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An Evaluation of Mobility Trends until 2030 under the Aspect of Sustainability

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ABSTRACT

The public is more and more demanding sustainable solutions. In case of mobility, consumers have experienced turbulent years regarding the change in economic stability, showing it in rapidly changing fuel prices, energy costs, or in general, prices for any goods and resources. Mobility and the ability to stay mobile is a driver for today's economy. People move to go to their work, goods and resources move around the globe to reach their customers. Thinking of restricted mobility capabilities may constitute an unpleasant scenario with serious consequences to common wealth. It is thus not surprising that the call for sustainable mobility, new concepts and technologies that are environmental friendly, economical and respect social values is more evident than ever. This paper discusses some of the current trends for mobility with a focus on their potential sustainable performance.

Key words: Sustainability indicator, Urban Transportation, Sustainable Transportation
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INTRODUCTION

Mobility is one of the pillars of today's society with a strong link to the development of mankind (Fahrzeugtechnik, 1991). It enables the distribution of resources such as people, goods, ideas, information and concepts (Canzler, 2009). More than ever before the modern society is a society on the move (Lash & Urry, 1994); hence the role of mobility is increasing. Canzler describes the world as "…a world of flows"; and further "…capitals, goods, working forces, knowledge and signs flow around the globe" (Canzler, 2009). This development manifests itself in the process of globalization (Lash & Urry, 1994). The basic etymologic meaning of the term mobility derives from the Latin word mobiles, meaning moveable (Petschenig, 1965). Close to that, the most general modern definition of mobility according to Kaufmann is movement in real or virtual spaces of people and objects (Kaufmann, 2002). This definition is taken in this paper too, as the authors believe it is an appropriate, general definition since other definitions of mobility refer to a specific type of mobility (Canzler, 2009). Overcoming as much distance as possible in a short time plays the key role in the process of mobility (Maurer, 2000). New inventions and innovations in the field of transportation systems shall enhance fast and safe mobility (Lash & Urry, 1994). The huge need for mobility induces many negative side effects that threaten the ecological, social and economical environment (Weinreich, 2004) such as traffic related costs and accidents, environmental pollution or land occupation (Hall, 2004). Based on Mobility and Traffic in the 21st Century (Mayinger, 2001), driving forces for the rising need of mobility can be grouped as follows:

Economical forces: Through mobility, the distribution of resources and products (Fahrzeugtechnik, 1991) as well as the division and specialization of labor (Mayinger, 2001) becomes possible. Due to globalization, the exchange of many different goods is increasing (Lachmann, Haupt, & Farmer, 2005) and therefore the need for mobility is increasing too. Mobility can be seen as the root for globalization, and vice versus, globalization can be seen as the root for enhancements and innovations in transportation systems.

Growing Affluence: In fast developing regions like China and India the demand for mobility is increasing very fast too. The demand for advanced mobility is rising on a global level; no significant decrease can be observed.

Technology: Technology has enabled the upswing of mobility and has made possible to reach almost any place at

any time (Mayinger, 2001). Nowadays, technologies enabling sustainable ways of mobility and traffic are highly demanded (Jolley, 2006).

Settlement Structure: Due to urbanization, new concepts of transportation have to be found in order to handle more and more people moving in city areas.

Demographical forces: The demographic structure influences the need for mobility. In this context, literature states the importance of factors such as age, gender, education, household size or profession. However, the interaction of these factors is of complex nature (Mayinger, 2001).

Political forces: Politicians have the responsibility to set general conditions for the population (Mayinger, 2001). They can control and guide mobility and the traffic system by the measures they set, such as taxes, laws or regulations.

