Transportation Research Part A 54 (2013) 67–77

Contents lists available at ScienceDirect

Transportation Research Part A

journal homepage: www.elsevier.com/locate/tra

Sustainable passenger transport: Back to Brundtland

Erling Holden [a,b], Kristin Linnerud [c,*], David Banister [d]

[a] *Sogn and Fjordane University College, P.O. Box 133, 6851 Sogndal, Norway*
[b] *Norwegian University of Science and Technology, 7491 Trondheim, Norway*
[c] *Cicero Centre for International Climate and Environmental Research, P.O. Box 1129, Blindern, 0318 Oslo, Norway*
[d] *Transport Studies Unit, School of Geography and the Environment, Oxford University, South Parks Road, Oxford, OX1 3QY England, United Kingdom*

ARTICLE INFO

Article history:
Received 2 October 2012
Received in revised form 4 March 2013
Accepted 18 July 2013

Keywords:
Sustainable development
Sustainable passenger transport
Sustainable transport indicators
The Brundtland Report

ABSTRACT

We argue that there is no clear definition of the concept sustainable passenger transport to help guide politicians in solving challenges at the global or regional level. Rather, the use of the concept has to an increasing extent reflected socially desirable attributes of local- and project-level problems, but these ignore the global challenges the concept was meant to solve. Going back to the Brundtland Report, we redefine the concept of 'sustainable passenger transport' and suggest an assessment method based on four equally important, main dimensions: safeguarding long-term ecological sustainability, satisfying basic transport needs, and promoting intra- and intergenerational equity. We also define indicators and threshold values that have to be met for each of these dimensions and then illustrate how to achieve sustainable passenger transport.

1. Introduction

There is as of yet no political or scientific agreement on the definition of sustainable passenger transport (Black, 2010; Schiller et al., 2010; Castillo and Pitfield, 2010; Litman and Burwell, 2006; Banister, 2005).[1] Rather, the use of the concept has to an increasing extent reflected socially desirable attributes of local and project level problems, while ignoring the global challenges the concept was supposed to solve. The diversity of definitions and interpretations of the concept has raised the risk that the concept will end up as mere rhetoric that offers little guidance for policy makers and scientists.

A review of sustainable passenger transport literature shows that the focus of mainstream literature on sustainable transport indeed has changed during the last two decades (Holden, 2007). Sustainable passenger transport problems are being addressed in new ways by researchers representing an increasing number of scientific disciplines applying different methodological approaches. The definition of the concept has changed to include a broader set of passenger transport types like work-related travel, everyday travel (e.g., Shiftan et al., 2003; Castillo and Pitfield, 2010; Amekudzi et al., 2009; Banister, 2011) and leisure-time travel (e.g. Black and Nijkamp, 2002; Mokhtarian, 2005; Banister, 2008; Holden and Linnerud, 2011). This has added to our understanding of the challenges posed by sustainable passenger transport but also to the complexity of how the concept is defined, measured, assessed and evaluated.

More importantly, the definition of the concept has changed to include a broader set of transport's impacts on society. Gudmundsson and Höjer (1996) focus on impacts on the environment and social equity. Black (2010) adds impacts on health

* Corresponding author. Tel.: +47 73594000.
E-mail addresses: erling.holden@ntnu.no (E. Holden), kristin.linnerud@cicero.uio.no (K. Linnerud), david.banister@ouce.ox.ac.uk (D. Banister).

[1] Applying the imperative of sustainable development to the transport sector has, however, led to several concepts denoted by terms such as sustainable transport, sustainable mobility, sustainable transportation, sustainable transport systems, and sustainability issues in transport (Holden, 2007). In the literature on transport and sustainable development, these terms are essentially synonymous. Variants of 'sustainable transport' seem to be the preferred term in North America, whereas 'sustainable mobility' variants are preferred in Europe (Black, 2003). We use the term 'sustainable transport' in this article.

0965-8564
http://dx.doi.org/10.1016/j.tra.2013.07.012

and security. Lautso and Toivanen (1999) include all of these impacts and add quality of life considerations. More recently, several studies have widened the list of impacts to include economic growth (e.g. Shiftan et al., 2003; Castillo and Pitfield, 2010; Amekudzi et al., 2009; UNCSD, 2007). Examples of issues dealt with by these and other studies include protecting wildlife and natural habitats, reducing levels of noise, promoting economic growth, facilitating education and public participation, reducing congestion levels, minimizing accidents and fatalities, ensuring stakeholder satisfaction, enhancing aesthetic dimensions of neighbourhoods, supporting cultural activities, increasing tourism's contribution to GDP, promoting liveable streets and neighbourhoods, and minimising transport-related crime.

Thus, sustainable transport is about to include every aspect of transport, which is socially desirable, but it also therefore risks becoming meaningless. To avoid a dilution of the concept, it may be helpful to first clarify the main dimensions of sustainable development by going back to its origin, the Brundtland Report (WCED, 1987), which set the standard and became the point of reference for every debate on sustainable development (Lafferty and Langhelle, 1999). We adapt these dimensions to the concept of sustainable transport, and by doing so, we redefine sustainable transport and suggest an assessment method based on four equally important main dimensions. We then proceed by defining suitable indicators and assign minimum/maximum thresholds for each dimension.

To construct a more precise definition of sustainable transport, we make some delimitations. First, we argue that *main* dimensions should be given priority over less important dimensions, and unless all threshold values related to these main dimensions are met, transport cannot be deemed sustainable.

Second, we argue that the main dimensions and their threshold values represent *equally important* targets where each needs to be fulfilled. This excludes the possibility of trading off an underperformance on one indicator against an over performance on another. Consequently, we argue against reducing sustainability to *one* single composite index (e.g. the Inclusive Wealth Index[2]). On the other hand, we have not chosen the other extreme, namely specifying a very long list of indicators (e.g. the 96 indicators suggested by the UN Commission on Sustainable Development (UNCSD, 2007).

Third, sustainability should ultimately be addressed at a global level. We are all part of a single human and natural system with complex interactions among all its parts. Although national territories, economies and societies are only one level of system organisations, it is perhaps the most *significant* level because governance is presently strongest at the national level (Dahl, 2012). Thus, dimensions, indicators and thresholds refer to the national level, although they are, as will be explained later, derived from global challenges.

Fourth, we focus on achieving sustainable transport in passenger mobility (including air transport), partly because of the need to limit the article's scope and partly because of our professional background. Nevertheless, many conclusions may eventually be relevant for the equally important challenge of achieving sustainable transport of goods.

The remainder of the article is organised as follows. In Section 2, we examine the Brundtland Report to derive four main dimensions of the concept of sustainable development. In Section 3, we adapt these four main dimensions of sustainability to the passenger transport sector. In Section 4, we discuss the challenges faced by different countries in achieving sustainable transport. We offer concluding remarks in Section 5.

2. The main dimensions of sustainable development

The large number of definitions and interpretations of sustainable development has made some scientists avoid using the term because it is too vague or even dismiss the concept altogether. Yet the persistence of the concept itself is remarkable. Despite all the problems in agreeing on a definition, sustainable development as an ideal is as persistent a political concept as are democracy, justice and liberty (O'Riordan, 1993; Lafferty, 2004).

2.1. Main and secondary dimensions

Four *main* dimensions of sustainable development can be derived from the Brundtland Report: safeguarding long-term ecological sustainability, satisfying basic human needs, and promoting intra- and intergenerational equity (WCED, 1987; Lafferty and Langhelle, 1999; Høyer, 2000; Holden and Linnerud, 2007).

