Mainstreaming Sustainable Urban Mobility
Revised DRAFT Chapter

For
Urban Transport in the Developing World:
Policy and planning perspectives from the early second millennium
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Introduction

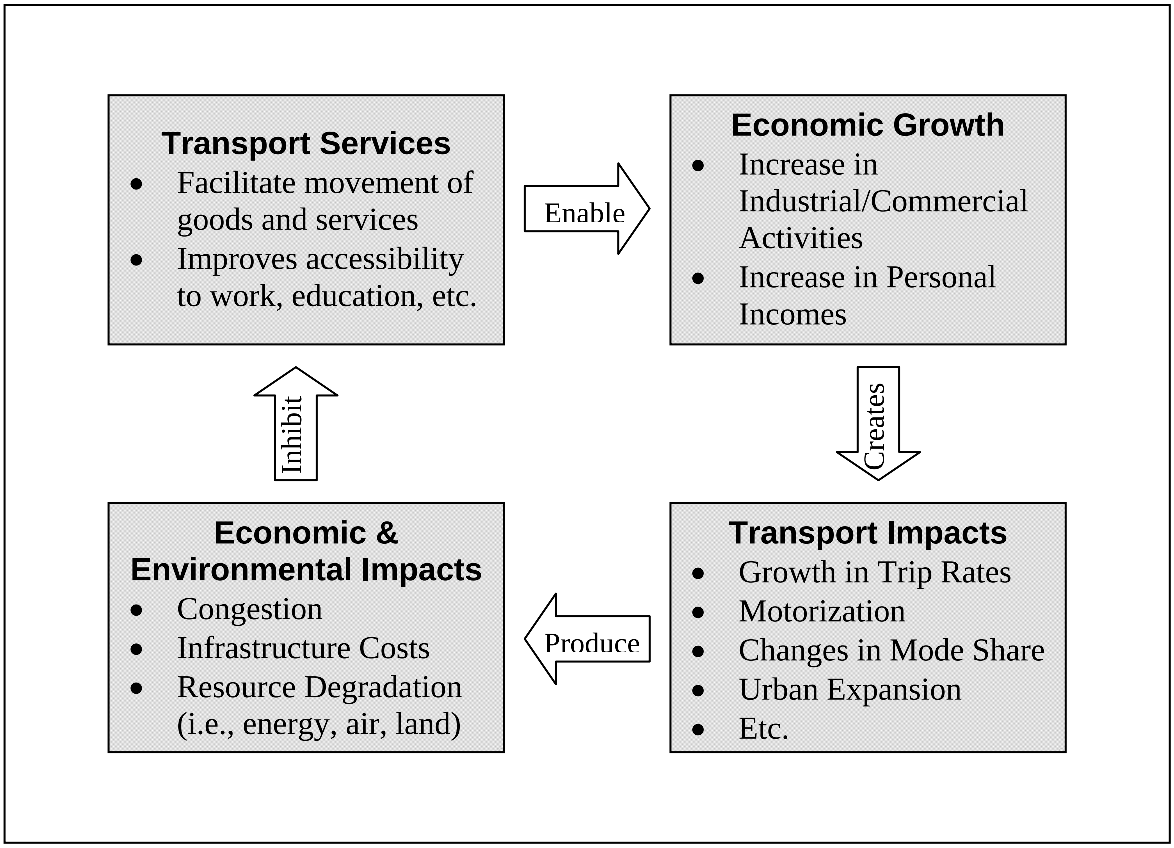
The term sustainability has plowed itself into mainstream development dialogue and literature, if not entirely into popular jargon. One does not need to look far to find references to sustainable housing, consumption, forestry, or agriculture. The concept of sustainability – meeting present needs while maintaining the capability to meet future needs – has proved useful 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 run the risk of watering it down. When sustainability becomes associated with more and more, does it start to mean less and less?

In the transportation sector, the use of the word sustainable dates back to the late 1980s (Replogle, 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 (e.g, 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 Chapter 3 emphasizes, this growth poses major planning and management challenges for a variety of urban sectors, such as housing, sanitation, water, *and* transportation.

Developing countries face, by definition, the fundamental *development* imperative – the need to improve the quality of life (human development) for large shares of their population. Transportation plays a major role in facilitating this development (see chapter 2) – providing for the movement of goods and persons that enables social and economic exchange. At the same time, development further fuels the demand for transportation – via increased trip rates, rising motorization, demand for speed, etc. – which, in turn, generates economic, social and environmental impacts. Such impacts can imperil the very benefits that transportation systems provide (see Figure 1).

Figure 1
The Urban Transportation Cycle and Sustainability Challenge



Source: Derived from Zegras, 1998.

On-going urbanization 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, we need transportation to continue to contribute to economic development and human welfare. On the other hand, we need to mitigate transportation's negative effects, both current - as exhibited by pollution and accidents - as well as future, seen through contribution to climate change risks and exhaustion of non-renewable resources. These developments, in other words, 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 presumably key elements for moving towards sustainable transport (e.g., Kennedy et al, 2005); that outline emerging innovations which apparently indicate promising movement in the right direction (e.g., Goldman and Gorham, 2006); or that develop and deploy analytical methods for assessing various land use and transportation strategies (e.g., 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, this Chapter 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 wants and needs. At the urban level, the interaction of the land use-transportation-social systems creates accessibility. Sustainable mobility, then, should aim to sustain these systems' capabilities to provide accessibility, over time.

Sustainability and sustainable development

The use of the word 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 (such as of fish, forests, soil), 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' (p.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*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 formalized 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 center stage, when the United Nations convened the Conference on Environment and Development in Rio de Janeiro (often referred to as the 'Earth

[1] Interestingly, however, Baumol recommends subsidized investments for such protections, not a lower general discount rate; beyond such 'irreversibilities,' Baumol suggests: 'the future can be left to take care of itself' (p. 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. Note, that this does not control for number of journals searched, nor the appearance of the term outside of the specific context implied here.

Summit') – organized 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 or institutional (see Brinkerhoff and Goldsmith, 1990 and Dimitriou and Thompson, 2001). But by extending sustainability to include all aspects of life and life-systems, we run the risk of having it simply slip out of our grasp as a useful construct. As Keiner et al (2004, p. 13) note: 'these terms [sustainability and sustainable development] are arbitrary and user-defined, and have lost their clear meaning.' 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, modernization.

