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Towards Sustainable Urban Transportation

Environmental Dimension

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To my parents and family

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Preface

The current research publications in the field of urban transportation show a rapid development towards Sustainable Transportation Systems (STS). The assessment of environmental quality is one of the issues of great concern in STS development. Today, environmental threats posed by transportation are well enough known to the general public. However, principles and procedures on how to evaluate the influence of urban transportation upon human beings and ecosystems, and how to prioritise the necessary measures, are still vague. Practical knowledge of the environmental impacts of urban transportation therefore needs to be widened and improved in order to properly inform decision-making and planning.

This monograph provides systematic, step-by-step theoretical knowledge, as well as case studies obtained via practical data collection, validation, aggregation, storage and finally reporting of the aggregated data for the purpose of management. These procedures go hand-in-hand with computational methods and modelling.

The author hopes this monograph will be of interest to professionals and academics working in the fields of environmental protection and urban traffic planning.

I am grateful to friends and colleagues from the Baltic University Programme (BUP) network for their valuable support, insights and comments during the writing of this monograph.

Linas Kliučininkas
Kaunas
November 2011

I. The challenges of urban transportation

1.1 Trends and features

In all modern societies, for a number of reasons, people tend to increase their mobility. The functioning of a modern society puts heavy demands on the ability of individuals to be mobile. Economic, political and social factors affect both the total volume of passenger transportation and its different modes. The worldwide increase in urban mobility since 1960 has been the direct result of increased affluence and the consequent improved access to private motor vehicles, as well as population growth. Cameron and his team (2003, 2004) investigated the cause of increased urban traffic in world cities between 1960 and 1990, and concluded that population growth, urban sprawl, increased car ownership, and decreased vehicle occupancy are the key factors causing the steep rise in vehicle kilometres (vkm).

In a broader sense, the increase in mobility can be illustrated by five main tendencies:

- longer distances covered in each trip;
- rapid growth of travel by car;
- increased importance of leisure-time activities;
- spatially more complex travel patterns;
- diffusion of mobility from a few groups to the broad majority of the population.

Mobility development in Sweden may be traced back to the beginning of the last century. Around 1900, the average distance travelled per person per day was roughly one kilometre. In the 1950s, mobility grew fast and increased to an average of more than ten kilometres a day. At the end of the last century, in the population as a whole it amounted to 35 kilometres per individual. Therefore over the course of the century people's ability to cover distances and interact with other places has increased by about 35 times (Tengstrom, Thynell, 1997).

Cities and towns act as engines for progress, often driving much of our cultural, intellectual, educational and technological achievements and innovations. However, today's trend of urban development results in increased consumption of energy, resources, transport and land, thereby raising greenhouse gas emis-

sions and air and noise pollution to levels that often exceed the legal or recommended human safety limits. This development, of course, has affected the lifestyles and daily activity patterns of most people, as well as the structure of cities and land-use in general. However, the ability to be mobile is not evenly distributed over the population. We can also observe that, in recent years, mobility has not grown as fast as has previously been the case.

Urban freight transport has to respond to changes in industry structure: in developed countries, it has had to adapt to high value-added production. This means increased value added per unit of weight, and consequently greater demand for more efficient transport. In addition, improved production technologies and management, as well as shorter production development cycles, tend to minimize inventories. Advancements in production and consumption have required smaller shipments and more frequent freight transport. The increased competition brought about by deregulation has stimulated higher quality services responding to these needs. Consequently the actual unit load carried per vehicle and trip has decreased (Nakamura et al., 2004).

However, mobility ought to be measured not only in terms of daily distance covered but also taking into account trip-frequency and the amount of time spent on travel. Daily trip-frequency is a crude measure of social interaction; that is, the number of out-of-home activities of a population. Travel-time per day reflects the role of transport in the daily time-budget; that is, how much time we can devote to travel considering everything else that has to be done.

Experience of development in most European countries suggests that mobility considered as trip-frequency does not change significantly in the long term. This means that people do not travel more and more often: they travel greater and greater distances. A similar observation applies to the travel time budget. People do not devote more time to travel: they travel faster. If people have the opportunity to choose, they generally use the fastest mode of transportation.

