fleet operators in Israel (where average use of car fleets is relatively high). Further, the government has set up a large programme to stimulate private persons to buy electric vehicles. In Denmark, the first joint ventures between municipalities and Project Better Place have been started for building e-mobility infrastructure. In Australia, first projects have also been launched. Several other countries have expressed serious interest; amongst them China, Canada, Hawaii and the USA (through California).[167]

[164] See Engel, R. (2009).

[165] See Green Car Congress (2010).

[166] See Better Place (2010).

[167] See Better Place (2010).

5.2.2. Car-sharing as an enabling concept for e-mobility

Car-sharing (chapter 5.1.3) is a promising concept for individualised collective transport. It has been discussed in many recent studies[168] as an "enabling concept" for electric mobility, since users can choose the appropriate car for a specific purpose (for example, a battery electric vehicle in urban areas and a conventional fossil fuel vehicle for longer distances). More recently, schemes have been established, which function similarly to bike-sharing programmes, where users can drop off the car wherever they like. If travelling for longer distances it might be possible to change the vehicle midway for a fully charged vehicle. Paris is starting the first of such initiatives with electric vehicles:

Autolíb

After the huge success of Paris' Velíb bike-sharing programme (see chapter 5.1.1), Paris mayor Bertrand Delanoë is following a similar structured car-sharing programme with 3,000 electric cars and 1,000 stations in Paris and 30 surrounding municipalities. The idea is the same as for Velíb; cars will be distributed throughout the City, for anyone to pick up and drop off when not needed anymore. The scheme, called Autolíb, is short for "automobile" and "liberté" and is supposed to start in autumn 2011. However, criticism has been raised that Autolíb could discourage bicycle and public transport use. Proponents of the programme argue Autolíb will encourage people not to buy a car for their own, rather than promoting driving. Therefore, the price for usage will be above public transport fees, but attractive compared to a privately owned car. The service will be available 24/7, and the price will be fixed at €15-20 per month plus €5 for every half-hour.

The programme will be operated as a public-private partnership, including AVIS (car rentals), the French national railway company SNCF, as well as the Paris transit authority RATP.[169] Additionally, Autolíb vehicles could be equipped with GPS systems to help to collect real time travel data.

In an online survey IFOP asked 598 persons aged at least 18 years about their perceptions and interest in Autolíb, of which 61% answered that they would be interested. Among the respondents were 42% car owners; that still so many are interested in Autolíb is most likely due to the fact that driving electric cars is different to their usual driving habits. 18% of Parisians are planning to use Autolíb a few times a month or several times a week, a number which is close to that of Velíb users (21%). 40% answered they would most likely use the car in the evenings during the week. 39% expressed no interest in the service.[170]

[168] See McKinsey&Company (2010); Roland Berger Strategy Consultants (2009c); Roland Berger Strategy Consultant (2010).

[169] See Liu, L. (2009).

[170] See IFOP (2009).

5.3. Concepts for public transport

There are several factors that influence the demand for a certain transport mode: access, skills and appropriation determine peoples' mobility significantly. Access is linked to availability, but also to financial and time issues. Skills are linked to the knowledge users have developed; it facilitates the use of different modes. Other skills are related to the ability to manage time and financial budgets. It is essential for users to be able to travel without undue concern about ticket purchase or planning the journey. It is seen as a benefit to travel without the need to think about such things. Public transport is seen as being attractive if it is easy to use and when no additional knowledge is needed.[171] Appropriation is linked to experience, habits and values, which affect the way people appreciate their own access and skills to different travel modes. In a qualitative study on travel choice, Hine et al. (2000) found out that descriptions of barriers to public transport use are expressed by the antonyms to describe the advantages of car use.[172] "Convenience" or comfort" are related to private cars and most likely express the desire for routines.

To alleviate access and egress for customers as much as possible, the whole transportation chain has to be considered; starting at the customers' home and ending at the final destination. High quality service is needed for the entire journey, including service expansion to the periphery. Having this in mind, several concepts concerning access and egress have been developed to facilitate the use of public transport. Most of them aim at the reduction of organisational and institutional barriers through additional services, better travel information or more attractive fares and ticketing arrangements. Other concepts use planning instruments to facilitate the use and access of public transport by building well-situated and designed intersections.

5.3.1. Service expansion

Most urban central areas have high population and employment density, which enables public transport to offer frequent services on adequate routes and to achieve high occupancy rates. Because metropolitan areas spread out into the suburbs, public transport operators are facing serious challenges to compete with private owned cars. To extend its service to low density and outlying areas, public transport providers have to find new ways and more flexible solutions to integrate suburban into city-centre services. A structural challenge in many urban areas is that public transport is frequent between city centres and suburbs, but peri-urban transport, directly connecting the suburbs, is rare. Dealing with these highly relevant issues requires considering the specific situation of the urban area. Different solutions are imaginable. Such new peri-urban transport services, car-sharing systems or inducing changes in land use patterns affecting the demand for such peri- urban trips.

In general, more flexible solutions are needed to make a combination between public transport and other modes of transport as easy as possible. In the following passage some examples are discussed:

[171] See Maertins, C. et al. (2008).

[172] See Hine, J. et al. (2000).

Dial-a-ride services

Dial-a-ride services are flexible solutions to fill the gap at poorly served routes by offering a range of vans, minibuses or taxi services to act as feeders to highly frequented routes. People are either picked up at home or at a central meeting point by these complementary vehicles and are driven to their point of destination or a transport node. The service is usually offered during off-peak times, when frequent connections are not profitable anymore in suburban areas. Usually, dial-a-ride services are still connected to a timetable but customers need to call half an hour before to actually book the service. This gives further flexibility and efficiency to the transport operator as well as to passengers.[173]

Bike & Ride and Park & Ride

Bike & Ride and Park & Ride facilities aim at to encourage more people to combine the bicycle, the car and public transport respectively for one trip. It is implemented to overcome a central weakness of public transport, especially when thinking about the periphery; the accessibility of stations. The use of the bicycle or the car as a feeder for public transport can substantially reduce the door-to-door travel time and bring public transport to additional customers. Park & Ride facilities are usually designed as extensive parking lots close to public transport stations in the periphery and could be especially interesting in the context of reduced range of electric vehicles. Bike & Ride facilities typically provide sheltered bike racks and convenient lockers. Highly frequented stations may offer additional services such as repair and maintenance, or bicycle boxes.[174]

5.3.2. Quality improvement

Much of the success of public transport depends on the convenience of using it. A high quality standard of service is therefore essential. This includes a wide range of possibilities, which can be set up by the transport operator, by planning authorities or by cooperation between different stakeholders.

Information and communication

Car drivers often overestimate the cost and time associated with travelling on public transport, while underestimating time and, in particular, costs of driving a car.[175] This implies a strong need for information and communication efforts, which is driven by demand to overcome existing preconceptions about public transport, such as the impression of regular delays or concern regarding insufficient frequency.[176] This includes information, delivered via ICT applications (see chapter 4.2), before and during the trip. Public transport route planners or journey planners, for example, are designed to provide customers with personalised information on available public transport options and are mostly available as web applications. More advanced route planners support different modes of transport, including metro, railways, buses, ferries or even bike and car-sharing stations. Another option of providing customers with tailor-made information on transport is the introduction of “mobility centres” at crucial transport nodes, to inform companies and citizens regarding existing travel options, such as information on carpool parks, park & ride and bike & ride facilities, car-sharing stations and taxi stands.

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[173] See Pucher, J. et al. (1996).

[174] For a monthly rate, users will be provided a key to a private box to stall their bicycle. Usually the municipality places them at highly frequented stations, such as the central station.

[175] See Harms, S. et al (2007).

[176] See Hine, J. et al (2000).