If we return to a 'purely scientific' basis, we can think of sustainability in terms of carrying capacities, biological processes and ecosystem functioning. Can the system 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. But, 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, 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? Is sustainability really a new concept, or simply new language for various interpretations of a good 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 a basic management and planning problem: 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). For example, we can 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/m^3.' 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 begin with an operational definition of the concept. Whether the principles implied in the

Brundtland definition – intergenerational equity and use of resources – can be effectively operationalized remains to be seen, in part because sustainable development refers to multi-sectoral, transboundary, complex systems, undergoing continuous feedback, with randomness and non-linearities (e.g., 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, 2003a),[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 2003b; 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 may include some of the most important aspects related to sustainability.

Measuring Sustainable Development

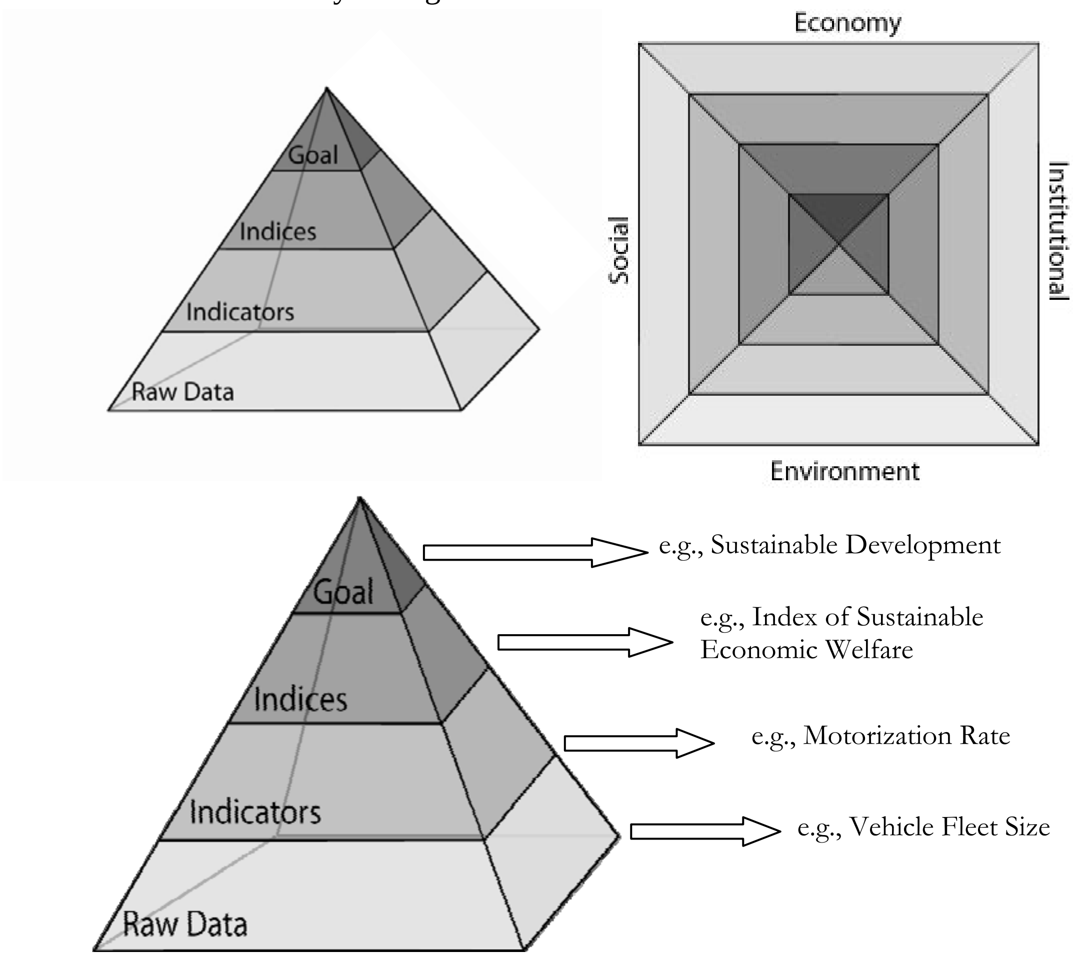
As no single agreed-upon operational definition of sustainability or sustainable development exists, neither does any single means of measurement. In fact, the plethora of sustainability definitions, initiatives, and projects seems matched by the number of efforts to measure sustainability. These range from macro-level, consolidated measures – typically some form of index – to multiple indicator frameworks, which often will aim to develop specific indicators in each of the sustainability 'dimensions' (Zegras et al, [2004] provide a review). A hierarchical perspective, suggested by the 'sustainable indicator prism' (see Figure 2), helps to 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, e.g., the United Nations' 58 indicators in the social, environmental, economic, and institutional dimensions (UN DSD, 2004); the urban level, e.g., the 'Sustainable Seattle' initiative's 40 indicators categorized by environment, population and resources, economy and culture and society (e.g., Newman and Kenworthy, 1999); and even the site-specific level, e.g., Hemphill et al's (2004) 52 indicators within five different categories (economy and work, resource use, buildings and land use, transport and

[3] Neumayer (2003b, 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.'

mobility, and community benefits) to measure the relative sustainability of urban regeneration schemes.

Figure 2
The Information Hierarchy through the Sustainable Indicator Prism



Source: Adapted from Zegras et al, 2004.

In attempting to measure sustainability via indicators, we face a number of challenges, including (Zegras et al, 2004): data availability, not only lack of the right information, but also the frequent mismatch between relevant functional and political/administrative units typical to data collection impacts (e.g., air quality); the need to capture the complexity of system feedback and interactions, including over time; and, future orientation, such that indicators can be forecast to estimate future conditions. 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: how can we 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. In 1989, 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' (p. 48). Many calculations of the ISEW (see, for example, Castañeda, 1999) suggest that a point of 'uneconomic growth' – 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 current 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 (2003a) 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 – i.e., assuming 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 – but it does not say anything about the relative benefit of the welfare-generating activity itself.

Sustainable transportation and sustainable urban mobility

One need not look far to find references to sectoral sustainability, such as sustainable housing, consumption, forestry, 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 transportation system, can we really analyze its sustainability? Can we further focus on urban <u>transportation</u> sustainability, or more narrowly still, urban passenger transportation sustainability? Such analyses, by necessity, impose artificial system boundaries and will lead to incomplete and perhaps misleading results. Nonetheless, from a practical implementation perspective, sectoral assessments may well be of most interest to responsible authorities (such as an individual ministry) (see, for example, Giovannini, 2004).