Culture: Culture influences the attitude towards mobility even if it is hard to quantify. Not only the need for mobility itself but also the choice for a particular mean of transportation may have cultural influences (Mayinger, 2001). There are only a few papers about world wide traffic statistics, a very detailed work is by Schafer (Schafer, 1998). Although from 1997, it is considered as a fundamental work in this field. Later papers, such as the ones from the World Business Council for Sustainable Development, are based on it. The statistics derived by Schafer shows that the average kilometers moved per person per year vary in a range of less than thousand kilometers in parts of Asia and Africa up to 15000 in Central Europe, Australia and Japan and up to 22500km in Northern America (Schafer, 1998). Further, data from Schafer shows that especially in those parts of the world that suffer from high traffic volumes, the car is the most important transportation mode. The share for each transport mode on global level for passenger transportation is: Cars 60%, buses 25%, trains 7% and air 8% (Schafer, 1998). The proportion of the modal split of freight transport is similar to that with the difference that also water transportation plays an important role (Larsson, 2009). Due to the fact that under ecological and economic aspects, conventional cars are not considered a sustainable way of transportation (Laffel, 2006), it is necessary to make public transport more attractive and to improve the sustainability of all means of transport. Air traffic has become a very important factor because the emissions of air traffic have nearly doubled between 1990 and 2003 in Europe (Linke, 2007). Although there is a much slower increase in European air traffic over the last few years , air traffic in other regions is increasing very fast. There is still a lot of potential to increase the efficiency of air traffic (Bettex, 2010). Having in mind that there are severe differences between traffic systems in the United States or European countries and those of developing countries, this paper is focusing on European traffic systems because they often serve as a model for developing countries. In the spotlight of the many negative side effects of mobility, the aspect of sustainability in transportation is getting more and more relevance (Weinreich, 2004), (Hall, 2004). This paper analyses existing trends in mobility with regard to sustainability aspects.

Trends then and now

The term trend has become popular during the 90s (Cannas, 2008). A trend is basically an "…observable movement into a certain direction" (Schnitzler, 2005). Trends can be classified in short-, middle- and long-term developments (Schnitzler, 2005). The paper focuses on middle- and long-term trends bearing in mind that it is difficult to predict how long an upcoming trend will last. Modern trend research is trying to find links between the past and the future. Due the future oriented character of trends, there are many uncertainties regarding the survival of a trend and its acceptance by public. In order to reduce those uncertainties in the analysis, this paper focuses on developments of big companies (e.g. Peugeot, Siemens or Doppelmayr), universities (e.g. TU Delft, MIT, Tokai University) or concepts that are already in use. There have always been visions of mobility and traffic systems. Finding out which trends have become reality and the reasons for their success is a chance to spot and overcome the barriers for the realization of current traffic concepts. Ziegler and Klemm published a book in 1972 where they summarized trends in transportation of the sixties and seventies (Ziegler, 1972). By comparing those trends of the past with recent developments it becomes obvious that a lot of ideas were existing since more than 50 years. There are several concepts which can also be found in today's visions, most important among them new flexible railway systems, combinations of railway systems and cars, electric cars or maglev trains (Ziegler, 1972). Most of those visions have not been implemented until now. The reason therefore is that many of these concepts often need a complete new infrastructure; it is thus economical beneficial to enlarge and improve existing infrastructure than building a new one (Wichser, 2011). Current trends are grouped into those for road traffic, rail transportation, water transportation and aviation. This is common in works dealing with traffic and mobility (Gudmundsson & Hojer, 1996). Some of the concepts discussed in the following are already in use and others are in an early stage of their development and may or may not become reality.

Road traffic: Most trends for road traffic are currently trying to reduce or avoid the use of fossil fuels. Two main approaches can be observed: electric vehicles and hydrogen cars. Especially electric cars are nearly ready for application (Brauner, 2011), although further improvements concerning the battery and the infrastructure are necessary . Other trends in road traffic are addressing the problem of urban and suburban transportation. Urban vehicles are becoming smaller (e.g. Peugeot-Ozone (Eaton, 2008)) in order to reduce the energy consumption. For suburban transportation, the combination of rail transportation and cars seems to be a hot topic (e.g. Monorail Cars (Stephan, Miller, Pacheco, & Davis, 2003)). Advanced car sharing concepts are also a promising trend for urban areas with high chances of implementation. Some of these concepts foresee the integration of cars into a smart grid system.

