MISTRA
The Swedish Foundation for
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Background paper

Developing sustainable future for transport

November 2014

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The contents of this background paper
are the responsibility of the authors.

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Content

1 Introduction

1.1 Transport as a market

A fundamental definition of sustainable development was given by the United Nations' Brundtland Commission (1987[1]): a "development which meets the needs of current generations without compromising the ability of future generations to meet their own needs". In transport terms, the greatest threat to compromising the future is that posed by global warming. Thus, a more sustainable transportation system is necessary to address global warming by reducing greenhouse gas emissions. This must be done in the context of limited government finance for new infrastructure investment and subsidies and the need to provide the transportation systems and services to support economic competitiveness and social cohesion/quality of life as well as minimizing the burden for human health, environment and climate. Future levels of mobility and accessibility are strongly linked to lifestyle choices and many stakeholders often with conflicting aims. Procedures for 'negotiation' between stakeholders towards acceptably sustainable solutions are essential. (See Hoppe, 2014)

1.2 Present trends and future challenges

The following issues are key when considering a more sustainable transport future:-

- **Internationalization of different quality:** Globalization 2.0 a shift of prosperity, economic and political power towards emerging economies leading to a "multi-polarization" of the world with international regulation gaps (e.g. the internet). Related to this demand for mobility, vehicle purchases, culture of mobility as well as the development of transportation technologies will shift.
- **Population:** World population will continue to grow especially in emerging economies. This will be accompanied by growth in prosperity with increased demand for goods, natural resources and energy. Increasing international trade and transport are consequences, while de-population in some European regions as well as urban sprawl in growth centers may lead to inefficiency and increasing cost of transport infrastructure.
- **Urbanization:** Increased urbanization is leading to the overloading of transport systems during traffic peaks, with resulting congestion, safety and emission problems. Urban sprawl can induce additional unsustainable levels of transport demand.
- **Increase in inter-/intra-national social disparities:** Prosperity gaps have grown in the past few decades, especially in emerging economies. Other social disparities accompanied the trend: access to employment markets, housing, education and health care – as well as in mobility, characterized by exclusive accessibility based

1 Brundtland Commission, 1987. Our Common Future. World Commission on Environment and Development. *Oxford University Press.*

on pricing for mobility services. The latter may occur as side effects of political measures aiming to reduce traffic, emissions and the burden of public funding.

- **Demographic and social change:** Europe, the USA, and Asia are characterized by an increasing share of population aged over 65. As todays' seniors are relative healthy, wealthy and have a more active lifestyle, the mobility demand of this age group is higher when compared to previous generations. Decreasing household sizes, ICT (Information and Communication based Technology) and social media based lifestyles are leading to different housing and mobility patterns which are hard to predict. Elsewhere, conflict and economic factors are leading to substantial levels of migration which can result in rapid changes in the level and character of transport demand.
- **The knowledge society and economy:** Economic change towards research and development and high-quality products requires new skills. This trend may lead to green transportation technologies, ICT supporting multi-modal solutions and new mobility concepts on the supply side, and revolutionize the demand side by supporting the use of alternative transportation services such as car-sharing, E-mobility or social-media-based and self-organized mobility.
- **Climate change, environmental pollution and environmental ethics:** Global pressure to address these issues by political measures such as taxes, and regulations tackling emissions are in turn pushing technical development towards more sustainable mobility.
- **Shortage of energy resources:** Transportation is heavily dependent on fossil fuels. Energy security, overall fuel availability and cost are considerable political and market drivers for change.
- **Crisis of mobility and policy reaction:** The limited human and financial resources to meet the many challenges require new strategies, priorities, and decision-making processes to solve problems in the long term. (Hoppe et al. 20145)
- **Transport technologies:** Market and policy drivers are leading to increased efficiency in terms of both vehicle design and operation. New powertrains are resulting in reduced use of fossil fuels, vehicle/vehicle and vehicle/infrastructure communications and the current move towards increasing driver support and vehicle automation with enhanced sensor systems will result in more effective traffic control and safety. However, new problems such as safety of novel technologies and security against system attack will need to be addressed. Any technology which supports mobility based on sustainable substitutes for fossil fuels (or at least having the potential to do so) and decreasing GHG-emissions has to be considered as a game changer. Electric vehicle technologies are promising as well as hybrid and more fuel efficient vehicles. Material technology or micro-mobility provide potential to support sustainable mobility. Breakthroughs in implementation of nano-solutions in batteries or engine technologies and materials occur would lead to less resource intensive production, more energy efficiency and thus improve sustainable mobility. Material technologies with lightweight construction could provide increased efficiency for vehicles. (Hoppe et al. 20134) Developments in electronic ticketing and payment technologies will support easier access to public transport, and new ways of generating revenue with novel policy instruments. (See figure 1).
- **Lifestyle Technologies:** Information and communication technologies have become significant in the everyday life of most people. New social patterns are emerging which will impact on transport decisions/requirements. Little is understood about the issues and opportunities in such a complex area which covers many fields, including the potential to use novel approaches to transport to influence behaviour.

