Navigating towards efficient urban transport: A compilation of actor oriented policies and measures for developing and emerging countries

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Abstract

In 2008, transport accounted for 27 % of the world's total final energy consumption. Currently, we are facing a rapidly expanding transport sector with continually increasing energy consumption. In the future, emerging and developing countries especially will experience an accelerated growth in transport energy demand due to rapid population growth, urbanisation and rising per capita income. The transport sector's inefficiency and its dependency on oil will become an economic burden for these countries. They will have to face increasing crude oil prices and uncertainties regarding energy security.

Thus, there is a need for an efficient transport system and particularly for decision makers in developing and emerging countries to have access to planning advice in order to identify suitable and effective measures for low-energy urban transport. To meet this demand, existing knowledge and measures about energy efficiency in urban passenger transport was compiled and a structured introduction to energy efficiency in transport is provided.

The main determinates of an energy-efficient transport system are explained and strategic approaches to increase energy efficiency are outlined. Success factors and barriers for energy efficiency policies are described. The main element of the paper is an overview of different energy efficiency policies and measures for the key actors in energy-efficient transport on local and national levels. A set of measures is assigned to each actor identified. The compilation was adapted to the circumstances in developing and emerging countries and includes examples for successful implementation of several measures. Thus, the document satisfies the need for a comprehensive introduction to energy efficiency in urban transport in developing and emerging countries.

Introduction

Transport is a fast-growing sector in terms of energy use. In 2008, the global transport sector had a final energy consumption of 96 million TJ (~2,300 Mtoe) and was responsible for approximately 27 % of the global final energy consumption (IEA 2010). Road transport is the largest user of energy in the transport system. Road passenger transport alone accounts for 50 % of the world transport energy consumption (IEA 2009). The enormous fossil fuel consumption of the transport sector is accompanied by high levels of greenhouse gas emission. In 2006, the transport sector was responsible for 7.5 Gt CO_2 emissions, which corresponds to 23 % of the total fossil-fuel related CO_2 emissions. More than half of the transport emissions are from passenger mobility (IEA 2009).

In the future, the energy demand of the transport sector will continue to increase and oil-based fuels will remain the dominant energy source (IEA 2009/IEA 2010). In light of growing oil demand, energy security threatened by oil supply disruption and decreasing oil production becomes a major issue. Natural hazards or political unrest as well as the concentration of market power held by a few oil-exporting countries can endanger a secure energy supply. Scientists are predicting the moment of "peak oil", which is the maximum rate of oil extraction, for the 2020s or 2030s (IEA 2010). Afterwards, the conventional oil production will decline. For all oil-importing countries it is important to reduce the energy demand of the transport sector and to become more independent from oil and increasing prices. Rising crude oil prices burdens the national economy as well as public and private households. Emerging and developing countries are hit especially hard by rising oil prices. They have limited financial resources and often relatively large shares of their GDP are spent for oil imports (IEA 2004). Thus they should make every effort to avoid inefficiency in transport.

The growth in global energy consumption of the transport sector is concentrated in emerging and developing countries. The IEA (2010/2009) provides projections for the most important developments concerning transport energy use:

- The IEA projects an overall increase of 49 % in the energy consumption of the transport sector by 2035 in non-OECD countries, if the current policies are not changed (IEA 2010).
- High population growth in developing countries results in growing transport needs (IEA 2010).
- Rising per capita incomes will contribute to an increase in motorisation, since income and automobile ownership are closely related (IEA 2009).
- In non-OECD countries, passenger travel by light duty vehicles (LDV) and motorised two-wheelers is projected to grow rapidly in the coming decades. In non-OECD countries, particularly in Asia, car sales are growing quickly. The global number of LDVs is projected to increase to six or seven times that of today before 2050 if no measures are taken. This results not only from growing populations, but also from an increase in the global vehicle ownership rate from 12 % today to 40 or 60 % in 2050. Most the increase in the global number of LDVs in comes from emerging and developing countries (IEA 2010 / IEA 2009).
- At the same time the share of bus and rail in urban passenger travel is projected to decrease from 80 % to 55 % in non-OCED countries if no measures are taken (IEA 2009).

Increasing numbers of cars and declining shares of more efficient modes in emerging and transition countries not only lead to increasing energy demand, but also to local air pollution, high levels of greenhouse gas emissions and to cities crowded with cars.

It is crucial to create more efficient systems for transportation in developing countries especially in urban areas. Three reasons are especially important: first, rapid population growth in developing and emerging countries is concentrated in the cities (Cohen 2006); second, the growing income of the urban population drives motorisation, since automobile ownership usually rises with increasing GDP per capita (IEA 2009); third, there is a great potential for increasing energy efficiency in urban transport because public transport can be operated more efficiently in densely populated areas.

Energy-efficient transport offers a huge potential to reduce oil demand and total energy demand. The IEA estimates that the energy intensity of passenger transport can be reduced by 46 % in OECD countries and by more than 50 % in non-OECD countries if energy efficiency measures are implemented on all levels (IEA 2009).

Decision makers in developing and emerging countries need planning advice to identify cost-efficient and effective measures for low energy urban transport. To meet this demand, this paper focuses on measures and instruments to increase energy efficiency in urban passenger transport while addressing the needs of stakeholders of cities and urban agglomerations in emerging and developing countries. It shows opportunities for decision-makers on the local and national level to enable the transition to energy-efficient transport systems. The presented principles are of course also valid for developed countries. However, in contrast to European or North American cities, the immature urban structures in developing countries offer a great potential for transformation towards higher sustainability.

In the following, an overview regarding the different strategies to increase energy efficiency in urban transport is given. Furthermore, difficulties in achieving an energy-efficient transport system are outlined as well as co-benefits of efficient transportation. The main part of the paper outlines and discusses different energy efficiency policies and measures for the key actors in energy-efficient transport on local and national levels. Several actors have been identified and numerous measures for a low-energy transport system are assigned to the different stakeholders.