In addition to these main dimensions, Høyer (2000) presents a number of *secondary* dimensions, which include preserving nature's intrinsic value, promoting protection of the environment, promoting public participation, and satisfying aspirations for an improved standard of living (or quality of life). Because these secondary dimensions are subordinated to the main dimensions, preserving nature's intrinsic value (a secondary dimension), for example, must give way whenever basic human needs (a main dimension) are threatened. Correspondingly, satisfying aspirations for a better life (secondary dimension) should be subordinated to safeguarding long-term ecological sustainability (main dimension).

Following this logic, we argue that economic growth is not one of the main dimensions of sustainable development. This runs contrary to the popular tripartite model focusing on the balance between environmental, social and economic issues. The desire for economic growth may be equivalent to aspiring for an improved standard of living far beyond what is regarded

[2] The International Human Dimensions Programme on Global Environmental Change (IHDP) launched of the Inclusive Wealth Report 2012 (UNU-IHDP and UNEP, 2012) at the Rio + 20 Conference in Brazil. The 2012 report features an index, the Inclusive Wealth Index (IWI), that measures the wealth of nations by addressing a country's capital assets, including manufactured, human and natural capital, and their corresponding values.

as ecologically sustainable in the long term. The Brundtland Report claims that: 'Sustainable development clearly requires economic growth in places where such [human] needs are not being met. Elsewhere, it can be consistent with economic growth, provided the content of growth reflects the broad principles of sustainability and non-exploitation of others. But growth by itself is not enough' (WCED, 1987, p. 44). The inclusion of economic growth as a main dimension of sustainable development is therefore not consistent with the Brundtland Report. Rather, economic growth is one of the *potential means* to facilitate the fulfilment of the main dimensions.

This does not imply that economic growth is unimportant. In fact, efficient allocation of the planet's resources to maximise the welfare of society across countries and generations may arguably be the most important target for development. Our point is, however, that from the perspective of a developed country and from the perspective of one generation, maximising economic growth may run counter to sustaining economic growth and welfare over space and time. Because the interests of future generations, nature and the poor are underrepresented in the political debate, social and environmental issues risk being ignored or allocated reduced weight as compared to economic issues. Thus, equivalent to firms being restricted by law from paying out dividends that decrease the value of the firm, politicians should enter into global or regional agreements that restrict them from pursuing short run economic growth if this aim runs counter to the aims of sustained economic growth for all generations and all countries. To utilise global resources in the most productive way means that constraints set by sustainability need to be satisfied.

Another possibly controversial aspect of our approach is that it is not based upon (local) stakeholder participation. This runs contrary to a number of recent studies that place stakeholder participation as a key to achieve sustainability (Castillo and Pitfield, 2010; Amekudzi et al., 2009; Shiftan et al., 2003; Xenias and Whitmarsh, 2012). Although it is agreed that participation and acceptance among stakeholders is vital to ensure efficient implementation of sustainable policies and measures, we disagree with the proposition that the choice of sustainable dimensions, indicators and threshold values should depend on what local stakeholders agree to include. Globally there must be an agreement, and the choice made here is based on the Brundtland Report.

Finally, by setting explicit minimum and maximum threshold values that should be met, our approach runs contrary to those focusing on relative changes. For example, suggesting that sustainability of transport equals 'the rate of change' (Amekudzi et al., 2009) for a country or region is not satisfactory. Changing a non-sustainable state to a less non-sustainable state is positive, but the result cannot be regarded as sustainable.

2.2. The sustainable development space

For each of the four main dimensions, we must choose appropriate indicators and assign threshold values that should be met in order for development to be deemed sustainable. The four threshold values form a four-dimensional space, which we call the 'Sustainable Development Space' (SDS). Amekudzi et al. (2009) uses the concept 'sustainability footprint' and the Living Planet Report (WWF, 2010) uses the concept 'sustainability box' for similar constructions.

Dimension 1: The ecological footprint (EF) is used as an indicator for safeguarding long-term ecological sustainability. The ecological footprint tracks humanity's demands on the biosphere by comparing its consumption against the Earth's regenerative capacity, or biocapacity. This is accomplished by calculating the area required to produce the resources people consume, the area occupied by infrastructure, and the area of forest required for sequestering CO2 not absorbed by the ocean (WWF, 2012).

EF covers a wide range of current major environmental issues (WWF, 2012; EEA, 2012; UNDP, 2011). It compares consumption against the Earth's regenerative capacity and illustrates the extent to which we may be 'over-using' natural resources (WWF, 2012). The method fits well with the notion of strong sustainability (UNDP, 2011), thus reflecting our no trade-offs requirement between the main dimensions. The concept and methodology are well established (Bastianoni et al., 2012; Wiedmann and Barrett, 2010; Ewing et al., 2010), and EF is one of only two measures of long-term ecological sustainability available for a large number of countries over a reasonably long period (UNDP, 2011).[3] Following the logic of Brundtland's low-energy scenario (WCED, 1987), we argue that the yearly per capita threshold value must be a maximum of 2.3 global hectares (see Table 1 for details).

Dimension 2: Gross Domestic Product Purchasing Power Parity (GDP PPP) is used as an indicator for satisfying basic human needs. This dimension is about basic human needs, not about living standards, well-being, quality of life or other concepts that entail aspirations for a better life; these aspects are all legitimate, but they are secondary dimensions. A high level of GDP PPP indicates that countries have sufficient means to provide its inhabitants with the necessary services to meet their basic needs, whereas a low level indicates otherwise. Following the UNDP's classification into human-development groups, we argue that the yearly per capita threshold value must be a minimum of USD 3350 (2000) PPP (see Table 1 for details).

We could alternatively use the Human Development Index (HDI) to indicate whether basic human needs are met. The HDI measures the average achievement in a country in three basic dimensions of human development: life expectancy at birth, adult literacy rate and per capita GDP PPP (UNDP, 2011). However, replacing per capita GDP PPP with HDI would not alter our analysis because the two measures are strongly correlated (Hanley et al., 2001).

[3] The World Bank's adjusted net savings is the other measure.

Table 1
Main dimensions, indicators and suggested 2030 threshold values for sustainable development and sustainable passenger transport.

Sustainable development			Sustainable passenger transport		
Dimension	Indicator	2030 Threshold	Dimension	Indicator	2030 Threshold
1. Safeguarding long-term ecological sustainability	Yearly per capita ecological footprint (EF)	Maximum 2.3 gha per capita[a]	1. Impacts of transport activities must not threaten long-term ecological sustainability	Daily per capita energy consumption for passenger transport	Maximum 5.6 kW h per capita per day[e]
2. Satisfying basic human needs	Yearly per capita GDP PPP	Minimum USD 3350 (2000) per capita yearly[b]	2. Satisfying basic transport needs	Daily per capita travel distance by motorised transport	Minimum 9.2 km per capita per day[f]
3. Promoting intragenerational equity	Gini coefficient	Maximum 0.40[c]	3. Promoting intragenerational transport equity	Public Transport Accessibility Level (PTAL)	Minimum PTAL 3[g]
4. Promoting intergenerational equity	The amount of renewable to total energy in primary energy production	Minimum 27%[d]	4. Promoting intergenerational transport equity	The amount of renewable to total energy used for transport	Minimum 15%[d]

[a] Based on Brundtland's low-energy scenario: The 1985 global energy consumption of 9.9 TW is allowed to increase to 14.4 TW by 2030 (WCED, 1987). Adjusted for global population growth, this increase calls for a 15% per capita reduction in energy consumption by 2030. Because EF is strongly correlated with energy consumption, we use the same rate of reduction for it: the world EF is reduced by 15% from its 1985 level of 2.7 global hectares (gha) per capita (WWF, 2008) to 2.3 gha per capita in 2030. Interestingly, Brundtland's low-energy scenario compares to the IPCC's low estimate for scenario group B1: global energy consumption in 2030 scenarios belonging to the B1 group varies from 16 to 28 TW. By 2100 the average of all 2030 B1 scenarios is estimated to 16 TW (IPCC, 2000).