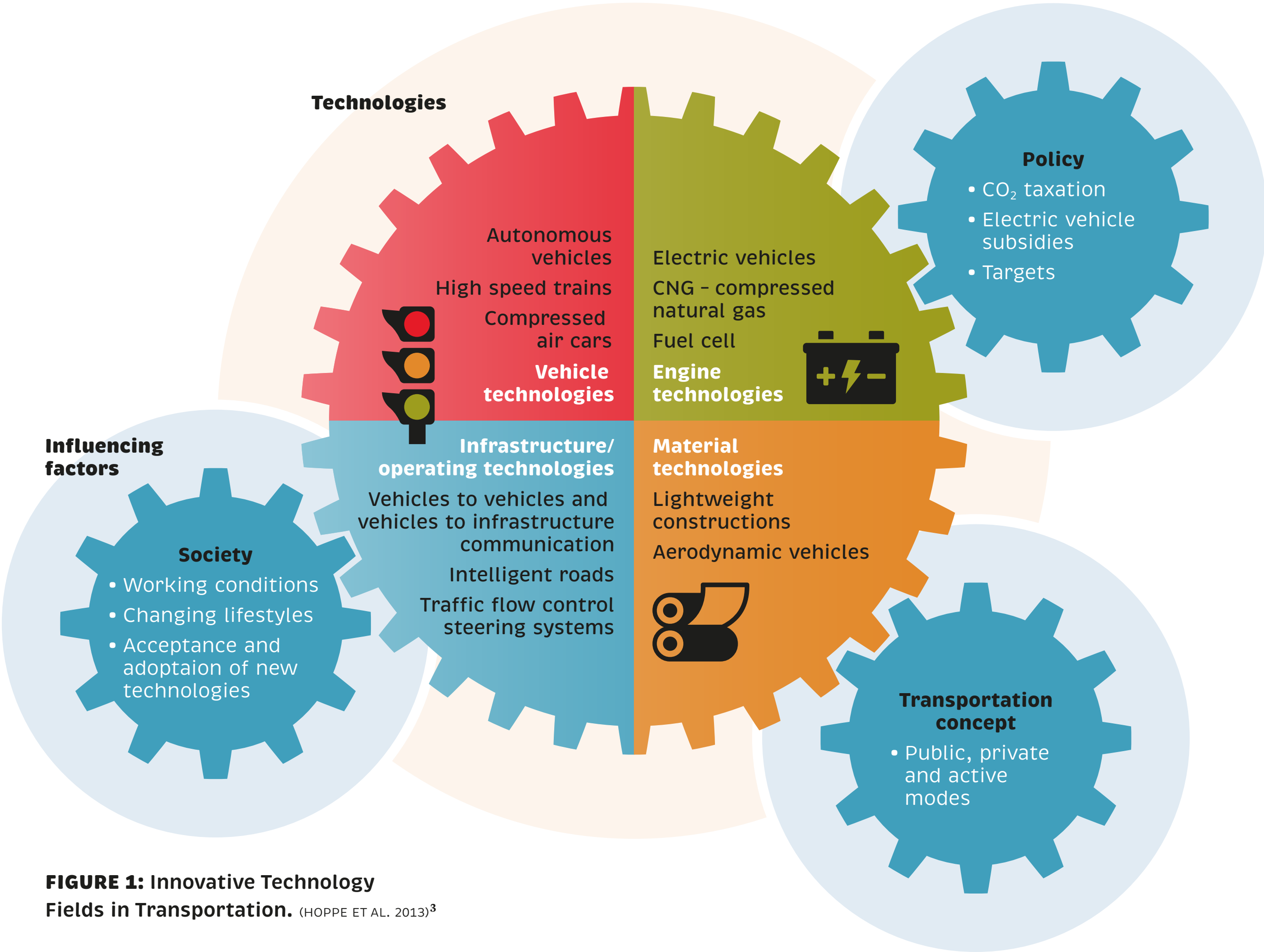


FIGURE 1: Innovative Technology Fields in Transportation. (HOPPE ET AL. 2013)[3]

Overview: The above trends point towards fundamental changes in transport conditions and requirements which will need to be addressed if we are reach a sustainable future, as transport becomes more:-

- Crowded, as mobility demand will further increase,
- Complex, as technological developments will require new skills and knowledge by all stakeholder groups,
- Exclusive, as affordability of mobility will lead to or reinforce social gaps,
- Vulnerable, as extreme or prolonged weather events or security breaches will affect the transportation system. Increasing technological complexity will add to vulnerability,
- Diversity, partly driven by shifts in economic growth may lead to mobility solutions tailored for Asian culture, with increased variety in mobility approaches. (see also Hoppe et al. 2014[2])

This is a complex set of problems in which a reduction in greenhouse gases must be achieved. Decision makers have to deal with the challenging trends, react to them and also take the opportunity to shape the future of transport as a basis for a sustainable future society and economy.

2 Hoppe, Merja; Christ, Andreas; Castro, Alberto; Winter; Martin; Seppänen, Tiina-Maria, 2014. Transformation in Transportation?, *European Journal of Futures Research.*

3 Hoppe, Merja; Christ, Andreas; Seppänen, Tiina-Maria; Winter, Martin; et al., 2013. Recommendations on the principles of sustainable mobility, *OPTIMISM (Optimising Passenger Transport Information to Materialize Insights for Sustainable Mobility)*, Brüssels, European Commission.

1.3 Ways to influence the transport system towards sustainability

To go from the present trends to a sustainable future that meets future challenges will need a many changes, some rather radical. History has shown that the world has addressed a number of environmental threats in the past and many studies have indicated potentially successful approaches, some of which are discussed below.

Regulation

The use of regulations to deal with the threat to the ozone layer posed by Freon and related substances is a good example of the use of planned future regulations. International agreement was made to ban the use of the more aggressive chemicals, with enough time for the industry to find better substitutions. Whilst this was a simple issue that did not involve fundamental social change, it still shows that regulations and international agreement are powerful tools to bring about change. Regulations have also been used to give incentives and support for the development of vehicles with better fuel economy, reduced emissions of NOx and other acidifying substances and improved air quality. A steady reduction in CO_2 emissions from transport in Sweden is to a large extent driven by the regulations for more fuel efficient cars. This trend depends on the EU regulation in combination with national incentives.