Rail transportation and cable cars: Trains and railways are not flexible concerning destinations (Ilgmann, 2007). Some approaches try to improve the flexibility of railway systems. One of those concepts is the RailCab which consists of small flexible units, which are automatically controlled. Another approach is the Punktbahn, which is created for suburban areas and has vehicles for about 70 people. The vehicles are driving on a track above the ground . A complete different trend is maglev trains driving through vacuum

tunnels. Such a system could reach up to 20.000 km/h (Hoffman, 2004). For urban areas with a very high population density, cable cars and cable liners are also considered as a sustainable alternative public mean of transportation. Further Shweeb developed a concept for a monorail bicycle system with tracks above the ground for bicycle capsules (Fisher, 2010).

Water transportation: There are many new auxiliary water transportation systems, which are reducing the fuel consumption of ships. There are systems that use the energy of the wind by using kites or solar ships (Müller & Knierim, 2010). Another approach is the use of waves in order to generate propulsion (Geoghegan, 2008). A different concept can be found in Ground-Effect Crafts, which use the fact that the rate between lift and drag is much higher near the ground. They suppose to close the gap between ships and aircrafts.

Aviation: One approach is to improve current airplanes. The ambitious goal of these concepts is to achieve reduction of fuel consumption up to 70% (Bettex, 2010) by e.g. light weight design, the use of new materials, improved aerodynamics or advanced propulsion systems. Another new concept is the Cruiser/Feeder system. There are cruisers, which are flying in stable routes in high altitudes and feeders, which are transporting passengers from the airport to the cruiser airplanes. Further, there is a trend to the re-launch of airships since new technologies can make them safer and more reliable. Airships can also carry high loads in an efficient and fast way (Dorminey, 2011).

Sustainability in transportation systems

The term sustainability is best defined in the Brundtland report where it describes a development that "…meets the needs of the present without compromising the ability of future generations to meet their own needs (Linke, 2007). Another common definition is by the International Institute for Sustainable Development: "Environmental, economical and social well-being for today and tomorrow". In order to evaluate the trends discussed in this paper as to their sustainable performance, indicators which are able to qualify and quantify the environmental, economical and social well-being are necessary. Literature proposes a great many indicators for particular aspects of sustainability (e.g. only environment or only economic). Some indicators have also been developed specifically for transport systems, but do not consider necessarily sustainability aspects. In an attempt to bring together relevant indicators for the evaluation of sustainability performance of transportation systems, following list of indicators have been derived through literature research:

1. Economical indicators:
   - Costs of production/implementation (Jeon & Amekudzi, 2005),
   - Affordability in using the transport system (Richardson, 2005)
   - Economic efficiency (Jeon & Amekudzi, 2005), (Castillo & Pitfield, 2010)
2. Environmental indicators:
   - Emissions and pollution (Jeon & Amekudzi, 2005), (Gilbert, Irwin, Hollingworth, & Blais, 2002)
   - Energy consumption during production and use (Gilbert et al., 2002), (Borken, 2003)
   - Occupation of land , (Richardson, 2005), (Gilbert et al., 2002), (Nicolas, Pochet, & Poimboeuf, 2003)
3. Social indicators:
   - Changes in demography and settlement structure (Jeon & Amekudzi, 2005), (Richardson, 2005)
   - Safety (the probability that an individual will be killed or injured in an accident (Mayinger, 2001)) (Jeon & Amekudzi, 2005), (Richardson, 2005), (Gilbert et al., 2002)
4. Others:
   - Reliability (Hall, 2004)
   - Travel time (Hall, 2004)

The discussed trends in this paper are evaluated in the following by considering the indicators above.