Travel training for public transport

Travel training for public transport intends to enable potential customers to use public transport independently by teaching them where to obtain and how to handle information, notifications about ticketing and valid fares and to demonstrate behavioural aspects. Travel training is most effective when target-group based; training for the elderly, people with disabilities, migrants or children. Furthermore, staff of hotels or shopping centres can be trained to provide customers with mobility information.

Attractive fare structures

The pricing of public transportation in Europe ranges from charging the full price to offering it for free. Most European cities supply public transport fares between those two extremes. Organizing a uniform, integrated and generally understandable fare structure is one of the most significant requirements of public transport and a core necessity for an easy access to public transport. For this reason, most public transport operators have implemented distinctive fare structures, such as monthly tickets, weekly tickets or the availability of semester tickets for university students, school pupils and apprentices, as well as stripe tickets or one-way tickets. In many cases, a wide range of ticket types exist which are suitable for the specific needs of distinctive groups of customers. Often, however, those fare structures are confusing and people are not willing to deal with this subject. Accordingly, this complexity can discourage the use of public transport. Again, ICT applications are a promising solution to fundamentally simplify ticket purchase. By implementing e-tickets (see chapter 4.2) customers do not have to be concerned about ticket purchase in advance; instead they are guaranteed the best price for their journey by paying afterwards. Moreover, e-tickets could integrate distinctive means of transportation, so that one single smart card can be used for all existing modes of transport within the city.

Box 5-1: ***Experiences with free public transport***

Since 1997, the Belgium city of Hasselt has offered public transport free of charge. Ten years previously, public transport in Hasselt was poorly available, since they only had two bus-lines with an hour-frequency in operation (for nearly 70,000 inhabitants) The city improved its bus service to a nine-line service, taking in every district of the city and a half-hourly service, with a 15-minute service during rush hour. From then on, the bus has been free of charge for everybody and available 24 hours, seven days a week. The introduction of the new public transport system came along with restricted access of the city centre for cars and the construction of extended cycle lane routes. The aim of the project was to multiply fourfold the number of passengers in three years.[177] The result exceeded all expectations; the number of bus passengers increased tenfold (from 331,500 in 1996 to 4,500,000 passengers in 2008). Due to the success, the public transport system has been extended to nearly 50 lines, running with a 5-minute frequency in many cases. In 1998, the cost for free public transport was approximately 1.26 % of the city's total budget, which is €1,750,915 per year, or €24 per capita per year. [178]

[177] See van Goeverden, C. et al (2006).

[178] See Gramm, M. et al (2009).

5.3.3. Planning instruments

Passengers who have to wait for trains or buses are more likely to do so in conditions of safety, cleanliness and comfort.[179] This includes a certain amenity value, which is induced by a quantity and diversity of possible activities at or close to intersections. When travelling by car people often combine routes to one single journey. Coming home from work, for example, is combined with commercial activities. The transition of public transport nodes from mono-functional to multi-functional sites can offer the same flexibility and fulfil in that way the growing requirements of the users. This includes a good supply of shopping and service facilities as well as restaurants. Moreover, constructional design and image play a significant role.[180] As a result, travel time might be considered more of a positive activity than wasting time. There are many similar concepts in land-use planning that cannot be described in detail here. A prominent approach is the city of short distances, which aims to have working, leisure and housing in one area, thus avoiding longer trips. A strong integration of land-use planning and transport planning is a general principle for supporting sustainable transport in urban areas. This could lead to new construction areas being built together with, or close to, public transport infrastructure.

5.4. Concepts for freight transport

Even though a lot has changed in the last few decades, the freight-transport sector still has considerable potential to improve. A lack of well-structured intermodal transport chains, a considerable number of uncoordinated transport operations and empty return runs typify existent inefficiencies. The growth in demand for intermodal freight services, namely the use of two or more transportation modes to move a shipment from origin to destination, has levelled out at about 5-7% of total tonnage.[181] Also for this sector, incentives are needed to move the industry towards a use of more sustainable transportation modes. Transportation companies, retailers, logistic providers and local/regional authorities are required to develop and introduce new standardised logistic concepts, including use of all available modes of transport. In this context, rail-bound systems for the combined transport of passengers and freight have a large potential for regional and city-bound cargo distribution.

An example of using a tram for goods transport is the freight tramcar in Dresden, Germany. The CarGo Tram project involves cooperation between DVB (local cargo enterprise), Volkswagen (VW) and the local authorities. The decision to start up the CarGo Tram was undertaken in 1999. A logistic concept was developed and the tramcars were planned and built within a rather short period of time. In March 2001, the CarGo Tram became operational. VW wanted a competitive solution compared to road transport to bring prefabricated parts just-in-time from one point of the city to another using the already existing tramway tracks, running directly through the city. The main key to the viability of the project is the length of the tram (60m) and the capacity of three lorries (maximum load 60 tons and a load space of 214m^3). The CarGo Tram runs six days per week for 16 hours a day.[182] It is used only for point-to-point transportation and is not readily transferable to different destinations.

[179] See Paulley, N. et al (2006).

[180] See Stark, J. et al (2009).

[181] See Giannopoulos, G.A. (2004).

[182] See Dresdner Verkehrsbetriebe AG (n.s.).

However, in recent years different approaches have been developed by DVB to adapt the idea of the CarGo Tram to other branches. Conceivable in Dresden is the adaption to hospital-logistics, roadwork's supply and disposal, theatre-logistics, extensive retail and circular economy (waste transport).[183] So far, several cities picked up the idea and have either introduced a cargo tram (Zurich, Amsterdam) or have undertaken a research project on it (Vienna).

Picture 5-3: Cargo Tram Dresden, Germany.

Source: Rail fot the Valley (2010)

5.5. Conclusions

The chapter illustrated that new business models and concepts offer new mobility services to the users in both passenger and freight sectors. For nearly all these concepts, information and communication technologies (ICT) can be considered as an "enabling technology" that built the organisational platform for bringing together demand and supply in an efficient way. Advanced information and communication technologies enable a new design of already existing business models. It indicates that in future innovative mobility services might also be enabled by progress in the ICT sector. Many of these concepts or business models are not completely "new". But due to the progress in ICT the rather high degree of efficiency, quality and convenience for the users are new and make these approaches more competitive. It is imaginable that – in co-evolution with ICT - even more innovative business models and mobility services will appear in future and make intermodal transport more successful. There is surely promising potential for more sustainable urban transport systems related to this approach. Furthermore, concepts such as car-sharing are considered as a potential enabler for alternative fuels and propulsion technologies, in particular for electric vehicles. As a result, it could be stated that these business models are pushed forward by technical developments in two different areas: in the ICT sector and in the fuels and propulsion sector.

The integration of diverse modes of transport into one system enables multimodal behaviour. In the ideal case, an integrated transport system enables smart door-to-door connections. An easy access to the different means of transportation is crucial. Therefore, concepts need to consider the issue of the first mile/last mile. Sharing vehicles is a possibility, though it is still a niche market, albeit becoming increasingly popular in many European regions and beyond.

[183] Oehlmann, W. (2007).

The huge success of some bike-sharing programmes, as well as the adoption of the car-sharing concept by car manufactures and other corporate actors illustrates that sharing is seen as a serious option for managing sustainable urban transport, both for the demand and for the supply side. Moreover, it could be seen as an indicator that stakeholders become more and more open to unconventional ideas and concepts. So far, some schemes have generated enormous interest from local authorities, national governments and the media from around the world. The chosen examples illustrate that schemes need to be implemented on a large scale to be recognised and to actually move vehicle-sharing from its niche position to a genuine possibility of organising transport.