However, one should be aware of the drawbacks of regulations. Sometimes regulations are criticized for been blunt, ineffective and lead to adaptions that do not improve the environment. When the USA introduced regulations for fuel-efficient standards for cars, a number of manufactures started to produce light trucks for use as cars. So instead of a market of fuel-efficient cars, the regulation led to a market of fuel inefficient light trucks. When the EU introduced clean car regulations such as Euro 4 and IV, it was criticized for leading to cars and trucks that had low emissions within the standard driving cycle but had high real-life emissions, as the test cycles do not reflect actual use. Also, in the tests, too little emphasis is put on including energy use for vehicle systems such as air conditioners, which are not included in the test cycle. Flaws in the test procedures not only lead to a lack of progress when it comes to energy savings, but also to customer mistrust. Thus, care has to be taken when introducing regulations, although, when correctly applied, they can be a powerful tool for change.

Incentives

Economic incentives, such as environmental taxes, are also a major influencing tool, especially in complex systems such as are found in transport, where it is difficult to foresee all effects of a regulation. Market based transitions driven by economic incentives such as the Swedish carbon tax, are considered to be cost-efficient tools for change. Specific taxes such as congestion charging have also been shown to give strong effects.

Sometimes even small economic incentives can result in large effects when combined with CSR activities. The Swedish Miljöbilspremie (premium for environmentally enhanced vehicles) had a surprisingly strong effect on the sales of cars generating less than 120 g CO_2/km. One of the reasons was most likely that companies used the 120 g value as a set standard for their cars fleets. Thus, a standard used for an economic incentive became a signal as to what was expected from society more generally. The signal value generated by an economic incentive should not be ignored.

Societal changes

A market is driven not only by regulations and economic optimization, but on norms as to how we act in a social context. Regulations and economic incentives can work within existing norms or they might change the norms. In the latter case it is likely that the effect will be stronger. Society have worked with campaigns, regulations and increased taxes on tobacco for a long time and with noticeable success.

Timing and the market

One aspect of making change successful is in the timing of its introduction. Sometimes is it impossible to identify the right timing beforehand. An example is the campaign by the Swedish EPA to increase awareness of climate change, during one of the coldest winters in memory. Other timing aspects can be taken into account. For instance, it is important to understand the timetables of industry. Inappropriate timing, that does not fit the industries timetable will be more expensive and also result in opposition. Good timing makes the transformation costs markedly lower. It is also clear that it is easier to change individual behaviour, when other transitions in life occur such as a change of job or home, or when a major incident or event necessitates short term change.

It is also important to the market that introduction are made at the right time. Too early an introduction of a measure, supported with temporary government incentives, can lead to a backlash from one or more stakeholder groups. Several examples of this can be seen from the past. The two most noticeable examples are of the introduction of alternative fuels; methane in the 1980's and ethanol in the 1990's. The problem of backlash is not only that it stops the introduction of that specific solution but it also leads to quite substantial market resistance towards any innovation. Shortsighted policies and volatile roles do not provide a sound basis for innovation. However, successful examples of the introduction of new solutions to the market have occurred as a result of long-term policies where the market and society have jointly helped to drive development. A good example is the strongly increased fuel efficiency in cars. The basic incentive is the EU legislation approach that prescribes how efficient a car should be, not now, but in a few years' time. This, in combination with indicative targets more than 10 years ahead, gives the industry time to develop and implement the necessary technical improvements. The tax system and other economic incentives can be adjusted to support the timing by giving a premium to energy efficient cars, such as the bonus-malus system of France or the CO_2 differentiated annual tax in Sweden,

In general, it is vital to understand the interplay between the private transport market and the government in introducing new solutions. The examples above illustrate relatively simple cases. To introduce changes that impacts on many system components and/or the character of the system itself will be more difficult and will involve many more actors.