Increasing energy efficiency in urban transport

To achieve an energy-efficient transport system, different determinates of energy consumption have to be addressed. The full potential for energy savings can only be realised by using a combination of strategies that takes all elements of the transport system into account, ranging from energy consumption of single vehicles to the overall city structure. As revealed from experience in other sectors, energy efficiency measures are sometimes difficult to implement or do not fully reach the intended energy savings. Decision makers should be aware of these difficulties, but they should also recognise the co-benefits of energy-efficient transport that can be an additional driving force for the implementation of efficiency measures.

THREE DIFFERENT LEVELS AND STRATEGIES OF ENERGY-EFFICIENT TRANSPORTATION

Energy-efficient transportation can be realised on three different levels. Potentials for energy efficiency are available for single vehicles (vehicle efficiency), individual trips (travel efficiency) and for the whole transport system (system efficiency). The overall energy efficiency of the urban transport system results from the performance on all three levels. Each approach has its own impediments that have to be kept in mind. Improvements in system efficiency can only be realised over the long-term, since they involve the whole settlement structure. Many cities in emerging and developing countries still have the chance to shape the city layout in the right direction since many structures are immature and new settlements are evolving. In order to achieve travel efficiency infrastructure, investments are necessary and also behavioural changes have to be induced. To overcome the peoples' restraints, hindering a change in behaviour, incentives and adequate information is necessary. Similarly, vehicle efficiency relies upon behavioural change towards purchasing more energy efficient vehicles and accepting the higher costs which can result from the more advanced technology.

System efficiency

System efficiency concerns how transport is generated and determines the suitability of different modes to satisfy everyday needs. It includes the important knowledge that infrastructure and city structure determines transport demand. Research has shown that energy consumption per capita is inversely proportional to the density of a city (e.g. Newmann and Kenworthy 1989). The reduction of traffic volume is a crucial aspect of energy-efficient transport. A dense structure with mixed uses is essential for high system efficiency, because it induces short travel lengths and a modal shift from motorised road transport to more efficient transport modes such as walking, cycling and public transport. Mixed neighbourhoods usually exhibit a reduction in vehicle-miles by 5 to 15 % (Litman 2011). Not only a dense city system but also proper transport demand management and a sufficient public transport network are prerequisites for system efficiency. In total, local land use factors including mixed land-use and dense structures can reduce miles travelled by vehicles between 10 and 20 % and thus, can lead to significant energy savings. Considering smart land-use planning in regional development can even reduce automobile travel by 20 to 40 % (Litman 2011).

Travel efficiency

Travel efficiency covers the energy consumption of different transport modes. The main parameters of travel efficiency are the split of transport modes and the load factor. Specific energy consumption per passenger kilometre or tonne kilometre varies highly between different modes of transport (IFEU 2008). In general, private cars are much less energy-efficient than public transport. Of course, non-motorised modes are important alternatives, which do not need any fuel at all. This is why an effective measure to enhance energy efficiency is a shift to more efficient modes of transport such as public transport and non-motorised modes, while reducing the share of private motorised modes.

The energy consumption per passenger kilometre is also highly dependent on the load factor, which describes the occupancy rate of a vehicle (Rietveld 2002). Rideshare matching for private vehicles and proper dimensioning of the public transport system as well as adaptation to peak and off-peak hours can optimise load factors.

Typically, public transport uses less than half the energy per passenger kilometre than passenger cars (IFEU 2008). Thus, each trip that is shifted from private motorised modes to public transport contributes to an increase in energy efficiency.

Vehicle efficiency

Vehicle efficiency can be improved by reducing the vehicle's fuel consumption per kilometre. Technological and design improvements as well as energy-efficient vehicle operation can increase vehicle efficiency. Technological measures can usually be clustered into three categories: Improvement of existing vehicles, new fuel concepts and the development of new car concepts. A combination of such measures can significantly reduce energy consumption compared to an average vehicle fleet. Studies in developed countries estimate that the potential for an increase in fuel economy ranges between 20 and 30 % for light-duty vehicles. If higher incremental costs for vehicles are included, even larger potentials are projected (IAC 2007). However, such potentials of course depend on the current composition of the vehicle fleet, which varies regionally.

Efficiency could also be improved for public transport vehicles. Several technical measures are available to increase the energy efficiency of buses, trams, trains or ferries (e.g. Mckain et al. 2000/Gunselmann 2005/Barrero et al. 2008). In addition to a lower energy consumption of public transport vehicles, the energy demand of public transport infrastructure can be reduced as well. For instance, energy-efficient lighting can be installed at stations. Eco Driving can increase vehicle efficiency even without any technical changes (Breithaupt and Eberz 2005).

The ASI-concept

To address the overall performance of the transport sector, a holistic approach is necessary which aims at improving energy efficiency on all three levels. In recent years, the Avoid-Shift-Improve (ASI) concept has been developed as a new paradigm for sustainable transport that meets the requirements of energy efficiency and climate change mitigation (e.g. Dalkmann and Brannigan 2007, ADB 2009). The ASI-approach includes three strategies:

- Avoid travel or reduce travel-length
- Shift travel to more energy-efficient modes
- Improve the energy efficiency of vehicles and fuels.

Each strategy addresses a different level of energy efficiency. Avoiding transport aims at improving the system efficiency. The strategy "shift" can be used to increase travel efficiency and "improve" targets the level of vehicle efficiency (Figure 1).

BARRIERS AND CO-BENEFITS

Before decision makers start to deal with concrete measures, they should be aware of the barriers that can be associated with energy efficiency programmes. The rebound effect and the investor-user dilemma are barriers that are widely known in energy efficiency initiatives. However, multiple co-benefits associated with an energy-efficient transport system can provide incentives for decision makers to overcome these barriers and invest in energy efficiency.

