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SUSTAINABLE MOBILITY

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Summary

Sustainable transport refers to an acceptable level of social cost associated with the movement of goods or people. Transport plays an important role in a country's environmental performance and the sustainability of its development. Several key aspects of the sustainability of transport are discussed in this contribution. Mobility and infrastructure have many effects on the ecological system and the spatial organization of economic activities. The demand for transport leads to a large pressure on the sustainability of the living environment. Technological development is often seen as one of the ways to increase sustainability of transport. Despite potential, there are some barriers to technological implementation that hinder short-term viability. Policy intervention can also steer transport development toward sustainability. A wide range of measures are available to policy makers, ranging from transport demand measures to spatial planning interventions.

1. Sustainable Transport: A Policy Challenge

Sustainable development is a policy concept very much in vogue since the publication of the Brundtland Report in 1987. It has generated worldwide debate on the conditions and policy strategies for the achievement of environmentally benign development. However, it was soon recognized that the global nature of the sustainability concept did not contribute to a clear and operational policy focus. Hence, new complementary concepts have emerged that are more fine-tuned towards clearly demarcated economic sectors, such as sustainable land use or sustainable transport.

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The present article is about sustainable transport. Sustainable transport is a concept that refers to an acceptable level of social cost associated with the physical movement of people or goods. These social costs are related to a decay of environmental quality (for instance, 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 key roles in the discussion on sustainable transport, in particular from the perspective of the relationships among growth, transport, and the environment.

(a) The relationship between economic growth and transport volumes. This issue has to do with the transport intensity of our economy (local, national, global). A decoupling (or delinking) can only be achieved if rising welfare is associated with a decrease (absolutely or relatively) in both the material consumption and the physical mobility of people. From a more structural perspective, one might also argue that a rising welfare can still be sustained if the physical distribution of transport movements become more favorable or cost-effective (for instance, short distances between home and work, and regionalized production systems). In the latter case, land use plays an important role (witness the discussion on compact cities, polycentric cities, edge cities, etc.).
(b) The relationship between transport and environmental consequences. Apart from the option of a decline in transport movements (as discussed in the last item), a delinking of 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 environmentally friendly transport technology or logistic systems (for instance, higher vehicle load factors or occupancy rates).
(c) The use of substitutes for physical transport. Leading up to the turn of the twenty-first century, interest has developed in various information and communication technology (ICT) opportunities for bridging physical distances, including telecommuting and teleshopping. Although actual use is rather low and the practice does not meet with 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 better environmental performance of the transport sector can be achieved. This paper aims to review these and related topics.

The paper is organized as follows. Section 2 describes 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 are discussed in Section 4, while social and behavioral aspects of transport are treated in Section 5. The role of technological innovation in transport will be outlined in Section 6. Section 7 covers some of the dynamic aspects involved. This is followed by the role of the government in creating a sustainable transport system in Section 8. Finally, Section 9 presents concluding remarks.

2. Conceptual Issues

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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 quite ambiguous. There is no such thing as a generally accepted definition of sustainable transport, and it is doubtful whether such a definition is possible. It therefore seems appropriate to spend a few words on difficulties surrounding the concept of sustainable transport, and to make explicit the interpretation used in this article.

The well-known 1987 Brundtland Report gave an intuitively appealing but 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." Countless attempts have subsequently been made at an operational definition of sustainable development. Different analysts attach different weights to various aspects of sustainability such as local and global environmental quality, intra- and intergenerational equity, economic efficiency, and more technical (but nevertheless essential) issues such as the extent to which different environmental goods may be substituted for one another for sustainability to hold true (weak vs. strong sustainability). It is evident that a first consideration for a definition of sustainable transport is a 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. Transport is usually a demand derived 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. Defining sustainability for either of these two systems in isolation, as a definition of sustainable transport requires, is even more problematic than defining sustainability for the entire system. In particular, such a definition easily ignores both adverse and beneficial repercussions that the realization of sustainability in the one sub-system would have on the other. To put it extreme: realizing environmentally "sustainable" transport by completely banning transport would induce a highly inefficient despecialization of regions and possibly greater instead of smaller emissions induced by production inefficiency. This scenario should not qualify as a "true" environmentally sustainable transport solution, despite the sustainability of its transport emissions. Instead, interactions with different subsystems should be taken into account when defining sustainable transport. Verhoef has conducted an analytical study along these lines.

