SUSTAINABLE TRANSPORT INDICATORS AND ASSESSMENT METHODOLOGIES

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Sustainable Transport: Linkages to Mitigate Climate Change and Improve Air Quality

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Christopher Zegras
Assistant Professor of Transportation and Urban Planning
Department of Urban Studies and Planning
Massachusetts Institute of Technology
77 Massachusetts Avenue, Room 10-403
Cambridge, MA 02139
Tel: 617 452 2433
Fax: 617 258 8081
czegras@mit.edu

1. Sustainable Development: Background to Measuring and Assessment

Measuring any concept – such as sustainability or sustainable development – requires, first, an operational definition. An operational definition should provide specific guidance on how the concept will be measured (Meier and Brudney, 2002). For example, an operational definition for meeting air quality standards for fine particulate matter ($PM_{2.5}$) is: "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 $\mu g/m^3$." In this case, the operational definition establishes how the concept, air quality compliance (for fine particulates), will be measured. Mean $PM_{2.5}$ concentrations serve as an *indicator* of compliance with air quality standards.

Regarding sustainable *development*, probably the most oft-cited definition comes from the Brundtland Report: "to ensure that [development] meets the needs of the present without compromising the ability of future generations to meet their own needs." Rather than an operational definition of sustainability the Brundtland definition offers more a general statement of principles. The economists' perspective offers one tractable approach to arrive at an "operational definition" of the sustainability concept. If we simply define sustainability as the capability to "maintain the capacity to provide non-declining well-being over time" (Neumayer, 2003), then we can utilize the economist's perspective of maintaining the value of total capital, including human, natural, social, and manufactured capital. By the mid-1990s, the World Bank which was already claiming that it would only fund projects that were "sustainable in *economic, environmental,* and *social* terms (Serageldin, 1996, p. 2 [emphasis in original]) and, ostensibly, was defining 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 clearly suffers from measurement challenges including, but not limited to, issues of how to measure the social capital "stock." Note, also, there are still two competing – both non-falsifiable – positions relating to the substitutability of capital: "weak" sustainability (natural capital can be substituted by other forms of capital) and "strong" sustainability (rejecting such substitutability) (e.g., Neumayer 2003).

2. Defining and Measuring Sustainable Transportation?

This discussion is more than pedantic when we enter into "sector-specific" efforts to measure sustainability. Difficult questions can be raised as to whether there is any real value in attempting to analyze a sector's "sustainability." Beyond attempting to analyze or assess "urban sustainability," can we further attempt to look at transport sustainability, or more narrowly urban transport sustainability, or more narrowly still, urban passenger transport sustainability?