Before entering into an exploration of sustainable transportation, 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 – travel across space using the

[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.'
[5] 'Adjusted' or 'genuine' savings rates attempt to account for investments in and depletions of various capital forms (see Hamilton and Clemens, 1999).

transportation system. In a sense, we can consider mobility and transportation as synonymous; a transportation system can also be called a mobility system. The transportation and land use systems, in turn, help create accessibility (sometimes referred to as access) – the ability to realize work, education, shopping, and other daily activities. These basic definitions illuminate the fact that mobility is often a 'derived demand.' We consume mobility, not for mobility itself, but because it provides us with accessibility.[6].

Sustainable transportation: Briefly tracing the evolution of a concept

The idea of sustainability in the transportation 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 (Weaver, 1965) on and analysts' critiques (Jacobs, 1961) of the dangers of urban 'sprawl.' The first global energy crisis of the 1970s implicitly introduced sustainability due to concerns about the potential reliability of transportation's primary energy source, petroleum.[7] In their seminal book on public transportation 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 have a paper on urban form, transportation 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 on 'sustainable transportation strategies' for the developing world.[10] 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 transportation sector and he explicitly makes the link between transportation, basic human needs, and environmental effects.

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 transportation planning, including a focus on basic needs, cost recovery, and system integration. In 1991,

[6] In practice, this may not always be the case, since we sometimes travel simply for the sake of travel.
[7] During this era, the Transportation Reseach Board's (TRB, of the U.S. National Research Council) 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) (looking for the terms anywhere in a document) 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 privatization 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 to me (personal communications with both authors; May, 2005) that it was related to their early research on transportation, energy use, and urban development patterns in Australian cities (e.g., Newman and Kenworthy, 1980).
[10] The paper was written in 1987 and presented at the January 1988 TRB meeting; Replogle provided me with an electronic copy of the original 12/15/1987 paper.

Replogle (1991), building upon his earlier work, considers the concept of sustainability vital for transportation development, calling for ‘a more holistic approach to policy and investment planning’ 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.[11] By 1994, the Organization for Economic Co-operation 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). Thereafter continues a steady stream of reports and initiatives from the private sector, non-governmental organizations, and others which will, essentially, all embrace the multi-dimensional aspect of sustainable transportation. 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 conceptualization of sustainable transportation seems necessary and, in any case, logically follows the evolution of society’s concerns about transportation’s social, environmental, and economic effects. On the other hand, once sustainable transportation 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 transport creates space for us to transparently assess the trade-offs and synergies between economic, social, and environmental effects. But, if sustainable transport loses a rigorous meaning, it can easily be co-opted as a ‘smokescreen,’ hiding ‘business-as-usual’ practices. What does sustainable transportation really mean?

Sustainable transport: Examples of definitions and principles

Attempts to concisely review the many activities related to sustainable transportation face the challenge that a single document may not clearly differentiate between goals (an articulation of values), objectives (a measurable end), indicators (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’ – guided by economic and financial principles (‘economic viability, financial viability, and efficiency’) together with environmental viability and ‘equitability, distributional viability, or effectiveness’ or the ‘the degree to which the

[11] The document, as cited in Rienstra and Piers, (2000), was titled *The Future Development of the Common Transport Policy: A Global Approach to the Construction of a Community Framework for Sustainable Mobility*.

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.

Perhaps predictably, the World Bank's 1996 policy document takes an economic-oriented focus, emphasizing the efficient use of resources and proper maintenance of assets (economic and financial sustainability); full 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 fulfillment of pollution guidelines and international goals related to climate change and stratospheric ozone depletion.

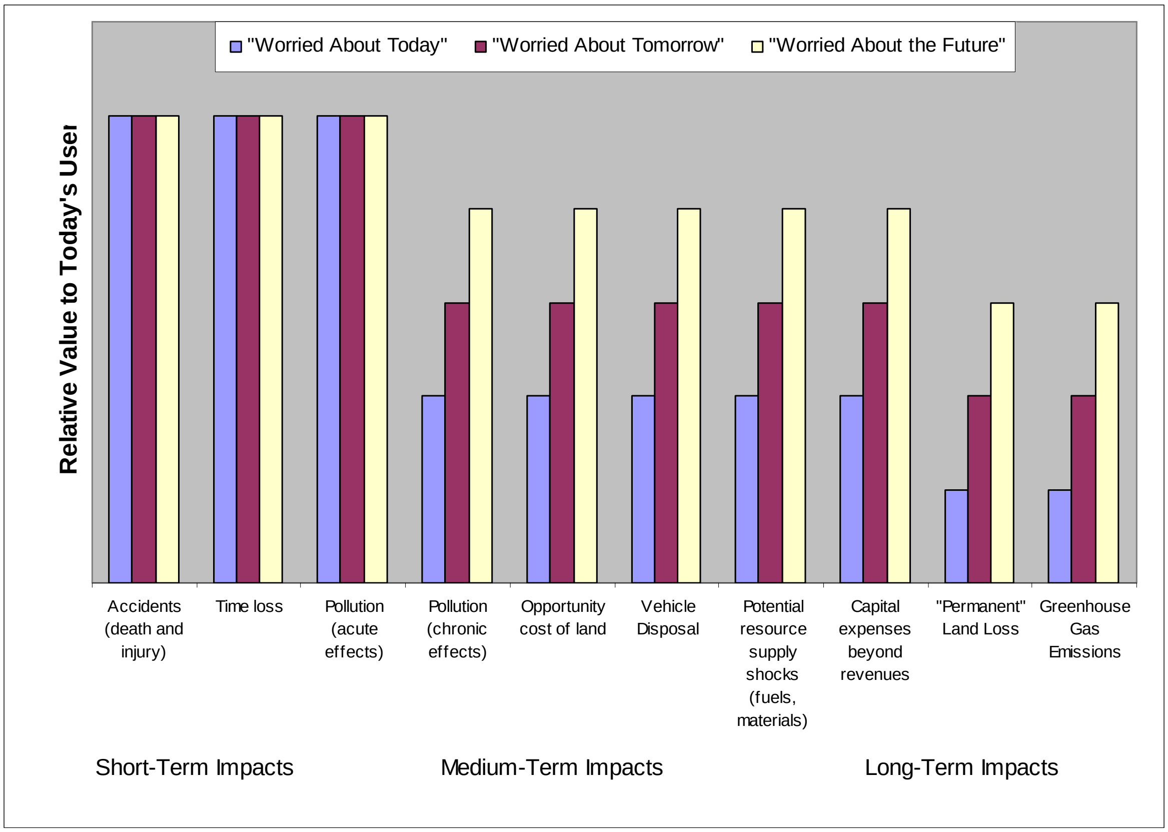
The Canadian-based Center for Sustainable Transportation (CST) offers an oft-cited definition, which – similar to the OECD EST – builds on the concept of access, identifying the need to fulfill 'basic access needs' within human, ecosystem, and economic/financial limits and in consideration of equity 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: '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, PROSPECTS, Minken et al (2003) 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 operationalizes transportation sustainability as an optimization problem: maximizing transportation's economic efficiency subject to constraints, both environmental constraints and, possibly, those related to 'livability' (the built environment). Schipper (1996), on the other hand, proposes that transportation 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, cultural), and equity (inter- and intra-generational).