[b] UNDP (2011) classifies countries into groups according to human development—very high, high, medium and low—according to their levels on the human development index (HDI). For 2009 the per capita GDP of countries with medium human development was USD 5077 (2009) PPP, corresponding to USD 3350 (2000) PPP (World development indicators, The World Bank). We take the view that the measure of the medium group reflects the minimum requirement a country must meet to ensure the basic human needs of its inhabitants.

[c] This threshold value equals the target level set by UN Habitat—sometimes called the international alert line (UN, 2010).

[d] This threshold reflects the amount needed by 2035 to be consistent with a 450 ppm CO_2eq stabilization level (IPCC 2011, p. 106). IPCC data is based on the IEA's World Energy Outlook 2010 '450 Policy Scenario'.

[e] Energy consumption for motorised passenger transport (all modes, including air travel) in 1985 was 1000 Mtoe (IEA, 2009). This corresponds to 6.6 kW h per capita daily in 1985, and given a 15% per capita reduction (as required in Brundtland's low-energy scenario), 5.6 kW h per capita daily in 2030.

[f] According to Schafer et al. (2009), the ratio between yearly travel distance per capita and GDP PPP per capita has been estimated to 1 km per USD. Thus, using the minimum GDP of USD 3350 (2000) PPP to satisfy basic needs, a minimum per capita transport level sufficient to meet basic transport needs would be 3350 km yearly or 9.2 km daily.

[g] A PTAL value of 3 corresponds to 'moderate accessibility' (TfL, 2010).

Dimension 3: The Gini coefficient is used as an indicator for promoting intragenerational equity. The Gini index is the most popular and widely used measure of inequality (UNDP, 2010). It measures the distribution of either household income or consumption spending in a country. A zero value implies perfect equality and a value of one maximal inequality. Using the target level set by UN Habitat, we set the threshold value to 0.40 (see Table 1 for details). Other measures for equity exist (e.g. the ratio of the income received by the top to the bottom 20% of a population), but the choice of measure rarely has a significant effect on results (Wilkinson and Pickett, 2009).

Dimension 4: The fraction of renewable energy to total primary energy is used as an indicator for promoting intergenerational equity. Intergenerational equity requires that future generations are able to meet their needs. Although we do not know these future needs, it is unlikely that future generations' needs can be met without access to some sort of energy. Expecting that fossil fuel will become more scarce and costly, the Brundtland Report emphasises that 'every effort should be made to develop the potential for renewable energy, which should form the foundation of the global energy structure during the 21st Century' (WCED, 1987, chapter 7, Section 88). Thus we argue that the amount of renewable to total energy in primary energy production is a good indicator for intergenerational transport equity. Following the *IPCC Special Report on Renewable Energy and Climate Change Mitigation*'s (IPCC, 2011) recommendation, we argue that the amount of renewable to total energy in global primary energy production must be a minimum of 27% by 2035 (see Table 1 for details).

Fig. 1 shows how pairs of main dimensions can be compared; thresholds are marked as horizontal and vertical lines in the figure. All countries where relevant statistics are available (130) are included. Sustainable development is defined as the area in the lower right quadrant where the maximum and minimum requirements are met.

All four indicators and their assigned threshold values have their shortcomings (Dahl, 2012; Singh et al., 2011; Aslaksen et al., 2010; Gasparatos et al., 2009; Heink and Kowarik, 2010; Moldan et al., 2004). Nevertheless, because all four indicators are based on high-quality, scientific-based sources we regard them as relevant and robust.

3. The sustainable transport space

We proceed by adapting the four main dimensions of sustainable development to the passenger transport sector and identifying suitable indicators and threshold values. These values define a four-dimensional space, which we call the 'Sus-

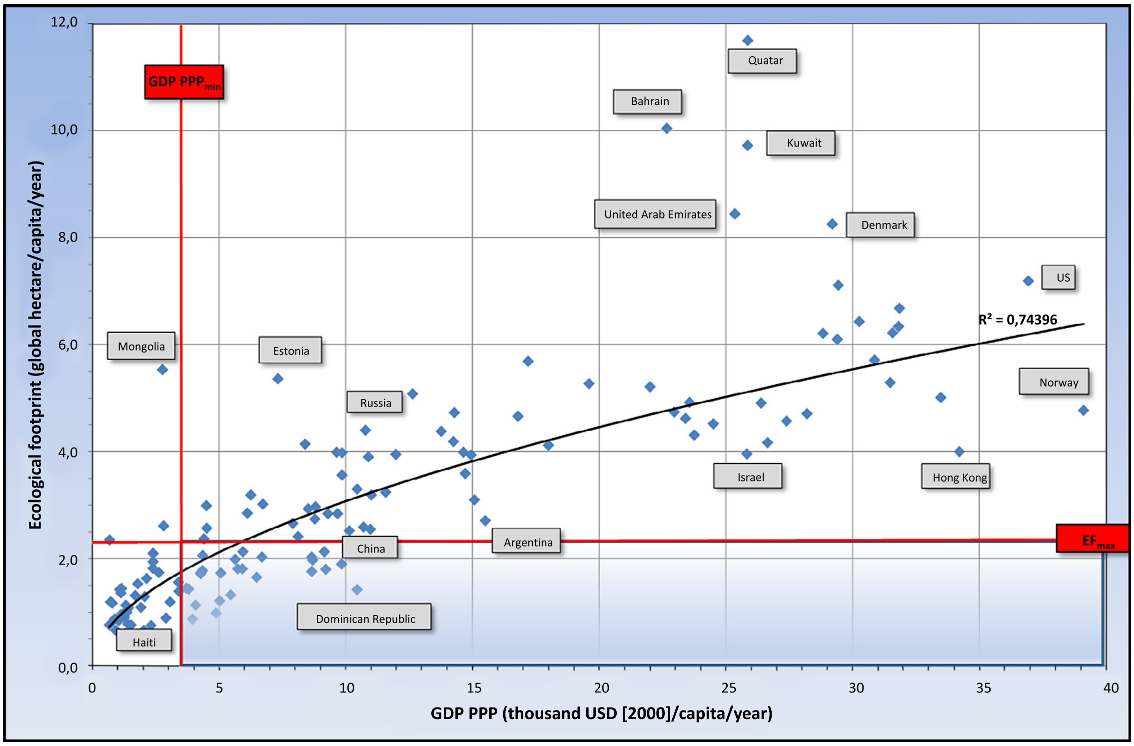

Fig. 1. The sustainable development space (SDS) for dimension 1 (ecological footprint) and dimension 2 (GDP PPP). SDS is in lower right quadrant. Country data is from 2008/2009. *Sources*: 2011 Key World Energy Statistics (IEA, 2011); Living Planet Report 2012 (WWF, 2012)

tainable Transport Space' (STS). An overview of main dimensions, indicators and threshold values for sustainable development and sustainable passenger transport is given in Table 1.