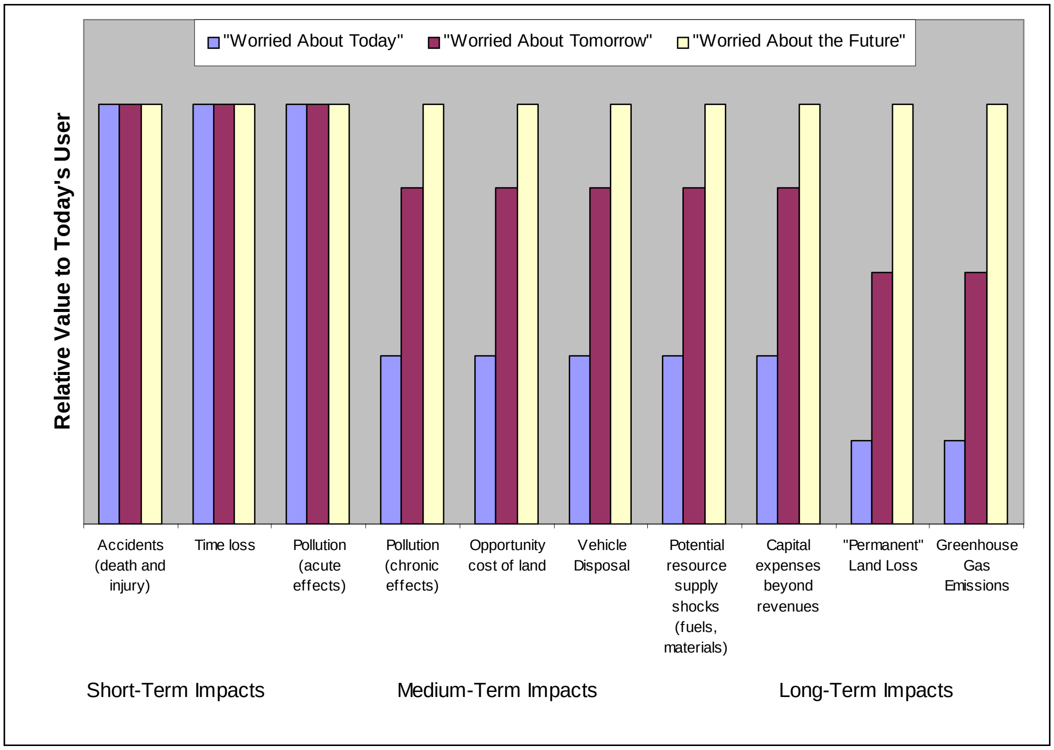
Of course, many of the problems that people today associate with threats to the "sustainability" of modern transportation – air pollution, traffic safety, sprawling urban development patterns, automobile dependence, etc. – have been recognized for 50 years or more (CARB, 2004; Pushkarev and Zupan, 1977; Weaver, 1965). The word sustainable transportation – as understood in the post-*Limits to Growth* context – emerges in the immediate wake of the Brundtland report, with Replogle's (1987) paper at the 1988 Annual Meeting of the Transportation Research Board on "sustainable transportation strategies" for the developing world, explicitly making the link between transportation, basic human needs, and environmental effects. Since then, we have seen an ever-increasing number of efforts searching to define, design, and measure sustainable transport (e.g., UN DSD, 1992; OECD, 1996; World Bank, 1996; WBCSD, 2001; Kennedy et al, 2005; Goldman & Gorham, 2006; etc.). Today one would be hard-pressed to find a transportation research project, conference, or increasingly even business propaganda that, in one form or another, did not include the word "sustainable." But, while many of us now use the word almost reflexively, what does it <u>really mean</u>: lower emissions? of local or global pollutants? Lower congestion? Higher accessibility? Fewer accidents? Decreased spending on transport costs? Does it mean all of these? Some of these? A combination of these, and if so, in what doses? How can we know we are being "sustainable" and, then, what can we do about it?

A great degree of complementarity (e.g., nearly all comprehensive efforts refer in one form or another to the so-called "Three-E's" – economy, environment, equity) tends to exist among the wide-ranging sustainable transport explorations/efforts. But, actual definitions tend to vary and few if any, *operational definitions* are proposed. The OECD (2002), for example, specifically defines a sustainable transport system based on fulfillment of WHO guidelines for air pollution, noise levels, acidification, and eutrophication, as well as general international goals related to climate change and stratospheric ozone depletion. Schipper's (1996) proposal, that transportation is "sustainable" when the beneficiaries pay their full social costs, including those paid by future generations offers, theoretically, an operational definition (and fully in-line with the "full cost school" of transportation analysis, particularly en vogue in the 1990s…), yet the challenges to implementing such a measurement approach are more than daunting.

2.1. Sustainable *To* Whom and *For* Whom?

A main challenge to operationalizing sustainable transport comes from the fact that we are dealing with resource constraints over multiple time horizons with uncertain impacts; furthermore, we want to ensure that future generations have the same benefits from transportation as we do; while also ensuring some fair distribution of benefits today. Asking for some trade-off in inter-generational equity becomes particularly challenging in the developing countries, where sustainability literally is a day-by-day reality for millions of people – living on less than one dollar a day makes it difficult to concern oneself with possible effects tomorrow.

Figure 1. Stylized Representation of a Person's Values Today as they Relate to Transportation and Sustainability and the Role of A Theoretical "Discount Rate"



Source: Zegras, 2005.