Values, system complexity and boundaries

As a multi-dimensional construct, sustainable transportation, like sustainable development more broadly, becomes complicated and possibly confused. We are dealing with resource constraints over multiple time horizons with uncertain impacts. Furthermore, sustainability apparently requires that we ensure that future generations enjoy, at minimum, the opportunity for the same transportation benefits as we do, <u>and</u> that those benefits have some fair distribution today. The latter point resonates at both the global and local levels. For example, the industrialized countries enjoy greatly higher levels of total mobility than developing countries (e.g., IEA, 2004); these mobility levels also partly account for the industrialized world's overwhelming responsibility to date for the accumulated levels of anthropogenic greenhouse gas emissions in our atmosphere – a potential threat to our existence on the planet. At the local level, the distribution of mobility benefits and costs also tends to favor wealthier segments of the population, particularly but not exclusively, within the developing countries.

Figure 3
A Stylized Representation of a Hypothetical Person's Values Today: Relation to Transportation Sustainability and the Role of a Theoretical 'Discount Rate'



As discussed above, in practice sustainable development inevitably involves value judgments. The transportation case exemplifies this reality, as Figure 3 attempts to show in a highly stylized diagrammatic way. In the figure, each bar represents a hypothetical person's level of concern today for various potential transportation 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 – for example, 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 (longer term).[12] 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.[13] 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.' For example, do we put ourselves and/or others at risk of death or injury (or illness) so we are not late for work?

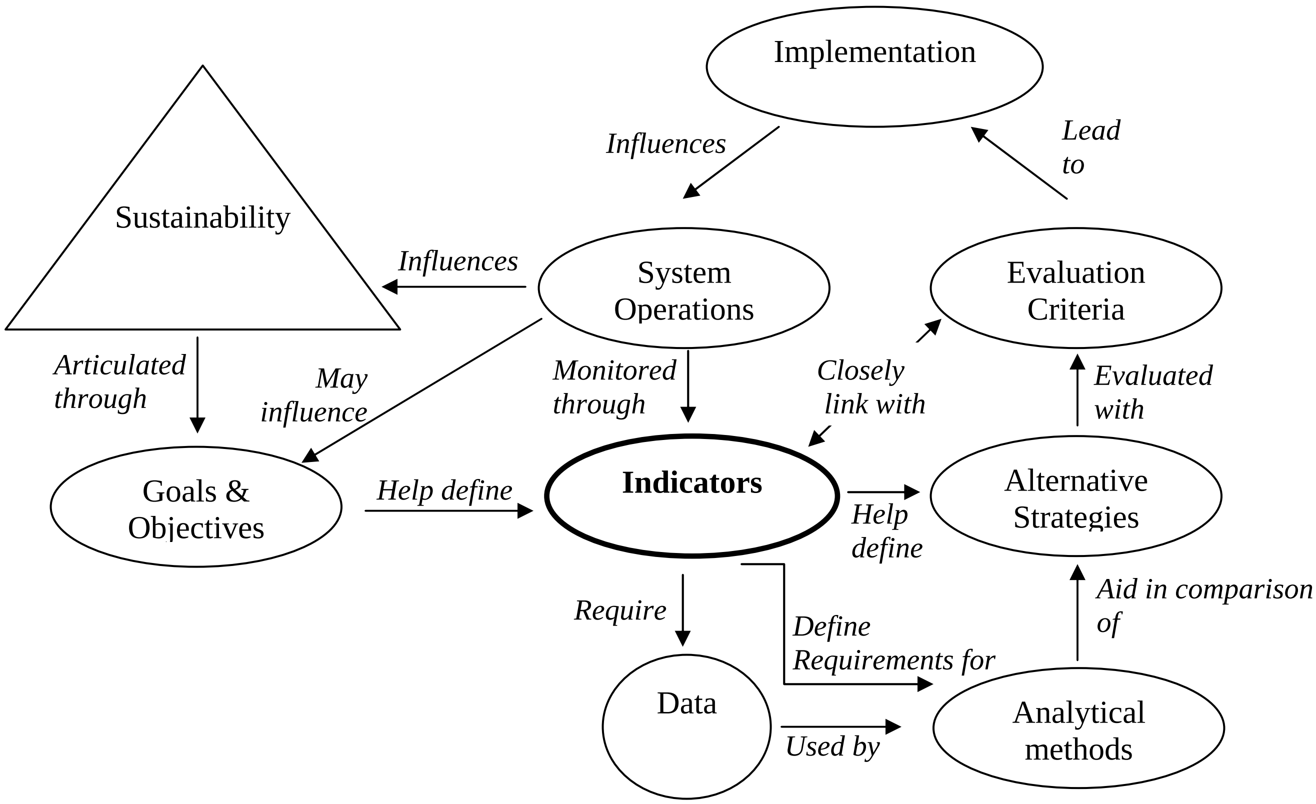
Another factor complicating efforts to operationalize the sustainable transportation concept in a specific context comes from the need to impose boundaries. While often necessary analytically, by sectorally bounding the transportation system we might ignore the fact that transportation enables other activities, such as consumption patterns (shopping at malls, eating strawberries in wintertime), which might be, on a larger scale, 'unsustainable.' This relates to fundamental debates about the sustainability of our global economy. The metropolitan level displays analogous effects, as, for example, 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-scale transportation we might miss sustainability challenges arising from a city's interactions beyond its region – such as via trade, tourism, and so on – and impacts well-beyond its borders. Furthermore, consider the impacts of roughly stable average travel budgets (i.e., percentage, on average, of income and time spent on travel) (e.g., 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 transportation?

