Sustainable mobi;ity

Nijkamp, Peter; Verhoef, Erik

2001

Faculteit der Economische Wetenschappen en Bedrijfskunde

SERIE RESEARCH MEMORANDA

Sustainable Mobility

Peter Nijkamp
Erik Verhoef
Barry Ubbels
Caroline Rodenburg

Research Memorandum 2001-8

March 2001

vrije Universiteit amsterdam

Sustainable Mobility

Peter Nijkamp, Erik Verhoef, Barry Ubbels, Caroline Rodenburg

Department of Spatial Economics, Free University Amsterdam
De Boelelaan 1105, 108 1 HV Amsterdam, The Netherlands
Tel. + 3 l-20-4446090 / Fax +3 l-20-4446004 / http://www.econ.vu.nl/re

1. Sustainable Transport: A Policy Challenge

Sustainable development is a policy concept very much 'en vogue' since the publication of the Brundtland Report in 1987. It has generated a world-wide debate on the conditions and policy strategies for the achievement of environmentally-benign development. It was, however, soon recognized that the global nature of the sustainability concept did not contribute to a clear and operational policy focus. And hence we have witnessed in the past years the emergence of new complementary concepts that were more fine-tuned towards clearly demarcated economic sectors, such as sustainable land use or sustainable transport.

The present article is about sustainable transport. Sustainable transport is a concept that refers to an acceptable level of social costs associated with the physical movement of people or goods (see Nijkamp et al., 1998; Banister et al., 2000). These social costs are related to a decay of environmental quality (e.g., CO_2 emission affecting the global environment, or noise annoyance affecting local quality of life), fatality rates as a consequence of accidents in the transport sector, or congestion causing a burden to the economy at large.

In the debate on sustainable transport various issues have come to the fore. It seems wise to make a clear distinction of factors that play a key role in the discussion on sustainable transport, in particular from the perspective of the relationship between growth, transport and the environment.

- The relationship between economic growth and transport volumes. This issue has to do with the transport intensity of our economy (local, national, global). A de-coupling (or de-linking) can only be achieved, if with rising welfare both the material consumption and the physical mobility of people would decrease (absolutely or relatively). From a more structural perspective, one might also argue that a rising welfare can still be sustained, if the physical distribution of transport movements will be more favorable or cost-effective (e.g., short home-work distances, regionalized production systems). In the latter case, land use plays an important role (witness the discussion on compact cities, polycentric cities, edge cities etc.).
- The relationship between transport and environmental consequences. Apart from the option of a decline in transport movements (as discussed above), a de-linking between transport and environment can only be attained by either a shift to more environmentally-benign transport modes or the introduction of more energy-efficient or environment-friendly transport technology or new logistic systems (e.g., increasing the load factors or occupancy rates of vehicles).
- The use of substitutes for physical transport. In recent years we have witnessed a rise in interest in various ICT opportunities for bridging physical distances (e.g. teleworking, teleshopping). Although the actual use is rather low and the practice does not meet great *enthusiasm, it should be recognized that ICT may offer an enormous and as yet untapped resource.

Transport thus assumes a central role in the debate on growth and environment. There are apparently many handles through which a better environmental performance of the transport sector can be achieved. This paper aims to review these and related topics.

The paper is organised as follows. Section 2 will describe shortly some conceptual issues regarding sustainable transport and sustainable mobility. Section 3 provides insight into the impact of transport on the environment illustrated by a few key statistics. The spatial aspects of transport will be discussed in section 4, while the social and behavioural aspects of transport will be treated in section 5. The role of technological innovation in transport will be outlined in the next section. Section 7 will carry on with some of the dynamic aspects involved. This is followed by the role of the government in creating a sustainable transport system in the Section 8. Finally, section 9 will present some concluding remarks.

2. Conceptual Issues

Despite the central role that concepts like 'sustainable transport' and 'sustainable mobility' play in contemporary transport policy formulation, it is important to emphasize here at the beginning of this review that these concepts are by no means unambiguous. In contrast, there is no such thing as a generally accepted definition of 'sustainable transport', and it is doubtful whether one would – or could – ever exist. It therefore seems appropriate to spend a few words on conceptual difficulties surrounding the concept of sustainable transport, and to make explicit the interpretation that will be given in the remainder of this review.

The well-known 'Brundtland Report' (WCED, 1987) gave an intuitively appealing but at the same time impractical definition of sustainable development in general: *"a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development and institutional changes are made consistent with future as well as present needs"* (p. 46). Countless attempts (see e.g. Pezzey, 1993, for an overview) have subsequently been made to formulate an operational definition of sustainable development, in which different analysts have attached different weights to various aspects of sustainability: local and global environmental quality, intra- and inter-generational equity, economic efficiency, as well as more technical (but nevertheless essential) issues such as the extent to which substitution between different environmental goods is allowed for sustainability to hold true (weak vs. strong sustainability). It is evident that a first impediment to an unambiguous definition of sustainable transport would be the lack of an unambiguous definition of sustainable development in general.