3.1. Dimension 1: long-term ecological sustainability

We suggest per capita energy consumption for passenger transport as an indicator of the first main dimension of sustainable transport. A large amount of data on energy consumption for transport is readily available, whereas data on the ecological footprint for transport is not. Moreover, calculating energy consumption from travel-survey data requires considerably less supplementary data than does calculating the ecological footprint. In addition, data on energy consumption shows a strong correlation with data on ecological footprints (IEA, 2011; WWF, 2012).

In fact, the importance of focusing on energy consumption as an adequate indicator of overall ecological sustainability was acknowledged in the Brundtland Report, because all types of energy—renewable and non-renewable alike—cause a large spectrum of environmental impacts and thus cause a threat to long-term ecological sustainability (WCED, 1987). Thus, we regard *total* energy consumption for transport (all modes, including air travel) as a key indicator for long-term ecological sustainability. In accordance with the Brundtland Report's low-energy scenario, the maximum threshold level was set at 5.6 kW h per capita per day (see Table 1 for details).

A threshold level of 5.6 kW h per capita daily is well below present levels in most developed countries and might therefore seem like a highly unrealistic goal. However, the International Energy Agency has estimated that 2050 energy consumption for passenger transport in their ETP 2012 2DS scenario is 4.4 kW h per capita per day. The ETP 2012 2DS scenario describes an energy system consistent with an emissions trajectory that recent climate science research indicates would give an 80% chance of limiting the average global temperature increase to 2 °C (IEA, 2012b).

3.2. Dimension 2: basic human needs

Basic transport needs should be satisfied. That is, all people should have access to affordable and appropriate means of transport that enable them to work and use other vital private and public services such as health and education. In this case, basic transport needs is not the goal in itself, but rather a necessary means to accomplish the goal of meeting basic human needs as defined in the previous section.

We have chosen per capita travel distance by motorised transport as an indicator of this second main dimension. This indicator tells us to what extent people are mobile in a modern world. A sufficiently high level indicates that people have access to appropriate and affordable modes of transport to meet their basic needs. A high per capita GDP indicates a country's potential to provide basic needs—including transport needs—to its inhabitants, and data on yearly travel distance shows a strong correlation with data on GDP PPP: 'Each additional unit of GDP PPP has generated a corresponding rise in PKT [passenger kilometre travelled] (through increased use of automobiles, buses, railways, and aircraft)—independent of the stage of economic development, the political system, or cultural values' (Schafer et al., 2009, p. 35).

The challenge is to set the minimum level of motorised travel needed to meet basic transport needs. We set the minimum level at 9.2 km daily (see Table 1 for details), assuming that people having access to motorized travel above this level would be able to meet their basic transport needs.

However, the motorised transport needed to meet basic needs will vary depending on location. People living in remote areas probably have to travel farther by motorised transport to meet their basic needs than people living in densely populated cities with well-organised cycling and walking paths. Furthermore, statistics on average distance travelled will not indicate whether there are differences between population groups. However, these and similar intragenerational equity issues are covered by the next main dimension.

3.3. Dimension 3: promoting intragenerational transport equity

Intragenerational transport equity means that access to transport does not vary systematically across population groups. However, more important than minimizing inequalities is ensuring that everyone has the possibility to meet their basic transport needs. This aspect was partly reflected in the previous subsection where the focus was on society's average mobility level. Here we take this aspect one step further by focusing on individuals' mobility level.

We argue that satisfying basic transport needs is the most important challenge when addressing social justice or intragenerational equity aspects of sustainable transport. Social justice may be defined as the morally proper distribution of goods and bads across members of society (e.g. Elster, 1992). Transportation systems can alter this morally proper distribution if there are systematic differences between population groups that benefit (use) and those that are negatively affected by a new transport system (Feitelson, 2002).

However, as noted by Feitelson (2002), assessing the extent to which transport negatively affects some population groups and not others raises some methodological issues that are difficult to resolve. First, correlation between population groups and negative externalities from transport does not necessarily mean that transport has caused this social injustice. For example, poor people may systematically choose to live in areas with polluting and noisy transport systems because these negative impacts reduce the price of housing in those areas. Second, if the focus of the study is on global or regional impacts, it may be impossible to determine which population groups are most negatively affected by transport. Global impacts (e.g. greenhouse gas emissions) will affect all people independent of the source of emission; regional impacts (e.g. NOX, ground-level ozone, flooding and ecosystem severance) are governed to a significant extent by meteorological variables. Thus, only local impacts (e.g. CO and NOX emissions, noise, accidents and congestion) will be relatively consistent over time and space and may be related to attributes of people living in a given area.

Thus, we delimit our focus on social justice issues to the opportunities created by transport and whether these differ across population groups. Our line of reasoning is in accordance with Martens (2006, p. 8) who emphasises that, to incorporate social justice in sustainable transport planning, it should be based on the principle of need: 'The goal of such a needs-based model would be to assess to what extent the existing or future transport network is able to secure a minimal level of accessibility for all population groups.' Such basic needs could include health, education, work and social contacts. A sustainable transport system should thus reflect the needs of the weak rather than the wants of the strong.

The challenge with such an approach is to set accessibility standards. Such standards are needed to assess the performance of a transport network in terms of its success or failure to provide minimal levels of accessibility to all population groups. Ideally, access should be defined in terms of travel costs (time and direct costs) and availability (what transport modes are within reach). Feitelson (2002, pp. 105–106) argues that in countries where access to cars is high (e.g. the US) and the cost of motoring is low, equity concerns related to transport may be smaller. However, cars can never provide access for all, because even in a wealthy community, substantial numbers of people are prevented from driving by age, disability, income, recent immigration or simply by personal preferences (Root et al., 2002; Tillberg, 2002; Rudinger, 2002; Uteng, 2006; Mees, 2010; Banister, 2009). To accommodate the basic needs of these population groups, a well-developed public transport system is essential.

A number of attempts have been made to develop accessibility measures. Examples include the policy goal for public transport in the Queensland region (Murray et al., 1998); Public Transport Accessibility Levels (PTAL) (TfL, 2010); the Public Transport Relative Accessibility Percentage (PTRAP) (Gent and Symonds, 2005); the Metropolitan Accessibility/Remoteness Index of Australia (Pitot et al., 2006); and the Land Use and Public Transport Accessibility Index (LUPTAI) (Pitot et al., 2006). As a starting point for discussing a minimum threshold level, we use the PTAL methodology. PTAL is a detailed and accurate measure of the accessibility of a point in the public transport network, taking into account walk access time and service availability. Walk access times are calculated from a specified point of interest to all public transport access points. The PTAL then incorporates a measure of service frequency by calculating an average waiting time based on the frequency of service at each public transport access point. A reliability factor is added and the total access time is calculated. A measure known as an Equivalent Doorstep Frequency (EDF) is then produced for each point. These are summed for all routes within the catchment, and the PTALs for the different modes are then added to give a single value. The PTAL is categorised from 1 to 6, where 6 represents an excellent level of accessibility and 1 a very poor level. We take the view that PTAL must be a minimum of 3 (moderate level) to satisfy basic transport needs. It is, however, important to note that PTAL was developed to study accessibility within Greater London, and it is therefore not necessarily an adequate method for assessing accessibility in rural areas.