Transportation planning has long used indicators, such as level of service (LOS), to assess system performance. As depicted in Figure 4, in an idealized transportation 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 transportation planning.' Appropriate (valid and reliable) indicators will vary depending on the scale of the analysis – such as an individual facility, a corridor, a regional network (Ewing, 1995) – and on the ultimate goals, although common indicators can often apply to several different goals and/or scales of analysis.

[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 with climate change, under the belief that he will be able to bequeath to his future generations the wealth needed for protection from possible negative effects. Furthermore, cultural, education and/or other factors may have more influence on future concerns than wealth.

Figure 4
The Role of Indicators in the Transportation Planning Process



Source: Adapted from Meyer and Miller, 2001.

In performance-based planning, indicators are closely tied to project evaluation criteria (Figure 4). If 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 transportation follows the growing concerns about transportation's increasingly recognized broad-ranging impacts (as discussed above). In terms of project evaluation, transportation planning has a long history of monetarily quantifying benefits and costs. However, by at least the 1960s, transportation planning – in part due to legal requirements – began incorporating a broader range of issues into the planning process, such as air quality, energy consumption, and community cohesion (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, e.g., potential violations of urban air quality standards (see Howitt and Altshuler, 1999). Dimitriou (1992) suggests the changes in fundamental goals and objectives of urban transportation 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 transportation evaluation criteria and sustainable transportation 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 (e.g., Vickrey, 1969).[14] By the mid-1970s, we can find attempts to quantify transportation 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) reviews some select efforts and their 'pitfalls'). The 'full-cost' movement ties back to Schipper's (1996) sustainable transport definition, mentioned above. By quantifying such costs, we can evaluate, in theory, projects' and programs' broader impacts via a common metric (money). Employing such a tack to measure transportation sustainability reflects the 'weak sustainability' perspective (see discussion above), since efforts to monetize all effects suggest some sense of their inter-changeable/substitutable nature. It also presumes that the relevant impacts can be quantified and comparably monetized.

Sustainable Transport Indicators and Indices

Efforts to measure sustainable transportation via indicators now appear innumerable. At the global level, as part of its 2001 global mobility assessment, the WBCSD proposed 12 indicators, grouped into categories of measures to be increased and reduced, and provided a qualitative and fairly sobering assessment of current trends (Table 1). Perhaps due to the relative vagueness of many of these indicators (e.g., 'appropriate mobility infrastructure'), in their follow-up study, the WBCSD (2004) proposed a modified indicator set (Table 2). These measures partly reflect a focus on tangibles, particularly those items 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 further below), and self-serving (e.g., defining accessibility in terms of individual access to motorized transport). The WBCSD's partial 'forecast' of indicators (see Table 2) leads to the conclusion 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 goals and actions.[15] The WBCSD indicators and forecasting efforts reveal: (1) the difficulty in operationalizing many of the chosen indicators; (2) questions about the sustainability significance to be measured by some of the indicators (e.g., lower goods costs); and (3) no indication of relative importance or comparability among the different indicators.

[14] Vickrey first analyzed 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, DC 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 highlights equity and accessibility concerns

Table 1
An Industry Perspective: WBCSD's Indicators of 'Sustainable Mobility"

	Industrialized world		**Developing world**	
	Level	**Direction**	**Level**	**Direction**
Measures to be increased				
Access to means of mobility	☑	+	☒☒	+
Equity in access	☒	-	☒☒	?
Appropriate mobility infrastructure	☒	-	☒☒	-
Inexpensive freight transportation	☑	+	☒	+
Measures to be reduced				
Congestion	☒	-	☒☒	-
'Conventional' emissions	☒	+	☒☒	-
Greenhouse gas emissions	☒☒	-	☒	-
Transportation noise	☒	+	☒☒	-
Other environmental impacts	☒	-	☒	-
Disruption of communities	☒	-	☒	-
Transportation-related accidents	☒	+	☒☒	-
Transportation's demand for nonrenewable energy	☒☒	=	☒☒	+
Transportation-related solid waste	☒	+	☒	?

Source: WBCSD, 2001.

Key:

☒☒ measure is at unacceptable/dangerous level
☒ measure is at a concerning level and needs improvement
☑ measure is at acceptable level or becoming so
\+ situation seems to be moving in desired direction
\- situation appears to be deteriorating
= no clear direction apparent
? inadequate information to render judgement

Table 2
An Industry Perspective II: WBCSD’s Modified Global Indicators and Partial ‘Forecast’

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

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

Perhaps the challenge to effectively operationalizing 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. The EU-funded SPARTACUS project looked at sustainable transportation in 3 cities in Europe (Helsinki, Naples, Bilbao). In a forward-looking analysis, assessing the effect of policies on urban transportation sustainability, the 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 2, 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 3
Indicators Used in the SPARTACUS project.

Sustainability Dimension	**Area**	**Indicators**
Environmental Indicators	*Air Pollution*	Emissions of greenhouse gases, acidifying gases, organic compounds; Consumption of mineral oil products
	Consumption of Natural Resources	Land coverage; Consumption of construction materials
Social Indicators	*Health*	Exposure to particulate matter (PM), nitrogen dioxide (NO_2), carbon monoxide (CO); Exposure to noise; Traffic deaths; Traffic injuries
	Equity	Justice of exposure to PM, NO_2, CO; Justice of exposure to noise; Segregation
	Opportunities	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
Economic Indicators	*Costs/Benefits By Type*	Transport user benefits; Transport resource cost savings; Transport operator revenues; Investment financing cost; External cost savings
	Overall Indicators	Total net benefits (sum of costs/benefits by type); Economic Indicator (total net benefits per capita)

Source: Lautso and Toivanen, 1999.

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 3-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 (e.g., 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.

Table 4
PROSPECTS' Simplified Indicators List

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

Source: May et al, 2001.