Moreover, additional complications arise because transport is an open sector that is contingent on other driving factors in the economy. Transport often is not a goal in itself. As will be argued below, the demand for transport usually arises as a derived demand from the desire to undertake different activities at different locations. At the same time, transport activities and the structure and shape of the supporting infrastructure network often strongly affect these same patterns of spatial organization. Transport and spatial structure can thus be seen as two, strongly interacting 'open' systems. The definition of sustainability for either of these two systems in isolation – as a definition of sustainable transport would require – seems even more problematic than the definition of sustainability for the entire system. In particular, such a definition would easily ignore – adverse or beneficial – repercussions that the realization of sustainability in the one sub-system would have on the other. To put it extreme: the realization of environmentally 'sustainable' transport by a complete ban on transport, inducing a highly inefficient de-specialization of regions and as a possible result greater instead of smaller emissions (induced by production inefficiency), should not be qualified as a 'true' environmentally sustainable transport solution, despite its seemingly sustainable character when counting transport emissions alone. Instead, interactions with different sub-systems should be taken into account when defining sustainable transport. For an analytical study along these lines, see for instance Verhoef, Van den Bergh and Button (1997).

Given these considerations, we abstain from providing a clear definition of the topic of our review. Instead, we will continue by discussing various aspects that have been identified as important elements of 'a more sustainable transport system'. Our main focus will be on environmental aspects, in relation to various dimensions of transport behavior (in that order: spatial, social, behavioral, technological and dynamic aspects), although also distributional and equity issues will sometimes be touched upon.

3. Transport and Environment

Transport plays an important role in a country's environmental performance and the sustainability of its development. It has many effects on the environment and on human health; these depend on the transport mode, its energy efficiency, the type of fuel used, and the rate of increase in related traffic volumes (passenger, freight). Major negative environmental effects of transport activities include air pollution, noise, consumption of energy, land and other natural resources, as well as congestion and accidents. However, environmental impacts are not solely caused by the operation and use of transport means, but also by the production and maintenance of vehicles, the construction of infrastructure, the provision of energy and fuel, and the disposal and decommissioning of vehicles.

Inappropriately designed transport systems can damage the living environment of people. Worldwide, more than half a million people die each year in road accidents (World Bank, 1996). In major cities of developing countries the air quality is already worse than that in cities of industrial countries, despite lower levels of vehicle ownership. Road traffic is not the only source of air pollution, but it is the primary source of some important categories of pollutants (such as carbon monoxide and nitrogen oxides). These emissions damage health, especially of persons living or working in the open air. In Mexico City, for example, high particulate levels contribute to an estimated 12.500 deaths a year (Serageldin, 1993). Transport is also responsible for noise, and intensively designed transport infrastructure is visually intrusive, and, by physically dividing neighborhoods, can have adverse effects on local amenities.

At a more regional level, a lack of attention for the impact of transport can damage habitats and biodiversity. Sea and inland waterway transport can, for example, contribute to the pollution in ecologically sensitive coastal waters, and automotive air pollution can contribute to acid rain and problems associated with forest degradation. One of the most debatable issues is the impact of roads – and the subsequent induced development – on forest and other ecological and cultural sites. These effects are nowadays often taken into account in the decision whether or not to construct infrastructure (e.g. via environmental impact assessment). People are more and more aware of the necessity to avoid destruction of habitats and cultural sites, and prevent soil erosion.

Transport also pollutes the global environment. Pollution from motor vehicles produces about one fifth of the incremental carbon dioxide in the atmosphere, arising from human activity (which potentially contributes to global warming or greenhouse effects), one third of the CFC's (which contribute to depletion of the ozone layer), and half of the nitrogen oxides (which contribute to continental scale acidification and ecological damage) (World Bank, 1996). This carbon dioxide is primarily related to fossil fuel combustion and is created by all motorized modes of transport (see Geerlings, 1999). It has to be taken into account that some modes of transport which are considered to be clean (such as rail transport and electric cars) nevertheless contribute indirectly to the emission of CO_2 due to the fact that the electricity they use has to be generated elsewhere. The elimination of fully halogenated CFC's, which are especially damaging, led to the reduction of the contribution of transport to ozone depletion. However, the situation with global warming gases is less favorable.

As mentioned earlier, the environmental effects of transport differ significantly by mode. Road motor vehicles are the dominant source of the emissions that have local and continental effects (e.g. acid rain) and they account for more than 75% of the transport sector's contribution to global air pollution (World Bank, 1996). Aviation causes local air and noise pollution at ground level, while gaseous emissions in the troposphere deplete the ozone layer and contribute to global warming. Air transport is likely to become a more important source of pollution, because, despite improvements in engine technology, its consumption of fuel has grown more than 3% a year and is expected to grow even more. In maritime transport the operational discharging of oil was reduced 60% during the past decade, and shipping now accounts for only about one quarter of the oil entering the marine environment, although major damage still results from tanker accidents (Peet, 1994). Rail transport is relatively environmentally-benign, although indirect and direct coal burning (to generate electricity) and rail generated noise can have heavy localized impacts. Furthermore, modem fast rail technology leads to relatively high levels of energy consumption. Inland waterway transport is relatively fuel-efficient and has rarely local environmental impacts. Non-motorized transport is almost entirely environmentally-benign, at least in a direct sense without considering the infrastructure.