Rebound effect

Actions that increase efficiency and reduce consumer costs can result in increased consumption. This phenomenon is called the rebound effect or offsetting behaviour. Fuel efficiency programs tend to have significant rebound effects. Efficiency gains reduce travel costs and can thereby cause additional travel (VTPI 2010a). This can result in an increased per-vehicle annual travel distance. Consequently, vehicles that are 10 % more fuel-efficient do not induce a 10 % fuel saving. Nevertheless, rebound effects do not eliminate the benefits of efficiency gains because net energy savings occur. For instance, the rebound effect can offset 1 to 3 % of 10 % fuel efficiency gains, but still 7 to 8 % net reduction in fuel consumption occurs (UKERC 2007). The magnitude of the rebound effect can depend on several factors like personal income or real fuel costs (Small

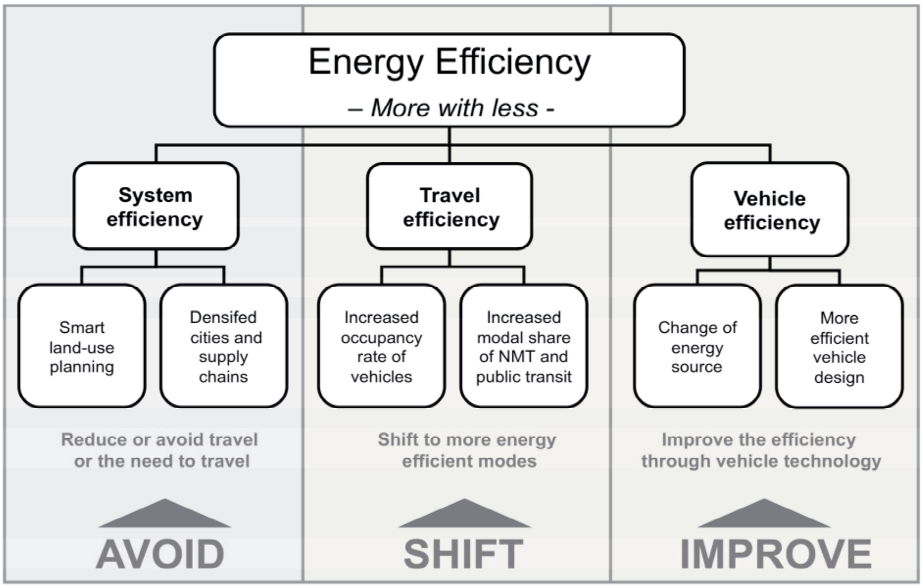

Figure 1: Three levels of energy efficiency in urban transport and the ASI-approach.

and Van Dender 2010). If additional automobile travel resulting from reduced travel cost leads to congestion, the rebound effect can be damped slightly, since travelling by car becomes less attractive (Hymel et al. 2010). It is important to account for rebound effects when policies and projects are planned or evaluated.

Investors-user dilemma

In some cases, investors do not, or insufficiently benefit from energy efficiency gains (e.g. Schleich and Gruber 2008). This phenomenon is named investors-user dilemma and is widely known in the residential sector. In the transport sector one example for an investor-user dilemma is that municipalities have to bear additional costs to provide an energy-efficient transport system, whereas its users benefit from such a system. Extending the public transport system will impose additional cost on the municipality, but provides cost or time savings for the user. Likewise, expansion of a cycling and walking infrastructure is beneficial to the user, who can reduce their transport costs.

However, the multiple co-benefits associated with energy efficient transport can provide additional incentives for the investor to implement energy efficiency measures. For example, an expansion of the public transport network can reduce the amount of vehicles in the city and thereby prevent the municipality from having to provide additional road and parking space. Hence, a holistic view of the transport system should be taken in order to identify all economic advantages of energy efficiency measures.

Co-benefits of energy efficient transport

Not only can the municipality profit from an energy-efficient transport system, but every resident of the city can also benefit from sustainable transport. Energy-efficient transport can contribute to healthy and comfortable living conditions in urban areas. Less energy consumption reduces emissions and enhances urban air quality. By promoting the role of public transport, traffic congestion, accident risks, crowded streets and noise pollution can be avoided or reduced. Furthermore, a major proportion of the population cannot afford to own a vehicle. Thus, investments in public transport offer mobility to low-income resident.

Also the society beyond the city borders can benefit from reduced automobile dependency and increased energy efficiency. A large proportion of the expenses for automobile travel are external costs. In transport, external costs are monetary and non-monetary costs resulting from transport activities but which are not covered by the 'consumer' and instead put upon society. They stem from (mostly negative) side effects of transportation, such as congestion, accidents, emissions and pollution, noise and aesthetic factors. Chang and Gou (2005) analysed the external costs of different transport modes in Taipei and came to the conclusion that the external cost of private motorised modes per person and kilometre are about three times the costs of public transport. External cost can even be imposed upon society beyond the city borders. Creutzig and He (2009) have shown that in 2005, the local external cost stemming from motor vehicle use and from global climate change externalities were between 7.5 and 15 % of Beijing's GDP. On the global scale, CO_2 savings are one of the most important benefits of energy-efficient transport.

Energy efficiency policies and measures

Many policies and measures are available to enhance energy efficiency in urban transport. The responsibilities to initiate and implement such measures can vary between different organisational levels and between private or public actors. On the national level, strategies and programmes for the transport sector are developed and a legal framework is set. Local measures can influence the city's transport system precisely and can initiate a development towards more energy efficiency on a small scale. This section shows potential activities for important local stakeholders and how the national body can support energy efficiency in urban transport. Furthermore, success factors, which can determine the amount of energy savings resulting from energy efficiency policy are described. To facilitate an easy entry to the development of an energy efficiency strategy, useful packages for enhancing energy efficiency on the local and national levels are provided.

SUCCESS FACTORS

To succeed in implementing a modern and energy-efficient transport system, a strategic foundation is crucial. On the city level, it is helpful to create a holistic concept that addresses the different levels of energy efficiency in transport. The concept should contain several policy packages, which include sensibly composed measures of various kinds. It should address energy efficiency on all levels, i.e. system efficiency, travel efficiency and vehicle efficiency. Furthermore, national strategies should support efforts on the local level by creating a favourable framework for energy efficiency.