Figure 1 provides a stylized representation of the concerns that a hypothetical person today faces, and how much she "values" those concerns based on her own sense of time importance (i.e., discount rate) and the approximate time-frame of potential impacts. Note that the time-frame of impacts generally correlate with uncertainties – for example, we are, typically, more certain about the acute effects of local air pollution (short term) than we are about the possible effects of climate change (long term). We also might expect (as from basic economic theory) a relation between discount rate (i.e., how much we value the future) and wealth; but, this may not always be the case. To current users (or contemporaries affected by current system use) the threats to immediate sustainability are short term effects; i.e., the main threats to sustainability are those that impact our immediate existence, e.g., accidents that kill or maim us, pollution that can make us acutely ill, loss of time that might make us late for work, etc.. We do not necessarily make rational trade-offs among these threats – do we put ourselves and/or others at risk of death or injury (or illness) so we are not late for work? – and these tradeoffs are both internal (related to "our own" sustainability) and external (impacts on "other's" sustainability).

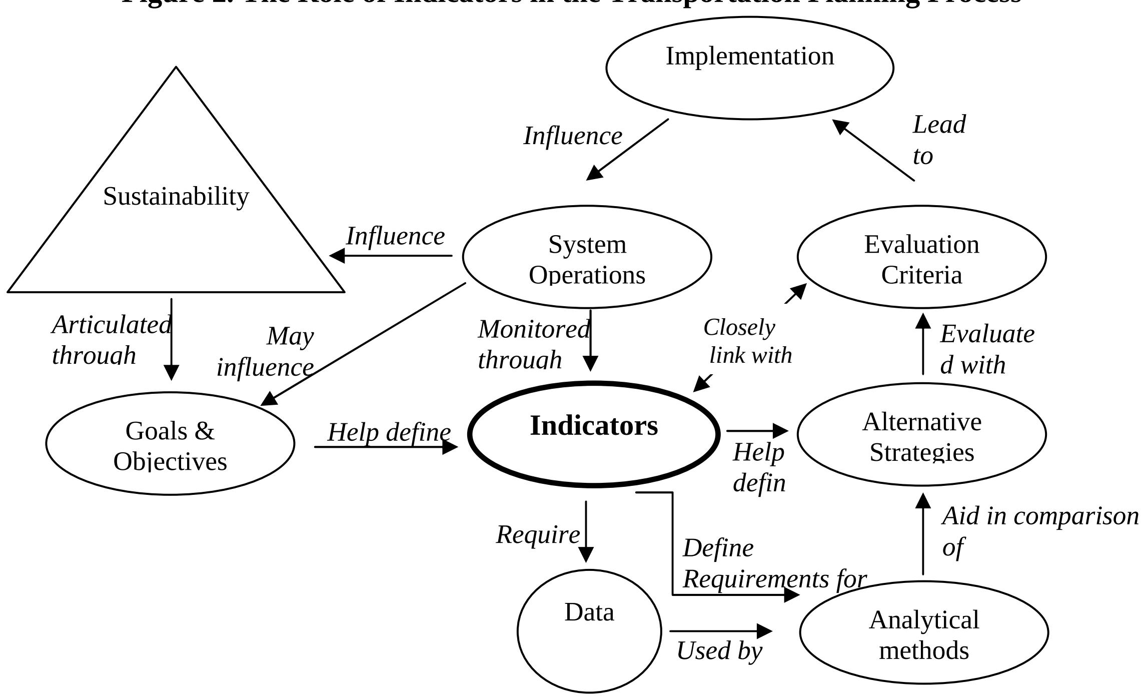
2.2. System Boundaries

In talking about sustainable transportation, we tend to – inevitably, for practical purposes – impose relatively artificial system boundaries: for example, bounding transport from the broader economic/social system, isolating urban/metropolitan transportation from the larger transportation system, and often even isolating the person-transport system from the freight transport system. There boundaries carry several relevant implications, such as: overlooking the fact that transportation enables other potentially "unsustainable" activities (e.g., shopping at malls, eating strawberries in wintertime) and land use changes (e.g, urban fringe development); not accounting for possibly stable average travel budgets (i.e., share of time/income spent on travel; e.g., Schafer, 2000), which might imply shorter urban trips being replaced by longer inter-urban travel; isolation of person and freight system interactions (including, e.g., home delivery of goods); etc.