Negative environmental and social externalities arising from transport impose a large cost on society. The non-internalized costs of transport, i.e. environmental and social costs relating to air pollution, noise, accidents and climate protection, are estimated to amount to at least five percent of GDP for industrialized countries (OECD, 1999). Road transport and aviation are primarily responsible for these costs, while rail transport contributes to less than one per cent of the social cost burden.

Table 1: Total transport emissions as % of total emissions (mid 1990s)

	Nitrogen oxides (NOx)	Carbon dioxide (CO_2)	Sulfur oxides (SOx)
North America	51	31	4
OECD Europe	60	24	5
EU 15	63	26	7
OECD states	52	27	5

Source: OECD, 1999

Table 2: Total transport volumes

	Passenger car traffic		Goods vehicle traffic	
	billion veh km, 1996	% change '80-'96	billion veh km, 1996	% change '80-'96
North America	2680	12	1201	75
OECD Europe	2410	63	463	66
EU 15	2184	65	401	69
OECD	5683	36	2004	76

Source: OECD, 1999

Table 3: Indicators of Transport Intensity in Europe, 1970-1995

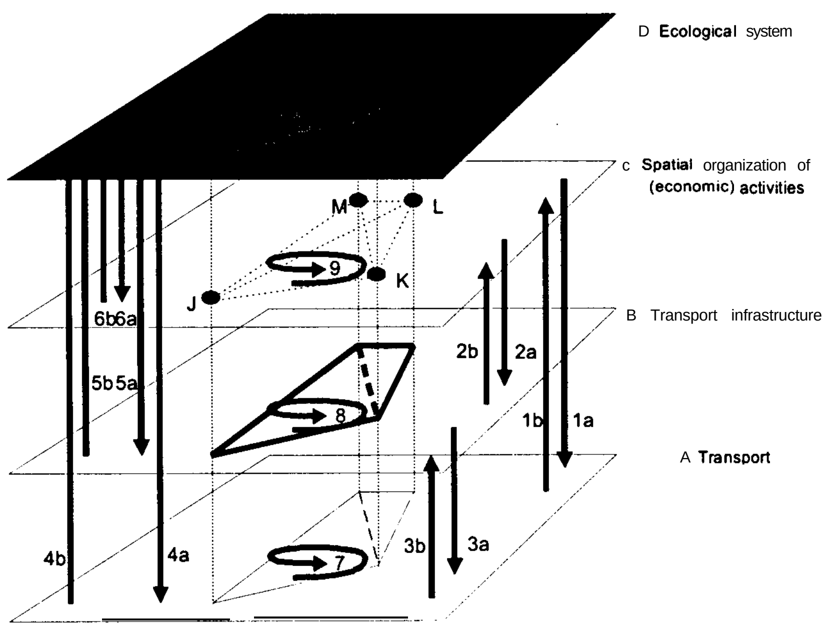
Type of measure	Indicator of transport intensity	1970 (EU 15)	1995 (EU 15)	% change
Economic efficiency	GDP per passenger kilometre	1.47	1.19	-19%
	GDP per tonne kilometre	3.74	3.82	2%
	GDP per net mass movement	3.87	3.93	2%
	GDP per unit of transport energy consumption	22.6	19.1	-15%

Source: Stead, 2000

In conclusion we can say that transport pollutes the environment in three broad ways. First, it imposes many local environment costs on those living, working or taking recreation near major pieces of transport infrastructure. These include such factors as noise, visual intrusion and local air pollution. A major problem here is that, unlike many other forms of environmental intrusion, it is generally difficult to move transport facilities away from sensitive areas, simply because users demand easy access and close proximity to roads and to public transport terminals (see Button, 1993). Second, there are transboundary effects such as emissions, which contribute to acid rain and maritime spillage. Thirdly, there is the contribution of transport to the environmental problems of global warming (e.g. CO_2 emissions). Below we will give an indication of some recent trends in industrialised countries (see Table 1 and 2). In addition, it is interesting to see the development in economic efficiency of transport. The development of GDP (indicator of economic activity) on the one hand and transport volumes on the other hand provides insight in the "decoupling" trends. Table 3 presents four economic efficiency indicators for Europe in the period 1970-1995.

4. Spatial Aspects'

The analysis of the environmental sustainability of transport and the design of associated policies will be complicated due to the inherently spatial character of the issues at hand, and to the existence of strong mutual dependencies between – at least – spatial organization, transport activities, transport infrastructure provision, and the ecological system. Figure 1 illustrates some of the main interactions that can be distinguished in this respect, adopting a multi-layer perspective. Four different, interacting layers A-D are distinguished, jointly representing the spatial incidence of the issues considered.



Source: Verhoef (l 996)

Figurel: Transport and environmental sustainability in a multi-layer representation

As a starting point, consider layer C, which represents the spatial organization of (economic) activities. The parentheses indicate that we use a broad definition of the term 'economic' here, including all possible kinds of productive and consumptive activities. It is assumed that these activities are located somewhere in space, and therefore various nodes are indicated, labeled J-

' This section draws heavily from Verhoef (1996) and Verhoef and Van den Bergh (1996).