3.4. Dimension 4: promoting intergenerational transport equity

Intergenerational transport equity requires that future generations be able to meet their transport needs. Although we do not know these future needs, it is unlikely that future generations' transport needs can be met without access to some sort of motorised transport and, subsequently, the need for fuel. We know that fossil fuel will become more scarce and costly, so to meet future transport needs, we should, according to the Brundtland Commission's exigency, reduce our current dependence on fossil energy sources. Thus, we argue that the amount of renewable to total energy used for transport is a good indicator for intergenerational transport equity. Following the *IPCC Special Report on Renewable Energy and Climate Change Mitigation*'s (IPCC, 2011) recommendation, we argue that the fraction of renewable energy for transport must be a minimum of 15% by 2035 (see Table 1 for details). Over time, the required fraction of renewable fuel should be adjusted to reflect changes in reserves and costs of fossil fuels. Note that the required fraction of renewable energy is lower for transport (15%) than for the total economy (27%), reflecting that the thought that there are less opportunities or it is more costly to substitute renewable for fossil energy in the transport sector as compared to the rest of the economy.

4. Achieving sustainable passenger transport

We now illustrate the challenges countries face when entering the STS, focusing on the first two main dimensions. Similar sustainability assessments should be made for each pair of the four main dimensions.

4.1. Different challenges country-by-country

Fig. 2 shows the relation between daily per capita energy consumption for passenger transport and daily per capita travel distance by motorised transport (including air) for selected countries. All countries where relevant statistics are available (34) are included in Fig. 2; most developing countries are excluded because of a lack of available data.

Sustainable transport is defined as the area in the lower right quadrant where the maximum and minimum requirements are met—per capita energy consumption is below 5.6 kW h/day and per capita travel distances are above 9.2 km/day. Countries in the STS area include Romania and Slovakia.

In the lower left quadrant, we find Armenia and Albania (and probably would find most of the developing countries if data were available). Their sustainable transport strategy should focus on increasing per capita motorised travel. These strategies should include sustainable land-use planning and improved public transport systems to ensure increased motorised travel at the lowest possible level of energy consumption. If developing countries were to adapt the US transport pattern, they would probably consume about four times as much energy per capita than if they were to adapt the European transport pattern (Kenworthy and Laube, 2002).

In the upper right quadrant, we find most developed countries, all of which exceed the maximum per capita threshold value of 5.6 kW h/day. Such countries must reduce their energy consumption for passenger transport while still satisfying basic transport needs. Fig. 2 shows that there are large variations between countries in this quadrant. For example, the US and Italy have comparable per capita travel distances but very different per capita energy consumption, whereas Italy and Korea have comparable per capita energy consumption but very different per capita travel distances. Consequently, achieving sustainable transport represents a very different challenge in the US, Italy and Korea, respectively.

4.2. The main approaches for developed countries

Basically, there are three main approaches for developed countries to enter the STS: efficiency, alteration and reduction. In everyday terms, the three approaches can be characterised respectively as 'travel more efficiently', 'travel differently' and 'travel less'.

The three approaches, under different names, represent established knowledge within the sustainable transport (and sustainable development) literature, for example, the IPAT equation (Commoner, 1972; Ehrlich and Holdren, 1971), the ASIF equation (Schipper and Lilliu, 1999); the ASI model (Dalkmann and Brannigan, 2007); the SMART model (Holden 2007); social, technical and infrastructural emission drivers (Sager et al., 2011); and the STPM index (Black, 2003).[4]

Low-, medium- and high-mobility countries face different challenges when entering the STS, and this has consequences for which approach—or combination of approaches—are needed to enter the STS. Fig. 3 illustrates this point. For simplicity

[4] $I = P \times A \times T$. Human Impact (I) on the environment equals the product of P = Population, A = Affluence, T = Technology. ASIF: CO_2 = Activity ∗ Structure ∗ Intensity ∗ Fuels. ASI – Avoid, shift, improve. SMART: $SM = g(A, R, T)$ where SM = sustainable mobility, A = changing transport patterns and public transport use, R = reducing growth in transport, and T = increasing pace of technological change. STPM index: based on the difference between the level of sustainable mobility and the level of potential mobility, standardized by population size and units of measurement.

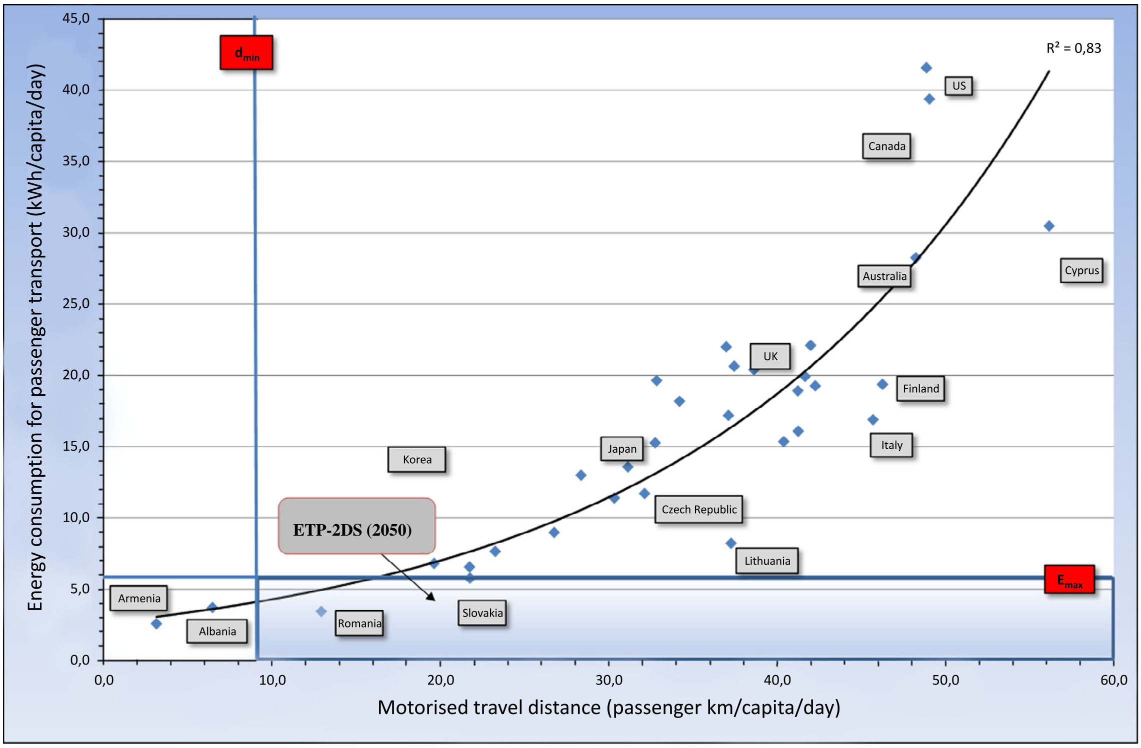

Fig. 2. The sustainable transport space (STS) for dimension 1 (daily per capita energy consumption for passenger transport) and 2 (daily per capita motorised travel distance). STS is in the lower right quadrant. Country data are from 2009/2010. *Note*: ETP is the IEA's Energy Technology Perspective 2012. 2DS describes an energy system consistent with an emissions trajectory that recent climate science research indicates would give an 80% chance of limiting the average global temperature increase to 2C. The ETP-2DS (2050) point shows the global 2050 target for passenger transport (IEA, 2012b). *Sources*: EU energy trends to 2030 (EC, 2010); Trends in the Transport Sector (OECD, 2011); IEA Data service (IEA, 2012a)

we assume a linear relation between travel distance and energy consumption for travel purposes; moreover, we do not consider any forms of compensatory effects, rebound effects, complementarity of potential energy savings, or other similar factors.