ROAD TRAFFIC

Economical indicators: Currently, electrical cars are the most discussed topic concerning road traffic. The costs for the use are lower than for conventional cars because of the cheaper maintenance. Also, electricity is (currently) cheaper than fuel (Lindner, 2008). However, the purchase of an electrical car is currently much more expensive than buying a conventional car, mainly because of expensive batteries (Van Vliet, Brouwer, Kuramochi, Van den Broek, & Faaij, 2010). Hydrogen cars are also a very current topic, but the production of hydrogen fuel out of renewable energy, which is the basis for a sustainable alternative to conventional cars, is very expensive (about 18€/100km (Linnemann & Steinberger-Wilckens, 2007)). Car sharing is a cheap alternative especially in urban areas. It is not necessary to pay for the purchase; taxes and insurance fees are only paid upon use of the car. Introducing a combination of cars and railways like the monorail concept is very expensive because of the high costs for building completely new tracks and stations. But such a system might have economical long-term advantages because the small cars are not expensive in production and use (Jensen, 2004).

Environmental indicators: Road traffic in comparison to other means of transport, is very energy-intensive; not only due to operation but also in the production of vehicles (Weirich, 2008). The technology of electrical propulsion and hydrogen, which is the basis for most new concepts, is depending on how hydrogen and electrical energy are produced. Under the aspect of occupying land, road traffic is covering huge areas (in Germany about 4,5% of the country's area and in Austria about 2,5% (Linke, 2007)), especially in cities.

Social indicators: Regarding changes in demography and settlement structure (urbanization) road traffic in densely populated areas is already breaking down (Linke, 2007). Road traffic is not able to solve the problem of transportation in mega cities. Further, road traffic does not meet the goal to provide a transportation system for aged people. Regarding the aspect of safety, road traffic is not considered to be the safest system, e.g. in 2009 in the EU-countries more than 39.000 people died in road traffic accidents. Although there have been concerns about the safety of hydrogen fuel for transport, the experience shows that it is not more dangerous than using fossil fuels (Stepken, 2003).

Others: Most concepts for road traffic use existing road infrastructure. However, the use of alternative energy sources

for the engine requires the establishment of new infrastructure (e.g. hydrogen production facilities, hydrogen gas station etc). Car sharing leads to a reduced number of cars in cities and therefore congestions would be reduced. Road traffic is a slow way of transportation. On the one hand it is not possible to reach high maximum speeds on public roads and on the other hand there are a lot of congestions, which make the movement on roads even slower.

RAIL TRANSPORTATION AND CABLE CARS:

Economical indicators: From an economical perspective, the RailCab concept has the advantage of using existing railway systems; investment costs in new infrastructure are low. Furthermore, cost for the operation of RailCabs is lower compared to conventional trains; RailCabs can move more people and goods with a higher degree of utilization (Kirsten, 2004). Maglev trains are very expensive in installation (Hall, 2004) and the concept of building vacuum tunnels is even more expensive than conventional maglev train tracks (Hoffman, 2004). Operation costs are also estimated to be very high due to high energy amount needed to establish a vacuum in the tunnel. Cable liners and cable cars are expensive in installation, but operation costs are rather low because of low energy consumption and maintenance costs. The Punktbahn concept and the bicycle monorail system also require new infrastructure with high investment costs.

Environmental indicators: Railways and cable cars are considered to be environmentally friendly concepts of transportation. Occurring emissions and wastes per person and kilometer are lower than other public transportation systems. Most of the trains and cable cars are powered by electricity. However, the environmental performance during operation depends on the energy sources used for the production of electricity. Under this aspect, the environmental performance during operation may differ from one country to the other, depending on the local energy mix. RailCabs and the Punktbahn concept have the advantage of lighter and flexible units/coaches compared to conventional trains. RailCabs for example are supposed to be available in different configurations: 6-10 passenger capacity for long-distance traffic, 20 passengers for local public transport (conventional trains have a capacity of about 80 passengers per railway coach) and also configurations for freight traffic. The high energy consumption for Maglev trains has a negative influence on their environmental performance (Gers, Hübner, Otto, & Stiller, 1997). Under the aspect of occupation of land rail transport and cable cars need much less space referring to the transport capacity than road traffic does (Kaufmann, 2002).

Social indicators: Regarding changes in demography and settlement structure, rail transport is more flexible than road transport for the changes that take place. Further they reach a higher degree of safety per passenger (Weber, 2008).