Policy packages should include different types of measures. Ideally, positive incentives ("pull" measures) should be supported by disincentives ("push" measures). For instance, improved walking and cycling infrastructure may result in little modal shift if negative incentives for private car use like road and parking fees or fuel taxation are not implemented. Strategic policy packages often have synergistic effects and can increase the transport efficiency far more than the sum of their single actions. Policy packages can be introduced in various depths and can, depending on their complexity, need involvement not only of the local government but also of the national government, industry, NGOs or other actors (Boraddus et al. 2009).

Each stakeholder only has a limited scope of action and only partial competence in decision-making. Thus, to implement an energy-efficient transport system on all levels, a close cooperation between all actors involved in the transport system is necessary. Thus, activities of different actors have to be linked to create a comprehensive energy efficiency policy. Round tables or thematic working groups can constitute a framework for close cooperation. Furthermore, it can be helpful to establish a multidisciplinary organisation unit within the city administration to make sure that the efforts of different departments intertwine perfectly. Political will for changes and a strong leadership are also crucial.

GETTING STARTED WITH ENERGY EFFICIENCY IN URBAN TRANSPORT

Before strategies for increased energy efficiency in urban transport are developed on the local or national level, it is important to analyse the current status of energy efficiency in the respective transport systems. The adequacies of measures depend on the circumstances in the individual cities or country. For instance, the implementation of road or parking pricing is only of limited success if alternatives like public transport or non-motorised modes are not available. It is curial that the authorities analyse the transport system in detail to identify areas where urgent action is necessary and where potentials for energy savings can be tapped.

In general, the measures can be clustered hierarchically into basic, advanced and complementary measures (see Table 1). Basic measures include the essential prerequisites for an energy efficient transport system. Only if these fundamentals are fulfilled, can the full potential of advanced and complementary measures be realised.

Decision makers on the local or national level should follow a three-stage process:

1. Decision makers should ensure that factors that trigger inefficient transport are removed. For local authorities, the basic package includes the provision of a proper infrastructure for public transport and non-motorised modes as well as the introduction of efficient land-use planning. Thereby, a future increase in transport demand is reduced and citizens are provided with a proper alternative to the private car. On the national level, such basic measures are the removal of fuel subsidies and the introduction of sufficient fuel taxation.

2. Advanced measures can be implemented, which support the success of the basic measures and make additional fields where available efficiency can be increased. On the local level, advanced measures should lead more people to switch from cars to public transport or non-motorised modes. The attraction of public transport and non-motorised modes should be increased and disincentives for automobile use should be implemented. The advanced package

Table 1: Overview of useful packages to address energy efficiency in urban transport.

	Basic measures	Advanced measures	Complementary measures
Objective	Remove factors that trigger inefficient transport	Lead to further increase in transport efficiency	Induce additional reductions in energy consumption and innovations in energy efficiency
Characteristics	Essential to enable a transition towards energy efficient transport	Support the success of the basic package or open up additional fields for energy efficiency	Additional effect might be smaller compared to the basic or advanced package
Example measures national level	• Removal of fuel subsidies • Additional fuel taxation	• Vehicle fuel economy standards • Annual vehicle registration tax • License scheme for cars • Financial incentives for energy-efficient modes	• Vehicle labelling • Cap system for vehicle manufacturers • Research and pilot projects • National cycling plan
Example measures local level	• Proper public transport network • Pedestrian and bicycle friendly infrastructure • Densified city structure • Transit oriented development • Mixed land-use	• Parking / road pricing • High quality public transport network • Plate restriction schemes • Continuous cycle network	• Job tickets and rideshare matching • Procurement of energy-efficient vehicles • Eco Driving • Car free Days

for the national level contains mainly "push-measures" for automobile owners and thus emphasises the new concept of public transport oriented development. In addition, financial incentives for the use of energy efficient modes can be introduced.

3. Additional measures can complement the basic and advanced packages. Even though their additional effect might by smaller compared to the basic or advanced packages, these measures allow further reductions in energy consumption or lead to innovations in energy efficiency. Local authorities and companies as well as local public transport operators should eventually improve their own energy efficiency. Additional measures for the national level include mainly instruments to initiate the development and the market penetration of advanced technologies.

LOCAL ACTORS

Local stakeholders can develop policies that are suitable for specific problems and challenges a city has to face. Whilst acknowledging the wide variety of practices between cities, specific tasks and responsibilities are assigned to different parties. For each measure, a key stakeholder is identified, meaning that this actor holds the main responsibility for its implementation. The measures and the level of efficiency they address can be displayed graphically for each actor in a 'navigator' chart'. Figure 2 shows an example graph for the local transport authority and public transport operator.

It is important to keep in mind that additional stakeholders can be involved in most of the measures because they have to be consulted or can provide advice. Sometimes, it is even necessary that a suitable framework (legal, financial or infrastructural) is created before a certain measure can be implemented.

The most important decision makers on the local level are:

- The city's transport authority
- The local public transport operator
- The land-use planning authority
- The mayor and city government
- Local companies and organisations

Transport authorities and public transport operators

Transport authorities are usually responsible for planning and management of the local transport system. The local transport authority has to plan the road infrastructure as well as the public transport network, and has to arrange transport services. The local transport authority bears a high degree of responsibility for the energy efficiency of the city's transport system, since the local infrastructure influences the citizen's choice of transport modes (Priemus et al. 2001). Financial and political support from the city council is of course necessary to realise an energy efficient transport system.

Sometimes, the provision of the public transport infrastructure is the responsibility of the local authority, but the system's operation is the responsibility of private companies. Many cities even have multiple public transport operators. In these cases, a close cooperation between public transport operators and local transport authority is necessary to establish an optimal public transport system.

Figure 2 illustrates which kind of measures can be the responsibilities of the local transport authority and the public transport operator. The width of the arrows indicates at which level of efficiency the stakeholders have the greatest potential to realise energy efficiency. As can be seen in this 'navigator' chart', the transport authority and the public transport operator can influence the travel efficiency with multiple measures.