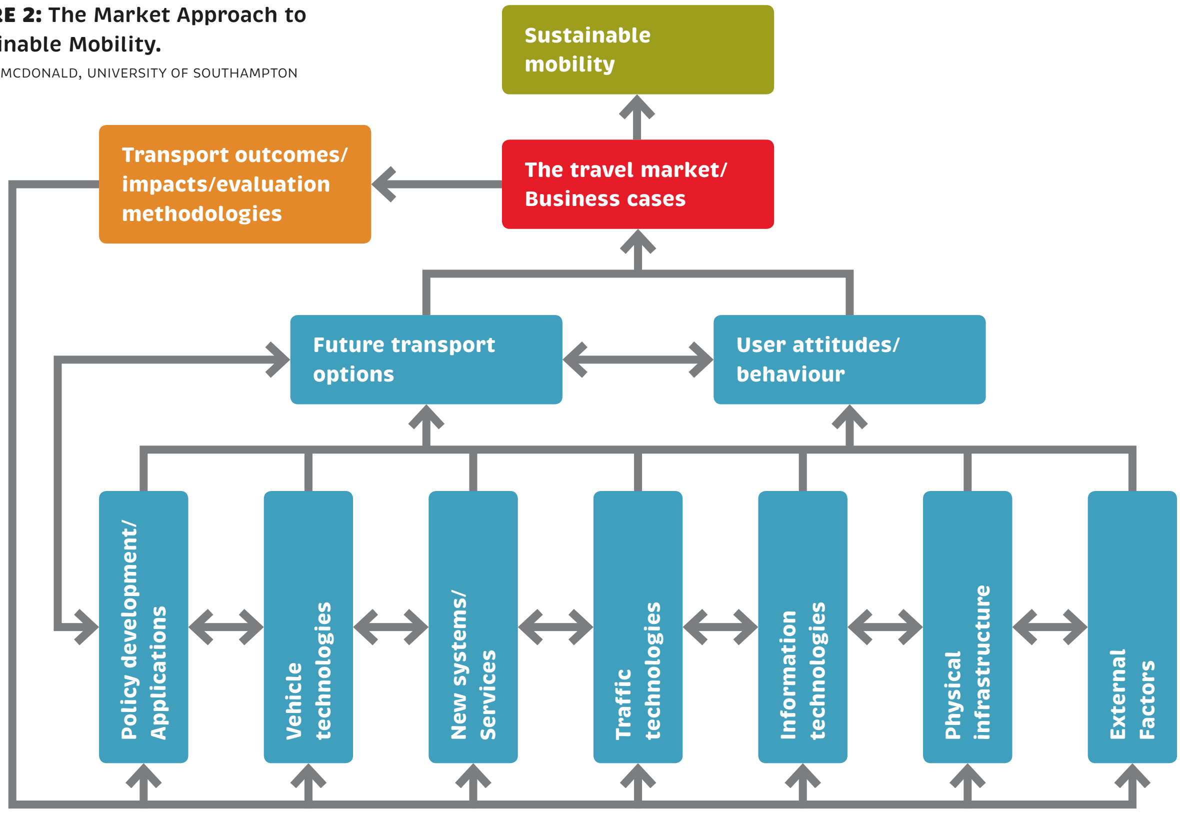
2 Background

2.1 Transport as a market

To achieve sustainability, those making travel and transport decisions for themselves, for others, or for the movement of goods and freight must make choices which lead to the overall levels of sustainability desired (Figure 2). It is a market process in which those involved will select the transport options which they want or need and can afford. Some transport options will be public, some will be private and subsidies and taxes will influence decisions. The levels of complexity increase because many options may be multimodal, and the behavioural actions of decision makers will have been influenced by varying levels of knowledge of options and their attitudes.

Short-term decisions such as the choice of mode of transport to be used for a single trip will be influenced by long-term decisions on, for example, car ownership or home location. In some situations more attractive outcomes may be to satisfy the trip purpose in other ways, such as by teleservices, the use of an alternative destination or by trip chaining.

FIGURE 2: The Market Approach to Sustainable Mobility.
SOURCE: MCDONALD, UNIVERSITY OF SOUTHAMPTON



Not all travellers or shippers can or need to achieve a fully sustainable solution for every trip, but, when taken together, the outcome of all trips should reach a target set. However, the overall process needs to be seen to be fair if it is to be sustainable in the long run. This will involve enforcement.

Whilst step changes in sustainability may be achieved by considering the systems/services or attitudes/behaviour separately, more can probably be gained by considering them together. This will involve increased understanding of the decision processes used by individuals, how they can be influenced, and the development of systems and services able to satisfy user needs in a sustainable way.

A brief consideration of the state-of-the-art/key issues associated with the boxes in Figure 2 is given in the following sections.

2.2 Policy development/applications

Most European cities have sustainability policies and plans. These are often presented as Sustainable Urban Mobility Plans (SUMPs), but the policies may be embedded in a more complex way in modal and land use documents. Urban plans are often a requirement of central governments, but are usually driven by the needs of the local population and where ownership by local politicians is clear. These plans contain the principles of sustainability, but there are considerable variations in the details of specification of how these principles will be met in practice, and there are often inconsistencies and conflicts where local commercial and other pressures lead to actions which are less sustainable. There is a general lack of an holistic approach to sustainability in transport which relates lifestyles, land use and economy to the ways in which we travel and interact as communities. However, policies are often short term and relate to physical and fiscal restraint with parking and access controls, reallocation of road space, support for public transport, walking and cycling, and a range of parking and road user charging schemes. Across Europe, Sweden is at the forefront of promoting and implementing sustainable urban transport policies.

The concept of "predict and provide" has been largely discredited. The many factors which influence policy decisions include public opinion, commercial and economic interests and political principles. This often results in policies and applications which are piecemeal and/or lack future vision. A typical example of this is that of land use developments where the incremental effects of individual decisions on developments can have major long term impacts. Future visioning is an inexact science, but more could be done to better understand the effects of a wide range of decisions on the future and on understanding how decision-making can be made more effective and consistent. This will involve a more fundamental understanding of the behavioural interactions between stakeholders and the ways in which they may be managed.

2.3 Vehicle technologies

In the last 5 to 10 years vehicles have become much more sustainable, with improved fuel consumption for conventionally driven vehicles and introduction of electric and hybrid power. Fuel cell technology has developed to the stage where prototypes are close to production. The drivers for change have been fuel price/fuel security and the need to reduce greenhouse gas emissions, the latter backed by national and international legislation. The generally higher initial costs of more environmentally efficient vehicles is offset to some extent by reduced taxation and fuel costs and, in some situations, preferential access.

The market driven development towards a better fuel efficiency is most noticeable for trucks and lorries where the energy cost is substantial for the trucking companies and purchasing is done after financial calculations. The car market is more driven by other factors such as “fun-to-drive”, prestige and a strong conservatism. Here, the international and EU based legislations have played a big role in the development of fuel efficient vehicles.

The motor industry in Europe at least, is facing a need for technology shifts to meet coming EU legislation (such as 80 g/km) since this is unlikely to be met by conventional technology. Therefore, a strong drive towards electric cars is taking place within the automotive industry. This drive towards electro mobility also relates to buses and trucks. Sweden is planning a full scale test of electrified roads i.e. trucks that continuously will be fed with electricity from the road either inductively or conductively. The development of electric busses and delivery vehicles toward electric solutions seems also to be fast.

A full scale introduction of electro mobility will, however, need a cooperation of the automotive industry, the infrastructure holder and the electricity supplier. And most likely involve new business models.