6. Out of the box: visions of technology futures

Changing trends in transport behaviour and the urgency to cut transport related CO_2 reductions will require a broader application of best available technology and, in the longer run, the development of new technology options. The previous chapters illustrated that many technologies exist or are emerging that are changing, or have the potential to change, urban transport systems. Amongst the most important technological streamlines are information and communication technologies (ICT) and alternative fuels and propulsion technologies. Battery electric vehicles are a typical example of an emerging technology, which is tested in many demonstration activities and pilot projects but does not have significant market shares for the moment. ICT applications offer interesting possibilities for new mobility services.

So, the transport system has always changed its technique-infrastructure basis and its service concepts, and it is likely that it will also change in the future. Some technological options that might be elements of future transport systems are described in this chapter. Several ideas are based on the idea of the “third dimension”, meaning that either the underground or the air is used more extensively; others are tackling the apparent contradiction of taking into account users’ demand for privacy and the requirement for sustainable public transport. The approaches will be discussed in terms of feasibility and their contribution to sustainable urban transport.

6.1. Rope bound transit systems

Until the present, rope bound transit systems in Europe are solely in use for very specific needs (e.g. gardening exhibitions, expos), for cargo transportation (e.g. underground mining) or as mountain railways in the alpine area for passenger transportation. The potential of ropeways for urban transport has not yet been fully recognised by European planners, whereas in North- and South America, Asia, and North Africa an array of applications have already been put into use. These applications prove that urban ropeways can be used to overcome topographic, architectural or traffic barriers, to reach areas with poor public transport (e.g. urban outskirts), highly frequented building complexes (such as universities or airports) or large areas (e.g. leisure parks, commercial areas).

The infrastructure for rope bound transit systems is space saving, since stations can be integrated into existing buildings and pillars can be placed wide apart from each other. Areas beneath the line can then be employed for alternative uses. Modern ropeways are able to connect more than two end points; the amount and density of stops depends on topography and the requirements of the city. Hubs enable passengers to change from one ropeway to another or to different modes of transport. When arriving at the station, cabins are on the same level as the platform, allowing mobility impaired passengers and wheelchair users to enter cabins smoothly. Cabins pass through the stations at slow pace and can be stopped when necessary, without affecting operations. Fully automatic operation allows a continuous transport without large deployment of personnel. The speed of the circulating rope can be adjusted, in order to suit demand. This guarantees short waiting times and allows high capacities of 500 – 7,500 people per hour, depending on investment and operational costs. Aerial ropeways can be installed and (if the use is only temporary) dismounted within a short period of time. Rope-bound transit systems have the advantage of being able to use energy of masses going downhill to move cabins uphill on the other side of the rope and are thus extremely energy efficient.

However, the special appeal of urban ropeways lies in its unique travel experience, while saving resources and being noise and cost-efficient. The company Doppelmayr estimates the costs for a circulating ropeway of 1,000 m length, with 8-passenger cabins at 6 million Euros (including drive- and return stations, line equipment and carriers).[184]

The German City of Koblenz, which will host the Federal Horticultural Show (BUGA) in 2011, has installed a ropeway as an important part of the BUGA concept. Visitors will be carried across the river Rhine to the Ehrenbreitstein fortress via the aerial ropeway 3S. Between July and October 2010, the system will be put into operation for demonstration purposes, before starting the actual business in 2011. For the first time, the 3S ropeway with 18 cabins, each with a capacity of up to 35 passengers, will be in use in an urban area. 7,600 passengers (3,800 per direction) can be transported per hour over a length of 890 metres with an average speed of 20 km/ h. [185]

Picture 6-1: Aerial ropeway in Koblenz, Germany.

Source: Doppelmayr; Graventa (2009)

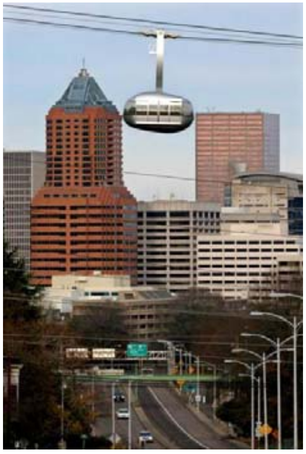
Another good example is the rope-bound tram in Portland, Oregon, U.S.A. The tram carries commuters between Oregon Health & Science University's south Waterfront Campus and the Marquam Hill neighbourhood. It is the United States' second commuter aerial tramway (the first is the Roosevelt Island Air Tramway in New York City). All of the city's modes of transport, buses, trams and the aerial tram are well integrated and connected in the Valley Station. After 10 months of operation, in October 2010, one million passengers have been carried by the ropeway system.[186]

[184] See Doppelmayr (2009).

[185] See Doppelmayr (2009).

[186] See Muschwitz, C. et al (2009).

Picture 6-2: Aerial tram in Portland, Oregon.



Source: Doppelmayr; Graventa (2009)

6.2. Personal Rapid Transport

Personal Rapid Transport (PRT; see Picture 6-3) is a new transport method running on a track system. It provides on-demand services for individuals or small groups travelling together by choice. PRT is ordered rather like an elevator: passengers push a button to call for a vehicle and then another to select the destination they wish to reach. The service combines advantages of individual mobility (flexibility, convenience, privacy) with those of public transport (sustainability, costs) by offering a direct origin-to-destination service in a podcar, without making intermediate stops along the way.[187]

The system consists of a network of fully automated electric vehicles, which operate 24 hours a day, seven days a week. A network of stations is connected by a track that drives around all stations in a system. Electric vehicles travel along these tracks, which are exclusively for their use. As soon as a vehicle reaches its destination, it can exit the track, to allow other vehicles to continue to travel. A central computer controls the system. The pods travel along pavement equipped with magnets placed every five metres. [188]

The idea to provide individual, on-demand transport is not new and goes back to the 1960s/1970s, but technology at that time was not sufficiently mature for implementation and acceptance to radically reshape urban environments was not given.[189] A first large scale testing has been operating at London Heathrow Airport since 2009 and will be opened up to the public in 2010. In Masdar City in Abu Dhabi, PRT is planned to be the primary source of transportation. However, both sites could provide the demonstration necessary to other cities, though they are special cases with controlled environments and are not necessarily transferable to other cities or uses. In the case of Masdar City, which is totally new and designed to emit no carbon, the organisation of buildings has exclusively been modified to accommodate the PRT system. [190]

[187] See Jeffery, D. (n.s.).

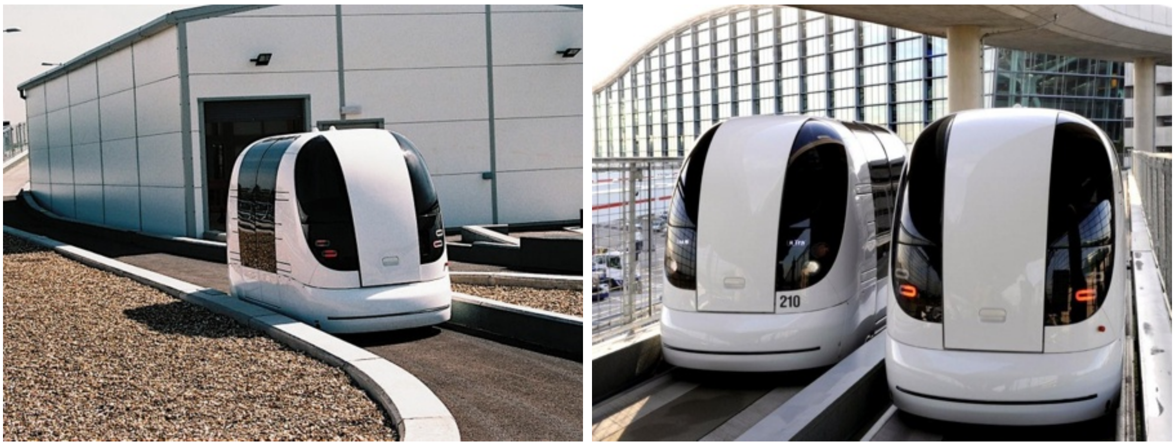
[188] See Bullis, K. (2009).