Given these considerations, we do not provide a clear definition of the topic of our review. Instead, we discuss various aspects that have been identified as important elements of a "more sustainable transport system." Our main focus is on environmental aspects in relation to various dimensions of transport behavior, including spatial, social, behavioral, technological, and dynamic aspects, although distributional and equity issues will also be touched upon.

3. Transport and Environment

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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 passenger and freight traffic volumes. Major negative environmental effects of transport activities include air pollution, noise, consumption of energy, land, and other natural resources, and 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. In major cities of developing countries the air quality is already worse than 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 per year. Transport is also responsible for noise. Intensively designed transport infrastructure is visually intrusive and can also physically divide neighborhoods and adversely affect local amenities.

At a regional level, a lack of attention to transport's impact 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 subsequent induced development on forests and other ecological and cultural sites. These effects are often considered in the decision whether or not to construct infrastructure (for instance 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 that arises from human activity (which potentially contributes to global warming or greenhouse effects), one-third of the CFCs (which contribute to depletion of the ozone layer), and half of the nitrogen oxides (which contribute to continental scale acidification and ecological damage). The carbon dioxide is primarily related to fossil fuel combustion and is created by all motorized modes of transport. Even 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 because the electricity they use has to be generated somewhere. The elimination of fully halogenated CFCs, 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 vary significantly by mode. Road motor vehicles are the dominant source of emissions with local and continental

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effects, such as acid rain, and these vehicles account for more than 75% of the transport sector's contribution to global air pollution. Aviation causes local air and noise pollution at ground level, while their 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 fuel consumption has grown more than 3% a year and is expected to grow even more, despite improvements in engine technology. In maritime transport, operational oil discharge was reduced 60% during the past decade, and shipping now accounts for only about one-quarter of the oil that enters the marine environment, although major damage still results from tanker accidents. Rail transport is relatively environmentally benign, although coal burning, both direct and indirect (to generate electricity), and rail-generated noise can have locally heavy impacts. Furthermore, modern fast rail technology leads to relatively high energy consumption. Inland waterway transport is relatively fuel efficient and rarely has local environmental impacts. Nonmotorized transport is almost entirely environmentally benign, at least in a direct sense, that is without considering the infrastructure.

Negative environmental and social externalities of transport impose a large cost on society. The noninternalized costs of transport, for instance environmental and social costs relating to air pollution, noise, accidents, and climate protection, are estimated to amount to at least 5% of GDP for industrialized countries. Road transport and aviation are primarily responsible for these costs, while rail transport contributes to less than 1% of this burden of social cost.

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

Values are percentages of total emissions for each region.

Table 1. Total transport emissions as a percentage of total emissions in the mid-1990s Organization for Economic Co-operation and Development (OECD). (1999). *Indicators for the Integration of Environmental Concerns into Transport Policies*, 70 pp. Paris: Environment Directorate.

	Passenger car traffic		**Goods vehicle traffic**	
	billion km traveled in 1996	**% change 1980–1996**	**billion km traveled in 1996**	**% change 1980–1996**
North America	2680	12	1201	75
OECD Europe	2410	63	463	66

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EU 15	2184	65	401	69
OECD states	5683	36	2004	76

Table 2. Total annual transport volumes
OECD. (1999). *Indicators for the Integration of Environmental Concerns into Transport Policies*, 70 pp. Paris: Environment Directorate.