M. At this level of abstraction, a node may also represent a more spatially dispersed 'node', such as an agricultural sector. In general, due to specialization of these nodes, fed by comparative advantages, scale economies or agglomeration economics, the nodes will not be self-sufficient, and therefore trade takes place. This trade is made possible by means of the presence of infrastructure (layer B) and gives rise to all sorts of transport activities (layer A). Finally, layer D represents the ecological sphere.

The arrows indicate various interactions that may occur in the system considered. The arrows on the right-hand side describe issues that are traditionally in the heart of regional- and transport economics. From the right to the left: (la) indicates that the demand for transport is a derived demand, following from the spatial organization of economic activities. Conversely, (lb) represents the effect of transportation (costs) on the spatial distribution of activities. Arrows (2a) and (2b) show that the (spatial) construction of infrastructure depends on the spatial distribution of economic activities, but that the (spatial) supply of infrastructure may in turn affect the (spatial) development of the economic system. Next, (3a) represents the restrictions that the existing infrastructure poses upon transportation activities, whereas the last arrow (3b) indicates that an increasing demand for transport may eventually result in the construction of additional infrastructure (for instance, if transport volumes between K and M grow sufficiently large, it may be desirable to add the 'missing link' K-M).

The arrows on the left-hand side represent the additional interactions involved when considering the question of environmental quality. The three ascending arrows (4b)-(6b) indicate the environmental impacts of transport activities, the existence of infrastructure and the performance of economic activities, respectively. These effects will to some extent be localized, which is represented by the reprint of the spatial structure of the other layers in the ecological sphere. Other environmental externalities will be non-localized, which is represented by the shading of the ecological layer. The three descending arrows (4a)-(6a) indicate that the state of the environment may in turn affect the other three layers. In particular, environmental degradation may affect both the productivity and the utility in the second layer. Additionally, the productivity in the transportation sector, and the quality of and possibilities for infrastructure supply may depend on environmental characteristics.

Finally, interactions may occur within each layer. The curved arrows may for instance represent: congestion effects in transport (7); inter- and intra-modal network dependencies in infrastructure (8); any form of spatio-economic interdependencies such as trade (9); and physical interactions within the ecosystem (10).

It is now clear that the analysis of sustainable transport, as well as the design for associated policies, results in the adoption of a quite complex spatial modeling system of multilateral interactions; not in the least place because an adequate understanding of transport cannot do without explicit consideration of the spatial dimension. Any change, in any single one of the layers, can have direct impacts on any other layer, as well as indirect impacts (via other layers, or because of substitution effects within that same layer). For instance, a decline in transport costs would lead to more transport, with direct impacts on the environment, but will also affect the spatio-economic organization, leading to additional indirect environmental impacts (which can of course be negative or positive). Likewise, an expansion of a certain industry may have direct environmental impacts, as well as indirect impacts via backward and forward linkages with other industries (the same layer), and because of induced transport flows (another layer).

Clearly, Figure 1 could be expanded further, for instance by including multiple transport modes, a (tele-)communications layer to investigate substitution (or complementarity) with transport, a time dimension, political borders, an institutional layer, etcetera. However, any attempt to make the figure more realistic will lead to a more – not less – complex picture, and will most likely lead to a further emphasis on the spatial dimension as one of the key determinants for the sustainability of transport. It therefore seems safe to conclude that the sustainability of transport cannot be seen in isolation from the sustainability of the spatial configuration, and that policies for a more sustainable transport system cannot be evaluated in isolation from (at least) the prevailing economic, spatial, trade and ‘other’ environmental policies.

5. Social and Behavioral Aspects

Transport is usually regarded as a ‘derived demand’; it is not a final consumption goal in itself. People travel to go to work and goods are transported to satisfy the consumer. Consequently, environmental decay as a result of physical movements of people or goods is never deliberately created, but just an unwanted side effect of decisions taken elsewhere. Nevertheless, in the long chain of transport activities various direct and indirect costs are emerging which ideally would have to be charged to the activity at hand. For an economist the basic message is to get the prices right in order to get right (Pareto-optimal) decisions.

Is transport behavior taking market principles as a guideline for physical movement? A main problem is that the externalities involved in each transport decision however are usually not – or only incompletely – charged to the cause of the externality. This applies to pollution, traffic insecurity and congestion in the transport sector. But a simple resort to market principles does not offer a straightforward solution, as there are many impediments to the implementation of such market measures. In the first place, there is the problem of high transaction costs; each traveler is a victim and a cause of externalities. To establish a clear charging system among millions of travelers mutually is impossible (the ‘large number case’), so that at best surrogate measures can be introduced, e.g. by introducing a public authority (e.g., the government) as an agency which on behalf of all victims and causes of environmental burden collects and redistributes the money. But such an institutional arrangement leads by definition to new types of failures (so-called government failures), while it also creates enormous policy questions on distributional equity and efficiency. Another problem is that transport is a network activity that generates benefits to all actors involved. Positive network externalities may be far higher than the direct charges for the use of networks and create transport-intensive modes of production. Furthermore, transport has also a social component (e.g., social trips making up a significant part of weekend trips). To intervene in such behavioral patterns of a social nature prompts hectic debates on the socio-psychological constellation of our society. As far as mobility is a reflection of a modem life-style, it will be difficult to realize a ‘mobility-poor’ society. The latter observation does not mean that mobility should not be charged for its social costs, but it is evident that any attempt to reduce mobility per se will meet fierce resistance in an open and emancipated network economy.