[189] See Voge, T. (2008).

[190] See Bullis, K. (2009).

PRT systems could be used to connect certain points of interest, for example a major transport terminal with other facilities such as universities or airports. The use of electric vehicles offers operation without emitting noise or pollutants. Since PRT systems do not have to stop frequently, they can be faster than buses and there is virtually no waiting time. A further benefit is that no drivers are needed and therefore operating costs are cheaper than for equivalent bus or tram services, though initial costs are high. Estimated costs for 1.6 km are 7.5 – 12 million Euros.

Picture 6-3: PRT vehicles at London Heathrow Airport.



Source: PRT Consulting (2009)

6.3. The foldable electric City Car

The Smart Cities group at the MIT Media Laboratory is working on a foldable City Car, a fully electric vehicle, which is not just a car, but a vehicle system designed specifically for shared-usage (see Picture 6-4). By folding and stacking it like shopping trolleys it shall mitigate pollution and expand limited public space. The system works like car-sharing or bike-sharing systems described in chapter 5.1, allowing users to take a City Car at available stacks densely located throughout service areas, to cover their first miles/last miles during a trip. The innovation of the system is the vehicle itself. A prototype is anticipated for 2011. Cities chosen for tests include Singapore, Boston, Taipei and Florence.[191]

The car does not have a central engine or traditional power train, but will be powered by four in-wheel electric motors. By having each wheel independently digitally controlled, the car will be able to spin around its own axe, making an O-turn (instead of a U-turn) possible. This enables the driver to move sideways into parallel parking spaces. The car can hold two passengers, sitting in the front compartment. Ingress and egress for passengers is provided from the front. The back compartment will provide storage room. The car folds vertically while the back compartment will stay level for easy access. According to the Smart Cities group, it is possible to park three or four City Cars in the length of a conventional parking bay. The City Car is designed for intra-urban trips only and equipped with Lithium-Ion batteries. It seems feasible that recharging can be provided automatically in parking spaces. The City Car is smaller and simpler than a traditional car and thus, in principal, much cheaper to manufacture, since most of the mechanical complexity is related to the wheel units. However, calculations do not include charging infrastructure.[192]

[191] See Clancy, H. (2010).

[192] See http://cities.media.mit.edu/projects/citycar.html

Picture 6-4: The City Car.

Source: Lark, W. (n.s.)

Cars can either be stacked in a parallel manner (like bicycles in bike-sharing systems), or in a first-in-first-out arrangement (like taxis). Parallel stacks allow users to choose any car available, which would be important if cars vary in design and size. First-in-first-out stacks can vary in length and cars would recharge as they progress through the stack. This system would work well when cars are uniform.[193]

Picture 6-5: Model of a First-in-first-out stack.

Source: Vairani, F. (n.s.)

6.4. Inductive charging for EVs

Energy supply for BEVs is still a weak link, and the comfort of charging is seen as crucial. Car manufacturers and suppliers are therefore looking for solutions to charge electric vehicles wirelessly. Wireless charging is based on concepts already known in domestic context; the same electromagnetic field technology is used to charge electric toothbrushes or for induction cookers.

[193] See Mitchell, W. et al (2008).

Inductive charging comprises two inductive coils; one is located in the vehicle under body, the other one is integrated in a mat located at a dedicated parking spot or even underneath the pavement on a highway. Power is inductively transferred from the primary coil to the secondary coil. The vehicle's battery will be recharged contact-free by roughly positioning the vehicle over the primary coil, while parking or even while driving along a dedicated highway. It is conceivable that parking spots that are equipped with this technology commence the charging process automatically, as soon as the car has identified itself via a wireless link. Charging takes place in accordance to presets of the driver. Self-learning software only releases as much energy as user profile, presets and remote supervision induces. Moreover, transfer of energy is supposed to work both ways, energy could be fed back into the grid from stationary electric vehicles. Therefore intelligent networks are needed, which are capable of switching between battery charges and electricity feedbacks automatically.[194]

For electric vehicles this would be an innovation, since charging procedures are not yet standardised and seen as a major barrier for a significant market penetration. Other, not yet solved problems related to public charging, would not apply. For example, safety problems of uncovered power cables lying around (like short circuits when becoming wet or if they become a tripping hazard for pedestrians) would be solved. Moreover, it is possible that the visual impact of charging stations in public space will become a matter of public concern.[195] Another advantage of inductive charging is that long contact times and a more frequent contact to the energy source might generally have a positive effect on the battery life. However, a major disadvantage of inductive charging are transmission losses (around 10%[196] or more), resulting from the distance between vehicle and the highway. Currently, efforts are made to optimise this distance; a conceivable approach would be an electronic ride control, which optimally adjusts the distance. According to automotive engineers of IAV, inductive charging will be ready for mass implementation in the next couple of years.[197]

That inductive charging works for electric vehicles has been demonstrated in Turin, Italy since 2003. In total, 23 buses are in operation, serving the city centre of Turin. The same system is used for electric buses in Lörrach, Germany, Lucerne, Switzerland and Genoa, Italy. Charging points are installed at the stations, each with the option to load two buses at the same time. While passengers are entering the bus, it waits a couple of minutes in order to recharge the battery for the next kilometres. Compared to trolley buses, inductive charging enables the buses to be flexible in their route.[198]

[194] See E.ON (2009).

[195] Aesthetic issues are often largely discussed, e.g. large concerns have been raised about the visual impact of windmills or about fine-particles sticker.

[196] See IAV (n.s.).

[197] See IAV (n.s.).

[198] See Conductix Wampfler (n.s.)

Picture 6-6: Inductively charged electric bus in Turin, Italy.

Source: Conductix Wampfler (n.s.)

6.5. Personal Aerial Vehicles

Science fiction writers and far-sighted engineers have incorporated personal flying machines for the use of the broader public since the early 1950s. Many people have developed ideas, but these failed due to a lack of adequate technology and business models. For several years, personal aerial vehicles (PAVs) have been discussed seriously by aviation engineers. Further, NASA has investigated concepts for personal air vehicles; the European Commission has also commissioned a study about ideas for the future of air transport, where PAVs are being discussed.[199]

Small aircrafts have already been developed that could be used as a kind of air taxi. Though none has reached commercialisation or even has been marketed. It's been generally recognised that the design of PAVs is not a problem; it is more likely that it will be possible to construct a PAV within this century. The major challenge of operating a system of large numbers of PAVs would not lie in constructing small personal aircrafts, but in operating them safely. To reach a safety level, the system requires efficient solutions to autonomous control, collision, avoidance and traffic management.

Unlike cars or current public transportation systems, PAVs would not require any large-scale facilities such as roads, rails, stations or airports, which are expensive to set-up and maintain. Moreover, by making use of the third dimension, they would avoid congested roads. But, concerns about fuel consumption, policing, licensing and regulation remain. Furthermore, it needs to be questioned under which circumstances users would accept PAVs and how they could be integrated into the existing transport system. Densely populated urban areas in particular would present a serious challenge. However, when discussing PAV it should be taken into account the helicopters and smaller aircraft for private usage are not a new phenomenon.

[199] See Truman, T. et al (2007).

6-1: Envisioned PAV designed by Prof. Dr. Gareth Padfield (left) and envisioned human machine interface (right).

6.6. CargoCap

CargoCap is “the fifth transportation alternative to the conventional systems of road, rail, air and water to transport goods fully automated through underground transport pipeline systems”[200] It is designed for freight transport in urban agglomerations, for long and regional distance traffic, up to 150 km. By being independent of other traffic infrastructure, traffic jams and weather conditions, CargoCap is a reliable and time saving alternative to existing freight options. So-called caps travel 24 hours a day in underground pipelines with a diameter of 2 metres, loaded with two euro-pallets each. Among the goods that are supposed to be transported are consumer and investment items, bulk goods, and cargo production components, building materials, parcels and express freight, as well as food and allied products.