GDP (measured in XXX) per	**1970**	**1995**	**% change**
Passenger kilometre	1.47	1.19	–19%
Ton kilometre	3.74	3.82	2%
Net mass movement (tonnes km^{-1} $person^{-1}$ $year^{-1}$	3.87	3.93	2%
Unit of transport energy consumption (tonne oil equivalent)	22.6	19.1	–15%

All values are for EU 15 countries.

Table 3. Indicators of transport intensity in Europe during 1970–1995
Stead D. (2000). Trends in transport intensity across Europe. *European Journal of Transport and Infrastructure Research* **0**(0), 41–56.

Transport pollutes the environment in three broad ways. First, it imposes many local environment costs on those living, working, or taking recreation near major 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. Second, transboundary effects, such as emissions, that contribute to acid rain and maritime spillage. Third, transport contributes to global warming through, for instance, CO_2 emissions. Tables 1 and 2 indicate recent trends in industrialized countries. 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 into decoupling trends. Table 3 presents four economic efficiency indicators for Europe in the period 1970–1995.

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Biographical Sketches

Prof. Dr. **Peter Nijkamp** graduated from the Erasmus University in Rotterdam, in the area of econometrics. He holds a PhD (cum laude) in nonlinear mathematical programming for industrial planning also from Erasmus University in Rotterdam. Since 1975, Peter Nijkamp has been a professor in regional and urban economics and in economic geography at the Free University, Amsterdam. He has a broad expertise in the area of public policy, services planning, infrastructure management, and environmental protection. In all these fields he has published various books and numerous articles. He has been an advisor to several Dutch ministries, regional and local policy councils, employers' organizations, private institutions, the Commission of the European Union (EU), the Organisation for Economic Cooperation and Development (OECD), the European Conference of Ministers in Transport (ECMT), the Asian Development Bank (ADB), the European Roundtable of Industrialists, the World Bank, and many other institutions.
Dr. Nijkamp has been a guest professor at several universities in Europe, Asia, and America. He is doctor *honoris causa* at the Vrije Universiteit in Brussels and fellow of the Royal Dutch Academy of Science and the World Academy of Arts and Sciences. He is past president of the Regional Science Association International and chairman of the Network on European Communications and Transport Activity Research (NECTAR). Peter Nijkamp was also the 1996 recipient of the Spinoza Award, most prestigious in the Netherlands.

Dr. **Erik Teodoor Verhoef** graduated in Economics from the University of Groningen in 1991, and obtained a PhD in Economics from the Vrije Universiteit in Amsterdam in1996. Since then, he has held a post doctoral research position at the Department of Spatial Economics, Free University, Amsterdam. He has been an elected Research Fellow of the Tinbergen Research Institute since 1996. His main fields of research include transport, urban, environmental, regional, and welfare economics. His research focuses on first and second best regulation of externalities, both in terms of efficiency aspects and issues of social feasibility; congestion analysis and road pricing; and integrated spatial and transport modeling with a focus on environmental effects. He has published in numerous international journals on these themes, and has, in addition, written and/or edited a number of books.

Dr. **Barry Johan Ubbels** graduated in December 1997 in the field of transport and regional economics. Immediately after the completion of this study, he began to work as a researcher (project based and externally funded) for the Department of Spatial Economics at the Free University. At this organization he carries out fundamental research for several organizations such as national and regional governments, firms, and the European Union. His main research interest is in the field of pricing and financing of transportation and infrastructure. He has completed several studies in this field, and also in related topics such as transportation planning and regional economic development. The results of this research have been reported in various publications in Dutch as well as in English. Besides this research work, he is working on his PhD thesis.

Dr. **Caroline Astrid Rodenburg** graduated in February 1998 in the field of transport and regional economics. Immediately after graduation, she started working as a researcher (project based and externally funded) for the Department of Regional Economics at the Free University of Amsterdam. Currently, she is also working on her PhD thesis on economics aspects of multifunctional land use. Her main interest is in the field of transport and regional economics. She has published various contributions to national and international journals on several transportation and regional economic subjects.

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