The upper line shows the 2010 relationship between daily per capita energy consumption for passenger transport and daily per capita travel distance, as well as their respective threshold levels (*d*min and *E*max). The middle line (2030-Eff) illustrates how an efficiency approach alone may change the relation between energy consumption and travel distance in 2030. The bottom line (2030-Eff + Alt) illustrates how combining the efficiency and alteration approach could improve the sustainability of transport even further. Typical low- (L), medium- (M) and high- (H) mobility countries are marked on the figure, with travel distances of *d*L, *d*M and *d*H, respectively.

The figure illustrates the challenges for countries with different mobility levels. High mobility countries must use all three approaches: increasing efficiency (*Eff*H), altering transport patterns (*Alt*H) and reducing their travel distance (*Red*H) as compared to their present levels. Medium-mobility countries may achieve sustainable transport through a combination of increased efficiency (*Eff*M) and altered transport patterns (*Alt*M). In the scenario presented in Fig. 3, they are, however, allowed to maintain their present level of travel distance. Low-mobility countries, on the other hand, can concentrate only on increasing efficiency (*Eff*L).

There are other key considerations. We have to consider the *level* of technological improvement and the *degree* of alteration in transport patterns (which determine the slope of the two 2030 lines). If, for example, more efficient engines are put into larger, faster and more comfortable cars, energy consumption might not be reduced by much. Thus the 2030-Eff line would run much closer to the 2010 line than indicated in the figure. Or, if we continue to travel more by car and plane than by bus and train, the alteration effect could in fact be negative.

These limitations are the main concerns of proponents of the reduction approach, namely that very strong assumptions are made in the efficiency approach regarding technological improvements and in the alteration approach regarding changes in present transport patterns. Rather than supporting the rather optimistic scenarios portrayed by the 2030 lines in Fig. 3, the reduction approach suggests that the 2030 lines are more likely to equal the 2010 line. In that case, the *only* way to enter the STS would be to reduce present per capita travel distance for low-, medium- and high-mobility countries alike.

The relevance of the reduction approach is powerfully demonstrated by Sager et al. (2011). In their 2050 light-duty vehicle scenarios, they forecast that meeting greenhouse-gas targets through technological improvements alone would require

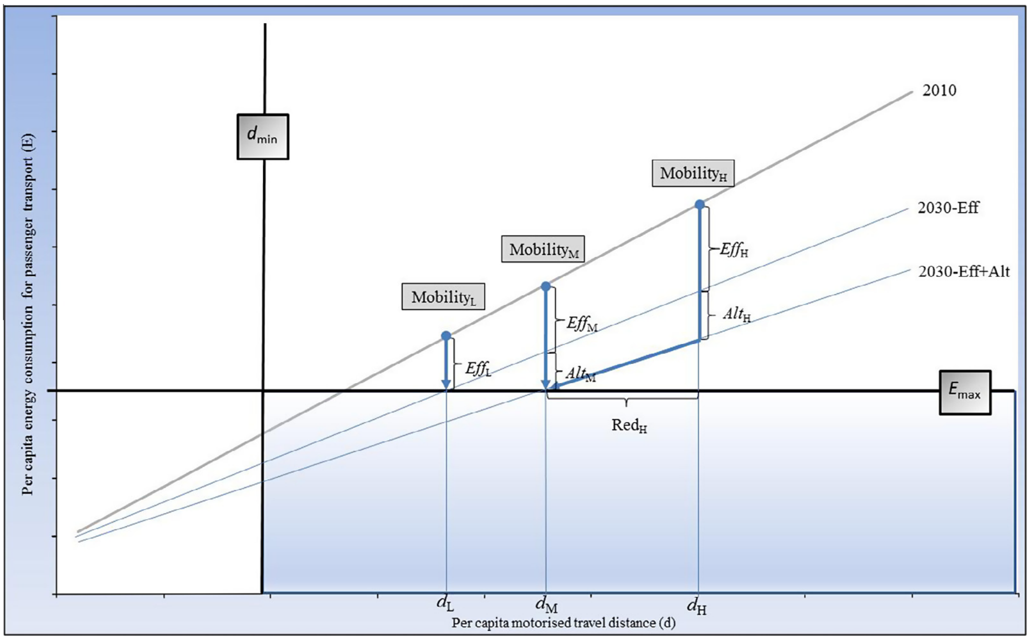

Fig. 3. The challenges for low – (L), medium – (M) and high – (H) mobility developed countries to enter the STS (dimensions 1 and 2). *Note*: Eff: increased efficiency; Alt: altered transport patterns; and Red: reduced travel distance.

universal deployment of one or more of the following clusters: electric vehicles running on nearly zero-carbon electricity, cellulosic biofuel-powered vehicles achieving 0.78 l per 100 km, or gasoline-fuelled vehicles achieving in excess of 0.24 l per 100 km. The researchers argue that these performance levels exceed even the most optimistic technology scenarios for the year 2050. Making substantial reductions in greenhouse gas emissions (and subsequently achieving sustainable transport) is a behavioural issue (i.e. alteration and reduction), not solely a technological (efficiency) issue. Their conclusion regarding the inadequacy of solely focusing of technological solutions is further supported by many other studies, notably that of the International Energy Agency in *Energy Technology Perspectives 2012* (IEA, 2012b).

5. Conclusion

Returning to the Brundtland Report, the concept 'sustainable passenger transport' has been reframed, together with an assessment method based on four main dimensions. Moreover, by selecting relevant indicators and assigning threshold values, the scale of the necessary changes to achieve sustainable passenger transport has been illustrated. The task may seem to be overwhelming, and the question can be asked about whether these changes are socially desirable and are they within reach? Assuming the answer to the first question is yes, each of the four threshold values can be evaluated to determine the feasibility and realism of the targets in the context of current and future conditions.

First, the maximum threshold value for daily per capita energy consumption for passenger transport has been set at 5.6 kW h (Dimension 1). No high-income country currently has such a low rate of energy use. However, Japan, Portugal and Poland are not that far off, with 13.6, 13.0 and 7.6 kW h, respectively. If we focus on high-income big cities, the picture is even brighter. Reporting only passenger transport by car, energy consumption in 2005, the levels were 3.2 kW h in Hong Kong, 6.0 kW h in Singapore, 8.4 kW h in Beijing and 8.7 kW h in Helsinki. It should be noted that the figure from Hong Kong has decreased since 1995 in spite of economic growth (Kenworthy, 2012).

The relevance of these figures cannot be underestimated. Today more than 50% of the global population lives in cities and this fraction is increasing rapidly (UNFPA, 2011). Compact cities may imply shorter travel distances and facilitate the development of public transport. It may be possible that a continued drop in energy use for land-based travel could be anticipated. The real challenge relates to a continued rise in travel by high-speed trains and air as predicted by Schafer et al. (2009). Only a sharp rise in fuel prices and/or the political will to reduce such travel may succeed in keeping the energy use for longer distance travel within the restrictions set by the threshold.