Expansion of the public transport network and improvement of its operation: The local transport authority and the transport operator should make sure that the existing network fulfils the transport demand and otherwise they should expand the system. A powerful public transport system can comprise different types of public transport. Which kind of system is appropriate for the city or a specific route depends on several factors like cost, construction time, passenger capacity and city structure. Possible options are commuter rail systems, metros, light rail transit and bus rapid transit. Bus rapid transit (BRT) systems have most notably been implemented in several cities as an alternative for rail systems, since they need lower investments and their flexibility is higher. Examples from Bogotá, Bangkok, Manila or Beijing show that BRT systems are able to compete with rail systems in terms of speed and capacity. For instance, Bogotá's BRT system moves 36,000 passengers per hour per direction (Wright 2005).

Demand-oriented public transport system: An energy-efficient public transport system should consist of several levels. Regional transport modes should be connected to the city system, which in turn is linked to neighbourhood systems. Feeder buses with large capacities and higher travel speeds should operate on routes with large passenger volumes. Small busses with more frequent stops should connect smaller and less frequently used stops. Transport hubs should be created to enable users to switch between different vehicles. Such a demand-oriented system is not only more comfortable for the rider, but it can also enhance the profitability and efficiency of the network (Wright and Fjellstrom 2004).

Enhance the attractiveness of the public transport system: Not only the availability of public transport determines its use, but also its level of comfort influences the citizen's choice of transport modes. Various improvements can enhance the attractiveness of the public transport system. Travel time determines the attractiveness of a public transport system. Separate bus lanes or bus priority at intersections can help buses to travel faster and ensures that timetables are kept (Broaddus et al. 2009). Improved rider information and comfortable stations and vehicles can also make the system more attractive. If different providers are involved in the public transport system, integration of public transport services can be necessary. Schedules have to be adjusted to minimise transfer times between different operators. Besides network integration, the fare system and the rider information system should also be integrated. The local transport authority can support transport providers by adjusting and coordinating the physical infrastructure and the route network. In Singapore, different private operators have been successfully combined. Today, integrated fares, information and networks facilitate seamless travel for commuters and wasteful duplications of lines are avoided (Broaddus et al. 2009).

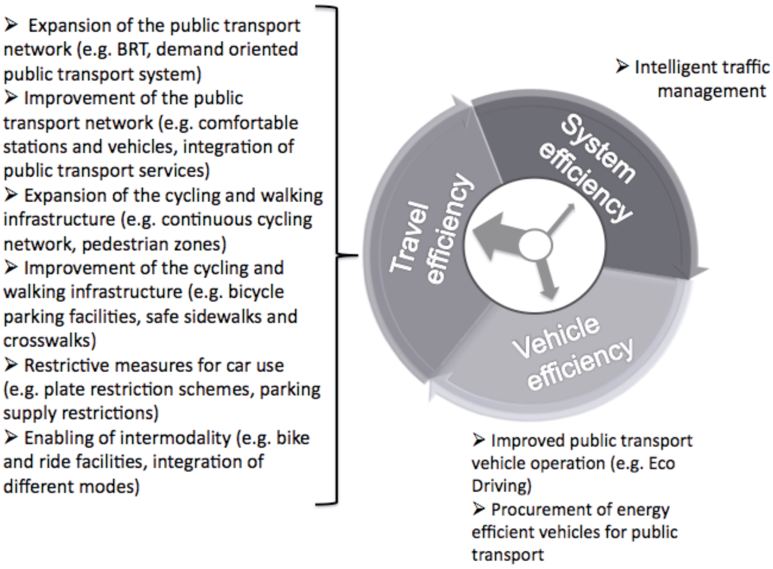

Figure 2: Potential measures for which the local transport authority is responsible.

Improve vehicle efficiency: The energy efficiency performance of the public transport system itself can also be improved. The use of energy efficient vehicles and the provision of Eco-Driving lessons for drivers can reduce the energy consumption per vehicle kilometre. In Santiago de Chile, Eco-Driving training for urban bus drivers resulted in significant reductions in fuel consumption with average fuel savings of nearly 20 % being achieved (Breithaupt and Eberz 2005).

Supporting non-motorised modes: As the most energy-efficient form of travel, non-motorised transport should be included in the transport strategy right from the beginning. Expansion and improvement of the necessary infrastructure for pedestrians and cyclists are promising instruments to avoid short-distance car travel. The creation of continuous cycle networks, the provision of bicycle parking facilities or route signage and maps designed for non-motorised modes are possible measures. In some cities safety issues keep the citizens from cycling or walking short distances. Safe sidewalks and crosswalks, separate bicycle lanes and pedestrian zones as well as separate crossing phases for pedestrians and cyclists can be beneficial. Litman (2011) found that residents of communities with good walking conditions drive 5 to 15 % less than ones in more automobile dependent communities. Shared bicycle services, which provide free or low-cost bicycles for public use, are a useful addition to the usual public transport system and can be operated by private companies. Furthermore, an integration of non-motorised modes and public transport can boost both means of transport. Proper bicycle stands at stations support “bike and ride” as energy-efficient inter-modality (Hook 2005).

Disincentives for automobiles: Besides providing incentives for the citizens to switch to energy-efficient modes of transport, the local transport authority should also make use of regulatory instruments to create disincentives for the use of private motorised vehicles. Speed restriction or parking supply restrictions make cars less convenient. Plate restriction schemes or environmental zones can even banish vehicles from entering certain areas of the city (Broaddus et al. 2009).

Careful traffic management: A constant traffic flow is beneficial for lower fuel consumption. Intelligent traffic management can be used to guide the traffic flow in order to avoid congestion. However, this measure should be used cautiously, since congestion reduction enhances the attractiveness to use private motorised modes. First and foremost, automobile travel should be avoided. All available measures should be taken to reduce private motorised modes. These measures should ensure that the disadvantages of automobile travel prevail over the advantage of reduced congestion. Only under these conditions, should intelligent traffic management be used to increase the efficiency of the remaining road traffic (Broaddus et al. 2009).