Examining a single metropolitan area, Kennedy (2002) takes a comparative modal approach, aiming to assess the relative sustainability of auto travel versus public transport travel in the Greater Toronto Area (GTA), Canada. He adopts a macroeconomic perspective, looking at transportation costs from the perspective of the region (quantifying the value of the GTA's trade relating to transportation) 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 kilometers of travel (VKT) targets for 2010 as the primary sustainability indicator. They go on to look at variation in automobile 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: (1) the overwhelming number of indicators derived and (2) 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 transportation, 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 2). 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.[16]

Sustainable mobility: Towards a consolidated, operational 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 conceptualization of sustainable transportation – including at least the economic, social, and environmental dimensions –

[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.

effectively covers the primary relevant societal concerns, it also runs the risk of watering down any clear meaning of sustainable transportation.

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

Such efforts 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 direction, Geurs and van Wee (2004) define accessibility as the 'extent to which the land-use and transportation systems enable (groups of) individuals to reach activities or destinations' (p. 128). This definition clarifies accessibility as the benefit derived from mobility and 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).

Table 5
Accessibility: Contributing Factors

Factors	**Effect on Accessibility (all else equal)**
Transportation	Improved with more links, faster or cheaper service
Spatial distribution of "opportunities"	Improved if proximity of opportunities is increased
Individual (personal/firm) characteristics	Improved with physical, mental, economic ability to take advantage of opportunities
Quality of opportunities	Improved with more, or better, opportunities within same distance/time
Information and communications technologies (ICTs)	Improved with more, more rapid, and more 'realistic' connections

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 hinges critically upon broad expansion of access to opportunities (educational, social, employment, health care and so on). Referring to Sen's (e.g., Sen, 1998) concepts of 'functionings' (everything that an individual may wish to be or do) and 'capabilities' (to achieve the functionings they 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' & 'Capabilities': Mapping Sen's Human Development Concepts to Accessibility and Mobility

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

Sustainable mobility: An operational definition

The accessibility-as-benefit orientation leads to a concise but comprehensive operational definition of sustainable mobility, derived directly from the 'economist's-oriented' view of sustainability as the capability to 'maintain the capacity to provide non-declining well-being over time' (as discussed above; Neumayer, 2003b). Drawing from this perspective and the above discussion leads to an operational definition of sustainable mobility as:

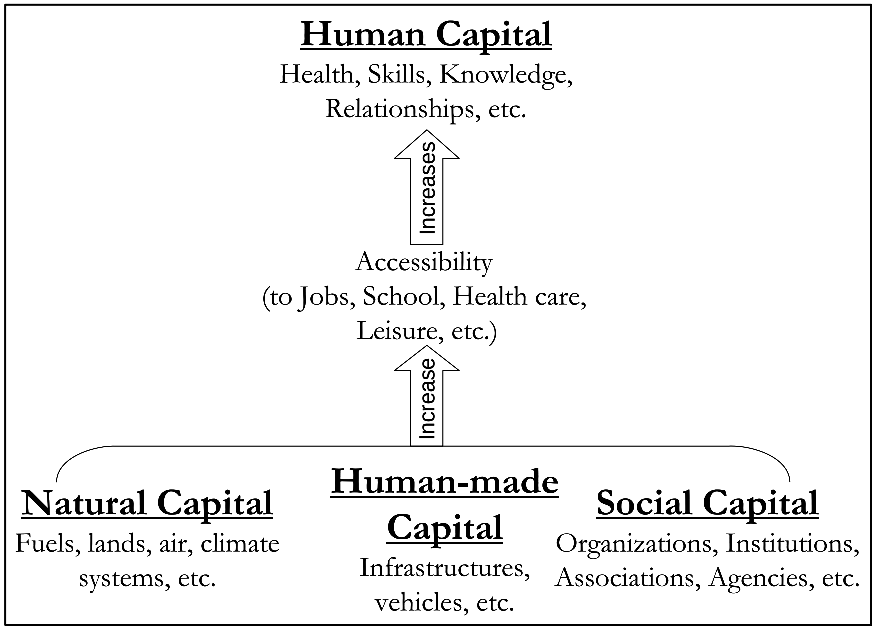
maintaining the capability to provide non-declining accessibility in time.

Relative to the approaches that conceptualize sustainability (such as the three 'dimensions'), this definition may be most consistent with the 'capital approach,' as discussed above (e.g., Neumayer, 2003b). Increasing accessibility (in passenger transportation) increases human capital – a positive contribution to sustainable development. At the same time, however, increasing accessibility requires depletion of other sources of capital: natural (in the form of fuels, lands, air and so on), social (in the form of, for example, the institutional and bureaucratic resources dedicated to accessibility creation), and man-made (such as infrastructures and vehicles) (see Figure 5).

Accessibility provides well being to current generations, but sustainability requires that we create current accessibility without damaging the possibilities for future generations to enjoy, at least, the same accessibility (well being) levels. In other words, sustainable mobility requires that today's mobility benefit (accessibility) does not come at the cost of reduced capacities to provide future welfare-increasing opportunities (see Figure 5).[17]

[17] Derived from Smith (2004) who does not apply it to mobility, per se.

Figure 5
'Building' on Capital: Accessibility and Sustainable Mobility



In this way, sustainable mobility can be manageably conceptualized as a balancing act between the expansion of accessibility (to, for example, health care, education) and the scarcity of resources (natural, social, and man-made capital). Human capital creation (accessibility) thus rests upon the other capital elements, as depicted in Figure 5. This depiction of sustainable mobility still suffers imperfections. For one, it incorrectly implies no feedback between capital sources. For example, increased human capital likely increases the possibilities to generate human-made or social (or even *re*-generate natural) capital (the 'weak sustainability' perspective, see above). In addition, Figure 5's very structure – with human capital on the top – might be interpreted as connoting some hierarchy of importance, with human capital the most important. While not necessarily the intention of the Figure, situating human capital above the other sources of capital does reinforce the idea that, ultimately, sustainability is a human-oriented enterprise: we want to sustain our existence and the possible existence of future generations.

This proposed operational definition of sustainable mobility leaves some issues unresolved, as in the case 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 distribution of benefits (accessibility) or costs among today's system users, though such incidence could be assessed via measurement.
- Intra-sectoral value of resource use. The definition does not, necessarily, enable a direct evaluation regarding the value of resources used to create accessibility versus these resources' use towards other ends (e.g., in other parts of the economy).