Others: Rail transport, and especially cable cars and cable liners, are already one of the most reliable ways of transportation. Railways can reach high maximum speeds, especially maglev trains but also cable cars and cable liners can considerably reduce travel time in urban areas. RailCabs also reduce the average travel time. Since it is not necessary to change trains to reach from one point to the other, the average travel speed can be increased.

WATER TRANSPORTATION

Economical indicators: Water transportation is a mean of transport with low costs for production and operation (Linke, 2007). However, there is still potential to reduce them by using different auxiliary systems (Höltkemeier, 2008). The costs for the production and installation are often low and they lead to savings in operation. Although the production of ground-effect vehicles is expensive and the price can be compared to small airplanes (Boecker, 2007), the advantage is that there are only negligible costs for the infrastructure and they are cheap in use (Jolley, 2006).

Environmental indicators: Water transportation is very energy efficient, ships only use 1,2 kWh in order to transport one ton over one kilometer (in comparison: rail transport: 3,7 kWh/tkm, road transport: 12,7 kWh/tkm). But it is still responsible for a lot of emissions (e.g. up to 4,5% of the world's greenhouse gas emissions (Marmer & Langmann, 2005)) and production of nitric oxide and sulphur dioxide because of the use of heavy fuel oils and the absence of filters (Marmer & Langmann, 2005).

Social indicators: Water transport is barely influenced by the change of settlement structure because there are only very few connections between suburban areas and cities with ships. Also the change in demography is not really relevant. Ground-effect vehicles are a new solution for areas with a lot of islands where they might succeed as a fast alternative to ships and a cheap alternative to airplanes.

Others: Water transportation is slow because of the high resistance of water it is not possible to travel with high speeds, but the reliability is high. Ground-effect vehicles travel over water with speeds up to 150 km/h.

AVIATION

Economical indicators: The presented improvements of airplanes are not more expensive in production than conventional planes in use today. Under the aspect of operation costs airplanes are very expensive; the suggested improvements have huge economical benefits because they can save up to 70% of fuel (Bettex, 2010). Airships are cheaper in production and operation than airplanes because on the one hand it is not necessary to build such a complex infrastructure (Linke, 2007) and on the other hand they consume less fuel (about 25% of the fuel that trucks need per ton/km).

Environmental indicators: Airplanes are producing a lot of emissions because of the high fuel consumption due to the high travel speeds. Further, airplanes emit pollutants in high altitudes, which is much more harmful (Gross, 2009). Cruiser/Feeder systems and the suggested improvements are trying to reduce the energy that is needed (Bettex, 2010). Because of the reduced energy consumption airships are less polluting than for example road traffic.

Social indicators: Aviation is a very safe way of transportation (Weber, 2008). New concepts do not differ from air traffic nowadays under the aspect of changes in demography and settlement structure and safety.

Others: Considering the high distances the reliability of aviation is high and the travel time is low.

CONCLUSION

The demand for mobility is steadily increasing and today's traffic systems are no longer able to satisfy this need in an economical, ecological and social way. Therefore it is necessary to think about new sustainable ways of transportation. New traffic concepts are being developed continuously; by analyzing past trends it turned out that improvements of existing means of transportation are more likely to become implemented rather than completely new concepts. In fact, many of the existing ideas and trends for innovative and sustainable mobility exists since years, e.g. the electric car, which is also to be found among Ferdinand Porsche's concepts in the early 20th century. Current trends in particular strive for sustainable traffic systems. However, some concepts only focus on particular aspects of sustainability, e.g. only economical aspect or only environmental aspect. Some other of the trends has the potential to satisfy all three aspects economical, ecological and social requirements for sustainable transportation. In any case, it remains difficult to predict if and when a particular trend will be implemented in future. It took almost hundred years to retake Ferdinand Porsche's concept of electrical car and to develop first prototypes that have a chance for mass customization. Mid-term trends may focus on the optimization of existing systems, infrastructure and technology. Long-term trends may involve complete different concepts of mobility. From a sustainable point of view it is also necessary to find concepts that reduce the demand for mobility. Advanced city concepts or local production and consumption of goods and resources have to be re-evaluated and seriously considered.

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