2.3. Sustainable Transportation Indicators

The use of indicators in transportation is not, of course, new. We use levels of service (LOS) to measure roadway system performance, internal and economic rates of return (IRR, ERR) to estimate investment effectiveness, etc. Indicators in transportation from a critical component of what Meyer and Miller (2001) call "performance-based transportation planning" (see Figure 2).

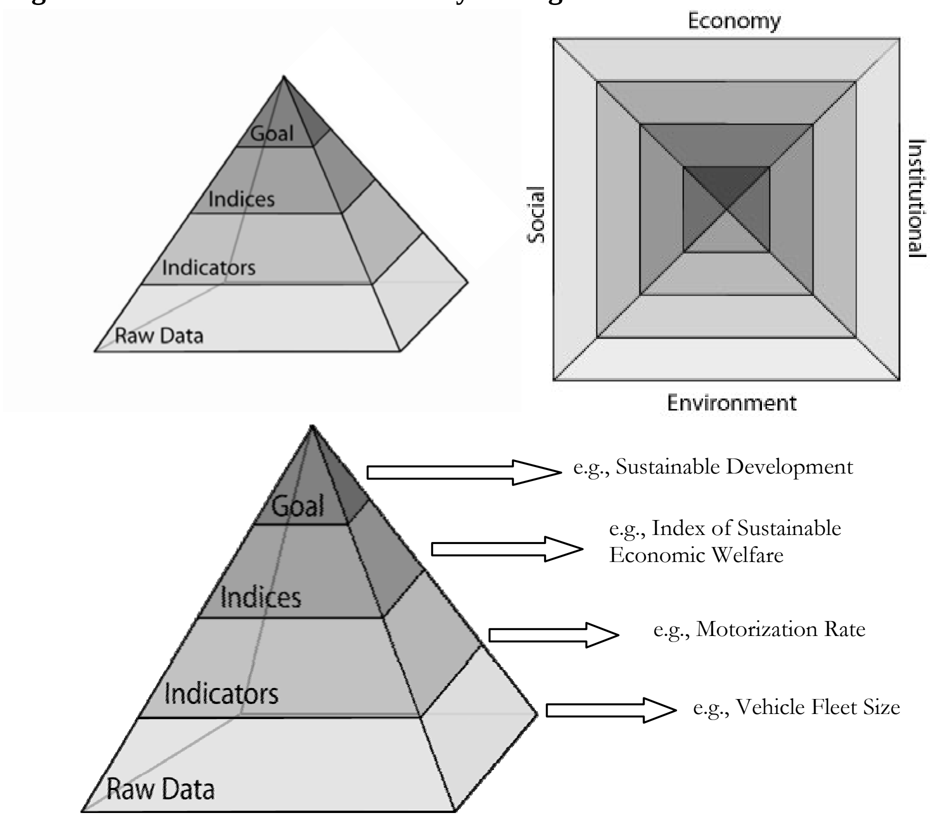
Figure 2. The Role of Indicators in the Transportation Planning Process



Source: Adapted from Meyer and Miller, 2001.

In such a planning approach, indicators, quite logically, tie closely to project evaluation criteria As we would expect, in the face of the boundary discussion above, indicators will vary depending on the spatial and temporal scale of the analysis and on the ultimate goals, although common indicators can often apply to several different goals and/or scales of analysis.

Figure 3. The Information Hierarchy through the Sustainable Indicator Prism



Source: Zegras et al, 2004.

It might be useful to situate performance-based transportation planning, sustainable transportation, and the role of indicators within the hierarchy of the Sustainable Indicator Prism (Figure 3). The top of the pyramid represents the goals and objectives, with the performance measures (indicators of varying degrees of specificity), building from raw data at the pyramid's base towards composite indices which converge towards the goals at the top. Examples of sustainable transportation indicator efforts can be found at each level in the implied hierarchy, including: corridor-level discrete indicators (e.g., Zietsman & Rilett, 2002); intra- and inter-city comparative efforts (Lautso & Toivanen, 2000; see Table 1); urban-level intermodal comparisons (Kennedy, 2002); macro-level global comparative efforts (WBCSD, 2001); among many others (see, e.g., Lee et al [2003], Jeon & Amekudzi [2005] for reviews). Most of the efforts tend towards the lower end of the Prism, i.e., multi-indicator efforts, although Zietsman and Rilett