Pipelines are designed similarly to those of drain-off sewage and are being installed in public streets next to, under, or above already existing supply and disposal lines, electric cables, metro or underground crossings and other underground constructions. By means of pipe jacking, pipes are being driven precisely to the centimetre several hundred metres or even kilometres via computer controlling; as a general law the depth will be 6 to 8 m. Transport pipelines will be equipped with tracks for the caps, contact free energy supply information technology, and also RFID transponders to locate the caps.[201]

Caps are locally emission free as they travel on rails through the underground pipeline system. Wheels at a constant speed of 36 km/h provide the drive electrically. The system is able to react flexibly to an increase of demand by grouping the single caps into collectives running close to each other. At their final destination, caps arrange themselves automatically into stations to be reloaded or unloaded.

Stations are located above ground or underground and serve as reloading points. These reloading points could be hubs on the outskirts where palletised goods are being reloaded by conventional modes of transport, such as lorries, to bring goods to their final destination. Further viable areas for distribution are city centres, industrial and commercial areas, as well as airports or logistics parks.

[200] CargoCap (n.s.).

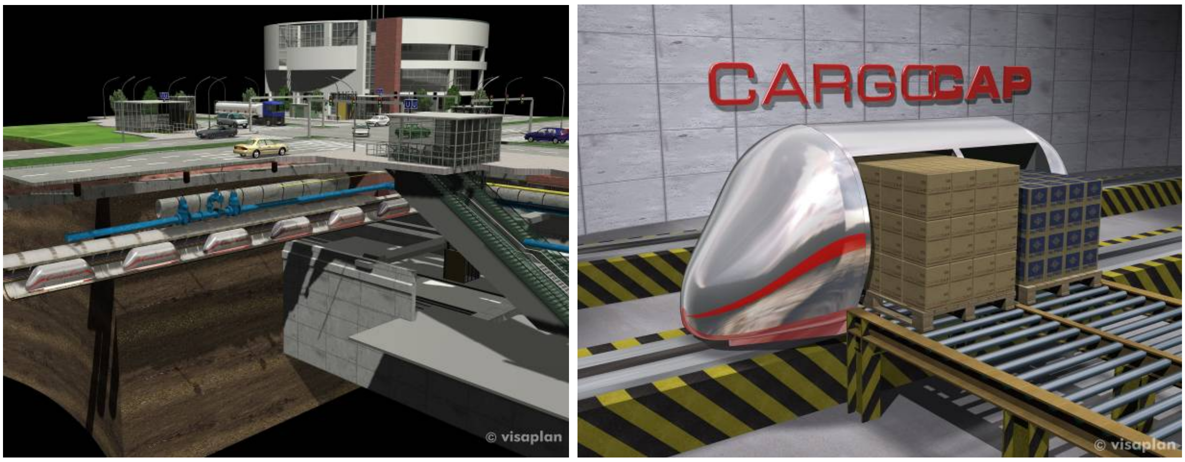
[201] See Kersting, M. et al (2004).

In future, it is also conceivable that goods could be delivered directly to households through underground pipelines. The use of euro pallets allows uncomplicated implementation into existing material flow systems.[202]

The theoretical and development work of CargoCap is based on the specific conditions of an 80 km long track through the Ruhr district. A test track has been developed, allowing examination of electrical and automation engineering, which would only be verifiable in real-life situations.[203]

The collaboration team claims that CargoCap has to be financially viable and feasible as a private enterprises' investment. According to a study, commissioned by the Ministry of Science and Research of the federal state of North Rhine Westphalia, low operating costs of CargoCap would - in the long run - compensate high investment costs. Total costs of conventional transportation via trucks and those for CargoCap do not differ much and can be seen equivalently.[204] However, it is difficult to assess long-term effects of new technologies for an economy, especially since transport systems are not static systems.

Figure 6-2: CargoCap underground pipelines (left) and loading ramp (right).



Source: www.cargocap.com

6.7. Conclusions

Several rather visionary technologies and concepts for the transport system were mentioned in this chapter. Some approaches have been dreamed of for decades, but technology wasn't mature enough. Other approaches might be familiar from different uses, but so far haven't been implemented in the urban context. Others have been tested in first demonstrations and seem not to be too far away from real-life application.

However, the examples should illustrate that new technology options are indeed imaginable and discussed among experts. The transport system is not static; it has always changed. These changes have been coined by the introduction of new technologies. The examples indicate that more changes might appear in the future.

[202] See Kersting, M. et al (2004).

[203] See Stein, D. (2002).

[204] See Ministerium für Wissenschaft und Forschung des Landes Nordrhein-Westfalen (2005).

7. Visions on Urban Transport: Examples from European Cities

Visions, paradigms (or "Leitbilder") are a central element of transport planning and play a significant role in the improvement of urban transport systems. They present the strategic direction for future developments by providing principles and guidelines for administrations, citizens and politicians. Transport-related visions can bring together an understanding of the challenges in relation to territorial priorities and are a useful instrument for mobilising different actors involved in a certain process, e.g. to bring new forward technologies, such as EVs. Visions outline explicitly, or at least implicitly, one or several goals which should be achieved. In doing so, they provide points of orientation for different actors; they can serve as a platform or a framework for integrating the activities of different actors. Due to changing social interests, visions are not fixed, but will change over time. [205]

It can be observed that, over recent decades, different transport-related visions have influenced the European transport system. Between the mid 1950s and mid 1970s, as car ownership and traffic volumes grew, the "car-friendly city" was the dominant vision of transportation planning in most European cities. Urban motorways with few intersections were built, streets widened and efforts made to strongly separate road-based traffic and pedestrians (e.g. by constructing road and pedestrian bridges or pedestrian subways in various types). Between the mid and late 1970s environmental concerns were rising. The Club of Rome and its 1972-published report "Limits to growth" gave rise to a continuing change of awareness. Rising concerns about negative impacts of transport, followed by the introduction of new technologies, gave rise to several structural changes in the transportation planning system. In the 1980s the vision of deregulation became dominant. With the formulation of the first common transport policy of the European Commission in the 1980s, the era was characterised by strong privatisation moves, gradual liberalisation of transport service provisions and a strong (and ever increasing) reliance on technology to solve problems.[206] In the 1990s, recommendations of policy interventions to integrate transport services and systems through technological progress were formulated.[207] Since then, the vision of the "sustainable city" has been rising. The traditional "predict and provide"[208] approach seemed no longer to be an option, since negative impacts had still not been solved and financial constraints gave administrations only limited means to materially provide for the predicted growth. Achieving "sustainable mobility" is still the goal of many European cities; tools are being introduced and increasingly also applied to reach this goal. In general, a strong focus is placed on an attractive public transport system and measures to promote cycling and walking.

In this section, we will therefore illustrate some examples of how several European cities anticipate and plan future developments in transport. We will consider plans, visions and concepts that are available in English and will compare them in relation to the ascribed role of existing and emerging technologies, the role of organisational innovation and to statements related to the anticipated development of demand patterns and user behaviour.

[205] See Hodson, M. et al. (2010).

[206] See Giannopoulos, G. (2003).

[207] See CEC (2001).

[208] Viegas (2008).

7.1. Copenhagen

Copenhagen is the capital and largest city of Denmark. With an urban population of 1,000,000 inhabitants (Copenhagen Metropolitan Area) it is one of the most densely populated areas in Northern Europe. Copenhagen's transport policy favours explicitly public transport, cycling and walking and gives restrictions to private cars, in order to have less air-pollution, accidents, CO_2 emissions and noise. However, since 1991, car traffic from trips crossing the city boundary is increasing 2% per year, but is decreasing within the city centre. In contrast, for bicycle traffic the exact opposite is happening.