In short, the proposed definition ultimately remains as a more general form of guidance in understanding relative sustainable mobility. Ultimately, the definition allows us to potentially recognize a <u>more</u> sustainable mobility: higher accessibility at lower total transport throughput, *ceteris paribus*. It does not tell us, however, whether this mobility will actually <u>be</u> sustainable.

Sustainable mobility: Measurement

Despite its shortcomings, the proposed operational definition of sustainable mobility allows us to zero in on an approximate and concise means of measurement. Considering accessibility akin to GDP or HDI, then we can think of a sustainable mobility system as one that increases human capital, but 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 above. For example, Daly (2002) suggests that development 'might more fruitfully be defined as more utility per unit of throughput' (p. 48); we can think of sustainable mobility in exactly the same way, as:

<u>providing more utility, as measured by accessibility, per unit of throughput, as measured by mobility.</u>

This conceptualization of sustainable mobility reflects the subtle shift implied by the accessibility-orientation of the term: accessibility is the goal, and mobility is the throughput cost of achieving the goal. Any mobility throughput represents depletion of capital stocks.[18] For example, walking wears out shoes and consumes energy (calories). Driving a car or riding the bus implies depletion of: the resources that went into the production and utilization of the vehicle; the energy used (both embedded and motive); land 'consumed' by 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 minimizing stock depletion. Rather, it means that we want less total mobility consumption per accessibility derived. For the same level of accessibility, walking is more sustainable than driving (or taking the bus, or biking). For motorized 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.

We can proxy mobility throughput as some kind of weighted measure of distance traveled, 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

[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 kilometers traveled (VKT) (mobility throughput) as a key (they suggest <u>the</u> key) indicator. Note that Black (2000) and Black (2002) are different authors.

(such as a Metro) may 'consume' less of the airshed 'stock'; and so on. As an initial indicator, then, I propose vehicle distances traveled (VDT) to represent the capital drain.[19] VDT could subsequently be differentiated according to technology, size, even time of day of travel and should reflect local concerns and priorities (and, for example, discount rates).[20]

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:

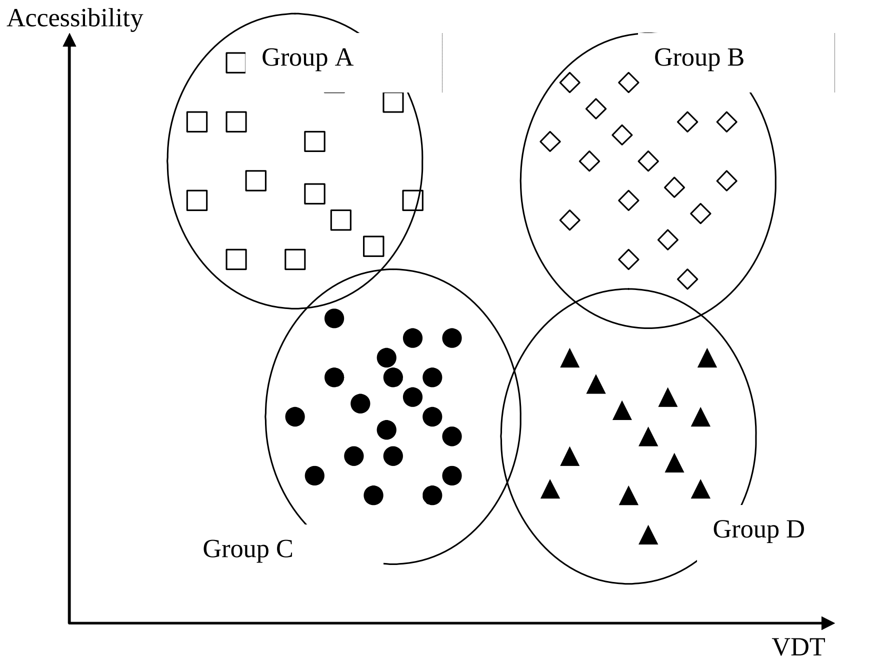
<u>Index of sustainable mobility = accessibility - mobility throughput</u>

Whether such an equation could actually be calculated depends, naturally, on whether the components could be measured in comparable units. Monetization seems a logical choice and in this case we see that sustainable mobility begins adhering to the 'full cost school' of sustainable transportation (as discussed above): in a sustainable transportation system the beneficiaries pay the full social costs, including those imposed on future generations (see, again, Schipper, 1996). Several controversies and difficulties lie in this path (despite some important progress; see Delucchi, 1997), not least of which might be doubts as to whether we can monetize 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, 2003b).

If, instead, we draw from the HDI/genuine savings framework (Neumayer, 2003a), then we can envision a sustainable mobility 'trade-off' space (see Figure 6). From Figure 6, we can make some relative (not absolute) judgments regarding sustainable mobility.[21] Assume the symbols represent individuals which might be grouped by some characteristic (e.g., neighborhood). In this case, 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, telling us what is more sustainable and pointing us in the right direction. Still, a major question remains: how do we measure the benefit: this idea of 'accessibility'?

[19] Others have suggested and/or used vehicle distances traveled as an important indicator. McCormack et al (2001) say travel distance 'is often a primary indicator of transportation activity' (p.27); Black et al (2002), in exploring indicators of transportation sustainability in Sydney, Australia, use vehicle kilometers traveled (VKT), 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] I thank Jinhua Zhao for the conversation that led explicitly to this framework.

Figure 6
Hypothetical Sustainable Mobility 'Trade-Off' Space



Accessibility: Measurement and usage in the sustainable mobility framework

Accessibility measures have a long history in planning, geography and related disciplines (Wachs and Kumagai, 1973). Not surprisingly, accessibility measures have been subject to extensive and multiple reviews over the years (Pirie, 1979; Handy and Niemeier, 1997; BTS, 1997; Journal of Transportation and Statistics, 2001; Geurs and Ritsema van Eck, 2001). Geurs and van Wee (2004) offer a useful framework for understanding accessibility, which Table 7 builds upon to include a basic assessment regarding suitability for measuring accessibility as it relates to the sustainable mobility concept.