The fields of activities of the local transport authority and the land-use planning authority are often closely related. Therefore, a close cooperation between these two actors is very important. For instance, to make sure that all districts are well connected to the public transport system and that sufficient space is reserved for non-motorised modes requires frequent communication between the transport authority and the land-use planning authority.

Land-use planning authority

Land use has a substantial effect on travel demand and travel patterns. The city structure is one of the main factors that determine the volume of travel generated in the city. Therefore, land-use planning authorities play a major role in creating an energy-efficient urban structure. Smart land use policies should be designed with the aim to reduce the need for travel and dependency on cars for transportation. Thereby, system efficiency can be significantly increased.

Utilize the space dedicated to the local transport network wisely: Traditional planning tends to prioritise roads for private motorised modes. Road space for cars should be limited. Reallocation of existing road space should benefit public transport or non-motorised modes. Instead of calling developers to build a minimum number of parking spots, land use planning authorities should cap new parking supply by setting maximums (Broaddus et al. 2009).

Mixed land use and dense settlement structure: A key characteristic of smart land use planning is mixed land use. If residential houses, offices, shops and public services are within close proximity to one another, the need to travel or the distances to be travelled can be significantly reduced. The density of people and businesses within an area is another crucial factor influencing the city's energy efficiency. Low densities lead to increased travel distances and consequently to high transport energy demand. In addition, low-density urban structures often increase car dependencies, whereas more dense cities promote the efficiency and profitability of public transport, since demand for transport is locally concentrated (Petersen 2004).

Transit oriented development: A set of different smart land use measures can be combined as Transit Oriented Development (TOD). TOD aims to increase the density of commercial and residential development along public transport corridors and stations. The transit station is supported as a centre of local commercial activity. Within walking distance, the centre is surrounded by high-density residential structures, employment places and services like health care. Thus, many facilities are within walking distance and longer distances can be easily travelled by public transport (Petersen 2004). The concept of Transit Oriented Development was applied in the Brazilian city Curitiba. In the 1960s, the city developed a new urban master plan, which encouraged commercial growth along arteries radiating out from the city centre and implemented a bus rapid transit system along the arteries. Today, Curitiba consumes 30 % less transport fuel than other comparable Brazilian cities (Bongardt et al. 2010).

Mayor and city government

Besides the land-use planning authority and transport authorities other local authorities can implement and support measures towards an energy-efficient transport system. The mayor and the city government have to coordinate the different initiatives. They should have a holistic view on the energy efficiency measures. The local government can identify and solve conflicts arising from measures proposed by different departments and should provide political support for suitable measures.

Favourable framework for energy efficiency: Continuity in political decision-making even beyond legislative periods is essential. Furthermore, the city council can serve as initiator of multiple measures and can create a common policy towards higher energy efficiency. The city council can also pave the way for efficient transport by laying down rules that can build a framework for energy efficiency. In addition, the leading authority of the city can support energy efficiency research by enabling and supporting the realisation of pilot projects in the city or by cooperating with national authorities, research institutions and companies.

Economic disincentives for automobile use: Together with the financial department, the city council can establish road or parking pricing schemes. Urban road pricing can be implemented for the whole city (city toll), for certain roads (toll roads) or facilities (e.g. bridge tolls). In some cities the pricing scheme is limited to peak hours (congestion charge) (Breithaupt 2004/Sakamoto and Belka 2010). The instrument comes with some weaknesses that should not be neglected. Comprehensive road pricing is fairly complex and costly. Investments in technology, infrastructure and personnel are required to collect tolls and monitor compliance. Road tolls can encourage vehicle owners to switch to cheaper routes leading to an increased travel distance. Parking pricing is advantageous compared to road pricing. It is politically easier to implement, since it can gradually be expanded and is already very common. Moreover, it is cheaper and often less complex. A shift from free parking to parking pricing, which reflects the full costs of parking facilities, can reduce automobile commuting by 10 to 30 % (VTPI 2010b). Parking pricing should be implemented city-wide, thus, participation of different stakeholders who provide public parking space is necessary. Local governments can also establish pay-at-the-pump surcharges, which impose an additional charge on gasoline sales at petrol stations in the municipal area. In Colombia, the city of Bogotá used a 20 % surcharge on all gasoline sales in the municipal area to finance the construction of a new public transport infrastructure (Sakamota and Belka 2010).

Financial incentives and information: The pricing schemes create supplementary revenues for local authorities. The financial department should allocate these incomes wisely. The money can be used to finance public transport projects or to subsidise public transport fares. Lower fares make the public transport system not only more attractive but also open the system to low-income families. Ideally, policy packages include expensive infrastructural measures as well as revenue generating economic instruments. Public awareness campaigns and events can help to gain support from the public for energy efficiency measures. They can be used to inform the public about the economical, environmental and social impacts of motorised transport or to promote alternative mode choices. The municipal public awareness department can carry out their own campaigns or can support the efforts of non-governmental organisations (Pardo 2006).

Ensure proper enforcement: Enforcement is an essential requirement for the success of measures such as road pricing or parking supply restriction. A penalty system should be developed by the city administration in order to enforce compliance. The police and associated institutions have to monitor compliance. Education and training can be necessary if new traffic laws are set up and it can be necessary that the institutional capacity has to be increased to control and enforce new instruments (Broaddus et al. 2009).

Similar to decision makers in private companies, the mayor can launch several measures that improve the energy efficiency of business trips and optimise the commuting behaviour of municipal employee. More details on corporate mobility management will be presented in the next section.

Companies and organisations

The private sector is a relevant player for increasing energy efficiency and city authorities should try to be in close contact with local companies. Especially if private companies operate the local public transport system, a close cooperation between city authority and company is essential.