The City of Copenhagen is widely known as the city of cyclists. Cycling in Copenhagen has a longstanding tradition; it is socially accepted and is practiced in all walks of life. It is Copenhagen's planning objective that bicycles are to play a central role in city traffic.[209] Cyclists travel a total of 1.2 million km by bike every day. There are a total of 350 km of cycle tracks and 40 km of green cycle routes in Copenhagen. Today, already 37% of those working or studying in Copenhagen cycle every day. The city has set itself several concrete goals in the time-horizon 2015: at least 50% of commuters shall choose to cycle to their place of work or education (in order to be able to save an additional 80,000 tons of CO_2 per year[210]), seriously injured cyclists shall drop by more than half compared to today and at least 80% of Copenhagen cyclists shall feel safe.[211]

Copenhagen has implemented access restrictions for private cars in inner-city areas through a mandatory particle filter for heavy vehicles older than four years and relatively high parking charges (up to €3.5/h). Further, city congestion charging similar to Stockholm and London are being discussed but not yet implemented.[212]

Copenhagen has an extensive public transport network including buses, metro lines and a Suburban-train (S-train) railway system. All residents live within 350 meters of public transport services. Nevertheless, Copenhagen has put forward a proposal to strengthen the use of ITS for improved passenger information, to improve the S-train rails and to expand the public transport network (especially rail-bound systems), as well as significant expansion of P&R and B&R facilities.[213]

7.2. Stockholm

The City of Stockholm is the capital of Sweden. Approximately 830,000 people live in the City of Stockholm and about two million in the larger metropolitan area. The city attracts international businesses, investments and tourists and is a national centre for research and development and the main driver of the national economy. As with many other large European regions, Stockholm is growing in terms of population, but also geographically and as a global marketplace, putting additional pressure on the transport system. The Regional Development Plan for the Stockholm Region (RUFS 2010) is based on the vision to become Europe's most attractive metropolitan region. The document is based on the overall principle that planning "is all about people".[214]

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[209] See The City of Copenhagen, Building and Construction Administration, Roads and Parks Department (2002).

[210] See The City of Copenhagen (2008).

[211] See Tørsløv, N. (2009).

[212] See Tørsløv, N. (2009).

[213] See The Capital Region of Denmark (2008).

[214] Regionalplanekontoret (2009).

The Stockholm Environment Programme replicates the vision of Stockholm as the most attractive city, mentioning explicitly the challenges regarding transportation. The intermediate goals for the city administration are to reduce the environmental impact of transport and to have only green cars in its fleet, being fuelled to 85% by renewable fuels.[215] The Stockholm Action Plan for Climate and Energy 2010-2020 (2010) is a very precise document, including a variety of conceivable measures for all modes of transport.[216]

Stockholm region is already characterised by a high degree of public transportation usage due to its extensive network of public transport. 61% of people passing the toll point are using public transport.[217] There exists a common ticket system across the entire region, allowing seamless and easy travel between different modes (metro, bus, tram, s-train and inner-city boats). Stockholm Public Transport is working to increase public transport through information strategies and increasing the frequency of services.[218] RUFS 2010 aims to increase the market shares of public transport. Therefore, more park & ride facilities are needed and an expansion of the rail facilities and (as a long-term vision) dedicated tracks for commuter trains to allow driverless systems will be provided. Moreover, cross-city connections for public transport are required to offer an alternative to the car. [219]

By 2050, the Stockholm region aims to derive all energy from renewable resources. For the transport sector, more energy-efficient and resource-efficient transport shall be stimulated by various incentives and instruments. Since the 1990s, the City of Stockholm, in close cooperation with manufacturers and retailers, has aimed to increase the number of clean vehicles on the roads. 25,000 cars in Stockholm are “green”. Since 2008, the city has been involved in setting up infrastructure for electric cars and testing of hybrid vehicles that can be driven on different fuels. Stockholm Public Transport (SL) has the world’s largest fleet of ethanol buses; almost 75% of public transport runs on renewable energy (for rail bound traffic it is 100%). The goal is to have all public transport fossil-free by 2025.[220]

[215] See City of Stockholm Executive Office (2008).

[216] See City of Stockholm (2010).

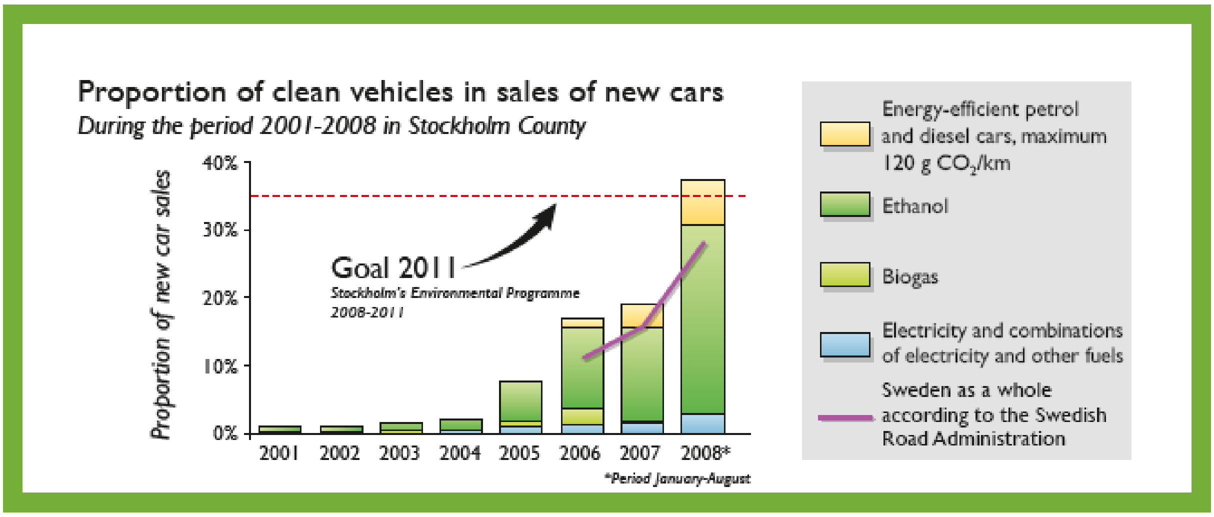
[217] See City of Stockholm Executive Office (2008) .

[218] See Stockholm Stad (2010).

[219] See Regionalplanekontoret (2009).

[220] See Stockholm Stad (2010).

Figure 7-1: Proportion of clean vehicles in sales of new cars in Stockholm.



Source: Stockholm Stad (n.s.)

In 2007, a congestion tax was introduced in the city centre of Stockholm. Since then, traffic to and from the city declined by nearly 20% and queuing times have decreased by 30 to 50%. Before introducing the tax, it was the subject of controversial discussions and many people opposed it. Now, however, since the system proved to work well and the number of cars in the city centre has declined, a majority of Stockholmers are positive about it. The congestion tax is applicable to cars registered in Sweden, driving in and around Stockholm between 6 a.m. and 6.30 p.m. on regular working days and cost a maximum amount of €6 per day. Cars are automatically registered at payment stations.[221]

7.3. Karlsruhe

Karlsruhe is a city in southwest Germany, close to the French border with a total population of 290,000 inhabitants. In 2006, the city developed Master Plan 2015, which aims to outline perspectives on how to develop Karlsruhe until 2015 and beyond. Citizens, politicians, the administration, different institutions and associations have been involved to bring in their specific visions and ideas of Karlsruhe in the year 2015. An important project of Master Plan 2015 is the provision of a transport development plan. It will point out possible measures available, allowing sustainable transport while considering economic development. It will be finalised by the end of 2010, but development paradigms have already been characterised and a condition analysis has been accomplished.[222] The transport development plan is seen as a framework for the envisioned development of the transport system in Karlsruhe for the coming 10 to 15 years. It takes into account all modes of transport, the city's urban structure, environmental aspects and equal opportunities for all in view of mobility.