Second, the minimum threshold value for daily per capita travel distance by motorised transport has been set at 9.2 km (Dimension 2). For most developed countries this threshold value is not a problem, as current travel distance is well above the threshold value (Fig. 2). For most developing countries this threshold value is within reach, as non-OECD countries have experienced a 75% increase in average per capita travel distance between 2000 (6.4 km) and 2010 (9.3 km) (IEA, 2012a), and travel distances are expected to increase further in the coming decades (IEA, 2012b).

Third, the minimum threshold value for Public Transport Accessibility Level (PTAL) is set at 3 or moderate accessibility (Dimension 3). According to Transport for London, large parts of central London already have a PTAL of at least 3 (TfL, 2012). Cities like Hong Kong, Zurich and Munich have higher levels of public transport travel than London and thus an even higher potential to overcome this threshold value (Kenworthy, 2012). Although an increasing number of people live in big cities, the challenge of an equal access to public transport in the rural areas must be dealt with. Perhaps PTAL is not a sufficient indicator for such areas and must be supplemented with car-based accessibility indicators.

Finally, the minimum renewable energy share for transport is set at 15% (Dimension 4). Statistics show that these shares have increased sharply, partly fuelled by political regulation, standards and subsidies. According to the European Commission, between 2006 and 2010, the transport renewable share increased from 2.0 to 6.1% in France, 3.0–7.8% in Slovakia, and 4.9–7.7% in Sweden (Eurostat, 2012). Achieving 15% by 2030 is therefore a realistic threshold.

Taken together, these are four tough targets for transport, and they do not necessarily operate in the same direction. For example, most countries and cities will achieve the distance threshold (Dimension 2), but greater distance might lead to more energy being consumed (Dimension 1). Different solutions need to be developed for each situation so that the most appropriate combinations of both technological innovation and behavioural change are used, as this is the only means by which "the international goal of limiting the long-term increase of the global mean temperature to 2 °C" can be reached (IEA, 2012b, p. 7). This paper has tried to interpret the Brundtland definition of sustainable development within the transport context, by highlighting the four key dimensions and then deriving a set of clear and transparent measures, so that progress towards sustainable transport can be measured, both at the national and city levels.

Two main conclusions stand out. Firstly, the approach and measures developed are based on thresholds that allow comparison to take place between different countries (and cities) and over time. This means that it is possible to monitor change and to learn from countries (and cities) that are making good progress towards sustainable transport. Secondly, positive conclusions can be drawn on some of the Dimensions, as several countries (and cities) have already reached the thresholds or are close to achieving them. This is good news that suggests transport is at last becoming more sustainable, but this optimism needs to be tempered with a note of caution, as some of the major countries are still a long way from the thresholds and the high energy costs of long distance travel are difficult to reduce.

References

Amekudzi, A.A., Khisty, C.J., Khayesi, M., 2009. Using the sustainability footprint model to assess development impacts of transportation systems. Transportation Research Part A 43, 339–348.

Aslaksen, I., Ericson, T., Funtowicz, S., Garnåsjordet, P.A., Giampieto, M., 2010. A general conceptual model for selection and specification of national sustainable development indicators (SDI) in a precautionary context. In: Paper presented to the International Society for Ecological Economies (ISEE) Conference, Oldenburg, 22–25 August.

Banister, D., 2005. Unsustainable Transport. Routledge, London.

Banister, D., 2008. The sustainable mobility paradigm. Transport Policy 15, 73–80.

Banister, D., 2009. Rural transport. In: Kitchen, R., Thrift, N. (Eds.), International Encyclopedia on Human Geography. Elsevier, pp. 460–464.

Banister, D., 2011. The trilogy of distance, speed and time. Journal of Transport Geography 19, 950–959.

Bastianoni, S., Niccolucci, V., Pulselli, R.M., Marchettini, N., 2012. Indicator and indicandum: 'Sustainable way' vs 'prevailing conditions' in the ecological footprint. Ecological Indicators 16, 47–50.

Black, W.R., 2003. Transportation: A Geographical Analysis. The Guilford Press, London.

Black, W.R., 2010. Sustainable Transportation: Problems and Solutions. Guilford Press, New York.

Black, W.R., Nijkamp, P. (Eds.), 2002. Social Change and Sustainable Transport. Indiana University Press, Bloomington, IN.

Castillo, H., Pitfield, D.E., 2010. ELASTIC – a methodological framework for identifying and selecting sustainable transport indicators. Transportation Research Part D 15, 179–188.

Commoner, B., 1972. The Environmental Cost of Economic Growth. Population, Resources and the Environment. Government Printing Office, Washington, DC, pp. 339–363.

Dahl, A.L., 2012. Achievements and gaps in indicators for sustainability. Ecological Indicators 17, 14–19.

Dalkmann, H., Brannigan, C., 2007. Transport and Climate Change. Sourcebook Module 5e, GTZ, Eschborn.

EC, 2010. EU energy trends to 2030 – update 2009. European Commission Directorate-General for Energy in collaboration with Climate Action DG and Mobility and Transport DG, Publications Office of the European Union, Luxembourg.

EEA, 2012. Environmental indicator report 2012. Ecosystem resilience and resource efficiency in a green economy in Europe. European Environment Agency, Copenhagen.

Ehrlich, P.R., Holdren, J.P., 1971. Impact of Population Growth. Science, New Series 171 (3977), 1212–1217.

Elster, J., 1992. Local Justice: How Institutions Allocate Scarce Goods and Necessary Burdens. Cambridge University Press, Cambridge.

Eurostat, 2012. Share of renewable energy in fuel consumption of transport <http://epp.eurostat.ec.europa.eu/tgm/printTable.do?tab=table&plugin=1&language=en&pcode=tsdcc340&printPreview=true> (accessed August 23).

Ewing, B., Reed, A., Galli, A., Kitzes, J., Wackernagel, M., 2010. Calculation Methodology for the National Footprint Accounts, 2010 Edition. Global Footprint Network, Oakland.

Feitelson, E., 2002. Introducing environmental equity dimensions into the sustainable transport discourse: issues and pitfalls. Transportation Research Part D 7, 99–118.

Gasparatos, A., El-Haram, M., Horner, M., 2009. The argument against a reductionist approach for measuring sustainable development performance and their need for methodological pluralism. Accounting Forum 33, 245–256.

Gent, C., Symonds, G., 2005. Advances in public transport accessibility assessments for development control – a proposed methodology. In: 2005 Planning and Transport, Research and Computation (PTRC) Annual Transport Practitioners' Meeting.

Gudmundsson, H., Höjer, M., 1996. Sustainable development principles and their implications for transport. Ecological Economics 19, 269–282.

Hanley, N., Shogren, J.F., White, B., 2001. Introduction to Environmental Economics. Oxford University Press, Oxford.

Heink, U., Kowarik, I., 2010. What are indicators? On the definition of indicators in ecology and environmental planning. Ecological Indicators 10, 584–593.

Holden, E., 2007. Achieving Sustainable Mobility: Everyday and Leisure-Time Travel in the EU. Ashgate, Aldershot.

Holden, E., Linnerud, K., 2007. The sustainable development area: satisfying basic needs and safeguarding ecological sustainability. Sustainable Development 15, 174–187.

Holden, E., Linnerud, K., 2011. Troublesome leisure travel: the contradictions of three sustainable transport policies. Urban Studies 48, 3087–3106.

Høyer, K.G., 2000. Sustainable mobility – the Concept and its Implications. Report 1/2000. Western Norway Research Institute, Sogndal.
IEA, 2009. Transport, Energy and CO_2. Moving Toward Sustainability. International Energy Agency, Paris.
IEA, 2011. Key World Energy Statistics. International Energy Agency, Paris.
IEA, 2012a. Data Service <http://www.data.iea.org/ieastore/default.asp?> (accessed 30.06.12).
IEA, 2012b. Energy Technology Perspectives 2012. Pathways to a Clean Energy System. International Energy Agency, Paris.
IPCC, 2000. IPCC Special Report on Emissions Scenarios. Intergovernmental Panel on Climate Change.
IPCC, 2011. Renewable Energy Sources and Climate Change Mitigation. Special Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, New York.
Kenworthy, J., 2012. Urban Transport trends in global cities: a sustainability report card on 33 urban regions. Curtin University, Perth and Goethe University, Frankfurt am Main. In: Presented to CARE-North Conference: Carbon Responsible Transport Strategies for The North Sea Area, Bremen, March 20–22.
Kenworthy, J., Laube, F., 2002. Urban transport patterns in a global sample of cities & their linkages to transport infrastructure, land use, economics & environment. World Transport Policy and Practice 8, 5–19.
Lafferty, W.M. (Ed.), 2004. Governance for Sustainable Development. The Challenge of Adapting Form to Function. Edward Elgar, Cheltenham.
Lafferty, W.M., Langhelle, O., 1999. Sustainable development as concept and norm, towards sustainable development. In: Lafferty, W.M., Langhelle, O. (Eds.), On the Goals of Development – and the Conditions of Sustainability. MacMillan Press Ltd., London, pp. 1–29.
Lautso, K., Toivanen, S., 1999. SPARTACUS system for analysing urban sustainability. Transportation Research Record 1670, 35–46.
Litman, T., Burwell, D., 2006. Issues in sustainable transportation. International Journal of Global Environmental Issues 6, 331–347.
Martens, K., 2006. Grounding transport planning on principles of social justice. Berkeley Planning Journal 19, 1–17.
Mees, P., 2010. Transport for Suburbia. Beyond the Automobile Age. Earthscan, London.
Mokhtarian, P.L., 2005. Travel as a desired end, not just a means. Transportation Research Part A 39, 93–96.
Moldan, B., Hák, T., Kovanda, J., Havránek, M., Kúsková, P., 2004. Composite indicators of environmental sustainability. Statistics, Knowledge and Policy, OECD World Forum on Key Indicators. Palermo, 10–13 November.
Murray, A.T., Davis, R., Stimson, R.J., Ferreira, L., 1998. Public transportation access. Transportation Research Part D 3, 319–328.
OECD, 2011. Trends in the Transport Sector 1970–2009. International Transport Forum/Organisation for Economic Co-operation and Development. OECD Publications, Paris.
O'Riordan, T., 1993. The politics of sustainability. In: Turner, K.R. (Ed.), Sustainable Environmental Economics and Management. John Wiley & Sons, Chichester, pp. 37–69.
Pitot, M., Yigitcanlar, T., Sipe, N., Evans, R., 2006. Land Use and Public Transport Accessibility Index (LUPTAI) tool: the development and pilot application of LUPTAI for the Gold Coast. Social Research in Transport (SORT) Clearinghouse. Paper 123 <http://www.sortclearinghouse.info/research/123>.
Root, A., Schintler, L., Button, K., 2002. Women and travel: the sustainability implications of changing roles. In: Black, W.R., Nijkamp, P. (Eds.), Social Change and Sustainable Transport. Indiana University Press, Bloomington, IN, pp. 149–156.
Rudinger, G., 2002. Mobility Behaviour of the Elderly: Its Impacts on the Future Road Traffic System. In: Black, W.R., Nijkamp, P. (Eds.), Social Change and Sustainable Transport. Indiana University Press, Bloomington, IN, pp. 157–164.
Sager, J., Apte, J.S., Lemoine, D.M., Kammen, D.M., 2011. Reduce growth rate of light-duty vehicle travel to meet 2050 global climate goals. Environmental Research and Letters, 6, 024018.
Schafer, A., Heywood, J.B., Jacoby, H.D., Waitz, I.A., 2009. Transportation in a Climate-Constrained World. MIT Press, London/Cambridge, USA.
Schiller, P.L., Bruun, E.C., Kenworthy, J.R., 2010. An Introduction to Sustainable Transportation: Policy, Planning, and Implementation. Earthscan, London/Washington, DC.
Schipper, L., Lilliu, C.M., 1999. Transportation and CO_2 Emissions: Flexing the Link. A Path for the World Bank. The World Bank, Washington, DC.
Shiftan, Y., Kaplan, S., Hakkert, S., 2003. Scenario building as a tool for planning a sustainable transportation system. Transportation Research Part D 8, 323–342.
Singh, R.K., Murty, H.R., Gupta, S.K., Dikshit, A.K., 2011. An overview of sustainability assessment methodologies. Ecological Indicators 15, 281–299.
TfL, 2010. Measuring Public Transport Accessibility Levels. Transport for London, London.
TfL, 2012. TfL Planning Information Database <http://www.webptals.org.uk/> (accessed 23.08.12).
Tillberg, K., 2002. Residential Location and Daily Mobility Patterns: A Swedish Case Study of Households with Children. In: Black, W.R., Nijkamp, P. (Eds.), Social Change and Sustainable Transport. Indiana University Press, Bloomington, IN, pp. 165–172.
UN, 2010. State of the World's cities 2012/2011. UN-HABITAT <http://www.unhabitat.org/documents/SOWC10/R8.pdf> (accessed 10.07.12).
UNCSD, 2007. Indicators of Sustainable Development: Guidelines and Methodologies, third ed. The UN Commission on Sustainable Development. United Nations, New York.
UNDP, 2010. Human Development Report 2010. The Real Wealth of Nations: Pathways to Human Development. United Nations Development Programme, New York.
UNDP, 2011. Human Development Report 2011. Sustainability and Equity: A Better Future for All. United Nations Development Programme, New York.
UNFPA, 2011. Delivering Results in a World of 7 Billion. 2011 Annual Report. United Nations Population Fund, New York.
UNU-IHDP and UNEP, 2012. Inclusive Wealth Report 2012. Measuring Progress Toward Sustainability. Cambridge University Press, Cambridge.
Uteng, T.P., 2006. Mobility: discourses from the non-western immigrant groups in Norway. Mobilities 1, 435–462.
WCED, 1987. Our Common Future. World Commission on Environment and Development. Oxford University Press, Oxford.
Wiedmann, T., Barrett, J., 2010. A review of the ecological footprint indicator – perceptions and methods. Sustainability 2, 1645–1693.
Wilkinson, R., Pickett, K., 2009. The Spirit Level. Why Equality is Better for Everyone. Penguin Books, London.
WWF, 2008. Living Planet Report 2008. World Wide Fund for Nature, Gland.
WWF, 2010. Living Planet Report 2010. World Wide Fund for Nature, Gland.
WWF, 2012. Living Planet Report 2012. World Wide Fund for Nature, Gland.
Xenias, D., Whitmarsh, L., 2012. Dimensions and determinants of expert and public preferences for low-carbon transport policies and technologies. Transportation Research Part A 48, 75–85.