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Sustainable Transport and Performance Indicators

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1 Introduction

Since the release of the report of the World Commission on Environment and Development (known as the Brundtland Report) in 1987 transport problems and policies have increasingly been framed with regard to the notion of Sustainable Development. According to the Brundtland Commission and many subsequent statements sustainable development refers to ‘. . . *development that meets the needs of the present without compromising the ability of future generations to meet their own needs*’.¹ The relevance of this notion for transport has chiefly been inferred from the fact the movement of people and goods serves present society while contributing to a range of pressures on the environment, from the impairment of air quality at urban and street level to the emissions of greenhouse gasses at the global scale.² Moreover, current and future expected growth patterns of transport appear to be at odds with what can in the long run be sustained by limited environmental and economic resources and capacity.³ While these concerns are not entirely new, the political prominence given to ‘sustainability’ at the international level appears to have forced governments and others to address the full range of transport impacts in a more integrated way than before, and also to reconsider the very role of transportation in the pursuit of further economic and social development. Despite variations in emphasis a new policy agenda calling

¹ World Commission on Environment and Development, *Our Common Future*, 1987, Oxford University Press, Oxford.

² D. L. Greene, Sustainable Transportation, in *The International Encyclopaedia of the Social and Behavioral Sciences*. P. B. Baltes and N. J. Smelser (eds.) Elsevier Science, Oxford, 2001, pp. 15335–15339.

³ US Transportation Research Board. *Toward a sustainable future. Addressing the Long Term Effects of Motor Vehicle Transportation on Climate and Ecology*. Transportation Research Board, 1997, Special report 251, National Academy Press, Washington D.C.

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for more ‘Sustainable Transport’ or ‘Sustainable Mobility’ has shaped national and local policy development in several countries, not least in the European Union.⁴

However, while it is most likely that transport will remain important for both the environment and society it has not been altogether clear what ‘Sustainable Transport’ would imply. Many questions have been raised, both from a theoretical point of view and as more practical concerns:⁵ First, what should be sustained, more precisely? Is it the transport systems, as we know them today or is it rather the services in terms of access and opportunity they provide? Sustainable in what respect one may ask next? It makes a difference if the perspective is a decade or a century, and if the context is a city or the entire globe. Furthermore, environmental protection may not be the only relevant concern; economic functions of transport may also have to be considered. Even in addressing the environmental dimension there are fundamental questions: Which are the critical ecological or health based limits to be observed and what is the role of transport in transgressing them? In other words it may not be entirely clear what kind of requirement a ‘sustainable transport system’ should fulfil, how far away the present systems are from satisfying them, and how policies can help to govern development in the desired direction.

Questions such as these have provoked a need for operational tools to navigate in an increasingly complex world. Among the most popular tools are *indicators* and *performance measures*. Indicators are selected variables that can help to make objectives operational and reduce the complexity in dealing with system management and intervention. They can function as guideposts in technical analysis and policy making as well as for the general public debate. When indicators are compared with standards or objectives they become performance measures, measuring the performances of systems, organizations or policies. Indicators and measures of transport have been incorporated into many different kinds of monitoring and assessment frameworks. Examples include transport sections in general sustainable development indicator frameworks such as the UK’s *Quality of Life Counts*,⁶ environmental indicator sets such as the ‘Environmental Signals’ from the European Environment Agency⁷ and many similar initiatives in a local context.⁸ However, more specific frameworks have also been set up to monitor or forecast the performance of transport systems or policies at

⁴ ECMT, *Sustainable Transport Policies*. European Conference of Ministers of Transport, Paris, 2000 and CEC, *The Future Development of the Common Transport Policy—a Global Approach to the Construction of a Community Framework for Sustainable Mobility*, Commission of the European Communities, Brussels, 1993.

⁵ See e.g. OECD, *Towards sustainable transportation, The Vancouver Conference, OECD Proceedings*, Organisation for Economic Co-operation and Development, Paris, 1997, and H. Gudmundsson H and M. Höjer. Sustainable development principles and their implications for transport, *Ecolog. Econom*, 1996, **19** 269-282.

⁶ DETR, *Quality of Life Counts. Indicators for a Strategy for Sustainable Development for the United Kingdom: A Baseline Assessment*, Department of the Environment, Transport and the Regions, London, December 1999.

⁷ EEA, *Environmental signals* 2001, European Environment Agency regular indicator report, Environmental assessment report No. 8, European Environment Agency, Copenhagen, 2001.

⁸ See e.g. Y. Rydin, *Indicators Into Action: Local Sustainability Indicator Sets in Their Context*, The Pastille Consortium, London School of Economics, London, 2002.



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both European, national and local levels.⁹ Within such frameworks dedicated indicators to monitor ‘sustainability’ aspects of transport have sometimes been incorporated, and researchers and experts have even devised whole systems to specifically monitor sustainable development in a transport context.¹⁰

Broadly speaking the literature represents three different approaches to make Sustainable Transport operational and measurable using indicators:

- In the first approach ‘Sustainable Transport’ serves as a metaphor of a broad policy agenda where transport policies take into account (also) sustainable development concerns. Policy planning and evaluation in this context typically incorporate some relevant indicators, such as growing transport volumes or carbon dioxide emissions from transport.¹¹
- In the second approach ‘Sustainable Transport’ is taken literally as meaning transport that can be sustained given certain limitations in time and space set by the environment and/or by certain demands of society. This approach derives from explicit reflections over the meaning of sustainability and what measuring it would entail in the more limited context of transport.
- The third approach represents a mixture of the above, in which ‘literal’ explorations of the sustainability concept are used to guide the construction of indicators that can inform either research or policy assessment subscribing to the ‘Sustainable Transport’ agenda.

While the first, metaphorical approach represents a typical stance adopted by many policy administrations throughout the world, the second, literal, one has mostly been pursued by some academics. In the third approach this is taken further by researchers or experts to more directly support, assess or critically examine transport trends or policies.

The present review focuses mostly on the second and third approach. This should not suggest that the numerous contributions in the policy realm are irrelevant. Rather, the scope in this chapter is limited to the more substantial conceptual contributions, thus aiming to provide an overview of how sustainability of transport may be measured and monitored using various kinds of performance indicators, as well as discussing some of the experience and implications of using them to support or assess policy making. Section 2 will set out overall aspects of sustainable transport indicators treating in turn conceptualization, operationalization and utilization issues. Section 3 will review a limited number of existing or proposed indicator sets of various origin. Section 4 concludes with a consideration of what may be inferred concerning the sustainability of transport systems from sustainable transport performance indicators and measurement frameworks.

⁹ H. Van der Loop, *Transport Policy Monitoring in Europe. Proceedings of the Workshop held in Amsterdam, 17–18 October 2002*, Ministry of Transport, Public Works and Water Management, AVV Transport Research Centre, Rotterdam, April 2003.

¹⁰ See examples later in this chapter or, for instance, R. Gilbert, N. Irwin, B. Hollingworth and P. Blais, *Sustainable Transportation Performance Indicators (STPI)*, Project Report on Phase 3, The Centre for Sustainable Transportation, Toronto, 31 December, 2002.

¹¹ Prominent representative of this approach are: 1993 European Commission White Paper *The Future Development of the Common Transport Policy — a Global approach to the construction of a Community framework for sustainable Mobility* and: UK Department for Transport, *A New Deal for Transport. Better for Everyone*. The Stationery Office, London, 1998.





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2 Making Sustainable Transport Operational

The use of indicators to measure and monitor sustainable transport involves several tasks. Drawing from the indicator literature¹² we will address three components of this process. The first component is *conceptualization*, which defines what is to be monitored, in this case sustainable development aspects of transport. The second component is *operationalization* in which concepts are made measurable by selecting parameters and indicator types. The third component is *utilization*, which refers to the ways in which the indicators are drawn upon in analysis or policy. In principle there are strong relations between these steps. The intended use should, for instance, influence the concepts to be specified, while indicator selection will again restrict possible uses (as when the choice of only quantitative emission data as environmental indicators may disregard concern for the more complex dimensions of urban liveability). In practice, however, there is not always a clear line from concept to measurement to use.

Conceptualization

As already indicated, sustainable transport is a somewhat nebulous concept, and various sources of inspiration have generally been drawn upon to specify it. We can distinguish between normative, analytical and strategic inspirations.¹³ One key inspiration is of course the international debate on sustainable development in general and the various normative concepts offered on that scene. This includes the 'Brundtland' concern for the well being of both present and future generations, as well as the specific attention given to maintenance of Earth's life-support systems. Another influential notion drawn from this debate is the three-dimensional, or 'triad',¹⁴ approach claiming that sustainable development must encompass economic, social and environmental dimensions (Figure 1). A fourth dimension is sometimes added, referring to institutions governing trade-offs or synergies within the three others.¹⁵

The above notions are present in practically all documented attempts to conceptualize sustainable transport. However, the emphasis put on various dimensions differ. While some explicitly address only 'sustainability' (effectively concerns for future generations, such as maintaining resources), most contributions include also 'development' aspects (transport outcomes of interest to the present generation, such as mobility, noise, accidents, *etc.*). Similarly, there is a division between those contributions that bridge all three dimensions *versus* the ones emphasizing the environmental dimension, often specified as 'Environmentally

¹² J. I. De Neufville, *Social Indicators and Public Policy: Interactive Processes of Design and Application*, Elsevier, Amsterdam, 1975.