Cycling has increasingly gained importance in Karlsruhe. The city has set itself the ambitious goal to become cycling-city number one in South-Germany by 2015. Therefore, a 20-point programme has been adopted. The programme includes the extension of cycling routes as well as safety aspects and accompanying marketing-measures to encourage more cycling.

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[221] See Stockholm Stad (2010).

[222] See Stadt Karlsruhe, Stadtplanungsamt (2008).

Particularly at district level, walking is given high relevance. In order to guarantee high quality of public space, improvements are necessary in areas where much space is designated to motorised traffic (moving and stationary) and where high speed is allowed.[223]

Public transport enjoys relatively popularity in Karlsruhe (in 2002, 18% of routes were covered by public transport). The backbone of the public transport system is the tram, which is able to handle the 750 Volts DC tram environment as well as the German rail 15,000 Volts AC system. This ensures fast connections from the suburban regions into the city centre, often without the need for interchange. Condition analysis for motorised transport has shown that the traffic situation is satisfactory.[224]

7.4. Vienna

The City of Vienna is the capital city of the Republic of Austria. With its 1.7 million inhabitants it is the largest city of Austria. The number of travellers using public transport, bicycles or foot rose from 60% (in 1993) to 68% in 2007. The City's aim is it to have covered 75% of inner city transport by sustainable modes in 2020.[225]

The City of Vienna develops its traffic and transport concept every ten years, the most recent concept has been set up in 2003. The 2003 transport master plan has been defined by the municipality and external experts and in dialogue with citizens. It is summarised under the term "Intelligent mobility – intelligence on the move". The master plan is based on two strategies:

- Traffic reduction (through land-use strategies, by promoting local shopping or by allowing working and housing in close proximity, length and numbers of trips shall be reduced);
- Modal shift towards more sustainable modes of transport (by changing behaviour patterns and/or by innovations in procedures, organisation, implementation, infrastructure and technology).

In Vienna, mobility management measures and increase in awareness are seen as of utmost importance. These measures include management of and between different transport systems, information on users, and communication between the transport users and operators and the range of mobility-related services.[226] In contrast to other transport strategies, the implementation of specific technology-related measures is not mentioned explicitly.

Similarly to Copenhagen, Vienna's reasons for setting up its transport objectives in this manner are less noise and accidents, better air-quality and more room for activities in public spaces. To achieve these objectives, Vienna has pledged to further improve its public transport system. Priority is given to all trams and buses. A further increase in the density of stops on the Vienna regional rail network and the expansion of the rail network, with trans-regional effects, is aspired. On top of that, all of Vienna's buses are using LPG engines.

[223] See ibid.

[224] See ibid.

[225] See Vienna City Administration (2008).

[226] See Vienna City Administration (2003).

Other key projects have been set up to increase the share of bike traffic and walking. Therefore, the expansion of the bicycle lane network is giving priority and the number of bike racks will be increased. In the next few years, special attention will be paid to shopping traffic by bike as well as to encouraging young people to use bikes more. Several small scale measures are being implemented to improve the walking quality, such as lowering and widening pavements (to at least two metres) or longer green light phases.[227]

7.5. Budapest

Budapest is the capital and largest city of Hungary, having 1.7 million inhabitants. Like many other European cities, the urban structure of Budapest was developed before the time of the car. Moreover, the expansion of Budapest took place in a time when automobiles were not desirable, due to the limitations of personal freedom. As a result, Budapest is not developed for the existing increase in the need for mobility. The transport network of Budapest has not been expanded strategically in the past 25 years, nor has the technology of transport kept up with the changes Budapest has experienced.[228]

The major long-term urban transport policy objectives are to protect the environment and to ensure economic growth and social development. A mobility strategy has been initiated that is based on the development of public transport, improvements for non-motorised traffic and balancing motorised traffic as well as on decreasing the need for mobility.[229] The development plan intends to create a transport system that improves "liveability" while ensuring the competitiveness of the region by taking into account operability, effectiveness and financing aspects. A very important issue is seen in the harmonisation of transport policies. Harmonisation will encompass the institutional, spatial and transport environments.[230]

The plan gives priority to the strategic improvement of public transport by increasing its quality and organising it into a network, including suitable linking of urban and suburban transport as well as unifying tariffs and information systems for all service providers. Further measures are being implemented to restrain automobile traffic. The development of the road network is to be justified by the development of the spatial structure. One of the most crucial tasks is seen in the reform of parking policies and infrastructure, since it is seen as a fundamental instrument of controlling automobile use. Users will be charged for parking in the city centre, but park & ride facilities will be provided in the outskirts. Another key feature is the reforming of the institutional background of transport by increasing the power of the transport authorities and by forming a lasting structure of financing. [231]

[227] See Vienna City Administration (2008).

[228] See FKT. URB. KONZORCIUM (2009).

[229] See Krzyxkowska, G. (2004).

[230] See FKT. URB. KONZORCIUM (2009).

[231] See ibid.

7.6. Kraków

The historic City of Kraków is located in southern Poland. With 760,000 inhabitants, it is one of the biggest cities in Poland. For several years, Kraków has focused on the drastic transformation of its industry, towards innovative and efficient technologies. The city development strategy envisages that Kraków establishes itself as a centre of culture, science and as a university city, where the economic activity is very strong and tourism growing.

Public transportation has – as in many other Central and Eastern European Cities – a relatively high share in modal split (around 60% of all routes are being covered by public transport), though car ownership is growing. Today, road infrastructure and the introduction of a high-quality and passenger-friendly public transport are the most important issues on the political agenda. Key priorities for transport policy are bus lanes, tram tracks, efficient traffic control allowing for priority and reliability of public transport as well as access restrictions to the old city centre. Kraków was the first city in Poland to adopt a transport policy of this nature.[232]

Among the most important measures for implementation of the policy are the modernisation of public transport vehicles (new vehicles with alternative fuels, vehicles meeting European emission standards) and the improvement of transport services, such as integrated tickets, real-time information at public transport stations and demand-responsive transport to serve less populated districts. As the first city in Poland, Kraków has introduced a bike-sharing system with cycle racks installed near bus/tram stops. It is seen as an integrated multi-modal approach, to promote the combined use of different modes of transport, especially within the historical city centre. In this sense, a feasibility study was conducted for setting-up a car-sharing scheme for Kraków, taking socio-economic as well as political conditions into account. The study came to the conclusion that car-sharing should be developed and implemented in the coming years. To communicate improvements and to inform about alternatives to the car, the City of Kraków has developed an integrated and extensive marketing concept, especially focusing on children and youth.

7.7. Ljubljana

Ljubljana is the capital city of Slovenia and is, with 275,000 inhabitants, one of the smallest European capital cities. Its geographic position is at a crossroad between Western Europe, the Balkans and the Mediterranean, and is thus influenced by cultural diversity. Steady traffic growth and increasing numbers of commuters contribute to air pollution, congestion problems and decreases in the quality of living. Ljubljana is currently working with CIVITAS in order to reverse these negative trends and to make Ljubljana more sustainable.[233]

[232] See Civitas Caravel (2009).

[233] See Civitas Initiative (2009)

The main objective of Ljubljana in terms of transport development is the improvement of modal shift towards more use of public transport and significant reductions in motorised traffic. Modernising the bus fleet is seen as highly important to make public transport more comfortable and efficient for passengers. By purchasing 27 hybrid buses, Ljubljana wants to promote clean and energy efficient technology and demonstrate the emission saving potential of hybrid vehicles. Another objective is to create an integrated e-ticketing system which will enable passengers to travel with one ticket in different modes of transport. The system will use contact-less smart card technology.