Ensure accessibility by energy efficient modes: Private companies cause traffic by business activities or by employee commuting. Therefore, the location of the company has a huge impact on traffic generation. It should be served by public transport and should be easily accessed by bike or by foot. If public transport is not accessible from a preferred location, the company could cooperate with the local land use planning authority to develop a sustainable mobility solution. To encourage walking and cycling, the company should provide the necessary infrastructure. They should ensure that the site is connected to a path network. Changing facilities and bicycle stands should be provided for cyclists (Litman 2004)

Financial support for the public transport network: Public Private Partnerships (PPP) to improve the public transport network are beneficial for both the company and the public. An extension of the network can help to connect the company to the public transport system. If a company adds a supplementary route, it can collect revenues from the operating company. Another PPP is to provide vehicles for the public transport system or to take care of bus shelters in return for advertisement rights. Such PPP has successfully improved bus shelters in Singapore, where private firms build or maintain and clean bus shelters in return for advertisement rights (Zegras 2006/ Broaddus et al. 2009).

Corporate mobility management: All companies, as well as municipal institutions can set up their own mobility policies to make business trips more energy-efficient. For instance, they can introduce a corporate travel policy that obliges employees to use energy-efficient modes for business trips whenever possible. For customers and business partners, the company can provide a transportation access guide that describes how to reach the company site by non-motorised modes or public transport. If the company has it's own fleet for passenger or freight transport, this fleet should be managed properly. Procurement of energy-efficient vehicles could be implemented as a guideline in the corporate philosophy. Additionally, drivers could be trained in Eco-Driving (Breithaupt and Eberz 2006). A firm with very large company grounds can provide bicycles or can operate a company bus to enable workers to reach their worksite.

Support energy-efficient commuting: There are also a lot of measures to alter employee's commuting behaviour towards more energy efficient modes. Instead of providing free parking spaces, the company can provide financial incentives comparable to the cost of free parking supply. In 2004, a hospital in Rotterdam successfully implemented a number of measures to reduce car commuting by its employees. The personnel was charged for parking and credited for every kilometre not travelled by car. Thereby, the number of commuters travelling by car has dropped significantly (Broaddus et al. 2009/Litman 2004). Alternatively, large companies or groups of individual firms can negotiate with the local transport operator to implement a job ticket system that reduces the cost for employees to come to work by public transport. For employees without proper access to public transport a rideshare-matching program can be implemented to organise carpools or vanpools. Flexible working hours can support the success of such measures by allowing employees to adjust to carpool and public transport schedules. Enabling teleworking, which allows employees to work at home is another possibility to reduce the company's travel demand (Litman 2004).

Involvement of non-governmental organisations: Other relevant players in transport policy are non-governmental organisations. Transport and environmental organisations can provide knowledge about sustainable mobility and can assist in strategical formulation and development of policy packages. Specialised organisations might even provide access to experts for energy efficiency. Local groups can perhaps easily communicate with the public to identify weaknesses in the local transport system. For instance, they can identify barriers for cycling and walking in the existing infrastructure. The Urban Cyclists' Association in Buenos Aires monitors bicycle parking and integration with commuter rail and gives recommendations to the municipal government about grievances in the system. Non-governmental organisations can also serve as disseminator of information on sustainable means of transport and can educate the public. They can organise public awareness campaigns like cyclist rallies, car free days or other communication measures. Many cities around the world have established a car free day, where city streets are closed to cars and cyclists and pedestrians take over the streets (Pardo 2006).

SUPPORTIVE NATIONAL FRAMEWORK

Decisions on the national level play a major role in the national transport system as well as on the local level. The national policy can help or hinder energy efficiency efforts on the local level. To achieve nation-wide energy-efficient transport and to support local initiatives, it is essential that national governments create favourable conditions which support local strategies. National strategies, programmes and legislations frame local policies. Furthermore, national authorities influence the local budget for the transport system.

The following actors are most commonly responsible for the implementation of energy efficiency measures in urban transport:

- The Transport Ministry shapes the transport system by developing national transportation policies, by organising public transport and by directing the construction and maintenance of necessary infrastructure.
- The Environmental Ministry should get involved in energy efficiency, since it is a prerequisite for an environmentally friendly and sustainable transport system.
- The Ministry of Finance and the Ministry of Energy can play a key role because fuel prices and fuel taxation shape the country's transport structure. If the national government subsidises fuel or does not implement proper fuel taxation, private motorised vehicles will easily dominate the transport system. Furthermore, without proper fuel taxation the government will probably lack the necessary financial resources to finance an appropriate transport infrastructure on the national and local levels.
- The Ministry of Economics can enable and support technological progress in energy-efficient transport.

The division of responsibilities and the organisational structures of ministries vary significantly from country to country. Therefore, national measures are not assigned to specific key actors, but clustered thematically.

Disincentives for automobile use

The national authorities can significantly influence the automobile use of the citizens. Especially in urban areas, where most distances are short and various alternatives to the private car are available, disincentives for automobile use can be successful in improving energy efficiency performance.

Fuel pricing scheme: Low fuel prices can lead to numerous negative consequences such as high shares of private motorised vehicles, excessive commuting by car, increasing size of vehicles and urban sprawl. If subsidies for fossil fuels are in place, the national decision makers should remove these subsidies as soon as possible. Instead, proper fuel taxation should be implemented, which increases the cost for automobile use directly proportional to a car's fuel economy. Rising prices for car-use encourages people to switch to more energy-efficient modes or to purchase more efficient vehicles and to drive more economically (Breithaupt 2004).

Motor vehicle taxation: Sales taxes or annual registration taxes as well as import duty are further possibilities to make automobiles less attractive. If the taxes are designed properly, they can reduce vehicle ownership and contribute to a fleet turnover increasing the number efficient vehicles. Sales taxes can provide rebates for cars with greater fuel economy and annual registration taxes can be differentiated based on engine size, type of vehicle and overall fuel consumption (Breithaupt 2004).

Control car ownership: License schemes can be introduced, which cap car ownership. The national authorities can set a threshold for cars registered in a given year. In Shanghai and Singapore licences are linked to a pricing scheme by selling them in auctions (Broaddus et al. 2009)

Strengthening the role of energy efficient modes

Similar to the local level, it is useful to combine disincentives for automobile use with incentives for energy-efficient modes on the national level. Many countries spend a large proportion of their budget for the expansion of car-oriented infrastructure. However, it is much more sustainable and cost-effective to invest in public transport and non-motorised modes.

Nation-wide expansion of infrastructure for energy-efficient modes: If necessary, the nation-wide public transport system should be expanded and improved. Thereby, the importance of automobile travel is reduced, which also favours a modal shift in urban areas. To underline the role of energy-efficient modes, comprehensive strategies and plans for efficient transport systems should be developed on the national level. Besides public transport, non-motorised modes have to be promoted. Many European countries developed a national cycling plan to support and promote cycling in urban areas (ECMT 2004). Such a cycling plan can be an extra document or it can be implemented in a wider transport policy plan, which outlines a set of actions that should be carried out on national or local levels. A national cycling plan demonstrates political will and commitment. Thereby, it raises awareness for cycling as an energy-efficient and sustainable mode.

Provide financial incentives for energy-efficient modes: The national tax scheme should not only increase the costs of automobile use, but should also encourage a shift to public or non-motorised modes by providing financial incentives. One possibility is to make public transport expenses tax deductible. Another possibility is to provide subsidies, which decrease costs of certain transport modes. Direct financial incentives will be created if public transport fares are subsidised. If the public transport network and its operation get financial support by the national government, customers can profit from resulting network expansions, higher frequency of services or renewed infrastructure (Breithaupt 2004).

Land-use guidelines: Planning guidelines should be developed on the national level to give advice on more energy-efficient urban structures and to require the realisation of mixed land-use or transit-oriented development (Petersen 2004). For instance, in India the central government influenced infrastructure in urban areas by implementing the Jawaharlal Nehru National Urban Renewal Mission. Several Indian cities were expected to formulate comprehensive city development plans in return for financial support for sustainable urban mobility projects (Bongardt et al. 2010).

Promotion of higher vehicle efficiency

Besides the reduction of automobile use, vehicle efficiency of the remaining fleet should be increased. Concerning technological and design improvements, the national government has many more possibilities and responsibilities than actors on the local level.

Support low-energy technologies: To enable further progress in alternative transport, the national government should support low-energy technology research in fields related to the transport sector. Similar to other sectors, innovative construction methods present a potential for future energy savings. Lightweight constructions, downsizing, aerodynamics or energy saving vehicle components are areas of research that can reduce a vehicle's fuel consumption. For instance, the fuel economy can be improved by 4 to 8 % with a vehicle weight reduction of 10 % (Kobayashi et al. 2009). Examples of energy saving vehicle components are fuel-efficient tyres. About 20 % of a vehicle's fuel consumption is used to overcome rolling resistance of the tyres. Today, tyres with low rolling resistance are available (Kojima and Ryan 2010). The national authorities can set maximum rolling resistance limits for tyres or can establish a labelling system. Furthermore, they can establish mandatory monitoring systems for new vehicles that help the user to operate the vehicle at maximum efficiency level. For example gear shift indicators or tyre pressure-monitoring system are new vehicle components to avoid wasteful fuel consumption (Kojima and Ryan 2010).

Support alternative fuels: In addition to vehicle technologies, alternative fuels as substitutes for petroleum can lead to fuel savings. Methanol, natural gas, liquid petroleum gas, ethanol, biodiesel, hydrogen and electricity are currently discussed as alternatives for gasoline and diesel. These fuels and new technologies offer opportunities for increases in efficiencies and reductions in emission for different vehicle categories. In addition, they provide the opportunity to become less dependent on oil, and offer new market options. However, these alternative fuels and associated technologies are in various stages of development. National ministries should evaluate different types of fuels and give advice on preferable fuels. National initiatives can provide incentives for necessary infrastructure investments (e.g. refuelling stations, pipelines) and can support market creation (Walsh and Kolke 2005).

Ensure market penetration of efficiency improvements: To make sure that the available improvements to vehicle and fuel technology are used in the national vehicle fleet, national decision makers have to establish incentives for more energy-efficient vehicles. Implementing vehicle fuel economy standards is an important tool to encourage the automotive industry to invest in technological improvements. Fuel economy standards have been implemented in several countries (e.g. South Korea, China, Japan, United States, and the European Union). In China, a fuel economy standard was issued in 2004. Its limits rank third globally, following Japan and Europe. Between 2002 and 2006, the average fuel consumption of the new light duty vehicle fleet in China was reduced by 11.5 % (Oliver et al. 2009). In line with this, the IEA (2009) found out that tight mandatory fuel efficiency standards are instrumental in achieving rapid technology uptake and avoids increases in vehicle size, weight and power. A similar instrument is a cap system for vehicle manufactures, which sets minimum values for the energy efficiency of the produced fleet or by capping the CO_2 emissions respectively. Even if a mandatory standard is not implemented, a national definition for efficient cars published as vehicle labelling can encourage customers to take efficiency characteristics into account when they buy a new car.

Conclusion

The global transport system emits approximately 7.5 Gt of CO_2 annually, is responsible for 27 % of global final energy consumption and relies 95 % on oil-based fuels. In the future, these alarming numbers will become even worse due to an increase in transport demand in motorisation in emerging and developing countries. It is up to decision makers in developing and emerging countries to take up this task and launch a transition to more energy-efficient transport. A suitable framework has to be set at the national level. Local actors can influence the city-wide transport system precisely with their own actions. The "investor-user dilemma" or rebound effects constitutes difficulties for energy efficiency policies, but co-benefits of sustainable urban transport can outweigh these barriers. The paper has shown that energy-efficient urban transport is not only necessary in developing and emerging countries, but also possible, affordable and beneficial for citizens, companies and public authorities as well as for the environment and the economy.

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