¹³ E. Becker, T. Jahn, I. Stiess, and P. Wehling. *Sustainability: A Cross-Disciplinary Concept for Social Transformations*, 1997. Most Policy Papers no 6, UNESCO, Paris.

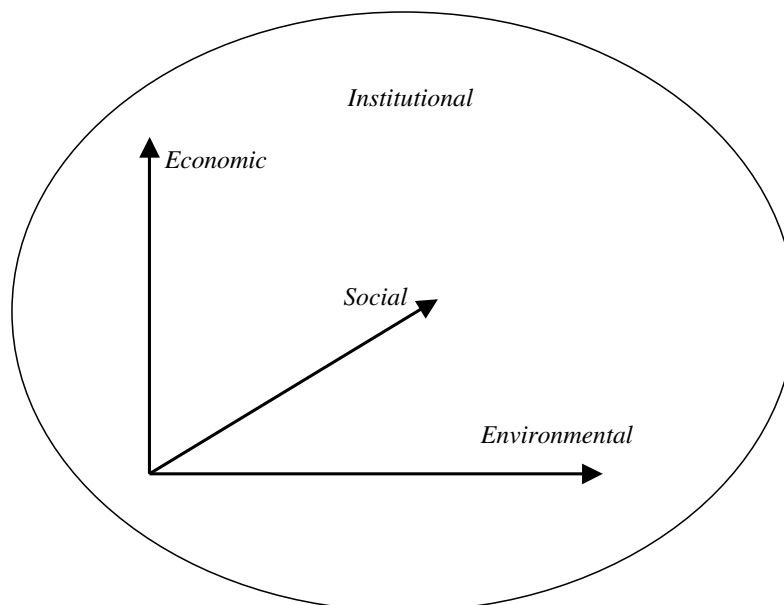
¹⁴ Expression from: N. Low, Is Urban Transport Sustainable? in *Making Urban Transport Sustainable*, ed. N. Low and B. J. Gleeson, 2003, pp. 1–21. Palgrave, Basingstoke.

¹⁵ Agenda 21, the key policy document endorsed at the United Nations Conference on Environment and Development in Rio de Janeiro in 1992, is often considered a key reference for the four dimension view. In the sustainable transport literature the three first dimensions (economic, social, environmental) are most often referred to.



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Figure 1 Dimensions of sustainable development



Sustainable Transport'.¹⁶ Table 1 suggests a grouping into these dimensions of selected key references from the conceptual literature on sustainable transport.

Secondly, different academic disciplines offer important analytic building blocks to set up more specific sustainability concepts, criteria and metrics. Environmental sciences have provided influential notions such as Carrying Capacity, and Critical Loads and have also formed the basis for more detailed assessment tools such as emission inventories, air quality models and Global Warming Potential index, all of which have been widely incorporated in sustainable transport indicators. Environmental economics has contributed several important ideas. Most fundamentally perhaps by defining sustainability in terms of preservation of society's capital base, often divided into so-called 'weak' and 'strong' notions of sustainability.¹⁷ Widely cited in the sustainable transport literature are the 'strong sustainability' rules proposed by ecological economist Herman Daly, according to which: (1) renewable resources should not be used faster than their regeneration rates, (2) non-renewable resources should not be used faster than substitutes become available, and (3) pollution should not exceed the assimilative capacity of the environment.¹⁸ Assessments of transport

¹⁶ As for instance the OECD project with this title (OECD-PPCG *Environmental Criteria for Sustainable Transport. Working Paper of the PPCG Task Force on Transport*, Pollution Prevention and Control Group, Organisation for Economic Co-operation and Development, Paris, 1996).

¹⁷ The 'weak' notion suggests that economic assets can be substituted for environmental ones, further implying that environmental assets should be measured in monetary terms, while 'strong' sustainability suggest non-substitution leading to a need for separate accounting principles defined by biophysical conditions and limits, see e.g. R. K. Turner (ed.) *1993 Sustainable Environmental Economics and Management—Principles and Practise*. Belhaven, London. In practice a 'strong' view is most often implied if a range of indicators of sustainable transport are proposed, as opposed to aggregating results in one figure such as discounted costs.

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Table 1 Approach to sustainable transport in selected references

	<i>Environmental</i>	<i>3 dimensions</i>
Sustainability (future generations)	a	
Sustainable development (present and future generations)	b-d	e-p

^a US Transportation Research Board, *Toward a Sustainable Future. Addressing the Long Term Effects of Motor Vehicle Transportation on Climate and Ecology*, Transportation Research Board, Special report 251, National Academy Press, Washington D.C., 1997.

^b Royal Commission on Environmental Pollution, *Transport and Environment. Eighteenth report. Cm 2674*, HMSO, London, 1994.

^c P. Kageson, *The Concept of Sustainable Transportation*, The European Federation for Transport and Environment, T&E 94/3, Bruxelles, 1994.

^d OECD-PPCG, *Environmental Criteria for Sustainable Transport. Working Paper of the PPCG Task Force on Transport*, Organisation for Economic Co-operation and Development, Paris, 1996.

^e J. Whitelegg, *Transport for a sustainable future. The case for Europe*, Belhaven Press, London, 1993.

^f UK Round Table on Sustainable Development, *Defining a Sustainable Transport Sector*, UK Round Table on Sustainable Development, London, 1996.

^g H. Gudmundsson, & M. Højer, Sustainable development principles and their implications for transport, *Ecol. Econom.*, 1996, **19**, pp. 269-282.

^h W. Spillmann, et. al. Criteria for sustainable mobility. (English summary from): *Nachhaltigkeit: Kriterien im Verkehr*, Ernst Basler & Partner, Zollikon, Switzerland, 1998.

ⁱ Wuppertal and Ökopol, *Baltic 21 Transport Sector Report*. Baltic 21 Series No 8/98, UBA-TEXTE 38/98, Federal Environmental Agency (Umweltbundesamt), Berlin, 1998.

^j Joint Expert Group on Transport and Environment, *Recommendations for Actions for Sustainable Transport, A strategy Review* Commission of the European Community Directorate-General Transport & Directorate-General Environment, Brussels, 26, September 2000.

^k W. R., Black. Toward a measure of transport sustainability, *Transportation Research Board Meeting, 2000, Conference Preprints*, Transportation Research Board, Washington, D.C., 2000.

^l E. Akinyemi and M. Zuidgeest, *Sustainable Development & Transportation: Past Experiences and Future Challenges*, World Transport Policy & Practice, 2000, Vol. 6, No. 1, pp. 31-39.

^m D. L. Greene, Sustainable Transportation, in P. B. Baltes & N. J. Smelser (eds.), *The International Encyclopedia of the Social & Behavioral Sciences*. Elsevier Science, Oxford, 2001, pp. 15335-15339.

ⁿ H. Minken, A framework for the evaluation of urban transport and land use strategies with respect to sustainability. Paper presented to the *Sixth Workshop of the Transport, Land Use and Environment (TLE) Network*, Haugesund, September 27-29, 2002.

^o T. Litman and D. Burwell, *Issues in Sustainable Transportation*, Victoria Transport Policy Institute, Victoria, British Columbia, 2003.

^p N. Low, Is Urban Transport Sustainable? in, N. Low and B. J. Gleeson (eds.), *Making Urban Transport Sustainable*, Palgrave, Basingstoke, 2003, pp. 1-21.

directly based on such rules often suggest that current transport trends are unsustainable.¹⁹ Other highly influential economic ideas in the sustainable

¹⁸ H. Daly, Toward some operational principles of sustainable development, *Ecolog. Econom.*, 1990, **2**, 1-6.

¹⁹ See for instance: J. S., Szyliowicz, Decision-making, intermodal transportation, and sustainable mobility: towards a new paradigm. *Int. Social Sci. J.*, June 2003, **55**, (2), 185-197, and H.



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transport literature include *eco-efficiency* (referring to an increase in economic output without an equivalent increase in environmental damage)²⁰ and the need to correct for *market failures* (e.g. the need to internalise external environmental costs in transport prices).²¹

Third, and finally, sustainable transport notions have been highly influenced by strategic issues, both in terms of policy recommendations from the international sustainable development process, and in terms of more specific issues on current transport policy agendas. The former has injected notions such as the call for closer integration of economic and ecological reasoning in decision-making,²² and the need to actively engage citizens in policy processes. The latter involve critical transport issues such as shifting to new technologies and alternative energy carriers, optimizing the logistical organization of transport flows, and mitigating urban congestion, air pollution and noise. All of these strategic topics have been flagged in various connections as key levers to more sustainable transport. In fact some scholars even claim that the only way to make sustainable transport operational is to explore the feasibility of practical policy options, rather than engaging in theoretical reconstruction.²³

What should emerge from the above is that there are many sources of inspiration behind the concept of sustainable transport, all of which do not readily assemble into a uniform idea. No common agreement therefore exists on a specific meaning of the term.²⁴ Among the key factors contributing to obscure the notions are:

- The idea of sustainable development itself is contested, normative and multi-dimensional, a wide range of methodologies and metrics being applied to measure various aspects of it.
- The transport sector, consisting of many technical and social subsystems interacting to produce social benefits as well as negative environmental effects.
- Transport not being isolated from the rest of society, meaning that sustainability of transport systems should in fact be considered as part of changes in the whole socio-economic system.

Nevertheless the predicament of sustainability can hardly be removed from the context of transport simply because it involves a number of complications.

Gudmundsson and M. Højer, Sustainable development principles and their implications for transport. *Ecolog. Econom.* 1996, **19**, 269–282.

²⁰ R. Montgomery, and L. Sanches, Efficiency: The sustainability criterion that provides useful guidance for statistical research, *Statistical J. UN ECE*, 2002, **19**, 29–40.

²¹ As for instance in the following proposition: 'Having a sustainable transport system means making each road user pay at least the full marginal cost of his or her journey'. (D. Maddison, O. Johansson and D. Pearce. *The True Costs of Road Transport*, Blueprint, nr. 5. Earthscan, London, 1996, p. 146.)

²² Environmental integration is a highly influential notion in the policies of the European Union, as for instance reflected in Article 6 in the EC Treaty: 'Environmental protection requirements must be integrated into the definition and implementation of the Community policies and activities (...) in particular with a view to promoting sustainable development'. (The Treaty on European Union and the Treaty establishing the European Community, *Official J. Eur. Communities*, C 325/1 24.12.2002).

²³ E. T. Verhoef and E. Feitelson, (eds.) *Transport and Environment: in Search of Sustainable Solutions*, Edward Elgar, Cheltenham, 2001.

²⁴ Greene 2001 (Reference 2).



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Moreover, the notion of sustainable transport has been conceptualised quite extensively in various forms. The most straightforward form is by *defining* it. Other forms include the statement of *criteria, principles, objectives* or *targets*. Most attempts can be summarized into a number of *issues* considered to be seminal to the concept. We will look into a few examples.

Definitions. Definitions of sustainable transport or mobility proposed in the literature chiefly extend the Brundtland concept mentioned above. One definition simply suggests that ‘... *sustainable transport is satisfying current transport needs without jeopardising the ability of future generations to meet these needs.*’²⁵ In the United Kingdom the former Round Table of Sustainable Development similarly proposed that a sustainable transport policy ‘... *seek[s] to minimise current and anticipated future adverse impacts and their associated costs, while continuing to deliver or improve existing benefits.*’²⁶ Definitions in terms of what kind mobility would be worth sustaining (rather than what factors would limit it) are more rare.²⁷

Other definitions are focussed on the environmental aspects. An OECD project defined in 1996, Environmentally Sustainable Transport as ‘... *transportation [that] does not endanger public health or ecosystems and meets needs for access consistent with (a) use of renewable resources below their rates of regeneration, and (b) use of non-renewable resources below the rates of development of renewable substitutes.*’²⁸ This influential contribution (drawing from Daly above) has been combined with other dimensions of sustainability by the Canadian Centre for Sustainable Transportation²⁹ and The European Commissions Expert Group on Transport and Environment³⁰ leading to a comprehensive definition of a sustainable transport system as one that:

- ‘Allows the basic access and development needs of individuals, companies and societies to be met safely and in a manner consistent with human and ecosystem health, and promotes equity within and between successive generations;
- Is affordable, operates fairly and efficiently, offers choice of transport mode, and supports a competitive economy, as well as balanced regional development;
- Limits emissions and waste within the planet’s ability to absorb them, uses renewable resources at or below their rates of generation, and, uses non-renewable

²⁵ W. R. Black, Socio-economic barriers to sustainable transport. *Transport Geog.*, 2000, **8**. (p. 141). This definition implies that sustainability of current transport trends are only considered in terms of their effects on future *transport* needs, a somewhat narrow perspective. As we shall see in Section 3 the same author also offers a broader approach.

²⁶ UK Round Table on Sustainable Development: *Defining a sustainable Transport Sector*. UK Round Table on Sustainable Development, London, 1996.

²⁷ One example would be the concept of ‘customised mobility’ (R. Kemp & J. Rotmans, *Transition Management for Sustainable Mobility*. MERIT, the Maastricht Economic Research Institute on Innovation and Technology of Maastricht University, Maastricht, 17 January, 2002)

²⁸ OECD, *Policy Instruments for Achieving Environmentally Sustainable Transport*, Organisation for Economic Co-operation and Development, Paris, 2002. One notes the reflection of Daly’s propositions, see Reference 18.

²⁹ see URL: www.cstctd.org/index.html

³⁰ Joint Expert Group on Transport and Environment, *Recommendations for Actions for Sustainable Transport. A Strategy Review*. Commission of the European Community Directorate-General Transport & Directorate-General Environment, Brussels, 26 September 2000.

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resources at or below the rates of development of renewable substitutes while minimising the impact on the use of land and the generation of noise.³¹

While these definitions may reflect overall dimensions of sustainable development as well as a range of transport policy concerns they do not provide criteria for more rigorous assessment of the sustainability of any particular transport situation or decisions. Definitions of a more technical kind have been proposed but tend to have much more limited applications.³²

Principles of sustainable transport refer to criteria to be followed in dealing with transport systems or policies. In the 'system principles' perspective transport is considered in regard to the threats they pose to overall sustainability principles such as resource conservation rules or principles concerning positive contributions such as economic efficiency. On the basis of such principles objectives and strategies may be proposed. In the second, 'policy principles' perspective, the starting point is taken in strategic governance principles that need to be adopted to influence transport development, such as internalization, participation or integration. If these principles are adhered to, a sustainable transport situation should ensue. A prominent example is the so-called Vancouver principles of sustainable transportation (combining both of the above) adopted at an OECD conference in 1996.³³

Targets of sustainable transport are quantitative measures of the reduction in transport volume or its impacts required for transport systems to fulfil sustainable development definitions, principles or criteria. While such targets may provide rigorous measures for assessment, it is nevertheless difficult to establish them based on empirical reference. Besides the problems involved in the definition of absolute environmental thresholds at a system level in general, there is the additional problem of allocating shares or reduction burdens across sectors. Different principles for such an allocation may be proposed,³⁴ but few attempts have been made to apply them fully in practice. The targets that have been suggested in a sustainable transport context mostly represent either political compromise or pragmatic notions for exploratory research. An example of the latter is shown in Table 2. In both counts targets may be very valuable tools (as discussed further in relation to performance indicators below), but the degree to which they reflect actual limits, dividing possible transport situations into sustainable and unsustainable ones, may often be questioned.

³¹ This formulation has even been officially adopted by the Transport Ministers of the European Union: Council (Transport/Telecommunications) Strategy for integrating environment and sustainable development into the transport policy, *Council Resolution 2340*, Council Meeting, Luxembourg (4/4/2001) Press:131 Nr: 7587/01.

³² For a definition in an urban planning context see, *e.g.*, H. A. Minken, Framework for the evaluation of urban transport and land use strategies with respect to sustainability. Paper presented to the *Sixth Workshop of the Transport, Land Use and Environment (TLE) Network*, Haugesund, 27–29 September, 2002. In a road traffic-modelling context see A. Nagurney, *Sustainable Transportation Networks*, Edward Elgar, Cheltenham, 2000.

³³ OECD, *Towards Sustainable Transportation. The Vancouver Conference, OECD Proceedings*, Organisation for Economic Co-operation and Development, 1997, Paris.

³⁴ See, *e.g.* P. Nijkamp and J. Vleugel, in *search of sustainable transport systems*, in D. Banister, R. Capello, P. Nijkamp, (eds.), *European Transport and Communications Networks. Policy Evolutions and Change*. John Wiley & Sons, Chichester, 1995, pp. 278–299.

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Table 2 Sustainable transport targets proposed for Europe (D. Banister, D. Stead, P. Steen, J. Åkerman, K. Dreborg, Nijkamp and R. Schleisher-Tappeser, *European Transport Policy and Sustainable Mobility*, Spon Press, London and New York, 2000)

<i>Environmental targets</i>
25% reduction of CO ₂ emissions from 1995 to 2020
80% reduction of NO _x emissions from 1995 to 2020
No degradation of specially protected areas
Minor (2%) increase of net infrastructure surface in Europe
<i>Regional development targets</i>
Improve relative accessibility of peripheral regions (both internal and external)
<i>Efficiency targets</i>
Full cost coverage (including external costs) of transport under market or equivalent conditions
Reduce public subsidies to all forms of transport to zero

Issues. The most widely applied approach to preparing the concept for operationalization is simply to list the major tangible problems or issues it is assumed to encompass. This typically includes environmental problems such as acidification or global warming, economic issues such as transport infrastructure investments or social issues such as access for all. The route towards establishing the list of issues may proceed from bringing overall sustainability definitions, principles or issues down to bear on the transport sector ('top-down'), or conversely by confronting a review of current transport problems with possible implications in terms of sustainable development ('bottom-up'). Either way there is scope for pragmatism since there is no generally accepted procedure for the application of general ideas of sustainable development to individual sectors. Table 3 lists the major issues of sustainable transport raised in several studies.

System Boundaries. An important complication in the conceptualization process is drawing a system boundary. In the examples above a general notion of the transport sector including transport by all modes is often assumed. This is at odds with standard national accounting procedures that exclude own-account and private transport from the sector per se. Another possibility is to also include production and disposal of transport system components. In any case the boundary drawn between transport and non-transport systems may be challenged. Often, focus is on a sub-sector or sub-system level where notions such as 'Sustainable Urban Travel',³⁵ 'Sustainable Road Transport',³⁶ 'Sustainable Supply Chains',³⁷ and even 'The Sustainable Car'³⁸ abound. Such examples raise additional

³⁵ ECMT, *Implementing Sustainable Urban Travel Policies. Final report*, European Conference of Ministers of Transport, ECMT, Paris, 2002.
³⁶ J. Schwaab and S. Thielmann, *Economic Instruments for Sustainable Road Transport—An Overview for Policy Makers in Developing Countries*, Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), Eschborn, 2001.
³⁷ J. Cooper, I. Black and M. Peters, Creating the sustainable supply chain: modelling the key relationships, in D. Banister, (ed.), *Transport Policy and the Environment*, Spon, London and New York, 1998, 176–203.
³⁸ N. S. Ermolaeva, K. G. Kaveline and J. L. Spoormaker. Materials selection combined with optimal structural design: concept and some results, *Mater. Design*, 2002, **23**, 459–470.

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Table 3 Overview of main issues of sustainable transport raised in selected references. (including References a–p to Table 1); note that the allocation of issues to dimensions is somewhat arbitrary

	<i>Environmental</i>	<i>Economic</i>	<i>Social</i>
Development (Present generation)	Healthy air quality Acceptable noise Limited pollution/Waste Visual quality/liveability	Mobility and access Travel time/congestion Travel costs and prices	Safety Equity in mobility/ access
Sustainability (Future generations)	Climate stability Protecting ecosystems/biodiversity Land conservation Resource conservation	Transport reinvestments Transport innovations Economic viability	Intergenerational equity in mobility Community cohesion

problems since it can be argued that sustainability is a system level condition, suggesting that the full context of interactions of any entity must be taken into account before its sustainability or the contrary can be claimed.³⁹ This means that, for instance, the number and actual use made of so-called ‘sustainable’ cars must be considered with respect to general system limits. In any case sustainable transport is most often conceived within specific political boundaries defined by either a state or a metropolitan region. Such boundaries may again be questioned, for instance, with respect to upstream or downstream environmental impacts from transport occurring outside the particular region, or by reference to problems such as transiting traffic.⁴⁰

Operationalization

Operationalization concerns what to do to make the concept of sustainable transport manipulable or measurable and how to provide for interpretation and decision on that basis. In the following we consider indicators and address briefly their roles in this respect.

Indicators. An indicator may be defined in technical terms as a variable representing an operational attribute of a system.⁴¹ Indicators are selected and constructed from underlying data to condense complex information into a

³⁹ E. Tengström, *Towards Environmental Sustainability? A Comparative study of Danish, Dutch and Swedish Transport Policies in a European Context*, Ashgate, Aldershot, 1999.

⁴⁰ This may be the reasoning behind the claim: ‘There can be no understanding of sustainability at any level other than global’, J. Whitelegg, *Transport for a Sustainable Future. The Case for Europe*, Belhaven Press, London, 1993, p. 11.

⁴¹ G. C. Gallopin, Indicators and their use: information for decision-making, in B. Moldan and S. Billharz, (eds.), *Sustainability Indicators. Report on the Project on Indicators of Sustainable Development*, Wiley, Chichester, 1997, 13–27. Another reference suggests that definitions of indicators vary according to application but always . . . ‘refer to a variable that is directly associated with a latent variable such that differences in the values of the latent variable mirror differences in the values of the indicator.’ (K. A. Bollen, Indicator: methodology, in P.B. Baltes and N. J. Smelser (eds.) *The International Encyclopaedia of the Social and Behavioral Sciences*, Elsevier Science Ltd, Oxford, 2001, 7282–7287.

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simplified form, providing a significant message about the system of interest. Indicators are used in many types of communication, from scientific analysis to every-day interaction. Indicators are widely used in most areas of policy analysis and policy making, not least environmental policy.

Different types of indicators convey different types of messages. The European Environment Agency distinguishes between the following types:⁴²

1. Descriptive indicators, measuring state or trend in some entity or area. For example, the emissions of carbon dioxide from transport modes in Europe.
2. Performance indicators, comparing state or trend with a standard, norm or benchmark. For example, the number of dwellings affected by noise compared with a target number.
3. Efficiency indicators (ratios, or combining related descriptive trends). For example, average fuel efficiency of new vehicle registrations.
4. Policy effectiveness indicators (the role of policy in observed changes). For instance, the effect of Emission limit legislation on actual emissions of NO_x from motor vehicles.
5. Indices aggregating several indicators into one message. For instance, combining several air pollutants into indices of acidification, ozone formation, or global warming.

Often there is a wish to apply complex types of indicators (type 2–5) to represent some problem, but in practice even basic descriptive indicators can be difficult to establish due to a lack of reliable data series. Data quality is a very important concern in operationalization, since unreliable data can mean that communication is distorted rather than facilitated. For some transport indicator systems like ones used by the European Environment Agency,⁴³ and the United States Department of Transportation,⁴⁴ systematic assessments of the quality and reliability of the underlying data are made available.

Other important operational characteristics of indicators include:⁴⁵

- Provision of a representative picture
- Simplicity, reduction of complexity
- Responsiveness to changes
- Theoretical founding in technical and scientific terms
- Adherence to international standards and international consensus about its validity
- Updating at regular intervals in accordance with reliable procedures.

Sustainability Interpretation. Not all types of indicators are equally relevant for

⁴² P. Bosch, The European Environment Agency focuses on EU-policy in its approach to sustainable development indicators, *Statistical J. UN ECE*, 2002, **19**, 5-18.

⁴³ EEA, Paving the way for EU enlargement, *Indicators of Transport and Environment Integration TERM 2002*, Environmental issue report No 32, European Environment Agency, Copenhagen, 2000.

⁴⁴ Bureau of Transportation Statistics, *Source & Accuracy Compendium for Performance Measures in the DOT 2001 Performance Plan and 1999 Report*, Bureau of Transportation Statistics, U.S. Department of Transportation, Washington DC, 2000.

⁴⁵ OECD, *Environmental Indicators, OECD Core Set of Indicators for Environmental Performance Reviews*, Environment Monographs No 83, OECD/GD (93)179, Organisation for Economic Co-operation and Development, Paris, 1993.

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reporting in a sustainable development context. If ‘development’ is understood as improvement in some aspect of immediate human interest (welfare, quality-of-life, environmental nuisance *etc.*), the trend may be derived purely descriptive indicators, whereas ‘sustainability’ indicators should aim to ‘... *reflect the reproducibility of the way a given society utilises its environment*’.⁴⁶ In a broader sense sustainability indicators may be expected to describe critical systemic properties or trends.⁴⁷ This means that basic descriptive indicators in themselves often will provide only limited guidance towards sustainability, whereas performance indicators or indices—if devised correctly and substantiated with reliable data—would be more to the point. Ideally, if one aggregate index of sustainable transport was available a positive or negative trend in this index would suffice. In practice, a meaningful index is difficult to apply because weighting factors to aggregate items such as, say, transport CO₂ emissions, resource depletion and accessibility can be challenged. How to interpret contradicting trends in a sustainability context may prove difficult. Obviously, the usefulness of particular types of indicators depends on how sustainable transport is approached in a specific context. The full range of indicator types may therefore be useful. The interpretation of the results will nevertheless still be critical.

Confidence. A final matter of operational importance concerns the trust and confidence held in indicators by the presumed users and stakeholders. While this is dependent on relevance, reliability, and scientific soundness as addressed above it is also often referred to as a matter of involvement and participation, in particular in a highly normative context such as ‘sustainability’ measurement.⁴⁸

Table 4 summarizes two sets of guidelines for the development of sustainability indicators. The sources are in wide agreement about key elements to consider, differing mainly in the level of detail in addressing each step.⁴⁹ However, none of the guidelines address the utilization phase of sustainability indicators, which we shall turn to now

Utilization

Users, Uses and Numbers. Even the best indicators are of little value if they are not used. Many functions and uses of indicators are reported in the literature. Initially, a distinction is often made between broad user groups: scientists,

⁴⁶ H. Opschoor and L. Reijnders, Towards sustainable development indicators, in H. Kuik, and O. Verbruggen, (eds.), *In Search of Indicators of Sustainable Development*, Kluwer, Dordrecht, 1991, p. 7.

⁴⁷ Wixey and Lake note: ‘In practice, much of what passes for policy on “sustainable development” has a much narrower remit. The chief focus of much policy claiming to be “sustainable” is on issues more usefully placed under the category of “quality of life”. Clearly there is a distinct overlap between “sustainable development” and “quality of life” agendas, but it would be foolhardy to equate them. Sustainable development goes beyond a shallow environmental approach or short term concern for living standards.’ (S. Wixey, and S. Lake, Transport policy in the EU: a strategy for sustainable development? *World Transport Policy and Practice*, 1998, 4, No. 2).

⁴⁸ J. E. Innes and D. E. Booher, Indicators for sustainable communities: A strategy building on complexity theory and distributed intelligence, *Planning Theory and Pract.*, 2000, 1(2), 173–186.

⁴⁹ The two references also diverge in the view of the environmental dimension—if it is to be considered as a fundamental pillar of sustainability in itself or if rather the integration of three dimensions is the basic notion.

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Table 4 Key steps and elements in the design of sustainability indicators

Stage/element	(1) ^a	(2) ^b
Conceptualization	Define sustainability goals	Consensus on Principles
Sustainability concerns to be considered	<ul style="list-style-type: none"> • Integrating dimensions • Forward-looking • Distributional aspects • Participatory input 	<ul style="list-style-type: none"> • Ecological system integrity • Futurity • Social equity (distribution) • Participation
Operationalization	Scoping Choice of indicator framework Define indicator selection criteria Identify potential indicators Evaluate and select final set Collect data and analyse results Prepare and present report Assess indicator performance	Identify issues of concern Construct indicators Augment Quality of life indicators with reference to sustainability principles Modify to account for Boundary difficulties Supplement with uncertainty indicators Evaluate indicators with respect to Objectives and Characteristics

^a V. W. Maclaren, Urban Sustainability Reporting. *J. Am. Plann. Assoc.*, 1996, **62**(2).

^b G. Mitchell, A. May and A. McDonald, PICABUE: A methodological framework for the development of indicators of sustainable development, *Int. J. Sustain Develop. World Ecol.*, 1995, **2**, 104–23.

analysts, decision-makers and the general public. According to general understanding these users have different information needs and handling capacities. While scientists are trained to manipulate large amounts of data, top decision-makers and the general public are expected to prefer selected information on key issues of importance to avoid ‘information overload’. In the terminology of indicators this is often envisaged as a layered pyramid (Figure 2) founded on data that provide input to a system of indicators to assist in planning and management, and from which a set of ‘headline’ indicators can be chosen (an example of the latter is given in Table 5).⁵⁰

Limiting the number of indicators can serve to reduce the perceived complexity of a particular issue. Conversely, important information may be lost in the aggregation or selection. Rather than necessarily minimizing the amount of indicators the challenge is to find the appropriate number for a particular context.

Indicator Functions. Four broad indicator functions will be distinguished here: (1) information, (2) assessment/forecasting/backcasting, (3) evaluation/monitoring and (4) control. These functions can either be embedded in customized indicator

⁵⁰ The simplification in this model is evident. Obviously scientists and analysts may also need to draw on aggregate indicators or use indices, while decision makers may be highly concerned with quite specific data.

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Figure 2 Simplified concept of 'Indicator pyramid'.

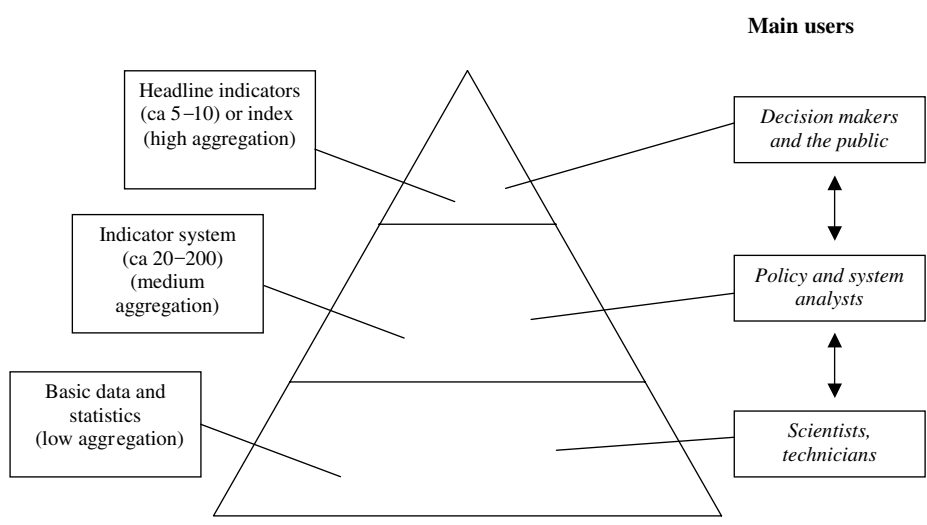


Table 5 Example of 'headline indicators' used by the EU. (Council of the European Union, *Environment-related Headline Indicators for Sustainable Development with a View to Monitoring Progress in the Implementation of the EU Sustainable Development Strategy*—Council Conclusions, Brussels, 28 November 2001)

<i>Environment-related headline indicators</i>
Combating climate change
Greenhouse gases emissions, in absolute terms (related to Kyoto target)
Share of renewables in electricity consumption
Ensuring sustainable transport
Volume of transport vs GDP (passengers – km, freight in tonne – km)
Modal split of transport (passengers – km, freight in tonne – km)
Addressing threats to public health
Urban population exposure to air pollution
Managing natural resources more responsibly
Municipal waste collected, landfilled and incinerated, in kg per inhabitant
General economic background
Energy intensity of the economy (energy consumption/GDP)

frameworks, or one set of indicators can aim to support several functions.

Information-oriented indicator frameworks can help policy makers, stakeholders or the general public increase their understanding and awareness of, for instance, environmental issues. The indicators used are typically descriptive rather than performance or index types. No specific requirements to use the information will normally exist, but information frameworks may nevertheless be influential in helping to form a basic, common awareness of a problem. In some cases the process of defining simple indicators has helped in fostering consensus on a course of action in local sustainable transport planning.⁵¹

Forecasting and assessment are integral tasks in transport planning and policy

⁵¹ European Commission, Integration of environment into transport policy—from strategies to good practice. *Highlights from the Conference on Good Practice in Integration of Environment into Transport Policy, 10–11 October 2002, Brussels, Belgium*, A Sourcebook, European Commission, Directorate-General Environment, Brussels, September 2003.

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preparation. In these contexts indicators may be employed to compare expected trends or the results of a particular project with policy objectives concerning, *e.g.*, traffic volumes or emissions. The types of indicators used can be descriptive, performance, index *etc.* In the context of assessment, ‘sustainability’ is in some cases considered as an overall objective while in others it refers only to environmental effects not covered by standard Cost–Benefit assessment procedures.⁵² *Backcasting* is the reverse case, where objectives are defined and necessary changes to achieve those targets assessed in an iterative process. This approach has been suggested as particularly relevant in sustainable transport analysis, considering the potential need for ‘trend breaches’.⁵³ The utilization made of assessment and fore/backcasting results will depend entirely on the particular circumstances but often there is a presumption that rational decision-making would at least take into account results indicated in well-performed studies.

Use of indicators in *evaluation and monitoring* is frequent in transport policy, especially to compare developments in transport systems or policies over time and space. Evaluation and monitoring will often rely on performance indicators, for instance by gauging the present situation or trend by a policy objective. Evaluation is typically a one-time event while monitoring provides repeated feedbacks to decision making. Evaluation and monitoring procedures are often infused with a strong pretence of policy utilization, but in practice direct instrumental use is not always found to take place.⁵⁴ A particular application is *benchmarking*, where the best performer in a certain area (*e.g.* public transport punctuality) is identified and used as a basis for comparison and possibly transfers of effective practices.⁵⁵ This usage further emphasizes the need for *comparability*.

Control frameworks employ indicators to steer actions towards desired objectives. This function is entirely dependent on the use of performance indicators. A control function exists if the indicators are systematically used to direct organizations or entities to adapt their activities according to measured or stipulated results, using penalties, rewards, budget allocations or similar incentives. This type of framework spans future and past by conditioning future actions on past results (Table 6). Control frameworks are widely used in managing transport contracts and outsource services, where penalties may for instance be routinely issued if punctuality or other service targets are not met. Another example is the performance-based budgeting approach adopted by the United States government.

⁵² L. Giorgi and A. Tandon. The theory and practice of evaluation, *ICCR Working Paper 407*, The Interdisciplinary Centre for Comparative Research in the Social Sciences (ICCR) Vienna, June 2000.

⁵³ D. Banister, D. Stead, P. Steen, J. Akerman, K. Dreborg, P. Nijkamp and R. Schleisher-Tappeser, *European Transport Policy and Sustainable Mobility*. Spon Press, London and New York, 2000.

⁵⁴ See for instance: L. Shulha, J. Cousins, and M. Bradley, Evaluation use: theory, research, and practice since 1986. *Evaluation Practice*, 1997, **18**(3), 195–208 and E. Vedung, *Public Policy and Program Evaluation*, Transaction Publishers, New Brunswick, 1997; also H. Gudmundsson, The use of environmental indicators—learning from evaluation research, *J. Transdiscipl. Environ. Stud.*, in the press.

⁵⁵ ECMT, Transport benchmarking: methodologies, applications and data needs’. *Proceedings of the Paris Conference, November 1999*, European Conference of Ministers of Transport, OECD Studies, September 2000, Vol. 1, No. 9.

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Table 6 Perspectives of different indicator frameworks

<i>Backwards</i>	<i>Forwards</i>
Information	Assessment/forecasting/backcasting
Evaluation/monitoring	Control

In this context the US Department of Transportation is obliged by law to produce annual performance plans and reports, which are tied into the national budget process.⁵⁶

Sustainable transport indicators could in principle be incorporated into all of the above frameworks. Their use and impact may, however, be very different, depending on the particular kind of utilization framework and practice. Considering the challenges involved in making sustainable transport operational one may expect that strongly control oriented frameworks have been difficult to apply for this purpose, since the exercise of control tends to depend on solid data and transparent concepts. Conversely, the rigor of a control framework could push operationalization forward, albeit it may entail a narrowing of perspective.

Summing up

To make sustainable transport into an operational concept that is measurable by indicators and useful for policy action is a complex task. The process may be hampered by difficulties in steps such as definition, boundary drawing, measurement, interpretation, confidence and utilization. Nevertheless many suggestions for performance indicators for sustainable transport have been made. From the analysis in this section we may infer that such indicators from an ideal point of view could be challenged to address the following points:

- Concern for both present (development) and future (sustainability) generations
- Consideration of all dimensions (economic, social, environmental, institutional)
- Identification of key transport contributions and shares of overall problems
- Considerations of transport system boundary (and induced effects elsewhere)
- Inclusion of sustainability criteria or targets to interpret performance
- Insurance of data quality, reproducibility, *etc.*
- Participation of stakeholders in indicator development
- Adoption of an appropriate number of indicators
- Catering to maximum utilization and impact

3 Sustainable Transport Indicator Sets

Overview

Over the last decade or so several indicator sets addressing sustainable transport issues have been defined in various contexts. Academics or consultants are the authors of most of the sets explicitly referring to sustainable transport, while the

⁵⁶ For instance: US DOT, *1999 Performance Report 2001 Performance Plan*, US Department of Transportation, Washington, DC 2000.

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officially adopted indicator systems tend to have a more pragmatic focus on transport and/or environmental policy issues. Table 7 provides an overview of a number of sets and systems of both types. In the following, we briefly review four of them, highlighting differences in approach with respect to the context and some of the criteria mentioned above (sustainability dimensions, indicator types, and interpretation). Particular features of interest from each will be highlighted. The aim is neither to make a comprehensive assessment of the systems nor to compare them directly. The purpose is rather to give an impression of various ways to tackle the problems involved in measuring and reporting on sustainable transport in different contexts.

(1) Lyon Study

Background and Purpose. A French research group has defined a set of indicators to monitor sustainable transport at the urban level.⁵⁷ The indicators have been applied to the case of Lyon, France (Table 8). The further aim is to extend the study to other cities in France and Europe. The analysis exploits a detailed passenger travel survey combining this information with various environmental and other data. The purpose is to provide analytical information to policy makers and the public. The indicators (types and number) appear to have been selected by the research group alone.

Sustainability Dimensions, Indicator Types and Other Features. The ‘Lyon case’ indicators explicitly aim to cover three dimensions of sustainability: environmental, social and economic. General mobility measures are also included (see Table 8). Most of the indicators measure aspects related to quality of life for the present generation. More long-term issues are also represented, including indicators for CO₂ emissions, energy consumption and land take. All of the indicators are descriptive rather than performance. Environmental efficiency by mode is also calculated. A strong feature of the study is the combination of indicators from different dimensions. This enables, for instance, a spatial breakdown of emissions, both in terms of where the more polluting trips are generated (by socio-economic groups) and where the emissions occur (emission densities). An interesting indicator measures space occupancy of transport mode in m² hours. Calculating the public space occupied by vehicles both while driving and parked over time suggests that private motor cars account for 96% or more than 40 times that of public transport, even though they account for only about 4 times the passenger transport.

Interpretation. The study is descriptive and the authors abstain from engaging in normative or performance-based considerations.⁵⁸ Therefore, the interpretation of trends in terms of sustainability is entirely open. In other words, what these indicators reveal in terms of sustainability of urban transport can be questioned. However, the authors suggest that the main relevance of their approach for sustainable transport is to consider the three dimensions separately, rather than

⁵⁷ J.-P. Nicolas, P. Pocheta, and H. Poimboeuf. Towards sustainable mobility indicators: application to the Lyons conurbation, *Transport Policy*, 2003, **10**, 197–208.

⁵⁸ Reference 57, p. 207.

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to attempt any aggregation. In addition, they suggest an interpretation inspired by a paretian⁵⁹ approach according to which increased sustainability would mean any improvement in one dimension without deterioration in any other. This is equivalent to the notion of strong sustainability introduced in Section 2.

(2) Sustainable Transport Index—USA

Background and Purpose. In a US study⁶⁰ five key threats to the sustainability of transport developments are identified as: petroleum scarcity; impact of emissions on local air quality and human health; the impact of emissions on the atmosphere; excessive number of injuries and fatalities; and high levels of congestion. The purpose of the study is to derive an index of transport sustainability reflecting these and other factors based on already existing data. The index is used to compare US states in terms of their sustainable transport performance (with possible extensions to other countries, cities, *etc.* if comparable data are made available). The aim is to facilitate the inclusion of sustainability concerns in transport analysis and policy debates. The study draws inspiration from previous academic research as well as policy studies, but the proposed index is derived and used independently by the author.

Sustainability Dimensions, Indicator Types and Other Features. A qualitative judgement forms the basis for identifying the issues that represent the major possible threats to transport sustainability. They address the environmental and economic dimensions, while issues of social equity are explicitly excluded.⁶¹ In addition to the threats also a number of presumed positive measurers of transport sustainability are identified, including public transport ridership and the number of alternative fuelled vehicles. The indicators used to construct the index are summarized in Table 9. All indicators are descriptive and directly drawn from existing general statistics covering the 50 US States. Some indicators have a quite indirect relation to the issue of interest (in particular congestion measured as classes of road traffic flows). The data material is used to derive an aggregate index of transport sustainability using Principal Components Analysis. The method reveals an underlying or latent variable assumed to be most representative of the data, in this case indicating a measure of transport sustainability.

The results show strong variation in the sustainability index between the US states. Since the data represent absolute values it is obviously the largest states (Texas, California) that come out as least sustainable. Interestingly, this does not alter after correction for population size, while the same operation does change significantly the sequence in the leading end of the table, where relatively undeveloped states such as Wyoming, Montana and Vermont score the highest. The analysis also shows that the ‘positive’ indicators (public transport ridership,

⁵⁹ After the Italian Economist Vilfredo Pareto (1848–1923).

⁶⁰ W. R. Black, *Toward a Measure of Transport Sustainability*, Transportation Research Board Meeting, 2000, Conference Pre-prints, Transportation Research Board, Washington, D.C.

⁶¹ Reference 60, p. 2.

Table 7 Overview of selected Sustainable Transport indicator sets

<i>Ref.</i>	<i>Status</i>	<i>Focus</i>	<i>Level</i>	<i>Purpose</i>	<i>No. of Indic.</i>	<i>Dimensions (main emphasis)</i>
a	Official	Transport system + policy	International (Europe)	Monitoring	≈35	<i>Environmental, economic, social, institutional, transport</i>
b	Official	Transport system + policy	International (OECD)	Monitoring	≈14	<i>Environmental, economic, social</i>
c	Expert	Transport system	International (Europe)	Backcasting	≈7	<i>Environmental, economic, social</i>
d	Official	Transport system	National (USA)	Evaluation	≈166	<i>Environmental</i>
e	Official	Transport policy	National (Canada)	Monitoring	≈80	<i>Environmental, economic, institutional</i>
f	Expert	Transport system	National (Canada)	Monitoring	≈14	<i>Environmental, economic, social, transport</i>
g	Expert	Transport system	National (USA)	Monitoring	≈14	<i>Environmental, social, economic, transport</i>
h	Expert	Transport system	National (Germany)	Forecasting	≈7	<i>Environmental</i>
i	Expert	Transport system	Sub-national (Hong Kong)	Monitoring	≈10	<i>Environmental, social, economic, transport</i>
j	Expert	Transport system + policy	Urban (General)	Evaluation	≈55	<i>Environmental, economic, social, institutional, transport</i>
k	Expert	Transport system	Urban (Lyon)	Monitoring	≈22	<i>Environmental, economic, social, transport</i>
l	Expert	Transport system	Urban (Siena)	Evaluation	≈14	<i>Environmental</i>



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m	Expert	Transport System	Corridor (IS10 Texas)	Assessment	≈10	Environmental, economic, social, transport
a	EEA, <i>Paving the way for EU Enlargement. Indicators of Transport and Environment Integration TERM 2002</i> , Environmental issue report No 32, European Environment Agency, Copenhagen, 2002.					
b	OECD, <i>Indicators for the Integration of Environmental Concerns into Transport Policies, ENV/EPOC/SE(98)1/FINAL</i> Organisation for Economic Co-operation and Development, Paris, 1999.					
c	D. Banister, D. Stead, P. Steen, J. Åkerman, K. Dreborg, P. Nijkamp and R. Schleisher-Tappeser, <i>European Transport Policy and Sustainable Mobility</i> . Spon Press, London and New York, 2000.					
d	US EPA, <i>Indicators of the Environmental Impacts of Transportation</i> . Updated Second Edition, United States Environmental Protection Agency, Washington DC, 1999.					
e	Transport Canada 2001–2002 Sustainable Development, <i>Strategy Progress Report</i> , Ottawa 2002 URL: http://www.tc.gc.ca/programs/environment/sd/sds0102/menu.htm .					
f	R. Gilbert, N. Irwin, B. Hollingworth, and P. Blais, Sustainable Transportation Performance Indicators (STPI). <i>Project Report On Phase 3</i> , The Centre for Sustainable Transportation, Toronto, 2002.					
g	W. R. Black, Toward a measure of transport sustainability, <i>Transportation Research Board Meeting, 2000, Conference Preprints</i> , Transportation Research Board, Washington, D.C., 2000.					
h	J. Borcken, Indicators for sustainable mobility – a policy oriented approach, <i>Proceedings: 1st International Scientific Symposium 'Transport & Environment'</i> , Avignon/France 19–2. June 2003.					
i	W.-T. Hung, Indicators for sustainable transport policy. Paper presented at: <i>Better air Quality Motor Vehicle Control & Technology Workshop 18–20th September 2000</i> , Hong Kong, 2000.					
j	L. Ricci, Monitoring progress towards sustainable urban mobility, <i>Evaluation of Five Car Free Cities Experiences</i> , EUR 19748 EN, Institute for Prospective Technological Studies, Seville, December 2000.					
k	J.-P. Nicolas, P. Pocheta, and H. Poinboeuf, Towards sustainable mobility indicators: application to the Lyons conurbation, <i>Transport Policy</i> , 2003, 10, 197–208.					
l	M. Federici, S. Ulgiati, D. Verdesca and R. Basosi, Efficiency and sustainability indicators for passenger and commodities transportation systems, The case of Siena, Italy, <i>Ecol. Indicators</i> , 2003, 3, 155–169.					
m	J. Zietsman and L. R. Rilett, <i>Sustainable Transportation: Conceptualization and Performance Measures</i> . Report No. SWUTC/02/167403-1, Texas Transportation Institute, College Station, Texas, 2002.					



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Table 8 Indicators of sustainable transport in the Lyon study (Reference 57)

<i>Dimension of sustainability</i>	<i>Indicators</i>
<i>Mobility</i>	
Service provided	Daily number of trips Structure of trip purposes Daily average time budget
Organization of urban mobility	Modal split Daily average distance travelled Average speed (global and per person)
<i>Economic</i>	
Cost for the community	Annual costs chargeable to residents of the conurbation, due to their mobility in this zone
Expenditures of the participants involved	Households: Annual average expenditures for urban mobility (per person) Companies: Costs of employee parking Subsidies to employees (company cars <i>etc.</i>) Possible local taxes Public authorities: Annual expenditures for investments and operates
<i>Social</i>	
	Proportion of households owning 0, 1 or more cars Distance travelled Expenditures for urban mobility: amounts for private/public transport; for fixed/variable cost of car share of the average income of households
<i>Environmental</i>	
Air pollution-Global	Annual energy consumption and CO ₂ emissions (total and per resident)
Air pollution-Local	Levels of CO, NOX, HC and particles (in g m ⁻² , total and per resident)
Space consumption	Daily individual consumption of public space involved in travelling and parking (in m ² h) Space taken up by transport infrastructures
Other items ^a	Noise intensity levels Risk of accident

^a Not included due to lack of data.

alternative vehicles) influence the index very little. The best ‘proxy’ for the latent index variable is vehicle miles travelled.

Interpretations. The obvious interpretation of the index is that some US states have a better transport situation than others do. To the extent the index reflects important conditions for sustaining transport systems it may be revealing. The

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Table 9 Issues and indicators in the Sustainable Transport Index (Reference 60)

<i>Issue</i>	<i>Indicator</i>
Global atmospheric pollution	Carbon dioxide emissions
Local air pollution	Carbon monoxide emissions Nitrous oxides emissions Volatile organic compound emissions
Dependence on petroleum fuels	Gasoline sales Number of motor vehicles Vehicle miles of travel
Accidents	Fatalities Injuries
Congestion	Urban population Miles of road with with 40 000 annual daily traffic
Use of mass public transit	Transit riders
Use of gasohol	Gasohol sales
Use of alternative fueled vehicles	Alternate fueled vehicles

index does not suggest any thresholds limiting the continuation of current trends, nor does it suggest the importance of the distance in ranking between best and worst performing states. As noted by the author, another approach using the same data could be to assign explicit weights to each of the indicators. While this would not provide a more objective assessment of sustainability it could perhaps cater to a more participatory use of indicators. As also noted, the method could as well be used to ‘backcast’ the required increase, *e.g.* in passenger ridership, to advance a particular state in the ranking.

(3) ‘TERM’ — European Union

Background and Purpose. The Transport and Environment Reporting Mechanism (TERM) is an official monitoring framework and system set up by the European Environment Agency in collaboration with the EU Commission and EUROSTAT. The mechanism consists of indicator reports based on an extensive database, with three (annual) reports so far.⁶² TERM reports around 35–40 different indicators (Table 10) for a wide range of transport and environment trends in EU Member States as well as accession countries. The main purpose is to support the political process of integrating environmental concerns into transport policy. TERM can be considered as influential since it is a pioneering system in EEAs sectoral monitoring efforts and since it draws on a large network of institutions throughout Europe.⁶³ TERM serves information, assessment and monitoring functions but is not linked to a control system.

⁶² EEA, Paving the way for EU enlargement, *Indicators of Transport and Environment Integration TERM 2002*, Environmental issue report No 32, European Environment Agency, Copenhagen, 2000; EEA, *TERM 2001, Indicators Tracking Transport and Environment Integration in the European Union*, European Environment Agency, Copenhagen, 2001; EEA, Are we moving in the right direction? *Indicators on Transport and Environment Integration in the EU. TERM 2000*, Environmental issues series No 12, European Environment Agency, Copenhagen, 2000.

⁶³ P. Bosch, The European Environment Agency focuses on EU-policy in its approach to sustainable development indicators, *Statistical J. UN ECE*, 2002, **19**, 5-18.

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Table 10 Indicators in the TERM system. Note that not all indicators are represented by actual data (EEA. Paving the way for EU enlargement. TERM 2002. Environmental issue report No 32. European Environment Agency, Copenhagen, 2000

<p>1 Environmental consequences of transport</p>	<p>Transport final energy consumption and primary energy consumption, and share in total by mode and by fuel Transport emissions of greenhouse gases (CO₂ and N₂O) by mode Transport emissions of air pollutants (NO_x, NMVOCs, PM₁₀, SO_x, total ozone precursors) by mode Population exposed to exceedances of EU air quality standards for PM₁₀, NO₂, benzene, ozone, lead and CO % of population exposed to and annoyed by traffic noise, by noise category and by mode Fragmentation of ecosystems and habitats Proximity of transport infrastructure to designated areas Land take by transport infrastructure by mode Number of transport accidents, fatalities, injured, and polluting accidents (land, air and maritime) Illegal discharges of oil by ships at sea Load factors for freight transport Accidental discharges of oil by ships at sea Waste from road vehicles (number and treatment of used tyres)</p>
<p>2 Transport demand and intensity 3 Spatial planning and accessibility</p>	<p>Passenger transport (by mode and purpose) Freight transport (by mode and group of goods) Access to basic services: average passenger journey time and length per mode, purpose (commuting, shopping, leisure) and location (urban/rural) Regional access to markets: the ease (time and money) of reaching economically important assets (e.g. consumers, jobs), by various modes (road, rail, aviation)</p>
<p>4 Supply of transport infrastructure and services</p>	<p>Access to transport services Capacity of transport infrastructure networks, by mode and by type of infrastructure (motorway, national road, municipal road, etc.) Investments in transport infrastructure/capita and by mode</p>
<p>5 Transport costs and prices</p>	<p>Real change in passenger transport price by mode Fuel prices and taxes Total amount of external costs by transport mode (freight and passenger); average external cost per passenger-km and tonne-km by transport mode Implementation of internalisation instruments i.e. economic policy tools with a direct link with the marginal external costs of the use of different transport modes Subsidies Expenditure on personal mobility per person by income group</p>

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6 Technology and utilisation efficiency	Overall energy efficiency for passenger and freight transport (per passenger-km and per tonne-km and by mode) Emissions per passenger-km and emissions per tonne-km for CO ₂ , Nox, NMVOCs, PM ₁₀ , Sox by mode Occupancy rates of passenger vehicles Uptake of cleaner fuels (unleaded petrol, electric, alternative fuels) and numbers of alternative-fuelled vehicles Waste from road vehicles (end-of-life vehicles) Size of the vehicle fleet Average age of the vehicle fleet Proportion of vehicle fleet meeting certain air and noise emission standards (by mode)
7 Management integration	Number of Member States that have implemented an integrated transport strategy Number of Member States with a formalised cooperation between the transport, environment and spatial planning ministries Number of Member States with national transport and environment monitoring systems Uptake of strategic environmental assessment in the transport sector Public awareness and behaviour Uptake of environmental management systems by transport companies

Sustainability Dimensions, Indicator Types and Other Features. TERM is not explicitly aiming to monitor sustainability. Nevertheless, it covers a wide range of the environmental issues in sustainable transport of relevance to present and future generations, including emissions, fragmentation of land, noise, waste, and oil spills. It also describes some economic factors. TERMS main focus is to monitor developments in key areas of policy intervention, such as improvements in technology, investments in infrastructure, changes in prices and taxes, changes in the split between modes of transport and changes in the institutional frameworks of decision making. The latter is a special feature of TERM not found in many other frameworks: Monitoring the way EU Member State governments integrate environmental concerns in their organizations and procedures, for instance by undertaking Strategic Environmental Assessments. (Topic 7, ‘management integration’ in Table 10). Most of the indicators are descriptive, but there are also occurrences of eco-efficiency and policy effectiveness indicators. There are no quantitative performance indicators, due to a lack of quantitative objectives for transport and environment at the European level. There are a few qualitative performance indicators, regarding environmental management integration issues (topic 7), of the dichotomous type (‘yes/no’ to the presence/absence of certain measures).

Interpretations. The direction of change as favourable or unfavourable is clearly

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signified by use of the ‘Smiley’ symbol for each indicator. The 2001 report conclude that . . . [o]verall, the report shows that transport is becoming less and not more environmentally sustainable, and integration efforts have to be redoubled.⁶⁴ Since the indicator system does not (even claim to) provide a criterion or aggregate measure for sustainable transport the basis for this conclusion is not quite clear. One interpretation could simply be that the majority of the indicators are in the negative in all three reports so far (for instance increase in emissions of CO₂, increasing pressures on nature, *etc.*) while only a few are positive (*e.g.* emissions of acidifying substances). Another interpretation could be that the EU has stated ‘decoupling of transport growth from economic growth’, ‘stabilization of modal split’ and ‘environmental integration’ as key objectives of its sustainable transport policy. Since the indicators for those objectives are mostly negative, one could infer that transport in EU is moving away from policy commitments to sustainability.

(4) Transport Canada

Background and Purpose. As a ministry of the Canadian Government, Transport Canada is obliged by law to produce a Sustainable Development Strategy (SDS), and to monitor progress in its implementation. Its first SDS was adopted in 1997 and the second revised one in 2001. The SDS is structured around a set of seven so-called Challenges (Table 11), broken down into 29 Commitments, and approximately 80 targets and performance indicators. Most indicators refer to progress in actions to be taken by Transport Canada to fulfil the strategy (*i.e.* take steps to implement a certain policy measure). A first review of progress was made in 2003.⁶⁵ This review was fed into Transport Canada’s so-called Departmental Performance Report,⁶⁶ which is a part of the preparation process for the political adoption of the national budget. The system can then be described as a monitoring system, linked to a control system.

Sustainability Dimensions, Indicator Types and Other Features. The strategy has a focus on the environmental dimension of sustainability. It concerns, in particular, institutional and policy aspects of the environment rather than physical environmental results. Most of the indicators are of the performance type. However, performance is not measured against quantitative sustainability targets but against the mostly qualitative policy commitments. To illustrate the approach a few extracts from the monitoring report are shown in Table 12.

The commitments are mostly of a short-term character and rather detailed. In this way the SDS monitoring system enables a quite specific assessment of what the ministry is doing or not doing. It can thereby support the notion of governmental accountability towards the public, in this case concerning the

⁶⁴ EEA, TERM 2001, *Indicators Tracking Transport and Environment Integration in the European Union*, European Environment Agency, Copenhagen, 2001, p 3.

⁶⁵ Transport Canada 2001–2002 Sustainable Development, *Strategy Progress Report*, Ottawa 2002. URL: <http://www.tc.gc.ca/programs/environment/sd/sds0102/menu.htm>.

⁶⁶ Transport Canada, *Departmental Performance Report. For the period ending March 31, 2003*, Minister of Transport, Ottawa, 2003.

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Table 11 Challenges for sustainable transportation (Reference 65)

<i>Strategic challenges for sustainable transportation in Canada</i>
Improving education and awareness of sustainable transportation
Developing tools for better decisions
Promoting adoption of sustainable transportation technology
Improving environmental management for Transport Canada operations and lands
Reducing air emissions
Reducing pollution of water
Promoting efficient transportation

extent to which policy efforts are being made to promote sustainability of transport. Beside the monitoring itself, the SDS and monitoring system is also reviewed by Internal management Control and by an external auditor, the Canadian Commissioner for Sustainable Development. There is a further controlling influence through the indirect linkage to the political budget process (not assessed here).

Interpretation. The review of the SDS indicated that about 80% of the commitments and 70% of the targets were either on track or complete. Transport Canada itself appears to assume that the progress achieved provides a positive contribution to the sustainability of Canadian transport systems, even if no such direct linkages or effects are documented through the SDS monitoring system. Other initiatives have been taken to develop ‘system level’ monitoring of Canadian sustainable transport, but the results have not been implemented at this point. The interpretation must be that only the institutional dimension of sustainable transport is measured, and the system level implications are unclear.⁶⁷

4 Discussion and Conclusion

Sustainable transport remains a challenge conceptually, but perhaps even more so for practical policy. Indicators are among the tools that can help in conceptual clarification as well as guide policy analysis, deliberation and decision-making. Many attempts have been made to specify and apply indicators in this field. This chapter has shown that there is not one uniform approach and not one general application—the function of sustainable transport indicators will be highly dependent on specific context, and can serve different users with different priorities and concerns.

Nevertheless, there appears to be agreement on many of the topics considered as important for sustainable development and transport, and the issues for which indicators are primarily defined. Chief among these topics are transport system contributions to climate change, regional air pollution, impairment of urban air quality, depletion of oil and land resources, as well as traffic induced death and injuries. Emphasis is also put on the impact of transport systems on biodiversity,

⁶⁷ R. Gilbert, N. Irwin, B. Hollingworth and P. Blais, *Sustainable Transportation Performance Indicators (STPI)*, Project Report on Phase 3. The Center for Sustainable Transportation, Toronto, 31 December 2002.

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Table 12 Extracts from Transport Canada (Reference 65)

<i>Challenge 5 reducing air emissions</i>	<i>Complete</i>	<i>On-track</i>	<i>No action to date</i>	<i>Behind</i>
<i>Commitment 5.1</i>				
Transport Canada will continue to lead the transportation component of the federal action plan on climate change . . .				
Targets (. .)				
(c) Initiate discussions with the freight transportation industry in 2001 to establish voluntary initiatives to improve the fuel efficiency of the freight system	X			
<i>Commitment 5.2</i>				
Transport Canada will work with ICAO to develop new aircraft emissions standards and operational practices that address concerns about local air quality and global climate change, from 2000/2001 – 2003/2004				
Targets (. .)				
(a) Develop new engine standards that include emissions limits for nitrogen oxides during climb and cruise modes of flight, beginning in 2000/2001				X

ecosystems, and general natural resource funds, and while some indicators in these areas exist, operationalization is often more difficult. Most references also include immediate social and economic issues such as transport costs, congestion, and accessibility into the equation, even though their implications for sustainability (as opposed to development) often is unclear. There appears to be few attempts to conceptualize, let alone measure, the functions of transport in the general sustenance of social and economic systems over the longer term, for instance in terms of ‘critical’ levels of transport infrastructure, investment rates or innovation capacities. The institutional dimension of sustainable transport is included in some indicator systems, but how changes in this dimension links to system changes also appears to be an area for further exploration.

There is little agreement how to measure sustainable transport more exactly, how to aggregate the available information and even how to interpret results in terms of transport sustainability, beyond a general notion of listing ‘positive’ versus ‘negative’ contributions. A transport system may be deemed sustainable in some respect (for instance in terms of impact on the ozone layer) and unsustainable in some others (for instance in terms of contributing to climate change). What would that imply? Proposing that the ‘majority’ of a particular range of indicators should be positive to merit sustainability is of course arbitrary and would in any case make indicator (de)selection highly critical. Proposing that unsustainability in one dimension can be compensated by sustainability in another rests on weak assumptions about substitution between various forms of resources and services, which cannot always be assumed but would have to be established empirically. Converseley, maintaining that the transport sector is sustainable only if all

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indicators in all dimensions are positive or neutral assumes that improvements in other sectors can never compensate for negative transport trends. This may hold only if some critical system limit was irreversibly transgressed solely because of, and attributable to, a particular transport effect. To identify such a situation would be difficult, to say the least, and this chapter did not reveal operational criteria and measures to detect it. The absence of any such evidence should not, however, lead to the assumption that transport trends are positively sustainable.

Notwithstanding such speculations, indicators should not be assumed to provide definite answers to complex problems. This would negate the very meaning of indicators: as guidance to navigate in complex territories where exact and full knowledge is not available, but where actions are necessary after all. At best, indicators can help to reduce the complexity of operation and communication. But does this mean that no particular line can be drawn between sustainable transport performance indicators and transport/environment indicators in general? Section 2 suggests some criteria that could help to police such a distinction. Adopting the full list would, however, most likely prohibit the identification of proper sustainable transport indicator systems and sets at all. As a minimum requirement the author would rather suggest that claims representing sustainable transport indicators were accompanied at least by (1) an explicit justification in terms of recognized notions of sustainability and development from the literature, (2) considerations over system boundaries and their implications, and (3) explicit reflections over which criteria on the list are included and which ones that are not considered in a particular application.