(2002) derive a corridor-level index (using multi-attribute utility theory [MAUT] and including travel time, travel rate, LOS, local pollutant emissions, noise levels, and fuel consumption); Black (2000) attempts to derive an international-comparative index (based on fossil fuel dependence, air emissions impacts, traffic accidents, and congestion effects); Yevdokimov (2004) proposes to a national-level index using the Genuine Progress Indicator (GPI); and several efforts aim to apply the "ecological footprint" approach (e.g., Barrett & Scott, 2003).

Table 1. Indicators Used in the SPARTACUS project.

Sustainability Dimension	Area	Indicators
Environmental Indicators	*Air Pollution*	Transport 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, 2000

2.4. Sustainable Transport: A Proposed Operational Definition & Metric

The numerous efforts towards defining and measuring sustainable transport – efforts consistent with performance-based transportation planning, which itself reflects a move towards more comprehensive multi-dimensional transportation planning – are pushing us in the right direction. Yet, we still lack a satisfying operational definition of sustainable transport, which is a basic fundamental requirement to measuring any concept (even one as elusive as this one). Towards this end, elsewhere (Zegras, 2005) I derive an operational definition of sustainable transport as: *maintaining the capability to provide non-declining accessibility in time*.

This definition is consistent with the capital approach to measuring sustainable development (e.g., Neumayer, 2003). Increasing accessibility – that is, the potential to engage in activities/opportunities – increases human capital; contributing positively to sustainable development. In this way, we explicitly recognize transportation's fundamental role in human development, much in line with Sen's (2002) definition of sustainable development as "enhancing human freedoms on a sustainable basis." Transportation, along with (and often in combination with) other factors, enables accessibility (Table 2).

Table 2. Accessibility: Influencing Factors

Factors	**Effect on Accessibility (all else equal)**
Transportation	Improved with more links, faster, cheaper, higher quality 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
Telecommunications	Improved with more links, faster, cheaper, higher quality service

At the same time, however, by increasing accessibility, transportation depletes other sources of capital: natural (e.g., of fuels, lands, air, etc.), social (e.g., institutional and bureaucratic resources), and man-made (e.g., infrastructures and vehicles). Accessibility provides well being (utility) to current generations, but sustainability requires that it do so without damaging the possibilities for future generations to derive, at least, the same well-being. Transportation increases accessibility (e.g., human capital), yet also decreases other capital stocks. Following Daly's (2002) suggestion that sustainable *development* "might more fruitfully be defined as more utility per unit of throughput" (p. 48); we can think of sustainable *transportation* in exactly the same way: ***providing more utility, as measured by accessibility, per unit of throughput, as measured by mobility***. The rate at which mobility – provided by the transportation system – depletes other sources of capital depends on the distance traveled, and vehicle technologies, weights, occupancies, time of day of travel, etc. A highly fuel efficient vehicle drains fewer natural stocks, for example; an electric mode (e.g., Metro) *may* "consume" less of the (local) airshed "stock"; etc. If we were able to magically transform the existing vehicle fleet to one based on "carbon neutral" fuels, than the relevant capital stock drain would be reduced, making mobility *more* sustainable (of course, other capital stock depletion would continue). All else equal, capital depletion increases with vehicle size/weight and use. This does not mean that we want to reduce total mobility; rather, it means that want less total mobility consumption per accessibility derived – sustainable transport is *efficient accessibility*.

3. KEY ISSUES RELATED TO SUSTAINABLE TRANSPORT INDICATORS AND ASSESSMENT METHODOLOGIES

The above offers a basic theoretical backdrop to the idea of sustainable transport, what we mean by it, how we might measure it, and where such measurement efforts fit into "performance-based" transportation planning. This last section identifies some of the key issues related to putting these ideas "into practice," including: development of meaningful indicators, techniques for assessing possible interventions, differences and similarities of techniques for examining various sustainability "dimensions," establishing appropriate baselines for developing counterfactuals, and implications for technical capabilities and decision-making.