Concerning cycling, Ljubljana will set up a comprehensive cycling strategy to increase the percentage of journeys by bicycle by 20% until 2013. In order to bring forward the use of bicycles, training will be conducted to teach participants how to cycle safely. Further, the municipal government offers bicycle rentals from various locations in the summer months. Though the scheme is primarily targeted at tourists rather than residents, it is planned to increase the network of locations and the number of bicycles, since it has proven very successful.

Ljubljana aims to be among the first cities to implement a congestion-charging scheme in order to reduce car traffic in the city. How the scheme will ultimately look is currently being discussed. However, it is anticipated that there will be a reduction of personal car traffic by 70% in the city centre.[234]

7.8. Conclusions

Governments have a leading role in formulating frameworks in which transport is to be developed. In particular, at the local level it is possible to include stakeholders and citizens in the development of visions and paradigms for the agglomerations they live and act in. By inspiring new strategic directions for future developments, governments constitute essential conditions for objectives and, to a certain degree, people act in accordance with these conditions. In line with Bertolini, L. et al (2008), transportation planning “is a discipline in the midst of a paradigmatic transition”[235] in the sense that transport is currently passing through a transition phase into growing interest in sustainable transport.

Even though the outlined visions cannot be seen as representative, they outline the emergence of new planning goals. Achieving sustainable mobility, liveability, and high quality cities while ensuring economic growth is in many places seen as priority. In other words, it is the avowed goal to offer more (accessibility, services, and social contacts) with less negative impact. Three main clusters of measures are applied to and increasingly introduced to achieve these goals: supply-oriented measures, regulatory-measures and demand-oriented measures[236]. Of course, all three clusters are mutually dependent and complement each other:

- Supply-oriented measures comprise actions aiming to change users’ behaviour of transport by changing the quantity or quality of the available transport infrastructure. Measures include the expansion of infrastructure (for all modes: road, public transport and cycling), the use of technology (mostly ICT), the modernization of vehicle fleets (both, in terms of fuels and performance), as well as giving priority to public transport.

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[234] See http://www.ljubljana.si/en/living-in-ljubljana/focus/67042/detail.html

[235] Bertolini, L. et al (2008).

[236] Following Vieira, J. et al (2007) and extended by Maffii, S. et al (2009)

- Regulatory-measures comprise actions aiming to change users' behaviour of transport by defining or changing sets of rules. Measures include stringent parking policy and congestion charging (even though it is not implemented in many sites, it is often discussed).
- Demand-oriented measures comprise actions aiming to change users' behaviour before the emergence of traffic demand. Measures include information and communication of sustainable transport modes (e.g. by the integration of fare structures or real-time information for public transport), coordinating activities of different partners and organising services. Those measures are being implemented in order to enhance the effectiveness of supply-oriented measures.

Tools have definitely differentiated over the past decades and there is large support for the emergence of sustainable transport. Supply-oriented measures are increasingly focused on sustainable transportation modes and the implementation of demand-oriented measures can be seen as indicators for a paradigm shift in transportation planning. But, effective implementations of those tools need the encouragement and engagement of different stakeholders to support the policy behind it and bring innovative ideas and initiatives forward.[237]

[237] See Banister, D. (2008)

8. Concluding remarks

Deliverable two is an interim report of an ongoing STOA project on technology options for urban transport. At the heart of the report are technologies and concepts that already exist or are emerging. Most of these approaches are considered as having the potential to change urban transport and, thus, to become relevant for a transition to a more sustainable urban transport system.

It was highlighted in the report that transport is not a static system but is characterised by constant changes and, sometimes, by trend-breaking, radical innovations. Recently, with respect to technologies, major contributors to changes that are anticipated or already observable, are developments in two technological work strands:

- Information and communication technologies are penetrating all areas of daily life and are also becoming increasingly indispensable in the transport sector;
- Alternative fuels and propulsion technologies are expected to substitute fossil fuels in future.

In addition to these technological developments, new businesses concepts are emerging that are both enabled by new technologies and are themselves enablers for technological advancement. In particular, the development of ICT technologies supports new concepts and business models for “individualised collective” forms of transport, such as car sharing, car-pooling or bike-sharing. The public transport system also profits strongly from ICT applications since they enable easier access to vehicles by handy ticketing, or easy access to information by mobile internet – at least for those societal groups that are familiar with mobile phones and the Internet. On the other hand, new business models, such as car-sharing, are supposed to support the market penetration of new fuels and propulsion technologies. This is because they are intended to allow users to select, from the car-sharing fleet, vehicles appropriate for specific purposes. For example, a battery electric car could be chosen for trips in the city and a conventional vehicle, or a vehicle with range extender, could be chosen for longer distances. It is documented in this report that car-sharing organisations are continuously growing and are becoming more and more professional in Europe. Recently, with Car2go run by Daimler and Mu run by Peugeot, well-established car manufactures have begun to enter the scene with ambitious concepts - based on advanced ICT applications.

When considering the transport development plans or city development plans of European cities, it becomes obvious that technologies play a crucial role in the visions of sustainable urban transport futures. Approaches, which are rather simple in terms of technology, are however, still considered as being important in efforts to make urban transport more sustainable. Amongst such approaches is the construction of cycle lanes, pedestrian networks or pedestrian areas in inner cities. The European Cities vary a lot regarding the infrastructure they provide for cyclists and pedestrians. This also reflects very different user habits and mobility patterns in European countries; a fact that has to be addressed in the next phases of the project.

In the mid to long-term, it can be expected that technologies, which challenge established technology-infrastructure systems will become increasingly relevant. It surely cannot be predicted which technologies these might be; however a couple of approaches that are discussed in more visionary contexts are also described in the report at hand. Examples are the cargo caps, the aerial ropeway and personal air vehicles. For the latter, in particular, it is not at all clear if they can make a contribution to sustainable urban transport.

The example of the personal air vehicles illustrates that, for governing a transition to sustainable transport, it is crucial to have a profound assessment of the potential impacts of the technologies on society, the economy and the environment. Undoubtedly, such an assessment should be carried out at an early stage of technology development, before the technology is established. For most of the “visionary” more unconventional approaches, only limited technology assessment is currently available.

The deliverable at hand clearly has focussed on the supply aspect of urban transport systems. It placed technologies and mobility services for urban transport, as well as related challenges and visions, at the heart of the analysis. In phase three of the project, barriers and success factors for innovative pathways to sustainable urban transport will be analysed. The idea is to elaborate on how the paradigm of sustainable urban transport could materialise in different urban contexts. In doing so, the work will be closely connected to the present report. But we will place a stronger focus on the framework conditions for successful implementation of approaches supporting a transition to more sustainable urban transport systems. Furthermore, in this phase, particular emphasis will be placed on the demand side. This will be done by analysing literature in relation to the role of the users. On this basis, an analytical framework will be developed for the empirical research to be carried out in phase four of the project, where perceptions and attitudes of specific user groups, in relation to selected innovation pathways, will be analysed. The project closes with the final report in December 2011.

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List of abbreviations

BEV	Battery Electric Vehicle
BRT	Bus Rapid Transport
CNG	Compressed Natural Gas
GHG	Greenhouse Gas
HEV	Hybrid Electric Vehicle
ICE	Internal Combustion Engine
ICT	Information and Communication Technology
ITS	Intelligent Transport System
Li-Ion	Lithium Ion
LEV	Light Electric Vehicle
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
NFC	Near Field Communication
Pedelec	Pedal Electric Cycle
PEV	Plug-In Electric Vehicle
RFID	Radio Frequency Identification
PEM	Polymer Electrolyte Membrane
V2G	Vehicle-to-Grid
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle