Chapter 19
Mainstreaming Sustainable Urban Transport: Putting the Pieces Together

Chris Zegras

Introduction

The term ‘sustainability’ has ploughed itself into mainstream development dialogue and literature, if not entirely into popular jargon. One does not need to look far to find references to sustainable housing, consumption, forestry, agriculture etc. The concept of sustainability – meeting present needs while maintaining the capability to meet future needs – has proved invaluable in making society explicitly aware of the need to pass on natural resources to future generations. Sustainability has also come to encompass a broader development agenda, focused on the balance of environmental, social and economic objectives. In this sense, sustainability has been useful in establishing a more level rhetorical playing field among possibly competing objectives. At the same time, the broadening of the meaning of sustainability and the increasing ubiquity of the term’s use runs the risk of watering down the meaning of the concept. When sustainability becomes associated with more and more, does it start to mean less and less?

The use of the word sustainable in the transport sector dates back to the late 1980s (see Ripoll, 1987) when sustainable development broke into mainstream development rhetoric. Since then, evidence of progressive mainstreaming can be seen, in inter-governmental organization efforts to define meanings and identify policy mechanisms (OECD, 1996; World Bank, 1996); private sector-driven global assessments of mobility conditions (WBCSD, 2001); the derivation of specific methodologies for sustainable urban land use and transport planning (Minken et al., 2003); and so on.

A considerable amount of the sustainable mobility research and practice targets metropolitan areas (such as the work of Kennedy et al, 2005), a logical focus given urban areas’ demographic and economic importance. For example, over the next thirty years, virtually all of the world’s net population growth will take place in the developing world’s urban areas (UN, 2001). As earlier chapters of this book emphasize, this growth poses major planning and management challenges for a variety of urban sectors, such as housing, sanitation, water and transportation.

Developing countries, by definition, face the fundamental development imperative – the need to improve the quality of life (human development) for large shares of their population. Transport plays a major role in facilitating this development, providing for the movement of goods and persons that enables social and economic exchange. At the same time, development further fuels the demand for transport of all kinds – via increased trip rates, rising motorisation, demand for increased speed, etc. – which, in turn, generates economic, social and environmental impacts. Such impacts can though imperil the very benefits that transportation systems provide (see Figure 1).
Chapter 19: Mainstreaming Sustainable Urban Transport

Figure 1: The urban transport cycle and sustainability challenges
Source: Derived from Zegras (1998)

<table>
<thead>
<tr>
<th>Transport Services</th>
<th>Economic Growth</th>
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</thead>
<tbody>
<tr>
<td>Facilitate movement of goods and services</td>
<td>Increase in industrial/commercial activities</td>
</tr>
<tr>
<td>Improves accessibility to work, education, etc.</td>
<td>Increase in personal incomes</td>
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<tr>
<th>Economic &amp; Environmental Impacts</th>
<th>Transport Impacts</th>
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<tr>
<td>Congestion</td>
<td>Growth in trip rates</td>
</tr>
<tr>
<td>Infrastructure costs</td>
<td>Motorisation</td>
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<td>Resource degradation (i.e., energy, air, land)</td>
<td>Changes in mode share</td>
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<td>Urban expansion</td>
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<td>Etc.</td>
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On-going urbanisation and economic growth mean that more people will be making more trips, across longer distances, in more and larger cities across the globe. In the face of this growth, urban transportation systems must balance two basic needs. On the one hand, the need for transport to continue to contribute to economic development and human welfare and, on the other hand, the need to mitigate transport’s negative effects, both current (as exhibited by pollution and accidents), as well as future (seen through contributions to climate change risks and exhaustion of non-renewable resources). These developments pose the fundamental challenge as to how we (as a global society) can make our urban transportation systems more sustainable.

One can find any number of analyses and reports that identify key elements for moving towards sustainable transport (as demonstrated by the various contributions to this book, for example); that outline emerging policy, planning and technological innovations which indicate promising movement in the right direction (see Goldman and Gorham, 2006) or that develop and deploy enhanced analytical methods for assessing various land use and transportation strategies (see Lautso and Toivanen, 1999).

In contrast to such efforts, this Chapter takes a primarily theoretical focus. It does not attempt to untangle the complex and context-specific policies, investments and other interventions that might lead cities and regions to a more sustainable mobility. Instead, it aims to explicitly re-orient the entire sustainable mobility enterprise around the concept of ‘accessibility’. This is of particular importance in cities of the developing world, where a large share of citizens still suffer from low levels of accessibility to daily needs and
wants. At the urban level, the interaction of the land use-transportation/social and economic systems create needs and aspirations for enhanced accessibility. Sustainable mobility (rather than transport per se), then, should aim to sustain these systems’ capabilities to provide such accessibility, over time, on an affordable basis.

**Sustainability and sustainable development**

**Use of the terms**

The use of the term sustainability has become almost trite. The concept itself can be traced far back in the fields of economics and natural resources, relating to the capacity of natural stocks (of natural resources such as fish, forests, soil etc), the Malthusian concern of population growth exceeding basic subsistence capabilities (Malthus, 1798) and fundamental Hicksian economic principles relating to income, consumption and wealth (Hicks, 1939). By at least the late 1960s, one can find prominent ethicists and economists focusing on relevant issues. Baumol (1968), for example, writing on social discount rates, highlights the special attention necessary for possible ‘irreversibilities,’ such as ‘if we poison our soil…[or] destroy the Grand Canyon’ (ibid 1968: 802).\(^1\) Rawls (1971), in his landmark *A Theory of Justice*, suggests that we (should) have a natural inclination to promote the well-being of our descendants.

The prevailing modern usage of the term sustainability finds its recent roots in the environmental movement. The 1972 UN Conference on the Human Environment and Meadows et al’s (1972) *Limits to Growth* greatly helped push environmental concerns onto the global agenda. A follow-up to *Limits to Growth*, *Alternatives to Growth* (Meadows, 1977), includes papers from a wide range of disciplines, aiming to chart paths to potential ‘sustainable futures,’ which are associated with a ‘steady state’ economy and a ‘just’ society.

Rees (1997) credits the World Conservation Strategy of 1980 with the first explicit use of the term sustainable development. By the late 1980s, the idea of (environmental) sustainability became formally integrated into mainstream development concerns with the release of the now well-known *Brundtland Report* (WCED, 1987). This report formalised the concept of sustainable development, recognizing the fundamental need to live within the earth’s means and the implications for passing on the same (or greater) amount of total resources to future generations.\(^2\) By 1992, sustainable development hit centre stage, so to speak, when the United Nations convened the Conference on Environment and Development in Rio de Janeiro (often referred to as the

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1 Interestingly, Baumol recommends subsidised investments for such protections, *not* a lower general discount rate; beyond such ‘irreversibilities,’ He suggests “the future can be left to take care of itself” (Baumol, 1968: 801).

2 While not rigorous nor comprehensive, a database search on the topics (sustainability, sustainable development or sustainable) in the ISI ‘Web of Science’ citation index (which includes journal articles from Science Citation Index, Social Sciences Citation Index, and the Arts & Humanities Citation Index) is somewhat indicative of the ‘growth’ of interest in sustainability. The number of articles cited including at least one of those topics returns the following number of citations (in 7 year periods; 1973 being the earliest period available, 1980 marking the supposed first appearance of ‘sustainable development,’ 1988 being the first year post-Brundtland): 1973-1980: 42; 1981-1988: 226; 1989-1996: 5,802;1997-2004: 18,583.
‘Earth Summit’) organised around the principal themes ‘environment and sustainable development.’

During the 1990s, sustainability grew beyond purely environmental concerns, as the ‘three dimensions’ came to the fore: environmental, economic, and social (or equity); the so-called ‘three E’s of sustainability’. Some have extended the concept to include another dimension, the political, institutional and governance dimension (see Brinkerhoff and Goldsmith, 1990; Dimitriou and Thompson, 2001). By extending sustainability to include all aspects of life and life-systems, however, we run the risk of having it simply slip out of our grasp as a useful construct. As Keiner et al note: “these terms (sustainability and sustainable development) are arbitrary and user-defined, and have lost their clear meaning” (Keiner et al, 2004: 13). In the international development context, some scholars (see Dimitriou, 1998) have also raised concerns that sustainable development represents nothing more than a neo-imperialist concept, imposing Western values while ignoring local circumstances and values. In this sense, sustainable development could be viewed as similar to relevant movements of other times, such as modernism and, its philosophical cousin, modernisation.

If we return to a ‘purely scientific’ basis, we can think of sustainability in terms of carrying capacities, biological processes and ecosystem functioning, raising concerns as to whether the system can sustain itself in time? Notably, the mainstreaming of sustainable development has paralleled growing acknowledgement of the climate change risk due to increasing anthropogenic greenhouse gas emissions, possibly one of the greatest threats to sustaining human existence on our planet. However, since sustainable development refers to human development and its impacts, the concept becomes heavily value-laden. Indicatively, religious (Pitcher, 1977) and ethics (Perelman, 1980) journals provide some of the first considerations of the implications of the sustainability idea. Some (see Crilly et al, 1999) go so far as to explicitly call sustainability a ‘political,’ and not ‘technical,’ issue. Ultimately, in this context, sustainable development depends on our values: how do we value future generations and what we leave to them (related to, for example, discount rates)? How do we value ‘non-economic’ resources? How do we value the distribution of resources among current generations? These questions pose an overarching question, namely: is sustainability really a new concept, or simply a new language for various interpretations of a good and just society that have existed throughout time?

**Defining sustainable development**

No shortage exists of attempts to define sustainable development. Quite possibly the most frequently cited definition comes from the *Brundtland Report* (WCED, 1987): to ensure that [development] meets the needs of the present without compromising the ability of future generations to meet their own needs. This definition, while conceptually straightforward and compelling, introduces however a basic management and planning problem of how do we know we are making progress? This requires some form of an operational definition to provide specific guidance on concept measurement (Meier and Brudney, 2002). We can, for example, establish an operational definition for meeting air quality standards for fine particulate matter (PM$_{2.5}$) as: ‘areas will be in compliance with the annual PM$_{2.5}$ standard when the 3-year average of the annual arithmetic mean PM$_{2.5}$
concentrations is less than or equal to 15 µg/m³.’ This definition establishes, quite precisely, how air quality compliance (for fine particulates) will be measured.

If we want to measure progress on achieving sustainable development, we *must* then begin with an operational definition of the concept. Whether the principles implied in the Brundtland definition (of intergenerational equity and use of resources) can be effectively operationalised remains to be seen, in part because sustainable development refers to multi-sectoral, trans-boundary, complex systems, undergoing continuous feedback, with randomness and non-linearities (see Innes and Booher, 1999).

Economics offers one potentially tractable path to an operational definition. Defining sustainability as the capability to ‘maintain the capacity to provide non-declining well-being over time’ (Neumayer, 2004: 1),³ leads to a capital-orientation of the concept: maintaining the value of total capital, including human, natural, social, and manufactured capital. By the mid-1990s, the World Bank defined sustainable development *as a process* by which current generations pass on as much, or more, capital per capita to future generations, with capital being defined as human-made, natural, social, and human (Serageldin, 1996). This definitional approach still suffers from measurement challenges including, but not limited to, issues of how to measure the social capital ‘stock.’ Furthermore, the capital-based operational definition of sustainability does *not* resolve different perspectives about the substitutability of capital, that is: ‘weak sustainability’, which assumes that natural capital can be substituted for by other forms of capital; and ‘strong sustainability’, which rejects such substitutability (Neumayer 2003; Kain, 2003). Finally, this ‘measurement-oriented’ discussion of sustainable development raises the danger that we focus on ‘measuring the measurable’ while ignoring the non-measurable, which can include some of the most important aspects related to sustainability.

**Measuring sustainable development**

As no single agreed-upon operational definition of sustainability or sustainable development exists, neither does any single means of measurement. In fact, the plethora of sustainability definitions, initiatives, and projects seems matched by the number of efforts to measure sustainability. These range from macro-level, consolidated measures (typically some form of index) to multiple indicator frameworks, which often aim to develop specific indicators *in each* of the sustainability ‘dimensions’ (see Zegras et al, 2004). A hierarchical perspective, suggested by the ‘sustainable indicator prism’ (see Figure 1) is intended to help clarify the relationship between data, indicators, indices and the ultimate goal of measuring the concept. Each side of the prism represents one of the sustainability dimensions, with the indicators building from raw data at the base towards composite indices which converge towards consolidated goals (e.g., sustainable development) at the top.

Numerous multi-indicator frameworks exist to measure sustainability at the national level, as in the case of the United Nations’ 58 indicators in the social,

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³ Neumayer (2003, p. 7) also offers the more technically rigorous, but slightly more awkward definition of sustainable development as not decreasing ‘the capacity to provide non-declining per capita utility for infinity.’
In attempting to measure sustainability via indicators, we face a number of challenges, including: data availability (not only the lack of the right information, but also the frequent mismatch between relevant functional and political/administrative units typical to data collection impacts as seen in measures of air quality); the need to capture the complexity of system feedback and interactions (including over time); and, aspects of future orientation, such that indicators can be forecast to estimate future conditions (Zegras et al, 2004). In addition, the multi-indicator efforts - crucial to representing the multiple dimensions common to today’s notions of sustainable development - pose a daunting interpretative challenge of how we should/can judge the ‘degree of sustainability’ or meaningful changes in time when we are forced to compare progress on numerous indicators, of varying levels of importance, and measured in different units?
Indices, typically composed of underlying indicators, provide one form of unified criterion for judging sustainability. Daly and Cobb (1989) propose the Index of Sustainable Economic Welfare (ISEW). Building from gross domestic product (GDP), the ISEW recognizes the fundamental value of wealth (or welfare) but also attempts to gauge whether, after taking into account the economic loss of natural and other resources, growth, at the margin, makes us poorer, not richer. Daly (2002) calls this possibility “uneconomic growth” – growth in throughput\(^4\) that ‘increases costs by more than it increases benefits’ (ibid 2002: 48). Many calculations of the ISEW (see, for example, Castañeda, 1999) suggest that a point of ‘uneconomic growth’ (i.e., when GDP continues rising but ISEW stagnates or even falls) can be reached (and measured).

One basic challenge to the ISEW comes from the difficulty in combining present day welfare, derived from the current capital stock, with the concept of sustainability, which relates to the value of the future capital stock into a single measure. In response to this and other weaknesses, Neumayer (2004) proposes a means to assess, at a national level, the sustainability of achieving a given level of human development by relating the UN’s Human Development Index (HDI) to estimated national levels of ‘genuine’ or ‘adjusted’ savings.\(^5\) Essentially, Neumayer’s approach allows a net capital effects ‘check’ on levels of Human Development.

Indexes derived along the lines of the ISEW represent the ‘weak sustainability’ perspective; it in other words assumes that depletion of natural capital can be compensated for by another form of capital. A sustainability index in the ‘strong sustainability’ camp would be the ‘ecological footprint’ which attempts to convert consumption and waste production into an estimate of the biologically productive area needed to provide these functions (Wackernagel and Rees, 1996). In this sense, the ‘footprint’ approach conveys the ecological ‘cost’ (measured in estimated carrying capacity) of human activity. It does not, however, say anything about the relative benefit of the welfare-generating activity itself.

**Sustainable transport and sustainable urban mobility**

**Sustainable transport: Tracing the evolution of the concept**

One need not look far to find references to sectoral sustainability, such as sustainable housing, sustainable consumption, sustainable forestry, sustainable agriculture, etc. Some of these sectors lend themselves naturally to the sustainability concept, forming the basis for modern ideas about sustainable development. Many credit German Hans Carl von Carlowitz for formalizing the concept of sustainability in his 1713 book on forestry practice (see Klöpffer, 2002; Häusler and Scherer-Lorenzen, 2002). But, when we turn to a complex socio-technical system, such as an urban transport system, can we really analyse its sustainability? Can we further focus on sustainable urban transport, or more narrowly still, on sustainable urban passenger transport? Such analyses, by necessity, impose artificial system boundaries and will lead to incomplete and perhaps even misleading results. Nonetheless, from a practical implementation perspective, sectoral

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\(^4\) Daly defines throughput in this sense as “the entropic physical flow from nature’s sources through the economy and back to nature’s sinks” (Daly, 2002: 18-19).

\(^5\) ‘Adjusted’ or ‘genuine’ savings rates attempt to account for investments in and depletions of various capital forms (see Hamilton and Clemens, 1999).
assessments may well be of most interest to responsible authorities, such as an individual ministry (see Giovannini, 2004).

Before entering into an exploration of sustainable transport, we should first clarify some basic terminology. The transportation system refers to the infrastructures, vehicles (including people themselves) and physical context within which persons and goods travel. Mobility, itself, refers to physical movement that travel across space using the system. In a sense, we can consider mobility and transportation as synonymous; a transportation system can then also be called a ‘mobility system’. Transportation and land use systems, in turn, help create accessibility – that facilitates the realisation of work, education, shopping, and other daily activities. These basic definitions illuminate the fact that mobility is often a ‘derived demand’ and that we consume mobility, not for mobility itself, but because it provides us with accessibility.6

The idea of sustainability in the transport sector followed the evolutionary pattern of sustainability more generally. Motor vehicle pollution regulations find their origins in late 1950s legislation in California (USA) (CARB, 2004). By at least the mid-1960s, we find government rhetoric (see Weaver, 1965) on and analysts’ critiques (Jacobs, 1961) of the dangers of urban ‘sprawl. The first global energy crisis of the 1970s implicitly introduced us to sustainability due to concerns about the potential reliability of transportation’s primary energy source, petroleum.7 In their seminal book on public transport and its inter-relations with land use, Pushkarev and Zupan (1977) highlight nearly all the problems currently recounted in most dialogues on sustainable transportation.

Few explicit references to sustainable transportation, as understood in the post-
Limits to Growth context, can be found before 1989.8 Newman and Kenworthy had a paper on urban form, transport and fuel consumption, presented at a conference session on sustainable urban form in Adelaide in 1980.9 In the immediate wake of the Brundtland Report, Replogle (1987) presented a paper at the 1988 Annual Meeting of the Transportation Research Board (TRB) on ‘sustainable transportation strategies’ for the developing world10 where he notes how the concept of sustainability (growing in influence in the development community at the time) had not yet had much impact in the transport sector overall. In this paper Replogle explicitly makes the link between transport, basic human needs, and environmental effects.

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6 In practice, this may not always be the case, since we sometimes travel simply for the sake of travel.
7 During this era, TRB’s relevant committee was on ‘Energy Conservation and Transportation Demand’ (e.g., circa, 1975).
8 A database search on the terms sustainability and transportation (and sustainability and transport and sustainable and transport) turns up few references before 1989. The search was done on WebSPIRS’ bibliographic database of transportation research and economic information, which combines databases from three sources: TRIS (Transportation Research Board), IRRD (Organization for Economic Co-operation and Development), and TRANSDOC (European Conference of Ministers). A few references include the word sustainable as it relates to: public transport finance in the face of privatisation and deregulation in the UK during the 1980s, and economic development and infrastructure in developing countries in the 1960s.
9 The authors could not provide a copy of the specific paper presented at that conference, but suggested (in a personal communications in May, 2005) that it was related to their early research on transport, energy use, and urban development patterns in Australian cities (see Newman and Kenworthy, 1980).
10 The paper was written in 1987 and was presented at the January 1988 TRB meeting.
In 1990, while he does not explicitly use the term ‘sustainability,’ Dimitriou (1990) presents the ‘developmental approach’ to urban transport planning, which contains many of the elements soon linked to sustainable urban transport planning, including a focus on basic needs, cost recovery, and system integration. In 1991, Replogle (1991), building upon his earlier work, considers the concept of sustainability vital for transport development, calling for ‘a more holistic approach to policy and investment planning’ in this field and contrasting existing patterns of transportation and land use with more ‘sustainable’ ones.

Agenda 21, produced at the Rio ‘Earth Summit’ (see above) highlights transportation’s ‘essential and positive role’ ‘in economic and social development’ and its threat to development due to contributions to atmospheric emissions, as well as ‘other adverse environmental effects’ (UN DSD, 1992). Numerous relevant efforts and reports follow in the wake of Agenda 21. In 1992, working towards development of a common transport policy, the Commission of the European Communities’ (CEC) established a framework for sustainable mobility. By 1994, the Organization for Economic Cooperation and Development (OECD) takes up the cause in a call for the development of ‘a definition of environmentally sustainable transport (EST)’ (OECD, 1996). And, by 1996 the World Bank published its new transportation policy, founded on the three principles of economic, environmental and social sustainability (World Bank, 1996). In 1998, on behalf of the World Bank, Dimitriou produced for the United Nations Development Programme (UNDP) a report which sought to translate the overall vision of sustainability into the urban transport sector as part of the development of a generic transport strategy to address problems of increased motorisation for medium sized cities in Asia (Dimitriou, 1998). This was among a steady and continuous stream of reports, studies and initiatives from international development agencies, non-governmental organizations, the private sector, and others which essentially embraced the multi-dimensional aspect of sustainable transport. Other examples include WBCSD (2001) and CST (2002); reviews of relevant initiatives can be found in Lee et al. (2003) and Jeon and Amekudzi (2005).

On the one hand, the movement towards an all-encompassing conceptualisation of sustainable transport seems necessary and, in any case, logically follows the evolution of society’s concerns about transport’s social, environmental, and economic effects, particularly on cities. On the other hand, once sustainable transport aims to cover ‘everything,’ it runs the risk of meaning less and less in practice, similar to the worry expressed above about sustainable development. Perhaps the idea of sustainable urban transport creates space for us to transparently assess the trade-offs and synergies between economic, social, and environmental effects. But, if it loses a rigorous meaning, it can easily be co-opted as a ‘smokescreen,’ hiding ‘business-as-usual’ practices. What then does sustainable transport really mean?

Sustainable transport: Examples of definitions and principles
Attempts to concisely review the many activities related to sustainable urban transport face the challenge that a single document may not clearly differentiate between goals (an

articulation of values), objectives (as measurable ends), indicators (as performance measures), and prescriptions. Some cases jump immediately to normative judgments while others focus more on objectives and principles. Despite shared basic principles, the actual definitions tend to vary, sometimes significantly; few, if any, *operational* definitions exist.

In his seminal paper Replogle (1987) takes a multi-dimensional view of a ‘sustainable transport strategy’. This is guided by economic and financial principles (‘economic viability, financial viability, and efficiency’) together with environmental viability and ‘equitability, distributional viability, or effectiveness’ or the degree to which the transport system meets the basic mobility needs of everyone. These multiple dimensions can be found in many subsequent definitional attempts, with emphases varying depending on the perspective adopted.

Perhaps predictably, the World Bank’s 1996 policy document takes an economic-oriented focus, emphasising the efficient use of resources and proper maintenance of assets (economic and financial sustainability); consideration of ‘external effects’ (environmental and ecological sustainability) and broad distribution of transport benefits (social sustainability) (World Bank, 1996). Some might view the Bank’s sustainable transport policy as a re-packaged justification of business-as-usual practices, which include the imposition of ‘Western’ development priorities and approaches. The OECD’s Environmentally Sustainable Transport (EST) project defined a sustainable transport system as meeting ‘access needs’ without endangering ‘public health or ecosystems in a way consistent with maintaining the stock of renewable and non-renewable resources (OECD, 2002). In EST’s view, sustainability can be measured according to fulfilment of pollution guidelines and international goals related to climate change and stratospheric ozone depletion.

The Canadian-based Centre for Sustainable Transportation (CST) offers an oft-cited definition, which (similar to the OECD EST) also builds on the concept of access, identifying the need to fulfil ‘basic access needs’ within human, ecosystem, and economic/financial limits, simultaneously giving consideration to equity concerns within and between generations (CST, 2002). In 2001, a prominent industry group, the World Business Council for Sustainable Development (WBCSD), put forth its definition of ‘sustainable mobility’ (similar to CST’s in basic principles) as: ‘the ability to meet the needs of society to move freely, gain access, communicate, trade, and establish relationships without sacrificing other essential human or ecological values, today or in the future’ (WBCSD, 2001). As part of a European Commission-funded research project on urban transport sustainability entitled PROSPECTS (see Minken et al (2003), also echoing CST, define sustainable transport in terms of providing access (to goods and services) in an efficient way, that protects natural and cultural heritages for today’s and future generations. Geared towards policy development for specific cities, PROSPECTS operationalises urban transport sustainability as an ‘optimisation problem’ of maximizing urban transport’s economic efficiency subject to constraints, both environmental and, possibly, those related to ‘liveability’ (the built environment). Schipper (1996), on the other hand, proposes that transport is ‘sustainable’ when the beneficiaries pay their full social costs, including those paid by future generations.

With the possible exception of Schipper (1996), none of the abovementioned efforts offers an operational definition of sustainable transport, per se. Yet, we can
observe three basic shared concepts: access (or accessibility), recognition of resource constraints (financial, economic, natural and cultural), and equity (inter- and intra-generational).

**Values, system complexity and boundaries**

As a multi-dimensional construct, sustainable urban transport, like sustainable development more broadly, becomes extremely complicated and open to much confusion as a result. We are dealing here with resource constraints over multiple time horizons with uncertain impacts. Furthermore, sustainability requires that we seek to ensure that future generations enjoy, at minimum, the opportunity for *at least* the same urban transport benefits as we currently enjoy, and that those benefits have some fair distribution. The latter point resonates at both the global and local levels. For example, the industrialised countries enjoy greatly higher levels of total mobility in urban areas than developing countries (see IEA, 2004). The urban mobility levels enjoyed in the developing world, furthermore, partly account for the industrialised world’s overwhelming responsibility to date for the accumulated levels of anthropogenic greenhouse gas emissions in our atmosphere. At the local level, the distribution of urban mobility benefits and costs *also* tend to favour wealthier segments of the population, particularly but not exclusively, within the developing countries.

As earlier discussed, in practice sustainable development inevitably involves value judgments. The urban transport case exemplifies this reality, as Figure 2 attempts to show in diagrammatic form. In this figure, each bar represents a hypothetical person’s level of today’s concern for various potential transport impacts, based on the approximate time-frame of the impacts and the person’s concern for the future (in economic parlance, a discount rate). Note the relationship between time-frame and uncertainties – here we are more certain about the acute effects of local air pollution (in the short term) than we are about the possible effects of climate change (in longer term). Furthermore, we might expect a relationship between concern for the future and wealth, as the wealthier may generally have a greater ‘luxury’ to worry about the future. For those alive today, the transportation system’s immediate threats to sustainability impact our existence. Trade-offs among these threats exist, and we do not necessarily make rational trade-offs among them; both with respect to our ‘own’ sustainability and the sustainability of ‘others.’

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12 This need not be the case; as for example, in the case of a person’s perception of accident risk.
13 Again, this might not always be the case; for example, a wealthy person might not concern himself/herself with climate change, in the belief that he will be able to bequeath to his future generations the wealth needed for protection from the possible negative effects. Furthermore, cultural, education and/or other factors may also have more influence on future concerns than wealth.
Another factor complicating efforts to operationalise the sustainable urban transport concept in a specific context comes from the need to impose boundaries. While sectoral bounding the urban transport system is often necessary for analytical purposes, this can often ignore the fact that transport enables other activities, such as shopping which (depending on the kind of shopping) might, on a larger scale, be considered ‘unsustainable.’ This relates to fundamental broader debates about the sustainability of our global economy. The metropolitan level displays analogous effects as transportation investments and services can induce changes in land use patterns which themselves might contribute to broader sustainable development challenges (such as ecosystem losses). Bounding the analysis geographically also poses analytical risks. For example, by focusing on urban transport we might miss sustainability challenges that arise from a city’s interactions beyond its region (via trade, tourism etc) and impacts well-beyond its borders. Furthermore, consider the impacts of roughly stable average travel budgets (see Schäfer, 2000). If these hold, then a city which produces shorter urban trips (ostensibly more sustainable, ceteris paribus) might generate more and longer inter-urban travel, as citizens invest the time and money saved in longer distance, high speed trips (including by air). In this case, locally ‘more sustainable’ outcomes could produce adverse global effects.

**Measuring sustainable urban transport**

**The role of indicators**

Transport planning has long used indicators, such as level of service (LOS), to assess system performance. As depicted in Figure 3, in an idealised transport planning process, indicators, which require data, reflect overall goals and objectives, help define alternative strategies and relevant evaluation methods, and ultimately aid in monitoring system performance. This leads to what Meyer and Miller (2001) call ‘performance-based
transport planning.’ The appropriate (i.e. valid and reliable) indicators for this kind of transport planning will vary depending on the scale of the analysis, as in the case of: an individual facility, a corridor, a regional network (see Ewing, 1995) and on the ultimate goals.

**Figure 3: The role of indicators in the transport planning process**

![Diagram showing the role of indicators in the transport planning process](Image)

Source: Adapted from Meyer and Miller (2001)

In performance-based transport planning, indicators are closely tied to project evaluation criteria (see Figure 3). If such indicators aim to reflect what is considered important, these same important aspects should be reflected in evaluations. The evolution of indicators and evaluation criteria used in urban transport follows the growing concerns about the sector’s increasingly recognized broad-ranging impacts (as discussed above). In terms of project evaluation, urban transport planning has a long history of monetarily quantifying benefits and costs. However, by at least the 1960s, in part due to legal requirements, urban transport planning began incorporating a broader range of issues, such as air quality, energy consumption, and community cohesion (see Meyer and Miller, 2001). These concerns entered into formal evaluation procedures, by for example, requiring environmental impact assessments to accompany traditional economic evaluations and/or subjecting proposed projects to hard constraints due to, for example, potential violations of urban air quality standards (see Howitt and Altshuler, 1999). Dimitriou (1992) suggests the changes in fundamental goals and objectives of urban transport development should be reflected in performance measures by differentiating between operational efficiency effects and developmental impacts. Today, many
recommended evaluation procedures echo the ‘sustainable transportation’ principles discussed above (e.g., UK CFIT, 2004).

The World Bank’s 1996 Transport Policy (World Bank, 1996) provides one bridge between more traditional transport investment evaluation criteria and sustainable transport concepts, via its call for ‘rigorous economic appraisal’ and ‘appropriate price incentives.’ ‘Appropriate’ pricing points towards the concept of ‘full cost’ accounting; efforts to quantify the relevant costs can be traced back to Vickrey’s pioneering work on congestion costs and congestion pricing (see Vickrey, 1969). By the mid-1970s, we can find attempts to quantify transport air pollution costs (Small, 1977) and by the early 1990s, we see an increasing number of pertinent studies attempting to monetize a broader range of impacts. Gómez-Ibáñez (1997) usefully reviews some select efforts in doing this and the ‘pitfalls’ of such studies. The ‘full-cost’ movement ties back to Schipper’s (1996) aforementioned sustainable transport definition. By quantifying such costs, we can evaluate, in theory at least, the broader impacts of projects’ and programmes via a common metric (monetized values). Employing an approach of this kind to measure transport sustainability reflects the ‘weak sustainability’ perspective, since efforts to monetize all effects suggest some sense of their inter-changeable/substitutable nature. It also assumes that the relevant impacts can be quantified and comparably monetized.

Sustainable transport indicators and indices

Efforts to measure sustainable urban transport via indicators are numerous. At the global level, as part of its 2001 global urban mobility assessment, the WBCSD proposed 12 indicators, grouped into categories of measures to be increased and reduced, providing a qualitative and fairly sobering assessment of current trends (see Table 1). Perhaps due to the relative vagueness of many of these indicators in their follow-up study, the WBCSD (2004) proposed a modified indicator set (see Table 2). This set of measures partly reflects a focus on tangibles, particularly those concerning areas that might be of interest to a business manager. At the same time, the WBCSD 2004 indicators seem redundant, particularly when one considers rigorous definitions of, for example, accessibility (discussed below), and self-serving access (as in the case of defining accessibility in terms of individual access to motorised transport). The WBCSD’s partial ‘forecast’ of indicators in Table 2 leads one to conclude that mobility is not sustainable today and not likely to become so under present trends. The report goes on to use these indicators to orient a set of transport goals and actions.15

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14 Vickrey first analysed congestion costs and pricing implications for the New York subway in the early 1950s and later extended the analysis to propose roadway congestion charging, including with electronic collection technologies for Washington, D.C. in the late 1950s (Arnott, 1997).

15 As an effort financed by the ‘mobility industry’ (primarily vehicle manufacturers and fuel companies), the report places heavy focus on technological solutions; commendably, it recognizes the massive challenge climate change poses and also highlights equity and accessibility concerns.
Table 1: An industry perspective I: WBCSD’s indicators of sustainable mobility

<table>
<thead>
<tr>
<th>Measures to be increased</th>
<th>Industrialized world</th>
<th>Developing world</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Level</td>
<td>Direction</td>
</tr>
<tr>
<td>Access to means of mobility</td>
<td>☑</td>
<td>+</td>
</tr>
<tr>
<td>Equity in access</td>
<td>☒</td>
<td>-</td>
</tr>
<tr>
<td>Appropriate mobility infrastructure</td>
<td>☒</td>
<td>-</td>
</tr>
<tr>
<td>Inexpensive freight transportation</td>
<td>☑</td>
<td>+</td>
</tr>
<tr>
<td>Measures to be reduced</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Congestion</td>
<td>☒</td>
<td>-</td>
</tr>
<tr>
<td>‘Conventional’ emissions</td>
<td>☒</td>
<td>+</td>
</tr>
<tr>
<td>Greenhouse gas emissions</td>
<td>☒ ☒</td>
<td>-</td>
</tr>
<tr>
<td>Transportation noise</td>
<td>☒</td>
<td>+</td>
</tr>
<tr>
<td>Other environmental impacts</td>
<td>☒</td>
<td>-</td>
</tr>
<tr>
<td>Disruption of communities</td>
<td>☒</td>
<td>-</td>
</tr>
<tr>
<td>Transportation-related accidents</td>
<td>☒</td>
<td>+</td>
</tr>
<tr>
<td>Transportation's demand for non-renewable energy</td>
<td>☒ ☒</td>
<td>=</td>
</tr>
<tr>
<td>Transportation-related solid waste</td>
<td>☒</td>
<td>+</td>
</tr>
</tbody>
</table>

Source: WBCSD, 2001

Key:
- ☑ measure is at acceptable level or becoming so
- ☒ measure is at unacceptable/dangerous level
- ? inadequate information to render judgement
- + situation seems to be moving in desired direction
- = no clear direction apparent

The WBCSD indicators and forecasting efforts reveal:
- the difficulty in operationalising many of the chosen indicators;
- questions about the sustainability significance to be measured by some of the indicators (e.g., lower goods costs); and
- no indication of relative importance or comparability among the different indicators.

Perhaps the greatest challenge to effectively operationalising sustainable mobility indicators in the WBCSD case comes from the global focus of the effort.

What about at the urban level? We can find numerous examples here: the EU-funded SPARTACUS project looked at sustainable transport in three cities in Europe (Helsinki, Naples, and Bilbao). In a forward-looking analysis, assessing the effect of policies on urban transport sustainability, this project combined an integrated land use transport model (MEPLAN) with tools to calculate spatially disaggregate indicators (see Table 3). The indicators can be combined, via user-defined weights and value judgments (to reflect, for example, different basic theories regarding equity), to develop indices of performance in the three basic sustainability dimensions (Lautso and Toivanen, 1999). In light of Figure 1, the SPARTACUS project encompasses a bottom up-approach, from indicators to indices. The indices facilitate the analysis of a large number of policies according to aggregate performance on the three dimensions, enabling sustainability to be measured in relative terms. SPARTACUS marks an important contribution for several reasons: its comparative (inter-city) research design, its effort to model the combined land use and transportation systems, and its transparency in the indicator-to-index construction.
### Table 2: An industry perspective II: WBCSD’s modified global indicators and partial ‘forecast’

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Passenger operationalisation</th>
<th>Goods operationalisation</th>
<th>“Themes” from current trend forecast</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘Accessibility’</td>
<td>% of households with access to personal vehicles + % living within certain distance of public transport</td>
<td>Combination of response time and travel distance to receive shipment</td>
<td>ICs: Increase in already high levels; DCs: more uncertainty</td>
</tr>
<tr>
<td>User financial outlay</td>
<td>Share of household (HH) budget devoted to travel</td>
<td>Total logistics cost per unit or share logistics’ costs share of good’s price</td>
<td>ICs: Constant HH budget share; ICs: uncertain; ICs &amp; DCs: declining goods costs</td>
</tr>
<tr>
<td>Travel time</td>
<td>Average time required from origin to destination</td>
<td>Average shipment origin to destination time</td>
<td>Congestion may increase in urban areas of DCs and ICs</td>
</tr>
<tr>
<td>Reliability</td>
<td>Variability in travel time for ‘typical’ user</td>
<td>Variability in travel time for shipments of different types</td>
<td>Congestion may increase in urban areas of DCs and ICs</td>
</tr>
<tr>
<td>Safety</td>
<td>Probability of individual accident; total number of accidents/year</td>
<td>Probability of shipment accident; value of goods damaged/destroyed</td>
<td>ICs: decline in death/injury rates; DCs: possible increase</td>
</tr>
<tr>
<td>Security</td>
<td>Probability of crime/harassment; total number of incidents</td>
<td>Probability of damaged/stolen goods; total value of such goods</td>
<td>Security will continue to be serious concern</td>
</tr>
<tr>
<td>Greenhouse gas emissions</td>
<td>Emissions</td>
<td>High growth, especially in DCs</td>
<td></td>
</tr>
<tr>
<td>Impact on environment &amp; public well-being</td>
<td>Conventional emissions; impacts on ecosystems; persons exposed to noise</td>
<td>Emission declines in ICs, mixed in DCs; noise will not decrease</td>
<td></td>
</tr>
<tr>
<td>Resource use</td>
<td>Total energy use by fuel; share of energy from ‘insecure’ sources; land devoted to transportation activities; volume of materials used; share of materials used; recycling rates</td>
<td>“Footprint” will increase due to materials, land, energy consumption growth</td>
<td></td>
</tr>
<tr>
<td>Equity implications</td>
<td>Information reflecting distribution of indicator values across different population groups</td>
<td>Elderly, poor will continue suffer lower access; mixed exposure to negative effects</td>
<td></td>
</tr>
<tr>
<td>Impact on public revenues &amp; expenditures</td>
<td>Level and change of public expenditures for transportation services and infrastructure</td>
<td>No forecast</td>
<td></td>
</tr>
<tr>
<td>Prospective rate of return to private business</td>
<td>Return on investment available to ‘efficient’ private business from mobility-related goods/services</td>
<td>No forecast</td>
<td></td>
</tr>
</tbody>
</table>

Source: author’s derivation/interpretation of WBCSD, 2004

**Note:** IC: industrialized countries; DC: developing countries; see WBCSD 2004 for more detailed regional breakdown; WBCSD admits to using an approach not capable of forecasting measures on all the indicators; in most cases, they render certain judgments regarding effects of business as usual trends.
Table 3: Indicators used in the SPARTACUS project

<table>
<thead>
<tr>
<th>Sustainability Dimension</th>
<th>Area</th>
<th>Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental Indicators</td>
<td>Air Pollution</td>
<td>Emissions of greenhouse gases, acidifying gases, organic compounds; Consumption of mineral oil products</td>
</tr>
<tr>
<td></td>
<td>Consumption of Natural Resources</td>
<td>Land coverage; Consumption of construction materials</td>
</tr>
<tr>
<td>Social Indicators</td>
<td>Health</td>
<td>Exposure to particulate matter (PM), nitrogen dioxide (NO₂), carbon monoxide (CO); Exposure to noise; Traffic deaths; Traffic injuries</td>
</tr>
<tr>
<td></td>
<td>Equity</td>
<td>Justice of exposure to PM, NO₂, CO; Justice of exposure to noise; Segregation</td>
</tr>
<tr>
<td></td>
<td>Opportunities</td>
<td>Total time spent in traffic; Level of service of public transport and slow modes; Vitality of city center; Accessibility to the center; Accessibility to services</td>
</tr>
<tr>
<td>Economic Indicators</td>
<td>Costs/Benefits By Type</td>
<td>Transport user benefits; Transport resource cost savings; Transport operator revenues; Investment financing cost; External cost savings</td>
</tr>
<tr>
<td></td>
<td>Overall Indicators</td>
<td>Total net benefits (sum of costs/benefits by type); Economic Indicator (total net benefits per capita)</td>
</tr>
</tbody>
</table>


Table 4: PROSPECTS’ simplified indicators list

<table>
<thead>
<tr>
<th>Sub-Objective</th>
<th>Level 1 (data and sound analytical techniques available)</th>
<th>Level 2 (data largely available)</th>
<th>Level 3 (qualitative assessments only)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic efficiency</td>
<td>Cost-benefit analysis</td>
<td>Time and money costs</td>
<td></td>
</tr>
<tr>
<td>Liveable streets and neighborhoods</td>
<td>Accidents by location, mode, victim</td>
<td></td>
<td>Feeling of freedom of movement, danger</td>
</tr>
<tr>
<td>Protection of environment</td>
<td>Environmental costs</td>
<td>Energy and land use, emissions</td>
<td></td>
</tr>
<tr>
<td>Equity and social inclusion</td>
<td>Accessibility for those without a car, mobility impaired</td>
<td>Losers and winners by category</td>
<td></td>
</tr>
<tr>
<td>Reduce traffic accidents</td>
<td>Accident costs</td>
<td>Accidents by location, mode, victim</td>
<td></td>
</tr>
<tr>
<td>Support economic growth</td>
<td>Changes in local GDP</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


As part of another multi-city European initiative funded by the EU, the PROSPECTS project starts with an explicit definition, maps objectives and sub-objectives to that definition, and develops indicators relevant to each sub-objective (Minken et al, 2003). They propose a three-level indicator structure, roughly corresponding to data and analytical technique availability (see Table 4): Level 1 includes measures and approaches which allow, in theory, integrated evaluation approaches (such as cost-benefit analysis); Level 2 involves indicators which can be measured separately,
with data, but not necessarily easily combined in evaluations; Level 3 entails qualitative assessments of goal achievement. The PROSPECTS project ultimately approaches sustainability as an optimization problem, literally: the sustainability objective function entails maximizing economic efficiency subject to a range of constraints. The indicators provide the appraisal framework.

Examining a single metropolitan area, Kennedy (2002) takes a comparative modal approach, aiming to assess the relative sustainability of motor vehicle travel versus public transport travel in the Greater Toronto Area (GTA), Canada. He adopts a macroeconomic perspective, looking at transport costs from the perspective of the region (quantifying the value of the GTA’s trade relating to transport) and also estimates accessibility benefits based on relative speeds and a time-constrained cumulative accessibility-to-work measure. Black et al (2002), looking at the Sydney, Australia case, simply bypass indicator development by accepting the New South Wales Government’s defined vehicle kilometres of travel (VKT) targets for 2010 as the primary sustainability indicator. They go on to look at variations in motor vehicle VKT based on differences in urban form across Sydney’s 40 local government areas.

A number of more thorough reviews of indicator efforts exist (e.g., Lee et al, 2003; Jeon and Amekudzi, 2005). These reviews lead to two observations:

• the overwhelming number of indicators derived; and
• the oft-committed failure to clarify the links between the proposed metrics and the goals/objectives (the EU-supported SPARTACUS and PROSPECTS projects are notable exceptions).

This range of multiple indicator initiatives represent ambitious efforts to provide a comprehensive picture of sustainable transport, from a range of perspectives, such as: the business sector (WBCSD, 2004), the social advocate (Litman, 2001), or the academic (Lee et al, 2003). They also reflect different purposes, different scales, and, to some extent, different value systems. Most of them reflect a ‘bottom-up’ approach to indicator development and use, meaning they outline numerous important indicators building, metaphorically, from the base of the Sustainable Indicator Prism (Figure 1). Absent integration of these measures, or some way of making the indicators explicitly comparable, the multiple indicator efforts make it difficult to gauge progress towards ‘sustainability.’ What if, for example, air pollutant emissions increase, while travel time decreases?

Indices provide one possible path through the dense multi-indicator forest. As mentioned previously, indices converge towards the top of the Sustainable Indicator Prism. Money provides one form of index via the ‘full cost’ analyses referred to earlier; although in terms of measuring sustainable transport, monetization of effects may face serious limitations. In general, few sustainable transport index examples can be found in the literature. Litman (2001) lists his indicators in a call for the development of a ‘sustainable transportation index.’ Examining specific travel corridors, Zietsman and Rilett (2002) derive an index as the weighted sum of several normalized mobility indicators (such as standard deviation of travel time, travel rate, LOS) plus local pollutant emissions, noise levels, and fuel consumption. The SPARTACUS project, discussed above, derives dimensional indices based on lower-level indicators (Table 3); this approach enables judgment of ‘more sustainable’ outcomes due to various policy, investment and pricing interventions in specific cities. At the comparative
national level, Black (2000) aims to derive an index from indicators of: fossil fuel dependence, air emissions impacts, traffic accidents, and congestion. Importantly, Black recognizes the ‘one-sidedness’ of the resulting index, pointing out that an index must be capable of reflecting environmental sustainability and mobility. In an apparent effort to move in this direction, Yevdokimov (2004) proposes to measure transportation sustainability through the Genuine Progress Indicator (GPI) (akin to the ISEW discussed above), aiming to capture changes in social welfare due to transportation.  

Sustainable mobility

Towards a consolidated definition

The previous sections show that the ‘mainstreaming’ of the sustainable mobility concept, has not produced a universally-agreed upon definition nor means of measurement. This is partly due to differences in scales of focus (e.g., global, urban), purposes, etc. Furthermore, while the broadly-encompassing conceptualisation of sustainable urban transport (including at least the economic, social, and environmental dimensions) effectively covers the primary relevant societal concerns, it also runs the risk of watering down any clear meaning.

To clarify purposes, we first need to recognise what, exactly, we are attempting to sustain. As discussed earlier, the urban transportation system and the mobility services it provides serve a primary purpose of allowing access to daily needs and wants. In other words, mobility contributes to the creation of accessibility. Unfortunately, however, accessibility itself does not have any such universally-agreed upon meaning. Many studies seek to operationalise accessibility: in terms of basic proximity, such as number of jobs within a certain distance (e.g., Miller and Ibrahim, 1998); as ex-ante characterisations of particular neighbourhood types (Krizek, 2003); road system performance (e.g., Allen et al, 1993); or, as simply access to motorized travel modes (WBCSD, 2004).

Such efforts merely reflect partial pictures of accessibility’s contributing components. We need a more complete definition of accessibility to understand how to sustain it, and thereby create sustainable mobility. In this regard, Geurs and van Wee define accessibility as “the extent to which the land-use and transportation systems enable (groups of) individuals to reach activities or destinations” (Geurs and van Wee, 2004: 128). This definition clarifies accessibility as the benefit derived from mobility. It helps reveal the relevant contributing elements: the performance of the transportation system, the patterns of land use, the individual characteristics of firms and people, the overall quality of ‘opportunities’ available and, increasingly, information and communications technologies (see, for example, BTS, 1997) (Table 5).

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16 The GPI includes value of services provided by transportation infrastructure, cost of commuting, cost of automobile accidents, cost of air and noise pollution by transportation, loss of farmlands and wetlands and some others. Yevdokimov’s approach is not entirely clear in the paper, but he uses this formulation to measure changes in transportation’s contribution to GPI in Canada over the period 1990-2002.
Table 5: Accessibility: contributing factors

<table>
<thead>
<tr>
<th>Factors</th>
<th>Effect on Accessibility (all else equal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation</td>
<td>Improved with more links, faster or cheaper service</td>
</tr>
<tr>
<td>Spatial distribution of “opportunities”</td>
<td>Improved if proximity of opportunities is increased</td>
</tr>
<tr>
<td>Individual (personal/firm) characteristics</td>
<td>Improved with physical, mental, economic ability to take advantage of opportunities</td>
</tr>
<tr>
<td>Quality of opportunities</td>
<td>Improved with more, or better, opportunities within same distance/time</td>
</tr>
<tr>
<td>Information and communications technologies (ICTs)</td>
<td>Improved with more, more rapid, and more ‘realistic’ connections</td>
</tr>
</tbody>
</table>

Understood broadly, accessibility links directly to Sen’s (2002) proposed re-orientation of sustainable development as ‘enhancing human freedoms on a sustainable basis.’ Such an orientation has particular relevance in the developing country context where human development especially hinges critically upon broad expansion of access to opportunities (educational, social, employment, health care and so on). Referring to Sen’s earlier concepts of ‘functionings’ – that is, everything that an individual may wish to be or do (see Sen, 1998) – and ‘capabilities’ – which facilitate the achievement of the functionings that individuals have reason to choose – we can see a logical link to mobility and accessibility by considering ‘functionings’ as potential trip purposes and the land use-mobility system as contributing to the ‘capabilities’ (Table 6).

Table 6: ‘Functionings’ and ‘capabilities’: mapping Sen’s human development concepts to accessibility and mobility

<table>
<thead>
<tr>
<th>Sen’s Concept</th>
<th>Meaning</th>
<th>Link to Accessibility/Mobility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functionings</td>
<td>Everything that an individual may wish to be or do (to ‘flourish’ as human beings)</td>
<td>Potential trip purposes (work, school, shopping, etc.)</td>
</tr>
<tr>
<td>Capabilities</td>
<td>Freedom to achieve the ‘functionings’ (or combinations of functionings) that individuals have reason to choose</td>
<td>The land use-transportation system directly influences individual’s ability to realize trip purposes and combinations of trip purposes</td>
</tr>
</tbody>
</table>

Toward an operational definition

Specifically orienting accessibility as the benefit created (in part) by our mobility systems, leads to a concise but comprehensive operational definition of sustainable mobility that is derived directly from the economist’s view of sustainability as the capability to maintain the capacity to provide non-declining well-being over time (Neumayer, 2003). Drawing from this perspective and the earlier discussion leads to an operational definition of sustainable mobility as: ‘maintaining the capability to provide non-declining accessibility in time.’

Relative to other approaches that conceptualise sustainability, this definition may be most consistent with the ‘capital approach’. Increasing accessibility (in passenger transport terms) increases human capital which in turn is a positive contribution to sustainable development. At the same time, however, increasing accessibility incurs the depletion of other sources of capital: natural (in the form of fuels, lands, air and so on), social (in the form of the institutional and bureaucratic resources dedicated to accessibility creation etc.) and man-made (such as infrastructures and vehicles).
Accessibility provides well being to current generations. Sustainability, however, requires that we create current accessibility without damaging the possibilities for future generations to enjoy at least the same levels of accessibility (and well being). In other words, sustainable mobility requires that today’s mobility benefit does not come at the cost of reduced capacities to provide future welfare-increasing opportunities (see Figure 4).

Figure 4: ‘Building’ on Capital: Accessibility and sustainable mobility

In this way, sustainable mobility can be manageably conceptualised as a balancing act between the expansion of accessibility (to, for example, health care, education etc.) and the scarcity of resources (natural, social, and man-made capital). Accessibility directly contributes to human capital creation, drawing upon the other capital elements, as depicted in Figure 4. This depiction of sustainable mobility still, however, suffers imperfections. For one, it incorrectly implies no feedback between capital sources. Furthermore, Figure 4’s very structure – with human capital on the top – might be interpreted as connoting some hierarchy of importance, with human capital considered the most important. While not necessarily the intention of the Figure, situating human capital above other sources of capital does reinforce the idea that, ultimately, sustainability is a human-oriented enterprise in that we (as humans) want to sustain our existence and the existence of future generations.

This proposed operational definition of sustainable mobility leaves some issues unresolved, as in the case of the treatment of:

- **Inter-generational well-being**: The definition steers clear of questions regarding how to value current versus future generations’ benefit.
- **Intra-generational well-being**: The definition does not explicitly address issues of the distribution of benefits (derived from enhanced accessibility) or costs among

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17 Derived from Smith (2004), in his discussion of sustainable development, more generally.
today’s transportation system users, although such incidence could be assessed via measurement.

- **Intra-sectoral value of resource use.** The definition does *not*, necessarily, enable a direct evaluation of the value of resources used to create accessibility versus the resources’ employed towards other ends.

  In conclusion, the proposed definition ultimately remains more a general form of guidance for understanding relative sustainable mobility than anything else. It allows us to potentially recognise the value of higher accessibility at lower total transport throughput, *ceteris paribus*. It does *not* tell us, however, whether this mobility will actually be sustainable.

**Sustainable mobility: measurement**

Despite the cited shortcomings, the proposed operational definition of sustainable mobility allows us to zero-in on approximate and concise means of measurement. Considering accessibility to be akin to GDP or HDI, we can then think of a sustainable mobility system as a means of increasing human capital (although, not to the point where it ‘overly’ depletes other capital sources). In this way, we can see the potential for adapting the ISEW or the HDI/genuine savings approaches discussed earlier. For example, Daly (2002: 48) suggests that development “might more fruitfully be defined as more utility per unit of throughput”. We can think of sustainable mobility in exactly the same way, in terms of ‘providing more utility, as measured by accessibility, per unit of throughput, as measured by mobility.’

This conceptualisation of sustainable mobility reflects the subtle shift implied by the accessibility-orientation of the term: whereby accessibility is the goal and mobility is the throughput cost of achieving the goal, where any mobility throughput represents depletion of capital stocks.¹⁸ For example, walking wears out shoes and consumes energy (calories). Driving a car or riding a bus implies depletion of: the resources that went into the production and utilisation of the vehicle; the energy used (both embedded and motive); land ‘consumed’ by the supporting transport infrastructure and related development; human-made stock in the form of infrastructure investments; and, social stock in terms of the dedication of institutions (for example, for planning). The capital depletion implied by mobility throughput varies, by mode, by time of day, by occupancy levels, and so on. But we can fairly safely say that, all else equal, relative capital depletion increases with vehicle size/weight and intensity of use.

This formulation of sustainable mobility does *not* mean that we want to reduce total mobility, per se, as a means of minimising stock depletion. Rather, it implies that we desire less total mobility consumption per accessibility derived. For the same level of accessibility, walking is more sustainable than driving (or taking the bus, or cycling). For motorised modes (or any mode that can be shared), occupancy plays an important role since, *ceteris paribus*, higher occupancy means more people receiving accessibility benefit at less total mobility throughput.

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¹⁸ This proposition closely aligns with Black’s (2000) observation of the need to be able to reflect the trade-off between mobility and environmental sustainability as well as Black et al (2002)’s recognition of vehicle kilometres travelled (mobility throughput) as a key indicator. Note that Black (2000) and Black (2002) are different authors.
We can proxy mobility throughput as some kind of weighted measure of distance travelled, with the weight representing the various capital ‘drains’ implied by the mode. A highly fuel efficient vehicle drains fewer natural stocks, for example; an electric mode (such as a Metro) may ‘consume’ less of the air-shed ‘stock’; and so on. As an initial indicator, then, vehicle distances travelled (VDT) can represent the capital drain. VDT could subsequently be differentiated according to technology, size, even time of day of travel and should reflect local concerns and priorities (including discount rates).

With the accessibility/VDT definitions in mind and returning to the ISEW framework, we could present an index of sustainable mobility in the following stylized equation: \[ \text{Index of sustainable mobility} = \text{accessibility} - \text{mobility throughput}. \]

Whether such an equation, however, could actually be calculated depends on whether the components could be measured in comparable units? Monetisation seems a logical choice and in this case we see that sustainable mobility begins adhering to the ‘full cost school’ of sustainable transport where the beneficiaries pay the full social costs, including those imposed on future generations. Despite some important progress, several controversies and difficulties lie in this path (see Delucchi, 1997), not least of which might be doubts as to whether we can monetise everything. Furthermore, doubts remain about the idea of combining welfare (in this case, accessibility) with stocks (Neumayer, 2000; Daly, 2002). Such an approach would be in the ‘weak’ sustainability tradition (Neumayer, 2003).

If, instead, we draw from the HDI/genuine savings framework (see Neumayer, 2004) we can then envision a sustainable mobility ‘trade-off’ space (see Figure 6). From Figure 5, we can make some relative (but not absolute) judgments regarding sustainable mobility. Assuming the symbols in the diagram represent individuals who might be grouped by some common characteristic (e.g. neighbourhood origin), we can say that: Group A has more sustainable mobility than Groups B, C or D; Group C has more sustainable mobility than Group D; and Group B has more sustainable mobility than Group D. This trade-off space offers normative guidance, informing us what is more sustainable and pointing us in the right direction toward enhanced sustainability. Notwithstanding all this, a major question remains; namely: how do we measure the benefit derived from enhanced accessibility?

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19 Others have suggested and/or used vehicle distances travelled as an important indicator. McCormack et al (2001: 27) suggest travel distance “is often a primary indicator of transportation activity”; Black et al (2002) use vehicle kilometres travelled, based in part on the fact that the New South Wales Government already had VKT targets set.

20 Note that the idea of the ‘ecological footprint’ could also be used to create an index of stock drains (measured by equivalent area of land required) by stratified VDT. Barrett and Scott (2003) and Wood (2003) offer explorations along these lines.

21 The author wishes to thank Jinhua Zhao for the conversation that helped lead explicitly to this framework.
Accessibility: Measurement and usage in sustainable mobility framework

Accessibility measures have a long history in planning, geography and related disciplines (Wachs and Kumagai, 1973) and have been subject to extensive and multiple reviews over the years (see Pirie, 1979; Handy and Niemeier, 1997; BTS, 1997; Geurs and Ritsema van Eck, 2001). Geurs and van Wee (2004) offer a useful framework for understanding accessibility, which Table 7 builds upon for measuring accessibility as it relates to the sustainable mobility concept.

Most accessibility measures have their strengths and weaknesses, depending on their purpose/application. Infrastructure-based accessibility measures, such as level of service (LOS), are among the most commonly recognised and employed. Such measures offer a limited view of accessibility as understood in its broader sense. Knowing travel times or speeds without possessing any information on the opportunities (i.e., activities) available to travel to provide an incomplete picture of accessibility as such metrics instead focus on throughput.

Table 7: Basic categorisation of accessibility measures

<table>
<thead>
<tr>
<th>Accessibility Measure Type</th>
<th>Examples</th>
<th>Suitability for Measuring Sustainable Mobility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrastructure-based</td>
<td>Travel speeds by different modes; operating costs; congestion levels</td>
<td>Weak - only reflect level of throughput, no explicit land-use component</td>
</tr>
<tr>
<td>Location-based</td>
<td>Distance measures (e.g., cumulative opportunities); potential measures (e.g., gravity-based measures); balancing factor measures (i.e., from the doubly constrained spatial interaction model)</td>
<td>Okay/Good - normally derived for some spatially aggregated unit; can represent stratified population segments</td>
</tr>
<tr>
<td>Person-based</td>
<td>Space-time prisms</td>
<td>Good - measured at the individual level, according to temporal constraints</td>
</tr>
<tr>
<td>Utility-based</td>
<td>Random utility-based measures (i.e., from discrete choice models or the doubly constrained entropy model)</td>
<td>Good - based on microeconomic benefit (utility) for individuals or stratified population segments</td>
</tr>
</tbody>
</table>

Source: Extended from Geurs and van Wee (2004)
The ‘ideal’ accessibility measure in the proposed sustainable mobility framework should reflect all relevant aspects contributing to welfare. These include (see Ramming, 1994; Bhat et al, 2000; Geurs and van Wee, 2004):

- **individual traveller characteristics and preferences**, such as: scarcity of time and money, vehicle availability, age, disability, etc.;
- **travel-related characteristics**, such as: safety, time, convenience, comfort and aesthetics;
- **destination-related characteristics**, such as: safety, convenience, aesthetics, and so on.

According to Geurs and van Wee (2004) to be useful as a policy and planning tool, measures must furthermore be operational, interpretable and easily communicated: based on these criteria, no accessibility measures fulfil this requirement.

Attractive theoretical features of utility-based accessibility measures include their ability to reflect individual preferences as gauged by individual choices (consistent with Sen’s ‘human freedoms’ perspective) and their direct links to traditional measures of consumer surplus (as in the case of the work of Small and Rosen, 1981). Those measures link back to the welfare-based definition of sustainable mobility presented earlier. In practical terms, utility-derived accessibility measures come from discrete choice models, widely applied in transportation system analyses (to predict mode choice). Ben-Akiva and Lerman (1979) explicitly link the discrete choice modelling framework to the accessibility concept, defining accessibility as “simply the utility of the choice situation to the individual” (ibid 1979: 656). Numerous examples of utility-based accessibility measures exist. For example, Niemeier (1997) uses a discrete choice model to measure individual accessibility benefits from the mode-destination choice for the morning journey to work, while Limanond and Niemeier (2003) use a similar approach to measure variations in neighbourhood accessibility. Martinez and Araya (2000) demonstrate the calculation of total user benefits due to accessibility changes in a land use-transportation interaction framework (a doubly constrained entropy model).

A more theoretically rigorous approach to measuring accessibility with some analytical traction would merge Table 7’s person-based (time-space) and utility-based measures, thereby, forming an ‘activity-based’ method. Activity-based analysis represents the ‘cutting edge’ of travel behaviour research (see Ben-Akiva et al, 1996) that aims to measure the benefits associated with people’s activities throughout the day. In this framework, travel decisions derive from a person’s entire pattern of daily activities. An activity-based approach provides obvious theoretical benefits for deriving meaningful accessibility measures consistent with Sen’s ‘functionings’ and ‘capabilities’ outlined in Table 6. Dong et al (2005) present activity-based accessibility measures for Portland, Oregon, USA. They demonstrate estimated user benefits accrued due to changes in the transportation system (resulting, for example, from congestion pricing) that drive decisions to change activity patterns. This offers accessibility measures that are not mobility-biased, as they effectively account for the accessibility benefits that can still be realised in the face of non-travel choices. While theoretically attractive, the activity-

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22 In practical terms, since utility is random and not directly measurable, Ben-Akiva and Lerman (1979) suggest the expected maximum utility (e.g., the denominator of the logit model) as a ‘reasonable alternative.’
based measures require, however, complex data sets on individual activity patterns and non-trivial modelling implementation.

**Accessibility as a current performance measure**

Despite its common employment in research and fairly common use in relevant professional rhetoric, accessibility does *not* find much currency as a formal performance measure for city and government authorities. Bhat et al. (2000) found limited examples of the use of accessibility measures among, for example, US states or cities. The UK government includes accessibility as an objective in its ‘New Approach to Appraisal: Appraisal Summary Table (AST),’ including three relevant categories (see ECMT, 2004; UK CFIT, 2004):

- access to the transportation system (for those with no car available);
- ‘option values’ (the value of having an alternative mode available); and
- severance (due to infrastructure impeding pedestrian travel).

The recommendations suggest qualitative assessment criteria for these categories, and consider Cost Benefit Analysis (CBA) takes into account “most aspects of accessibility” (UK CFIT, 2004: 37). This perspective is largely consistent with that of the PROSPECTS project described earlier. A review of appraisal techniques applied to a road project reveals the practical difficulty in estimating accessibility within these UK appraisal frameworks, in that techniques for estimating ‘accessibility’ were judged as ‘fairly crude’ compared to CBA, which might lead to decision-makers *not* focusing on these criteria (ECMT, 2004:177). This disconnect between theoretical and practical needs may well be one of the reasons that most efforts to operationalise sustainable mobility have not taken on a more explicit accessibility orientation in the UK and elsewhere.

**Implications for developing cities**

While the above discussion on measurement might seem luxuriously academic, it aims to highlight the importance of accessibility. In the developing city context, sustainable mobility must, first and foremost, orient to focus on creating accessibility for human development. Put quite plainly, the great majority of developing world urban (and rural) residents suffers a *severe* lack of accessibility – they cannot afford it under existing systems. The explicit grounding of sustainable mobility in the accessibility concept thus aligns closely with fundamental development priorities. By putting the primary emphasis on accessibility, the proposed operational definition of sustainable mobility puts mobility ‘in its place.’ Mobility provides a valuable means of creating accessibility; but mobility comes at the cost of draining other valuable sources of capital. Mobility represents a throughput – a valuable means to an end - but rarely the end itself. The accessibility-orientation of sustainable mobility enables us, at least in theory, to act on the range of possible interventions to improve accessibility as illustrated in Table 5.

For developing world cities, the range of their sizes, incomes, cultures, histories, environmental/social challenges etc. precludes any specific ‘recipe’ for sustainable mobility. The particular elements and priorities might or might not be the same for Johannesburg versus Jakarta, São Paulo versus Shanghai, Medellin versus Mumbai. One *could* effectively argue that these and most other cities of the developing world face such
dire transport situations that we should focus our energies on immediate-term improvements. In this case, efforts to refine conceptual and definitional issues related to sustainable mobility might seem pedantic. Yet, without a clear operational definition of sustainable mobility and a clear means of measuring it, we run the risk of letting the concept ‘run amok’ so to speak, leading the concept of sustainable transport quickly to mean all things to all people, and lose any real value in so doing.

Implementing the proposed sustainable mobility framework will require considerable effort by governments, citizens, international development organisations and others to derive locally operational performance measures that are up to the task. Some cities will have to begin with simple measures for accessibility, such as trips realised or cumulative opportunity measures. Other cities, with sophisticated transportation and land use modelling capabilities, and good underlying data, should be able to implement a more theoretically rigorous approach. Santiago de Chile, for example, with an operational land use-transportation model founded in micro-economic theory in the discrete choice tradition (see Martinez and Donoso, 2001) should be able to derive rigorous, utility-based measures of accessibility for incorporation in programme and project assessment. On the mobility ‘throughput’ side, impact measures need to be locally derived and applied. They comprise the capital stock drains against which accessibility enhancements must be weighed for sustainability assessment.

This implies no small agenda for moving forward in the developing context. Sustainable mobility - aiming to ultimately allow sustained development of human capital - requires the exploitation of other capital sources, including social capital, which requires investments now. Yet, here the developing world (and, much of the ‘developed’ world too) faces major challenges. Fiscal realities and institutional and bureaucratic fragility can hamper data collection, rigorous analysis, and coordinated long-term planning and decision-making, all of which seem crucial for moving towards more sustainable mobility and which any conceptual re-orientation itself cannot resolve. The sustainable mobility definition framework does enable the clear recognition of trade-offs. It does not, however, resolve long-standing debates regarding the proper role of the market versus the state, nor does it overcome the challenge that political and jurisdictional authorities tend not to operate at the relevant scales.

Conclusions

The evolution of the sustainable urban transport concept has followed the path of sustainable development more broadly. The modern sustainable development dialogue, at a minimum, attempts to more firmly situate a number of development dimensions on more equal footing and explicitly recognise potentially exhaustible resource stocks. In the urban transport sector, the ubiquity of the sustainability idea can be seen in relevant initiatives originating from a variety of sources. These efforts, often highly ambitious, have not however been matched by a common language; indeed, they sometimes confuse definitions, principles, and prescriptions. While this may partly result from the complexity of the concept - which typically requires the imposition of (artificial) boundaries in space, scale and within the sector itself - this may mask broader sustainability challenges. Further complications arise from the fact that sustainability is
inherently value-laden, as seen, for example, in the weak versus strong sustainability perspectives and varying individual concerns for, and uncertainties about, the future.

This Chapter articulates an operational definition of sustainable urban mobility as maintaining the capability to provide non-declining accessibility in time in urban areas. Accessibility, essentially, represents the welfare that people derive from the transportation-land use and social and economic system interactions and access to daily needs and wants that allow people to survive and thrive. Capability can be thought of in terms of the natural, human-made and social/institutional stocks that enable the mobility system to function. Sustainability requires that we bequeath future generations the capability for future generations to achieve, at least, the accessibility levels that we enjoy today. Accessibility (to employment, education, recreation opportunities etc.) increases the stock of human capital, but, in so doing, also depletes other capital stocks. The rate of that depletion depends on the nature of the mobility which will vary, among many other influencing factors, according to vehicle technologies, time-of-day of travel, occupancy levels and operational conditions.

This normative sustainable mobility framework allows us to make relative judgments. A more sustainable mobility system for cities provides more welfare (accessibility) per unit of throughput (mobility). From the ‘strong sustainability’ perspective, the throughput metric might build from the ‘ecological footprint’ approach, for example. In the ‘weak sustainability’ tradition, the throughput metric might look to transport ‘full cost’ analysis. In the latter approach, one could imagine an estimable sustainable urban mobility equation, converting (for example) a utility-derived accessibility metric into relevant currency units, from which the relevant mobility ‘costs’ could be deducted, moving towards ‘least cost,’ ‘full cost’ integrated sustainable urban mobility planning possibilities.

The proposed operational definition of sustainable urban mobility provides a simple and straightforward, albeit not necessarily obvious, way of conceptualising sustainable mobility in urban areas. The framework, which builds primarily from existing terminology and analytical tools should be intelligible to transport and land use planners, and fully derivable with the ‘tools of the trade.’ With a little work, the theoretical framework and metric should also be translatable to a broader audience of policy-makers and the general public. Indeed, policy-makers and the broader public need to be involved in the ultimate derivation of the relevant measures. Only then will we truly begin ‘mainstreaming’ sustainable urban transport.
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