3.1. Valid and Reliable Indicators for Monitoring and Evaluation (M&E)

When it comes to identifying and using indicators, there are at least two key issues to consider: validity and reliability. Validity refers to the accuracy with which the indicator measures the concept of interest – does accessibility and mobility throughput, for example, validly represent sustainable transport? Do we measure sustainable transport by more traditional indicators (since they are more readily available), such as travel time and LOS, and thus fall into the trap of defining the concept of interest based on what we can measure? Ultimately, finding valid measurements remains "an art" (Meier & Brudney, 2002). Indicator reliability, on the other hand, tells us whether repeated measures of an unchanged phenomenon using the same indicator will give us the same value (i.e. it is not affected by anything other than actual changes in what is measured). This can be influenced by our own "subjectivity," if our judgment influences the indicator value (e.g., "good" transportation quality) and imprecision, which can be influenced, for example, by sample size (e.g., when estimating travel demand). The role of valid and reliable indicators for M&E can be seen in Figure 2.

If we accept the idea that sustainable transportation is "efficient accessibility," then a fundamental question arises: how do we measure accessibility? Despite some 50 years of history, calculating truly meaningful accessibility measures remains a challenge in practice. The most rigorous accessibility measures – those which capture the essence of the concept – are, naturally, complicated to implement (data- and computationally-intensive). However, the simpler measures, such as the infrastructure-based measures (travel times/speeds, etc.) are biased fundamentally towards mobility (a capital drain), not accessibility, per se (Table 3). Examples of deriving rigorous accessibility measures for informing transportation decision-making include: Minken et al (2003) in several European cities; Geurs and van Wee (2004), in the Netherlands; Hunt (2003) in Edmonton, Canada; and Martínez and Araya (2000) in Santiago de Chile.

Table 3. Basic Categorization of Accessibility Measures

Accessibility Measure Type	Examples	Suitability for Measuring Sustainable Transport
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.

If accessibility is the ultimate benefit we derive from the transport system (actually, the land use-transport system), sustainability makes us ask: "at what cost or what rate of capital drain?" How "efficient" is our accessibility provision? Some of the costs (infrastructure, vehicles, fares, etc.) are fairly straightforward – they are expenditures that "deplete" our public and private financial capital stocks. The other "capital drains" of, e.g., "natural stocks" (airsheds, watersheds, etc.), can be estimated with varying degrees of reliability. But, out indicators, ultimately, need to return to a "common denominator": accessibility, and its efficiency. For example, the key indicator for transportation's "carbon efficiency" should not be carbon/km traveled; rather, it should be carbon per accessibility-derived (or, at its simplest, per trip).

3.2. Transportation Analysis: the "State of the Art"

If we can derive valid and reliable indicators of sustainable transport, can we predict – with adequate confidence – the impacts of interventions? Influencing factors in any relevant analysis of sustainable transport include:

– Scale (e.g. metropolitan, intrametropolitan, neighborhood, site-specific);
– Scope (e.g. air quality, energy consumption, housing);
– Timeframe (e.g. short, medium, long-term).

In rigor, the sustainability concept should cover all scales and scopes over the long-term; the very word implies a long-term view (i.e., can accessibility be "sustained" for present and *future* generations?"). In practical terms, however, we obviously cannot consider *all* impacts, at *all* scales, for *eternity*. And, in many cases, e.g. a fuel switch or vehicle technology transfer, the scale, scope and timeframe are basically determined by the technology. The requisite analysis, in such a case is also fairly straightforward (note, however, that lack of empirical evidence can still pose a major challenge; Browne et al (2005), for example, show the wide variation in estimates for hybrid bus fuel consumption rates).

With larger-scale interventions, involving broader transportation system changes, the analyses inevitably grow in complexity. Such analyses have been the “bread and butter” of transportation analysts for at least half a century. Today, the state of the art in transportation-land use analysis includes simulation models of the integrated decision processes related to land development, household/firm location choice, household vehicle choice decisions, and household/individual and firm activities, and – finally – household/individual and firm travel activities. With these models, transportation interventions can be analyzed (i.e., alternatives analysis) and, ultimately, assessment of benefits and costs made. In practice, there are several difficulties. The state-of-the-*art* remains fairly distant from the state-of-the-*practice*; meaning that the great majority of places use fairly straightforward analytical models (if any), most of these models virtually ignore commercial/freight transportation, few integrated land use-transportation analyses are carried out and, finally, the evaluation procedures (to assess the benefits and costs of alternatives) are not fully capable of analyzing the broad range of relevant impacts. In addition, and perhaps most importantly, the impact of these techniques (whether state-of-the-art, or not) on *implementation* (i.e., decisions made and acted upon) remains fairly case-by-case and, inevitably, strongly influenced by the political process.

In practice, an interesting question arises regarding the potential to standardize relevant analytical procedures. In short, can we? It is not clear the degree to which procedures can be standardized, as the scale of the analytical effort should be matched to the scale of the problem context (setting) and problem(s). We can see several challenges to effective application of appropriate techniques: lack of information/data (on passenger/freight transportation behaviors); and lack of technical capacities, time and resources to carry out the requisite analyses. However, one could imagine a matrix providing guidelines for the type of analysis, depending on, for example, the scale, scope, timeframe dimensions outlined above.

At a bare minimum, any relevant analysis should be required to explicitly identify the analytical boundaries (i.e., Section 2.2), and possible effects on impacts of interest.

3.3. Accessibility and the “State of the Art”

In practice, it appears that few authorities use accessibility as a performance metric for transportation systems. Bhat et al (2000) found limited examples of practical use by government agencies of accessibility as transportation performance measures. The UK Government’s

Guidance on the Methodology for Multi-Modal Studies (GOMMMS), issued in 2000, includes 3 categories within its "accessibility" category. The relevant recommendations suggest qualitative assessment criteria for these categories, considering (rightly or wrongly) that cost benefit analysis takes into account "most aspects of accessibility" (UK CFIT, 2004, p. 37).

Hunt (2003) reports on a "quasi" nested logit model (trip generation-destination choice-time period choice-mode choice-route choice) for the city of Edmonton in which the composite utility (a measure of accessibility, derived from discrete choice models) fed up to the trip destination choice provides the measure of aggregate mobility benefits; he demonstrates this model for estimating GHG emissions reductions and the associated negative effects (decreased utility) implied. Martínez and Araya (2000) directly link utility-based accessibility measures to the doubly constrained entropy model (i.e., spatial interaction model); this model is, reportedly, operational in the Santiago de Chile context.

For a variety of theoretically and practically appealing reasons (truly adherent to the "accessibility-as-benefit" for sustainable transportation approach), the "future" lies in activity-based analyses. Activity-based analyses can allow assessment of travel re-investment and/or re-allocation (i.e., induced travel, or longer-trips compensating shorter trips). Operational examples exist; for example, Dong et al (2005) – using the Portland, OR (USA) case – estimate an activity-based (as opposed to trip-based) accessibility measure. Despite their theoretical attraction, the activity-based measures are data hungry and computationally complex.

3.4. Key Methodological Similarities and Differences in Evaluating GHG reductions and "Co-benefits"

Many may argue that GHG emissions are the fundamental concern for sustainable transport. Whether that is truly the case depends, at least in part, on one's perspective (Figure 1). Fortunately, measuring transport GHG reductions should be entirely compatible with measuring *many* other transportation (so-called) co-benefits. After all, fuel consumption, directly related to GHG emissions is historically a key aspect of traditional transportation evaluation techniques. But, the similarity depends on the "co-benefit" of analysis; for example, if available methodological tools are capable of producing fuel consumption estimates, then local pollutant estimates should also be derivable. Pollutant emissions estimates have more influencing variables (cold starts, stops/starts, fuel quality, emissions controls technologies, etc.) and, furthermore, the need to translate pollutant estimates into ambient concentrations (and ultimately, effects on health) complicates matters. This remains an area of considerable research activity (e.g., incremental v/s. revolutionary improvements to the USEPA Mobile model). While local air quality analysis has the challenge of the "downstream" estimation (from the tailpipe to the airshed concentration), GHG emissions face the "upstream" problem (from source through to end-use consumption) – although we often ignore the latter.

In terms of additional co-benefits (e.g., accidents) within a broader "sustainability" framework, these may not always be relevant (e.g., in the case of a basic fuel switch); however, as the intervention becomes more wide-ranging (e.g., new public transportation infrastructure), the complexity of analyzing the effects increases. This increased complexity will generally be reflected in all sustainability dimensions (even fuel consumption calculations will become more complicated as travel demand and network modeling must be carried out properly). When we attempt to look at accessibility, distribution of accessibility, the challenges become greater – although, again, a unified and sophisticated forecasting tool (i.e., an integrated land use and transportation model) should be able to provide the necessary information (accuracy of predictions of various effects will likely vary). The EU PROSPECTS project (see Minken et al, 2002) should offer some useful guidance on the possibilities.

3.5. Project Counterfactuals and Relevant Assumptions

In the end, when estimating the impacts of particular interventions, we face the challenge of establishing the baseline. What would have happened "without the project." At some broad level, far into the future, we might be able to use basic mode shares as indicators of potential future. For example, will Lima's non-motorized mode share (in, let's say, 2025) look more like the U.S. or Germany? What types of policies will influence that outcome (urban development policies, vehicle and fuel pricing policies, public transport policies, infrastructure investment policies, etc.)? The current rate of change – for example, reported 70% annual growth in Beijing's motor vehicle fleet and concomitant wholesale restructuring of the urban fabric – will greatly influence our willingness to accept the assumption of, e.g., "no change" in OD patterns.

In terms of the impacts of ambitious proposed schemes (such as large-scale infrastructure interventions), we must recognize that such projects will likely induce subsequent real estate investment changes and, quite possible, future additional transportation investments. One project can redefine an entire city's trajectory (a "no return" departure from the baseline) and carry major residuals (social, economic, environmental); it is very difficult assess *ex ante* all these effects and their subsequent impacts on GHGs, accessibility, equity, etc. Standard assessment techniques will not likely suffice either.

3.6. Final Words on Tools, Techniques, Capabilities

Ultimately, we know that no model of the complex land use-transport system can accurately predict what will happen over a 25 year period. Models can really only be used to predict the range of possible futures and the impacts that policies today may have on the future; estimates have been shown to vary significantly depending on the modelling approach used (e.g., Hunt, et al., 2001). Error compounding in the modeling process can result in errors larger than the differences between performance of the alternatives (Wachs, 1998). One problem is we don't really know, in an ex-post sense, how good our predictive capabilities are; ex-post assessments tend to relate to, for example, an apparent propensity to over-predict public transport ridership or other demand forecasts and costs (Pickrell, 1992; Skamris & Flyvberg, 1997).

Ex-post assessment of the accuracy of these models is rarely carried out, in part because of the difficulty in assessing a model's effectiveness for predicting a future that almost always differs from the future that actually plays out (e.g., due to differences in projected vs. actual economic/demographic growth rates, fuel prices, implementation of different projects or policies than expected, etc.). In Santiago de Chile, transportation model (ESTRAUS, considered the *state of the art*, in practice) runs in 1990-91 were used to evaluate a proposed new Metro Line, the model over-estimated morning peak loads by 15 to 20% upon line opening in 1997; this over-estimation can be at least partially attributed to the fact that the original model runs had been based on (1) higher relative Metro fares than those actually charged at the time of modeling and (2) feeder bus services at the southern terminal that were never implemented (de Cea, et al, 2003).

None of this is meant to discredit the need for analysis. We will always be better off with better analytical tools, and the data-gathering, analysis and understanding, exploration, and learning and new insights that will almost certainly come with them. And, in many cases, analytical tools will at least be able to tell us the directionality, if not the exact size of the change in many of the indicators of interest. But, when we are concerned with precise estimates – particularly of, e.g., GHG emissions for the purpose of financing a project based on a future flow of carbon revenues – then the question of how to account for the inevitable uncertainty arises. Will the investor force improved *ex-ante* analysis (screening "white elephants")? Can we monitor year-by-year effects (via, e.g., stratified surveys) in conditions where almost everything else is also changing? Should the international community "cut transport some slack" in terms of the rigor of the required estimates due to its (possibly) crucial role in sustainability? If so, how do we define and measure the broader sustainability?

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