If mobility is seen as a basic right in a modem society, then any attempt to reduce road congestion is not likely to be very successful. If a road authority wants to reduce the stress on a congested road by introducing charging principles, then the reduction in road users will be compensated for by new users who will again use the road up to full capacity (unless of course the price would become unacceptably high). But as long as rising incomes, increased labor force participation and spatial segmentation of homes and facilities (jobs, social facilities, cultural facilities) continue to be present, there is no way to make a shift to another type of society with radically different spatial patterns of mobility (see also Section 4).

Clearly, there may be a few trendsetters who advocate a different life style. Such ‘time pioneers’ ought to be taken seriously, as they might set the tone for a different type of behavior, with less stress, a lower time preference, a shorter commuting distance or less working hours. But, in general, the inevitable consequence will be a lower income and a lower position on the social ladder. Whether such type of behavior will become widely accepted and will offer a significant contribution to sustainable mobility remains to be seen (see Nijkamp and Baaijens 1999). For the time being, the impact of alternative life styles is almost negligible.

6. Technological Aspects

New transport technologies have been vital for economic development since the outset of the Industrial Revolution. In fact, they have been so influential that historians have named whole periods of economic development after various transport infrastructures, e.g. the 'age of canals' or the railway and coal era (Geerlings, 1999). The oil and automobile alliance was the symbol of 'the age of the automobile'. The car is one of the main contributing factors to a period of expansion unprecedented in the economic history of mankind.

For this reason the process of innovation and diffusion of technological developments traditionally enjoys a great deal of attention in the transport sector. Sometimes technological revolutions became usefully applied in the transport sector (e.g. the steam engine and the telegraph) for the first time. Technological changes have formed, transformed and extended the spatial-temporal range of human interaction patterns, leading to unprecedented levels of performance in terms of speed, spatial division of activities and quality of services. Technological developments (innovations) can be related to: (1) new types of technology, concerning the means of transport, (2) new modes of transport, (3) new means for upgrading the performance and service of existing modes of transport, (4) new types of organization and provision of transport services and/or traffic arrangements, and (5) other changes related to the existing transport system (Nederveen et al., 1999).

The impact of technologic development was mainly aimed at the improvement of the technical performance of vehicles until the 1970s. More recently the environmental impacts became more important and recognised. The Antopocentric School of thinking takes an unlimited confidence in technology as part of the solution to environmental problems. However, as a counterpart for a complete dependence on technology, the current way of thinking is that of a deliberate selection and implementation of a certain direction of technological development which is deemed preferable from the standpoint of sustainability (Cramer, 1992). Technology provides many possibilities to reduce the impact of transport on the environment. For example, technology is responsible for the progress made in reducing engine noise and noxious emissions from vehicles.

However, there is a limit to what technology can do on its own. We point out that the development and implementation involve several different complexities, barriers and, in relation to this, great uncertainties and risks. For example, the chances of a successful introduction and implementation will very much depend on the technological complexity. For this reason, incremental developments within the transport system have more potential than the development of complete new techniques. Another example is the social status of a technology being a barrier to introduction, e.g. the image of electric has been inferior compared to cars with combustion engines. In sum, the following key factors triggering innovations can be mentioned (Vleugel et al., 1994):

1. Economic conditions; conditions such as economic growth, competition or the quality of management have a great influence on innovations, i.e., conditions on a macro, meso and micro level;
2. Government intervention; this takes place by the introduction of policies, e.g., emission regulation, taxes or subsidies (see also Section 8);
3. Changes in transport demand; these induce the transport industry to develop new (types of) vehicles, new modes and services;
4. Societal perception; if society is focussed on technology, innovations will be accepted more easily and more money will be spent on innovations as well.

It may be clear that implementation requires a clear strategy and a multidisciplinary approach. In order to enable a comprehensive assessment of the introduction and implementation of new technologies, the most prominent factors for failure and success are the following (Nederveen et al, 1999):

- Implementation conditions; three necessary conditions to successfully introduce a new transportation technology are: (1) a sufficient voluminous and purchasing powered demand, (2) the technology should successfully apply to its required specifications and performance, and (3) a large-scale acceptance of the new technology.
- The process of implementing the technology in society can develop along two lines: incremental change (a gradual phasing out of generations of transportation) and leapwise progression (innovations are competitive to the old and matured system and may conquer markets in a short notice).
- The feasibility of technological change and innovation depends on technological factors such as flexibility, compatibility and generic characteristics as well as on societal factors regarding transportation, e.g., demographic and migration aspects and environmental awareness.

So there are many obstacles for the successful large-scale introduction of process-integrated technologies caused by the above mentioned barriers. Although there is the impression that end-of-pipe technologies offer more viable prospects in the short term (due to their availability and cost aspects), there is evidence from other sectors that in the longer term the introduction of process-integrated technologies offers larger benefits, not only from an environmental perspective, but also for technological, administrative, economic and technical interests (Geerlings, 1999). Nevertheless, the real challenge for sustainable development is to be found in fundamental change, which will, however, take many decades. A suchlike time-perspective demands a phased approach, and is no longer concerned with improving existing technologies, but stimulates the challenge of finding new technological combinations and concepts by which the proposed improvement of environmental efficiency can be realized.

7. Dynamic Aspects

The achievement of improvements in the above discussed fields – spatial, social, behavioral and technological aspects – for the purpose of realizing a more sustainable transport system can of course not be expected to be accomplished overnight. Changes in human behavior typically evolve only slowly; the development of new technologies and changes in spatial structure may require even more time. In this section, we will therefore discuss a few dynamic aspects that are relevant for the study of sustainable transport.

On a conceptual level, various important barriers to a smooth transition towards a more sustainable transport system may be due to *path-dependency:* the current situation may co-determine (often restrict) future possibilities. Path-dependencies require transport planners to adopt a (very) long-run view in designing policies, not in the least place to avoid the situation that the solution to short- or mid-term problems would prevent attractive long-term perspectives from being viable. A few concrete examples may clarify this statement.

A first example concerns the rapid growth of (in particular US) cities in the days after mass-motorization and increased car ownership had taken off. As a result, the design of these cities relies completely on car ownership, which is visible in particular as low-density residential areas and a relatively strong dispersion of activities. Although tailored towards car owners, such a spatial configuration – in particular the absence of well defined 'thick' passenger flows now often prevents public transport from being economically viable in these cities, simply because most if not all public transport modes *do* flourish particularly when clear main connections exist in a city. If, in contrast, a public transport system would have been built up in these days, the induced spatial organization – with clustering around its main nodes – possibly would have supported its use to acceptable levels. There is little doubt that an equivalent of the London Underground, transplanted to a city like Houston, would lead a problematic if not disastrous economic life, whereas Houston's average car mileage in London would probably be even more unthinkable. This is a clear example of path-dependency: the transport system available when a city's main structure is defined co-determines the transport systems that may be viable in future years.

A second example involves 'technological lock-inns'. The current choice for, for instance, a certain type of 'conventional' high-speed trains for a trans-European network would probably imply that magnetic train systems, or other competing technologies, are 'off the list' for a considerable time period. Other examples of technological lock-inns can easily be thought of.

Both examples demonstrate that for the planning of a sustainable transport system in the future, not only a 'simple' trade-off between current costs and future benefits has to be made. In addition, there are important questions of possible path-dependencies, implying that also current costs and benefits have to be traded off against future *options*.

Partly to cope with such questions, analysts and policy makers have resorted to the use of scenario analysis in studying sustainable transport. Whilst the future policy-making environment is uncertain, it is necessary to identify the key issues of policy-making to be of importance over the medium and long term if effective strategic decisions are to be made. Scenarios can be very helpful in coping with the uncertainties generally present in the transport system. In general, scenarios can be regarded as descriptions of possible future developments that seem plausible under different sets of assumptions and provide a background against which policy assessments can be made. In the context of sustainable mobility future images may show what sustainable mobility might look like and how it might materialize. The idea is to provide policy makers a framework for analysing consequences as well as conditions for the realisation of sustainable mobility.

8. The Role of Policies in Creating Sustainable Transport

Although transport is widely recognized as being important from an economic point of view, it is responsible for some negative effects as well. We have seen that transport can be regarded as one of the largest sources of environmental pollution (see Section 3). The large number of significant environmental impacts associated with transport range from local to global, and across a large range of issues including air quality, energy use, waste production and health. Many of these impacts are increasing in quantity and intensity. Others are beginning to decrease, but these impacts may start to increase again in the longer term, unless action is taken to reduce transport growth. Transport policy-making has begun to respond to these environmental issues and is increasingly aimed at achieving a sustainable transport system. Transport policies are focused on reducing congestion and mobility levels and stimulating public transport use. These policies do not seem to be very successful; in every European country the mobility levels are increasing, the modal split has changed in favor of the car and airplane, and, emissions of greenhouse gasses are rising (Rienstra, 1998). These are noteworthy developments, since almost no individual in society wishes to accept these negative effects. Apparently, there are forces that push the system into an undesirable direction.

This is one of the points where social acceptability of public policies comes into play. In an idealised environment government intervention would negatively affect the Pareto-optimal outcome of a freely operating market. However, three conventional arguments are often used to justify government intervention. The infant industry argument (often used to justify subsidies in less favoured regions), the market imperfection argument and the ethics and justice argument (see Nijkamp et al., 1995). The second argument witnesses intervention when market failures occur and a Pareto efficient allocation of resources is not achieved. A well-known market failure is the absence of markets. Governments may then decide to intervene in the market for different motives, for instance, to reduce negative externalities. From the above, it becomes clear that the current transport sector is characterized by those negative environmental effects (externalities). From this point of view, creating a more sustainable transport system allows the interference of policy makers. Authorities have several possibilities to implement policy measures, which are likely to steer the transport system into a more desired (i.e., sustainable) direction. In the following we will discuss shortly a broad range of possible (available) policy measures that can be used by policy makers aiming for a more sustainable transport system. We have categorized these under four headings. For reasons of simplicity we will focus on passenger transport and give only a few concrete examples.

The first category is transport demand management and can take several forms. The most directed instrument is pricing, which gives clear messages to users of the transport system about priorities. There is a strong case for internalizing the external costs of transport. It is increasingly stated (e.g., the EU-policy is aiming at the realization of fair and efficient pricing in transport) that users should pay according to their use of the system, particularly when travel takes place under congested conditions. Several examples are available for governments, such as road pricing, parking controls and vehicle taxes. Other demand management instruments that can be thought of are priority regimes (e.g., for public transport) and car-pooling.

Secondly, transport supply measures can be distinguished. Governments can invest in various ways to stimulate the use of particular means of transport and to promote the introduction of new technologies. So, this category is not only characterized by supplying new infrastructure for road and rail users, but it can also imply traffic management and improving public transport service via ticketing, information and- fares. Facilitating and stimulating developments to make better use of new technological possibilities to enhance efficiency or even substitute transport (e.g. teleworking) could also be a consequence of supply measures.

Another important possibility to influence the transport sector is (land-use) planning and spatial development measures. By affecting where people live and where activities take place, land-use policies influence the sort of journeys made, the distance traveled and the mode used (OECD, ECMT, 1995). Land use policies can seek to limit car travel through two mechanisms. First, it can reduce the need to travel either through ensuring reasonable proximity between places of residence, employment and other facilities (leading to shorter trips) or through creating mixed facilities (multipurpose trips). Secondly, land use planning can increase the scope for non-motorized travel (such as walking and cycling) or public transport. In achieving a more desired modal split towards public transport for example, new residential and business areas could be planned around nodes of the public transport system. Nevertheless, the influence of planning policies on transport related problems is less direct than with transport policies (ECMT, 1995).

Finally, governments often set targets and standards to intervene in the transport market by achieving reductions in some of the unwanted side effects of travel and urban living. They may also set targets to boost particular impacts of policies, which are considered to be beneficial and set standards which vehicle manufacturers and local authorities are required to meet. Examples include targets for improved road safety, reduction of noise and air pollution levels and certain types of traffic (e.g., heavy goods vehicles). The United States and international organizations, such as the EU, have prescribed many of these standards and targets adopted by individual countries.

One should keep in mind that some of the foregoing policies are concerned solely with land use planning, others with transport. In order to deal effectively with some problems it will not be enough to design and implement transport and planning policies independently. A combination of carefully selected policies that reinforce each other and avoid adverse side-effects will be required. In addition, some measures are more suitable to be implemented at a regional level, while others should be dealt with nationally. For example, standards and targets for emission controls are generally set at the national, or even international, level, but some cities have set emission targets or designed policies to achieve specific emission levels. Finally, it may be clear that adaptability and acceptability by people and firms plays a crucial role in the final result of measures taken.

Creating a more sustainable transport system requires efficient policy interference. Above we have highlighted the possibilities for governments as they are nowadays available. For the time being, there is hardly any successful example of sustainable transport policy (Banister et al., 2000). New – more sustainable – transport alternatives may be adopted by travelers but this does not necessarily mean that less sustainable forms of transport will be used less. It seems that the drive for mobility is so strong that new – more environmentally friendly – options are not acting as a substitute for older forms of transport, but merely as an addition. This paradox leads to formidable policy challenges at all levels.

9. Conclusion

Sustainable transport is an uneasy concept, from both an analytical and policy perspective. Clearly, there have been successful attempts to reduce the environmental burden of transport, in particular in regard to the emission of lead, carbon monoxide, benzene and volatile organic compounds. But other emissions have gone up, in particular carbon dioxide and nitrous oxide. A change in the environmental stress of the transport sector may come from different sources, in particular *technological* (vehicle technology, infrastructure technology, alternative fuels), *institutional* (regulatory regimes in transportation, logistic management), *spatial* (land use, location, tele-working) and *behavioral* (modal choice etc.). The combined result of all such possibilities creates an interesting spectrum of opportunities for transport policy. But to find the right balance is a difficult policy task.

Transport prompts always conflicting views on the socio-economic and ecological aspects of physical movements. From an economic perspective, transport may be seen as an input factor in a societal goal to favor economic growth; in which case containment could be motivated on the basis of cost minimization considerations. But one may also conceive of transportation as an opportunity for growth, spatial accessibility and competitiveness. In the latter case the transport performance may have to be encouraged. These two viewpoints do not only hold in case of a narrow view on transport, but also in combination with ecological or safety constraints. Clearly, in all cases economizing on energy consumption is a wise strategy, so that the adoption of a 'no-regret' policy is in any case something to be striven for. Against this background, technological improvements in transportation systems are always warranted, in particular if they aim to improve the performance at lower energy costs.