For a long period, commuting between home and work was the main purpose of travel and structured traffic-flows into regular patterns in time and space. But, at least in the more wealthy European states, during recent decades leisure trips have shown the biggest increase (defined as visiting friends and relatives, or other social/recreational activities). These “free time” trips now account for between one third and one half of total trips and daily distance covered. So we can see that change in the location of home and work, or the *suburbanization* of city life, represents only a minor part of the evolving mobility pattern. Another aspect of developments in mobility is an increased geographical distribution of activities, in addition to the growing complexity of spatial relations. After a first wave of suburbanisation – spatially concentrated, close to old city centres and well served by public transportation – new patterns have emerged. A second wave has meant

an increased attraction for low-density areas – rural places, small towns, outer suburbs – for housing developers. At the same time, there has been a suburbanisation of jobs, shops, and healthcare and leisure services. Many of the new places are not easily served by public transport, and this has engendered new and complex spatial relationships with regard to travel. Traffic within and especially between suburbs ("tangential" trips) has increased, while the old patterns of regular trips from suburbs to city centre ("radial" trips) has stagnated. *Conurbations* are also attracting commuters from increasingly large catchment areas.

Suburbanisation in the US was proceeding rapidly, with more workplaces being progressively relocated to the suburbs of large cities. This resulted in a phenomenon called suburban gridlock, in which traffic congestion occurred not only in the city centres but also in the suburbs. In Europe, where cities are frequently very old, there are many cases where urban areas are very compact. Since it was difficult to construct new trunk roads in such localities, urban traffic policy with regard to motorisation was focused on improving pedestrian spaces and public transport facilities: for example by the construction of transit malls and LRT (Light Rail Transit) lines. Although underground railways were also constructed, most cities opted to continue with the operation of trams, and increased their efforts to make these more convenient and agreeable.

One final significant feature of mobility development is the spread of mobile life-styles from few to many segments of the population, and to different social groups and households. This includes aspects of age and gender. The mobility of the elderly has increased thanks to the simple fact that the first generation of car owners is now reaching old-age. The entrance of women into the labour market during recent decades has of course increased demand for travel among women. But the most important factor by far is that, in the wealthiest countries over the last fifty years, almost 80 per cent of all households have been able to buy a car.

Experiences from most countries show that by far the most important factor in mobility level is car ownership. In countries like Denmark, Germany, Finland and Sweden, the car accounts for 70 to 80 per cent of the total daily distances of passenger travel. Car ownership is largely influenced by household income; other influences include, of course, the cost of buying and then using and maintaining the car. Differing levels of political control, taxes on fuel and vehicles, and charges such as import duties influence demand in different countries.

Is there a saturation level in car ownership? It is hard to give a straightforward answer to this question. In Sweden, there is on average one car per household, which may seem a plausible point of balance. However, in the United States this figure had already been reached in the 1950s. Today there are almost 0.7 cars per person in the US, which means that there is more than one car per licence-holder. But economic factors – such as the price of petrol, the structure

of cities and value systems, and general culture – differ. In Europe, there are clear signs that the car is regarded as a source of individual mobility, rather than a commodity related to the household in general. This individualisation of car ownership and use is certainly one possible impetus for further mobility expansion in the wealthier nations.

Regions with high densities of population and settlements tend to have fewer cars per capita and thus lower mobility levels than regions that are sparsely populated and with dispersed settlement patterns. At the same time, the tendency for cities and activities to spread out over large areas is a result of the increased mobility of the population.

Another important factor – at least in densely populated areas – is the standard of public transportation. Areas served by public transportation of high quality – high frequency, high speed, well-integrated routes and networks that are secure, comfortable and reasonably priced – have proportionally lower car ownership levels. If public transportation cannot live up to such relatively high standards it runs the risk of entering a vicious circle. More people turn to the car, leaving public transport to a diminishing group of people who, for various reasons, cannot use other modes: these are the so-called “captive riders”.