All of the accessibility measures have their strengths and weaknesses, depending partly on the purpose/application. Infrastructure-based accessibility measures, such as level of service (LOS), may be the most commonly recognized. Such measures offer a limited view of accessibility as understood in its broader meaning here. Knowing travel times or speeds without any information on the opportunities (that is, activities) available to travel to provides an incomplete picture of accessibility. Such metrics focus on throughput (capital drains).

Table 7
Basic Categorization of Accessibility Measures

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

Source: Extended from Geurs and van Wee, 2004.

The 'ideal' accessibility measure in the proposed sustainable mobility framework should reflect all the relevant aspects contributing to welfare. These include (see, also, Table 5): individual characteristics, including preferences, 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, again, safety, convenience, aesthetics, and so on (Ramming, 1994; Bhat et al, 2000; Geurs and van Wee, 2004). Furthermore, to be useful as a policy and planning tool, the measure must be operational, interpretable and easily communicated (Geurs and van Wee, 2004). Based on these criteria, no accessibility measure would be perfect.

Attractive theoretical features of utility-based accessibility measures include their ability to reflect individual preferences as measured by individual choices (consistent with Sen's 'human freedoms' perspective; Table 6) and their direct links to traditional measures of consumer surplus (e.g., Small and Rosen, 1981). Those measures link back to the welfare-based definition of sustainable mobility presented above. In practical terms, utility-derived accessibility measures come from discrete choice models, widely applied in transportation system analyses (e.g., to predict mode choice). Ben-Akiva and Lerman (1979) explicitly link the discrete choice modeling framework to the accessibility concept, defining accessibility as 'simply the utility of the choice situation to the individual' (p. 656).[22] 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 AM journey to work,

[22] In practical terms, since utility is random (hence the 'random utility' label given to discrete choice models) 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.'

while Limanond and Niemeier (2003) use a similar approach to measure variations in neighborhood accessibility. Martínez 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 – forming an 'activity-based' method. Activity-based analysis represents the 'cutting edge' of travel behavior research (e.g., Ben-Akiva et al, 1996) which 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, accounting for the practical constraints implied (work hours, family schedules, etc.). An activity-based approach provides obvious theoretical benefits for deriving meaningful accessibility measures consistent with Sen's 'functionings' and 'capabilities' (Table 6). Practically, some explorations in deriving 'activity-based' accessibility measures exist. For example, Dong et al (2005) present an activity-based accessibility measure in Portland (OR, USA). They demonstrate estimated user benefits due to changes in the transportation system (e.g., congestion pricing) that drive decisions to change activity patterns (e.g., work at home). This provides an accessibility measure that is not mobility-biased, effectively accounting for the accessibility benefits that can still be realized in the face of non-travel choices. While theoretically attractive, the activity-based measures require complex data sets on individual activity patterns and non-trivial modeling implementation.

Accessibility as a current performance measure

Despite its common use in research and fairly common use in relevant official rhetoric, accessibility does not find much currency as a formal performance measure for authorities. Bhat et al (2000) found limited examples of the use of accessibility measures among U.S. 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: access to the transport 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) (ECMT, 2004; UK CFIT, 2004). The recommendations suggest qualitative assessment criteria for these categories, and they consider that cost-benefit analysis takes into account 'most aspects of accessibility' (UK CFIT, 2004, p. 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 UK appraisal frameworks – techniques for estimating 'accessibility' were judged as 'fairly crude' compared to cost-benefit analyses, which might lead to decision-makers not focusing on these criteria (ECMT, 2004, p. 177). This disconnect between theoretical and practical needs may well be one of the reasons that most efforts to operationalize sustainable mobility have not taken on a more explicit accessibility orientation.

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 bluntly, the great majority of developing world residents suffers a severe lack of accessibility. 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. That is, mobility represents a throughput – a valuable means to an end, but rarely the end itself. The accessibility-orientation of sustainable mobility enables us, in theory, to act on the range of possible interventions to improve accessibility (Table 5).

For developing world cities, the range of sizes, incomes, cultures, histories, environmental/social challenges and so on 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, Medellín versus Mumbai. One could effectively argue that these and most other cities face such dire transportation 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 clear means of measuring it, we run the risk of letting the concept 'run amok' – in other words, sustainable transport can quickly come to mean all things to all people and lose any real value.

Implementing the proposed sustainable mobility framework will require effort by governments, citizens, international organizations 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 realized or cumulative opportunity measures. Other cities, with sophisticated transportation and land use modeling 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 and the discrete choice tradition (see Martínez and Donoso, 2001), should be able to derive rigorous, utility-based measures of accessibility for incorporation in program and project assessment. On the mobility 'throughput' side, impact measures – in a full well-to-wheels, cradle-to-grave framework (including, for example, embedded energy of infrastructures and vehicles; eg, Schäfer et al, 2006) – 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 (eg, institutions and analytical techniques, capabilities and data), which requires investments now. Yet, here the developing world (and, in fact, much of the 'developed' world) 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 transportation concept has followed the path of sustainable development more broadly. At the least, the modern sustainable development dialogue attempts to more firmly situate a number of development dimensions on more equal footing and explicitly recognize potentially exhaustible resource stocks. In transportation, the ubiquity of the sustainability idea can be seen in relevant initiatives originating from the public sector, the private sector, non-governmental organizations, academia, etc. The efforts, often highly ambitious, have not been matched by a common language and they sometimes confuse definitions, principles, and prescriptions. This may partly result from the complexity of the concept, which typically requires the imposition of boundaries (in space, scale and within the sector itself), which 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 mobility as maintaining the capability to provide non-declining accessibility in time. Accessibility essentially represents the welfare that people derive from the transportation-land use-social system interactions: access to daily needs and wants that allow people to survive and thrive. Capability can be thought of in terms of stocks: 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 doing so, it depletes other capital stocks. The rate of that depletion depends on mobility, and will vary based on vehicle technologies, time-of-day of travel, occupancy levels, operational conditions, among many other influencing factors.

This normative sustainable mobility framework allows us to make relative judgments. A more sustainable mobility system 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 transportation ‘full cost’ analysis. In the latter approach, one could imagine an estimable sustainable 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 mobility planning possibilities.

The proposed operational definition of sustainable mobility provides a simple and straightforward, albeit not necessarily obvious, way of conceptualizing sustainable mobility. The framework, which builds primarily from existing terminology and analytical tools should be intelligible to transportation 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 (of accessibility and mobility throughput). Only then will we truly begin 'mainstreaming' sustainable transportation.

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