A variety of driver support systems are increasingly available as standard or as options on new vehicles. These include adaptive cruise control, brake assist, parking assist, and lane keeping. Navigation/information systems are common. These systems are market driven and are seen as desirable/beneficial by the purchasers and the benefits to the network operator are often marginal. Some systems may result in new accident types which need to be monitored and understood. Issues relate to functionalities being defined generically, but with very different operating characteristics between manufacturers and vehicles. For example, a driver moving between a Volvo and a Nissan might be confused and react inappropriately to a brake assist function initiated in a different way. Also, the complexity and variations in HMI between manufacturers may confuse drivers, particularly if new models of ownership and usage become common. The engines, drivetrains and bodywork on modern cars are generally excellent and many manufacturers expect them to last 15 to 20 years. However, the technologies of driver support and vehicle control have not yet reached the same levels of reliability and durability and are continuing to be developed. This is a potential problem area for older vehicles where second hand vehicles with less “troublesome” technology may attract a premium.

There are two distinct strands of research into full vehicle automation. The first is for vehicles on fixed routes which provide a flexible or short wait time and carry a small number of vehicles. Trials of such systems are current in several European cities. These will provide energy efficient services somewhere between taxis and conventional buses, and have the potential to be part of multimodal trips with a service sufficiently attractive to compete with private car use. These systems will operate in a mixed traffic environment and whilst software and hardware technologies are improving rapidly, they are currently limited to speeds of about 15 km/hr in such operating scenarios. The second strand of research, by the major vehicle manufacturers, has been more generally focused on high speed automation on segregated interurban lanes. Automation is some way from maturity and it is probable that many safety and capacity benefits are over inflated in current research.

Totally new concepts have also been developed that seem to have the opportunity to change the transport system. One such invention that could be seen as trivial but might have significant impact is the electric bicycle. By having electricity as a helper an ordinary cyclist can double the speed and it will enhance the distances that are “bikable” dramatically.

Particular issues relate to the management of HMI and how to support the more rapid evolution of the vehicle fleet so that more vehicles meet the higher sustainability standards.

2.4 New systems and services

Demand responsive systems have been successfully deployed around the world for several decades. They have tended to target the elderly and there are a wide range of operational and financial models. They usually involve minibuses with drivers and can be expensive to operate with generally small numbers of passengers. There is potential for such services to be broadened as feeder services to higher capacity routes and integration could offer a practical alternative to the car. The use of automated electric vehicles would reduce staffing costs (the largest part of the conventionally services) and add a degree of attractiveness. Such systems have increasing potential in an ageing society where a growing number of people may be neither willing nor able to drive.

The increasing number of car and cycle sharing schemes provides a flexible alternative to the private car. Whilst many are small scale systems which cater for non car owning households' occasional needs, several have now reached a scale and level of availability which make them the first choice of mode for regular trips. However, there are huge differences between schemes, with little uniformity of system or payment characteristics. This impacts on the ease of use in longer distance multimodal journeys. Although safety and security were seen as potential problems with shared systems, there is little evidence that they have materialised in practice. Little is understood about how a step change can be made from single/multiple car owning households to the general use of public/shared modes, the characteristics needed from the systems, how business models could work to achieve the scale of operations needed, and how stakeholders could be influenced.

The situation when it comes to freight and delivery services is quite similar. The number of small scale tests that have been done in EU with coordinated delivering services, truck-sharing systems etc. is large. But the number of large scale successful systems seems to be limited. Often the lack of success is due to failures in the business model. A large scale shift to new models and systems might need changes even outside the transport sector.

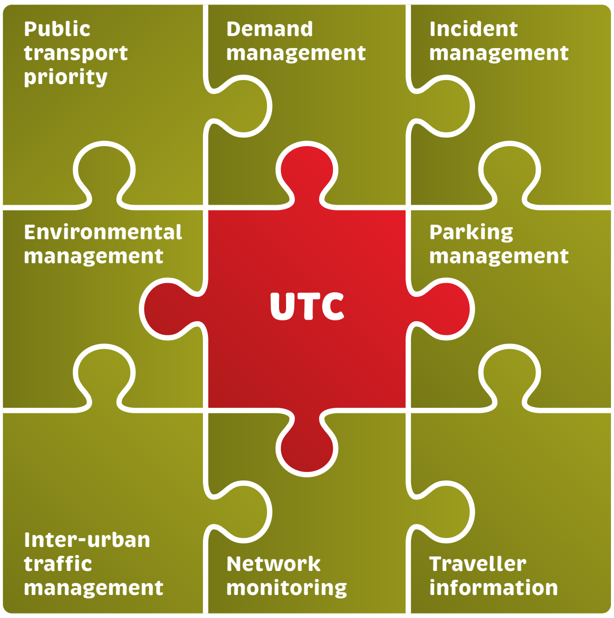
2.5 Traffic technologies

Traffic control by signals at isolated junctions evolved into fixed time linked signal systems and then into vehicle actuated systems. At the same time, the initial objectives of highway capacity and safety broadened to include a much wider range of features for coherent management. A typical set of functions of a modern state-of-the-art system can be seen in Figure 3. The concept is that an Integrated Urban Traffic management System has a complete knowledge of what is happening on the network, including forecasting. Decisions are then made to optimize against predetermined objectives. However, there are many systems available in the market and, whilst most will claim a wide range of functionalities, there are huge differences in the ways in which they perform. For example, a bus priority system may identify a bus on the approach to a set of signals and immediately give it priority. This is a crude approach, as delays and pollution for the whole traffic stream may be increased. In another system, individual buses may be recognized and only be given priority if they are behind on their individual schedules. There are no common standards and evaluations are rare. A particular problem of such systems is that they only receive information from the detectors and these are generally limited to main roads. Knowledge becomes weaker near the boundaries. There is considerable potential to enhance databases from increasing range of available sources such as route guidance systems or mobile phones.

Interurban traffic management systems involve speed control and enforcement technologies. There are also substantial systems for incident detection and man-

FIGURE 3: Integrated Urban Traffic Management.

SOURCE: HOUNSELL AND MCDONALD, UNIVERSITY OF SOUTHAMPTON



agement. As with urban traffic control, cameras are used to send back images to control centers so that operators can develop a more subtle understanding of conditions. The information is used to provide route information pre-trip and during trips using variable message signs. Some ramp metering systems are in place although they are not particularly effective.

Recent developments relate to vehicle/vehicle and vehicle/roadside infrastructure. When deployed, such systems can have considerable benefits for both the operator and the road user. A range of other technologies to track and trace vehicles and gather information on the network are available. They include the tracking of GPS signals.

In general, technologies are available to manage the whole road network in a coherent way against holistic lifestyle choices. However, applications are piecemeal and visionary solutions are rarely tried. Also, when vehicle/vehicle and vehicle/infrastructure communications are fully implemented, drivers will have greater knowledge and hence control, which may make radical solutions more difficult.

The traditional traffic engineering approaches to optimizing network operations need to be revisited and expanded to take into account evolving and future policy objectives and address new threats and opportunities. The latter include information and communication technologies and behavioural responses by all stakeholder groups, and need coordinated input from a wide range of physical, engineering and social disciplines.

As spare capacity in networks is eroded, even small incidents such as damage only accidents need recovery plans and, whilst most traffic control centres have such plans, most are crude.

2.6 Information technologies

People are increasingly connected in all aspects of their life. There are a very large number of apps which relate to the provision of travel and transport information, and individuals also seek information from friends and other sources. There are major differences in usage with age and, for example, young people in the UK spend about 7 hours a week on average using social media. The general quality of apps is excellent, although the base data is often incomplete and/or out of date. A major issue is the role of local and central authorities in providing such data. Some authorities are focused on total control of traffic and travel data, with a single quality guaranteed source, although this is a very expensive option. More are focused on developing open data source systems from which apps can select and use whatever data they require. There is a lack of understanding as to how apps, and ICT more generally, are used and may be used to effectively contribute to a sustainable future.

There are considerable variations in the ways in which information is presented and gathered for ICT use. HMI's may be specific only to certain groups and how HMI and ICT system use and needs evolve with age is poorly understood. The accumulation of large multisource databases of travel and transport related information, their consistent interpretation, and what and how information is best passed to users in a variety of situations are areas of current and future research. Dealing with incidents in the context of specific user requirements (people and goods) can be particularly problematic.

Much hope has also been given to the use of IT solutions to substitute trips with virtual meeting, and there has been a broad introduction of new concepts such as video meetings and telecommuting during the last 10 years. However, the overall effects of this activity are unclear. The use of IT as a substitute for trips leads to possibilities of organizing companies in new ways that encourage people to work together from remote locations and to enable people to live far from their working places. However, changes can lead to increased travel.

2.7 Physical infrastructure

The road network is congested at certain times and in certain places, and we cannot build our way out of these problems. However, we can manage the system using physical and fiscal techniques combined with effective enforcement. Also, those contemplating travelling will finalise their decisions on the basis of their understanding of the conditions they will encounter. Those moving freight may have less flexibility, but increasingly use technology to plan more efficiently. Given that capacity is largely defined by the physical infrastructure available, there are fundamental issues as to what should be reasonably expected by and of the various stakeholder groups. There is little fundamental understanding of what is 'reasonable' or 'acceptable'.

Ramp metering has generally had little effect because the flow window where it is beneficial is quite small. However, it seems illogical to allow uncontrolled access to our highest capacity roads which results in their congestion and reduced effectiveness. The lack of an holistic approach to how we manage our local and national roads in an integrated way is an issue which has not generally been effectively addressed. Better knowledge is needed of historic, current and future conditions using existing and novel hardware, software and data bases.

The characteristics of our vehicle fleet are changing. We do not fully understand the implications of this for our design standards. For example, platoons of electronically linked vehicles will change merging and overtaking requirements, acceleration behaviour of alternatively powered vehicles may impact on intersection capacities, and electric cycles may necessitate new priority designs.

Considerable research has been undertaken on the provision of charging facilities for electric vehicles. However, much research is still needed on how use and attitudes evolve over time.

2.8 External factors

There are several eternal factors which may impact on behaviour or the transport opportunities available and which need to be better understood. These include energy supply, climate change events, population and lifestyle changes, changes in attitudes and use of technology, resource depletion, economic growth and wealth distribution, media impacts and political changes.

2.9 The travel market

A sustainable transport future may be arrived at in many different ways. There is no single solution for a region or population group. The market, i.e. the travel and transport options available, will involve both public and private organisations which operate to very different time frames and objectives. Public organisations can influence the market by investment (new roads will generate more traffic), subsidy (reduced bus fares will generate more bus trips although few are attracted from cars by fares changes alone), or by legislation (difficult to legislate sufficiently precisely to avoid unexpected consequences. Many unfortunate examples!). Private companies want to have a predictable future for which they can develop products. Key to this process is the development of a vision to which all stakeholders can subscribe. Most visioning processes have a limited focus and do not differentiate sufficiently between prediction based on current trends and the development of fundamental understandings linking attitudes and behaviours to transport futures.

2.10 Understanding impacts and processes

There are increasingly sophisticated ways of collecting information to understand what is happening on our transport networks and why it is happening. However, there is potential to use this in innovative ways to influence attitudes and behaviour. Too little is made of understanding what will happen without major change, and the long term implications of decisions made in the short term need to be clearly articulated and understood by all stakeholders.