1.2 Towards sustainable urban transportation

Traditionally in transport policy, three main types of policy instruments have been used to implement concrete measures:

- technical development;
- urban planning;
- economic incentives.

However, it is also important to consider that traditional policy instruments are insufficient to realise the goals of sustainable mobility. Other political measures include legal framework, making information available to the general public, and education. At the same time we should consider that there are a lot of powerful actors – for example oil companies, among others – who are opposed to any significant move away from the present fossil-fuelled car, be it through the introduction of biofuels and/or a change of vehicle concept.

Technical improvements can be discussed on two different levels: long-term technical potential and short-term possibilities. The potential for passenger transport is generally greater than for cargo transport. Improved transport technologies are challenges for car manufacturers. Current technical solutions are geared towards decreasing specific energy use or specific emissions (per vehicle kilometre).

The long-term technical potential for reducing energy use is related to reducing greenhouse emissions.

The internal combustion engine is a mature technology that has undergone a massive amount of technological development, and continues to receive enormous research and development support. It is therefore likely to sustain its dominance of the automobile and lorry market in at least the medium term.

The main attraction of electric vehicles is the complete absence of tail-pipe emissions, and consequently the promise of improved urban air quality. A further advantage is that using electricity to power vehicles affords much greater primary fuel flexibility: this reduces dependence on petroleum products, but importantly may also ultimately enable vehicles to be powered by renewable energies such as solar, wind or hydroelectric power. Consequently, electric vehicles have the potential to be essentially pollution-free on both a well-to-tank and tank-to-wheels basis.

A hybrid vehicle, which takes peak power from the buffer store and requires about five times less power than a conventional car, is another branch of development. One important task is to reduce so-called cold-start emissions, which represent a considerable proportion of emissions from a car equipped with a catalytic converter. Another problem is the reliability of the entire emission-control system during a car's whole life-span.

Technical improvements are necessary but not enough. There are significant correlations between town planning and urban transport, and energy-use and pollution emissions. But while relationships between the availability of urban transport and energy-use and pollution emissions are approximately proportional, the correlation between town planning and urban transport is more complicated. In general, the internal relationships between housing, employment and shopping are important. The longer the distances between these functions, the higher the energy consumption. This is caused by two factors: increased transport work and more journeys by car, both of which increase consumption per mile.

Urban transport is reduced when these relationships are balanced within each urban society and the functions are distributed across the region, whilst concentrating them in regional centres results in increased traffic. Urban transport seems to be minimized in towns and cities of between 200,000 and 300,000 inhabitants with a high number of cars. Households with cars travel twice as much as households without.

Migration from rural areas to cities, further industrialisation, continuously growing consumption, service-sector growth, developments in building technology, plus the explosive increase in private transport: all these factors place demands on cities that cannot be immediately met within the existing frame of operation. Solutions have been sought in the heavy-handed reconstruction or total replacement of town centres. Old industry, workshops and housing have had to yield to

the expansion of city occupations. This has altered the basis for urban planning. Improving existing central areas has been made possible through suitable conservation and housing-oriented renovation, as well as by developing necessary public and private services, recreational open spaces and traffic improvement.

At the same time, access to city centres has been increased by the development of extensive traffic systems, including urban motorways linking the new central business districts to existing urban areas as well as to new suburban residential and industrial areas.

There are energy savings to be found by increasing density in built-up areas. It has been shown that, in a town with 30 inhabitants per hectare, the use of energy for transportation is 20 per cent lower than in a town with half that density. It follows that the urban-growth problem should be partly solved by the regeneration of debilitated urban areas and a more intensive use of the existing urban structure.

This has made it possible to keep undeveloped areas close to the city free from urban development, and for them to serve instead as ecological zones contributing toward the city's oxygen renewal, the maintenance of the ecological cycle and the recreation of its citizens.

It has also been shown that the availability of transport and energy consumption increase significantly when the distance between housing and the city centre rises. The energy consumption of households 40 kilometres from the city centre is close to twice as much as that for households located in the city, if local shopping and service facilities are poor; it is 30 per cent higher if there are good local services.