Clearly, if transportation systems' improvements would lead to a velocity increase, then the question will emerge whether the rise in discretionary time will be used up immediately for more trips or whether it will be spent otherwise. Travel time budget studies appear to indicate that the total daily travel time budget is on average fairly constant in metropolitan areas. In that case, the costs and benefits of additional trips would have to be evaluated from a sustainability perspective.

The spatial constellation of transport systems is also an important factor. Whether or not a compact city is an efficient geographic configuration from a transportation perspective, is an open question. Much uncertainty arises from the steep rent gradients in dense urban areas and these spatial-economic implications would have to be traded off against possible environmental benefits. Actual developments in many countries seem to move towards more diffuse patterns of living and working, so that it will be hard for urban and transport policy to change the current tide. In any case, a more integrated land use and transportation perspective is a *sine qua non* for sustainable mobility policy. Such a policy is increasingly leading to a complex portfolio of initiatives, in which issues like public facility location, public transport hubs, multifunctional land use, intermodal transport, ICT and e-commerce, mobility management, car sharing, road pricing and many other elements play a role. There is a multiplicity of goals involved in sustainable mobility policy, and there is also a multiplicity of policy strategies. To identify an optimal policy mix is for the time being still an open but intriguing research challenge.

References

Banister, D., D. Stead, P. Steen, K. Dreborg, J. Akerman, P. Nijkamp, and R. Schleicher-Tappeser, 2000, *European Transport Policy and Sustainable Mobility,* Spon Press, London

Button, K.J., 1993, *Transport Economics,* Edward Elgar, Aldershot.

Department of Environment, Transport and the Regions (DETR), 1999, *Transport and the Economy,* the Standing Advisory Committee on Trunk Road Assessment, London

ECMT, 1995, *Urban Travel and Sustainable Development,* OECD, Paris

Geerlings, H., 1999, *Meeting the Challenge of Sustainable Mobility; the Role of Technological Innovations,* Springer-Verlag, Berlin/Heidelberg

Janse, P., C. Nauta and B. Bach, 1997, *Energiebesparing in Verkeer en Vervoer door Ruimtelijke Ordening* [in Dutch], Novem, Delft

Nederveen, A.A.J., J.W. Konings and J.A. Stoop, 1999, Transport Innovations; an Inventory of Future Developments in Transportation, TRAIL Research School, Delft

Nijkamp, P. and S. Baaijens, *Growth & Change,* vol.. ., no.. ., 1999, pp. . . .

Nijkamp, P. and S. A. Rienstra, 1995, Private sector involvement in financing and operating transport infrastructure, *The Annals of Regional Science, 29,* pp. 221-235.

Nijkamp, P., S. Rienstra, and J. Vleugel, *Transportation Planning and the Future,* John Wiley, Chichester / New York. 1998

Nijkamp, P., C.A. Rodenburg and B. Ubbels, *2000, Globalisation, International Transport and the Global Environment (GITAGE): Transport Scenarios,* Economic and Social Institute, Vrije Universiteit, Amsterdam

OECD, *1999, Indicators for the Integration of Environmental Concerns into Transport Policies,* Environment Directorate, Paris

OECD and ECMT, 1995, *Urban Travel and Sustainable Development,* Paris.

Peet, G., 1994, International Cooperation to Prevent Oil Spills at Sea: Not Quite the Success It Should Be, In: *Green Globe Yearbook of International Co-operation on Environment and Development,* 1994, New York. Oxford University Press.

Pezzey, J., 1993, Sustainability: an Interdisciplinary Guide, *Environmental Values,* vol. 1, pp. 32 l-62.

Rienstra, S., 1998, *Options and Barriers for Sustainable Transport Policies,* NEI, Rotterdam.

Serageldin, I., 1993, Environmentally Sustainable Urban Transport: Defining a Global Policy, paper presented to the fiftieth International Congress of the Union Intemationale des Transport, Sydney, Australia, May processed.

Stead, D., 2000, Trends in Transport Intensity across Europe, *European Journal of Transport and Infrastructure Research,* Volume 0, Number 0, pp. 41-56.

Verhoef, E.T., J.C.J.M. van den Bergh and K.J. Button, 1997, Transport, Spatial Economy and the Global Environment, *Environment and Planning,* vol. 29A, pp. 1195- 12 13.

Verhoef, E.T., 1996, *The Economics of Regulating Road Transport,* Edward Elgar, Cheltenham.

Verhoef, E.T. and J.C.J.M. van den Bergh, 1996, A spatial price equilibrium model for environmental policy analysis of mobile and immobile sources of pollution. In: J.C.J.M. van den Bergh, P. Nijkamp and P. Rietveld (eds.), *1996, Recent Advances in Spatial Equilibrium Modelling: Methodology and Applications.* Springer-Verlag, Heidelberg, 201-220.

Vleugel, J., S. Rienstra a.o., 1994, *Comparative Analysis of Options for Sustainable Transport and Traffic Systems in the 21"' Century; phase 1,* State of the Art, Free University, Amsterdam.

WCED (World Commission on Environment and Development), 1987, *Our Common Future.* Oxford University Press, Oxford/New York.

World Bank, 1996, *Sustainable Transport; Priorities for Policy Reform,* Washington D.C.

www.novem.nl