2.11 Sustainability assessment

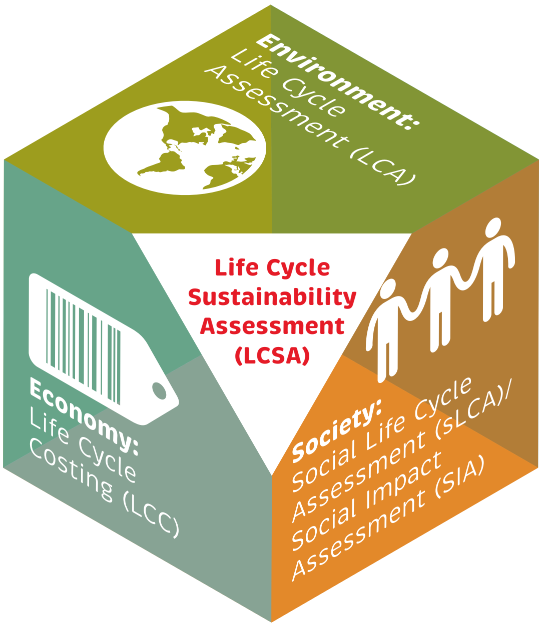
It is generally agreed and accepted that a sustainability assessment must be made to assess future smart transportation in comparison to existing conventional transportation systems. The three dimensions of sustainability are (Figure 4)

1. environment
2. economy and
3. society

FIGURE 4: The three dimensions of sustainability.

SOURCE: JOANNEUM RESEARCH, AUSTRIA

FIGURE 5: Methods of Sustainability Assessment: Environmental, economic and social assessment of sustainability based on scientific indicators.
SOURCE: JOANNEUM RESEARCH, AUSTRIA



For each of these three dimensions indicators must be developed and assess to judge on the overall sustainability of a smart transportation system, e.g. There is international consensus that the environmental effects of new transportation services can only be analyzed on the basis of life cycle assessment (LCA) including the production, operation and the end of life treatment of the transportation system in comparison to conventional systems.

The methodology used is the "Life Cycle Sustainability Assessment (LCSA)" which is a combination of the following three single methods (Figure 5):

1. Life Cycle Assessment (LCA) for the environment
2. Life Cycle Costing (LCC) for the economy and
3. Social Life Cycle Assessment (SLCA) for the society.

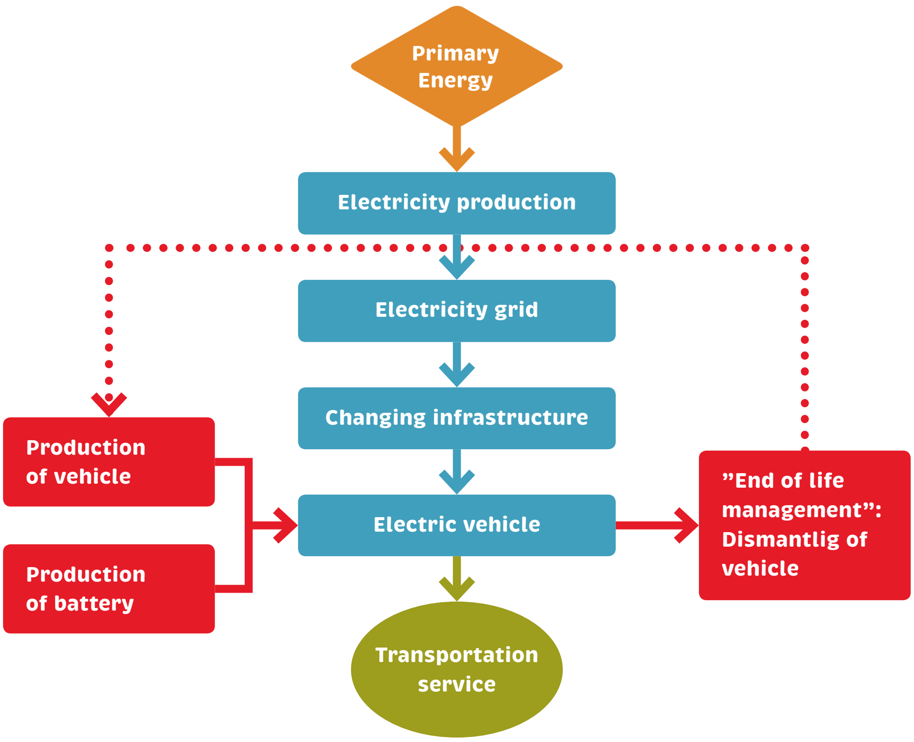


FIGURE 6: Sustainability Assessment Lifecycle.
SOURCE: JOANNEUM RESEARCH, AUSTRIA

The sustainability assessment must be made based on the whole value chain covering the whole life cycle of the smart transportation system including the three main phases:

1. Production of the facilities and necessary infrastructure
2. Operation of the transportation system incl. the fuel supply
3. End of life: dismantling, recycling or reuse of the facilities and infrastructure.

An example of the life cycle of an electric vehicle is shown in Figure 6.

2.12 System integration

The integration of a single smart transportation system into the overall transportation sector is essential. The most relevant interfaces and possible interactions with the existing transportation sector must be analyzed and assessed. Examples for most relevant interfaces are:

1. Optimal integration in existing infrastructure, e.g. electricity grid, rails, roads
2. Minimizing additional infrastructure
3. Interactions with the people's needs
4. Necessary change in users behaviors, education and training

It is necessary to analyze and understand the interactions of the technological, social, and economic systems in order to create an environmental sustainable system.

2.13 Research

Transport research is largely funded by governmental transport agencies, industry, or by grants for the study of fundamental research ideas generated by academic researchers. The research objectives, timescales and levels of funding are often very different for each of these groups. Thus, transport research, at least in Sweden, may be seen as fragmented. Traditionally, transport research has often been done in small groups or by individuals in organizations whose focus is mainly on other issues. The reason for this is quite understandable. Swedish research is mostly done in universities and to a much lesser extent in research institutes. Universities are normally organized according to academic subjects, such as economics, mechanics or biology, whereas transport research normally requires a cross-disciplinary and applied approach. It is often physically impractical for individuals with interests in transport to work closely together.

In addition to the government funded road and transport research institute in Sweden VTI, several efforts have been made to generate transport research bodies with enough critical mass for them to have a major impact. Different centers of excellence have been created such as the K2 centrum for public transport research. Most pronounced has been the formation of several centers of excellence within the automotive research area. Centers such as for Combustion and Catalyze resulted in critical masses of scientists working together.

In general, Sweden has a relatively strong position within the automotive research, mostly driven by the Swedish automotive research program FFI that has an annual turnaround of more than 1 billion Swedish crowns, with more than 400 Mkr from the government (Swedish Energy Agency, VINNOVA and The Swedish Transport Administration) and the rest from the Swedish automotive industry. Also, the Energy Agency has its own research programmes and some additional input comes from VINNOVA and Swedish Transport Administration. Less has been done when it comes to train research, although the Swedish Transport Administration has supported one center, Gröna Tåget. Now, a big initiative Shift-to-rail under the EU Horizon 2020 program will allow significant funding for train research. In the maritime sector, the Lighthouse centre has led to a coherent research structure.

The freight transport and logistics research initiative, Closer, at Lindholmen science park, is an arena for cooperation for research, development and innovation for transport efficiency. However, it is not a center for Excellency and the amount of research money going to freight transports and logistics is less than that for personal travel.

An area that does not currently have a strong research representation is that of traffic operations, traditionally a core research topic. It is clear that multidisciplinary research is not strong within the transport sector generally, despite it being clear that many of the challenges of tomorrow will need a broad understanding of the transport system and radically new solutions.

An area of strength of Swedish research is the often close cooperation between the public and the private sectors. However, this can also be a drawback, as areas without a strong private sector tend to receive less attention. It is also quite clear that a better interaction between the traditional transport research sector and other sectors such as electricity and city planning is urgently needed. It is also vital for a small country such as Sweden to cooperate internationally.

3 Towards a smart and sustainable future

3.1 Introduction

The current transport system is not sustainable and incremental improvements and isolated technical solutions are unlikely to be sufficient to establish a sustainable and smart future transportation system. New technical innovations and other approaches necessary for transformational change will need to be accepted. Therefore, understanding stakeholder attitudes and behaviours in what might be considered to be a transport marketplace will be a crucial element of any research. This is true for all modes and for multimodal research, although the stakeholder groups will vary with the research focus.

Decision makers will have to face and overcome great challenges if we are to reach a future in which transport is sustainable. All the factors relating to the global and local environment, energy, social stability, congestion and the economy make decision making complex and subject to many different and often conflicting demands. Financial opportunities for investment may be limited for some time because of market forces and global economic constraints. In such situations, the easiest decisions are often those which relate to incremental developments and which may be inconsistent with long term sustainability aims. Research is needed to identify and understand market drivers, to identify and develop the systems and services that will address future markets, and to deliver credible evidence to support sustainable decision-making.

3.2 Recommendations to be considered in a call for research proposals

The research sought in this call should lead to a step change towards a sustainable transport future. This may relate to the development of technology, systems and services and/or of understanding the behaviours of stakeholders. The above Sections give an indication of the thinking behind the call, and the following points highlight what should be taken into consideration when preparing a proposal.

1. The multifactorial complexity of the transition towards a smart and sustainable transportation system indicates that a consortium should normally be multidisciplinary in its approach. The range of competences of the consortium partners to deliver the technical and sustainability assessments (environment, economy and society) should be reflected in the proposals. A typical consortium would be expected to include partners from academic and applied research, from industry active in the various elements in the whole value chain and life cycle, governmental institution covering implementing issues and social organizations and NGOs representing people's needs with their social and ethnic attitudes.

2. The inclusion of international partners with expertise and experience from abroad would support the spread of results internationally and may also, in some situations, provide market opportunities for any systems and services developed by the consortium.
3. The consortium should address other stakeholders relevant for the transition to a smart transportation system with adequate measures and activities to include them in the project deployment via discussion and dissemination of the (intermediate) results. Adequate strategies for a strong stakeholder involvement would further strengthen the consortium.
4. Co-funding from partner(s) of the consortium or relevant stakeholders groups would further underline the practical relevance and approach of the project.
5. The focus should be on solving transport needs in a sustainable way rather than optimizing single modes of transport. The research should have a system perspective including LCC, LCA social lifecycle assessment. It is often too easy to sub optimize when studying only specific parts of a transport system. Such research will not be funded.
6. Our analysis show that transport is not sustainable and incremental improvements and technical solutions not enough. It will therefore be a need to understand transformational changes including behavior changes.
7. Transforming the transport system towards sustainability will need to understand system, attitudes and behavioural norms and future trends, as stakeholders will determine what solutions will reach the market successfully.
8. It is important to understand the interaction of the technological, social, and economic systems in order to create an environmentally sustainable system. Furthermore, since many of the changes might be unattractive to the individual stakeholders, new incentives and new thinking of how to bridge the gap between individual wishes and the long-term collectively needs.
9. Research is needed to address complex systems in transformation and decision making in complex environment in order to shape the future. This includes consistency across sector borders.

Thus,

- Applicants are encouraged to consider future market drivers
- Applicants are encouraged to include use a part of the transport system as a case in the study.
- Applicants are encouraged to include stakeholder involvement and may include co-funding
- The program may include international cooperation

MISTRA

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