In most countries, a number of different taxes and charges are in place in the road transportation sector. These charges may be interpreted as economic policy instruments, even though many of them have been introduced for other purposes, such as raising revenues for the government. The most common traditional economic policy instruments are the following:

- fuel taxes,
- mileage taxes,
- annual vehicle taxes,
- parking fees,
- subsidies for scrapping old cars.

Making existing cities and new urban development more ecologically based and liveable is an urgent priority in the global push for sustainability. Kenworthy (2006) discusses ten critical responses to this issue and summarises them in a simple conceptual model that places the nexus between transport and urban form at the heart of developing an eco-city. This involves compact, mixed-use urban forms, well-defined higher-density and human-oriented centres, priority given to

the development of superior public transport systems and conditions for non-motorised modes, along with minimal road capacity increases, and the protection of the city's natural areas and food producing capacity. These factors form the framework in which everything else is embedded and must operate, and if they are not addressed only marginal changes in urban sustainability can be made. Within this framework, environmental technologies need to be extensively applied. Economic growth needs to emphasise creativity and innovation and to strengthen the environmental, social and cultural amenities of the city. Public areas throughout the city need to be well-designed and maintained, and sustainable urban design principles need to be applied in all urban development. All these dimensions need to operate within two key processes involving vision-oriented and reformist thinking and a strong, community-oriented, democratic sustainability framework for decision-making.

Urban form and spatial development have major consequences for sustainable development, encompassing not only environmental issues but also social and economic aspects. The concept of compact city development aims to optimize energy use, promote renewable energy sources, provide integrated transport networks with a focus on enhancing public transport and cycle routes, change the culture of energy and resource consumption and increase social inclusion (Jenks and Jones, 2010).

Most of the National Strategic Reference Frameworks submitted by the member states of the European Union include sustainable urban transport as an area for action. Extension, rehabilitation and upgrading of clean urban public transport such as trolley buses, trams, metros and suburban rail as well as other sustainable urban transport projects should continue to be promoted and supported by the EU. Pollutant emissions from vehicles have been successfully reduced through a gradual tightening of the EURO emissions standards (Green Paper, 2007). It has become clear during the consultations that in order to create a new “urban mobility culture” in Europe there is a need to set up partnerships. New planning methods and tools can also play a major role in this new urban mobility culture. Education, training and raising awareness have an important role to play.

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II. Environmental impacts of road transportation

2.1 Energy consumption

The transport sector is the fastest growing energy-consuming sector in the OECD, and is the most problematic for environmental policy. A rough estimation of energy use in OECD countries might include three constituents: one third of energy is used for residential purposes, one third is used for commercial-industrial purposes, and one third of energy is used for transportation. The fact is that a high proportion of residents of OECD countries prefer to travel by automobile, and most manufacturers find it more convenient to ship their products by lorry. Getting people to switch to public transport is difficult and of course requires substantial investment in infrastructure in order to make alternatives to private travel available in the first place. The effectiveness of fuel taxes is unclear, since it is questionable how much consumers take fuel costs into consideration either when buying a car or when deciding how much to use it. An alternative to a fuel tax is an excise tax on new cars, differentiated by the fuel efficiency of the car, which, though not a popular measure, is thought by some experts to be more effective than fuel taxes in changing consumer behaviour. Also being implemented or under consideration in some countries are road taxes, increased parking fees and restrictions on employment-related incentives such as company cars. As noted, there is also a continuing discussion on fuel economy standards imposed on manufacturers (similar to the Corporate Average Fuel Economy – CAFE standards in the US). As with energy policy, however, individual states have very different transport systems and have correspondingly different ideas about what constitute (politically and economically) feasible policies and measures. The best that can be expected in this sector in the short term is that other problems, such as congestion and air pollution, will prompt the adoption of policies which will, as a side benefit, limit growth in CO_2 emissions.

All OECD countries have, either specifically or as part of their broader climate change programmes, adopted measures intended to encourage greater use of public transport. However, no country has succeeded in increasing the use of public transport relative to private vehicle use. Germany has done the most to