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Developing Indicators for Comprehensive and Sustainable Transport Planning

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Abstract

This paper discusses the selection of indicators for comprehensive and sustainable transportation planning. It discusses the concept of sustainability and the role of indicators in planning, describes factors to consider when selecting indicators, identifies potential problems with conventional indicators, describes examples of indicators, and provides recommendations for selecting indicators for use in a particular situation.

Jan Vermeer - The Astronomer (c. 1668, Oil on canvas)

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Introduction

How things are measured can affect their perceived value. A particular activity or option may seem desirable and successful when measured one way, but undesirable and ineffective when measured in another. It is therefore important to understand the assumptions and implications of different types of measurements.

For example, doctors usually check their patients' weight during medical exams. But weight by itself indicates little about health. It would be wrong to assume that everybody who weighs less than 175 pounds is healthy and everybody who weighs more than 175 pounds is unhealthy. People with different heights and builds have different optimal weights, so medical professionals must use weight-height tables or body-mass indices to interpret the health implications of a person's weight. Weight is relatively easy to measure, but it is just one health factor. Focusing too much attention on weight may distract doctors from considering other important but more difficult to measure health factors, such as whether patients' diet, fitness activities, and other behaviors.

Comprehensive and sustainability planning rely on measurable *indicators* (1). Such indicators have many uses for planning and management, regardless of whether a decision-making process is considered *sustainability planning*. This data can help establish baselines, identify trends, predict problems, assess options, set performance targets, and evaluate a particular jurisdiction or organization. Which indicators are selected can significantly influence analysis results. A particular policy may rank high when evaluated using one set of indicators, but low when ranked by another.

Key Definitions (2)

Baseline (or *benchmark*) – existing, projected or reference conditions if change is not implemented.

Goal – what you ultimately want to achieve.

Objective – a way to achieve a goal.

Target – A specified, realistic, measurable objective.

Indicator – a variable selected and defined to measure progress toward an objective.

Indicator data – values used in indicators.

Indicator framework – conceptual structure linking indicators to a theory, purpose or planning process.

Indicator set – a group of indicators selected to measure comprehensive progress toward goals.

Index – a group of indicators aggregated into a single value.

Indicator system – a process for defining indicators, collecting and analyzing data and applying results.

Indicator type – nature of data used by indicator (qualitative or quantitative, absolute or relative).

Sustainable Transportation

There is growing interest in *sustainability* and its implications for transport planning (3). Sustainability reflects the fundamental human desire to create a better future world and leave a positive and durable legacy. Sustainability emphasizes the integrated nature of human activities and therefore the need to coordinate decisions among different sectors, groups and jurisdictions. Sustainability planning (also called *comprehensive planning*) considers society's overall, long-term goals. It means that local, short-term decisions are consistent with strategic, regional and global, long-term goals. This contrasts with *reductionist* planning, in which problems are assigned to a profession or organization with narrow responsibilities and goals, which can result in solutions to one problem that exacerbate other problems facing society (4).

There is no universally accepted definition of sustainability, sustainable development or sustainable transport (5). Below are examples of definitions:

> Sustainable development "meets the needs of the present without compromising the ability of future generations to meet their own needs." (6)
>
> "Sustainability is equity and harmony extended into the future, a careful journey without an endpoint, a continuous striving for the harmonious co-evolution of environmental, economic and socio-cultural goals." (7)
>
> "…sustainability is not about threat analysis; sustainability is about systems analysis. Specifically, it is about how environmental, economic, and social systems interact to their mutual advantage or disadvantage at various space-based scales of operation." (8)
>
> A sustainable transportation system is one that (9):
>
> - Allows the basic access needs of individuals and societies to be met safely and in a manner consistent with human and ecosystem health, and with equity within and between generations.
> - Is affordable, operates efficiently, offers choice of transport mode, and supports a vibrant economy.
> - Limits emissions and waste within the planet's ability to absorb them, minimizes consumption of non-renewable resources, limits consumption of renewable resources to the sustainable yield level, reuses and recycles its components, and minimizes the use of land and the production of noise.
>
> "The goal of sustainable transportation is to ensure that environment, social and economic considerations are factored into decisions affecting transportation activity." (10)

Concern about sustainability can be considered a reaction to the tendency of decision-making to focus on easy to measure goals and impacts while ignoring those that are more difficult to measure. Sustainable decision-making can therefore be described as *planning that considers goals and impacts regardless of how difficult they are to measure*. Interest in sustainability originally reflected concerns about long-term risks of current resource consumption, reflecting the goals of "intergenerational equity" (i.e., being fair to future generations). But if *future* equity and environmental quality are concerns, it makes little sense to ignore equity and environmental impacts occurring during this generation. Thus, sustainability ultimately reflects the goals of equity, ecological integrity and human welfare, regardless of time or location.

Ecological economics (a discipline concerned with valuing ecological resources) defines sustainability in terms of *natural capital*, the value of natural systems to provide goods and services, including clean air and water, and climatic stability (11). Preserving these services is equivalent to a business maintaining the value of its productive assets. Ecological economists argue that consumption should not deplete natural capital at a faster rate than it can be replaced by viable and durable human capital. This suggests, for example, that non-renewable resources such as petroleum should not be depleted without sufficient development of substitutes, such as renewable energy sources.

Sustainable economics maintains a distinction between *growth* (increased quantity) and *development* (increased quality). It focuses on social welfare outcomes rather than simply measuring material wealth, and questions common economic indicators such as Gross Domestic Product, which measure only the quantity but not the quality of market activities. Sustainable economics strives for *sufficiency*, as opposed to neoclassic economics which generally assumes that continually increasing consumption is desirable. Sustainability requires a *conservation ethic*, which maximizes resource efficiency. For example a *consumption* ethic supports lower road, parking and fuel prices to make vehicle travel affordable. A *conservation* ethic might increase such fees while implementing programs to improve mobility options, encourage more accessible land use, and increase vehicle fuel efficiency, so accessibility requires less resource consumption.

Sustainability is sometimes defined narrowly, focusing on a few specific problems such as resource depletion and pollution, but is increasingly defined broadly to include other economic, social and environmental issues. Narrowly defined sustainability can overlook connections between issues and opportunities for integrated solutions. For example, comprehensive analysis helps identify strategies that achieve multiple planning objectives, and so are truly optimal. For example, comprehensive analysis allows planners to identify the congestion reduction strategies that also help achieve equity and environmental objectives, or at least avoid those that are socially and environmentally harmful. These integrated solutions can be considered the most sustainable.

Factors to Consider When Selecting Indicators

Indicators are things that we measure in order to evaluate progress toward goals and objectives. For example, teachers track students' participation and test scores to evaluate their learning progress. Motorist track their vehicle's fuel and oil consumption rates, engine and brake noise to determine when it requires servicing.

Indicators should be carefully selected to provide useful information. In most situations, no single indicator is adequate, so a set should be selected. An indicator set should reflect various goals and objectives. For example, it is desirable that a sustainable transportation indicator set reflect the impacts listed in Table 1, and possibly more. People using indicators should understand their perspectives and limitations.

Table 1 **Sustainable Transportation Impacts (2)**

Economic	Social	Environmental
Traffic congestion Infrastructure costs Consumer costs Mobility barriers Accident damages DNRR	Equity / Fairness Impacts on mobility disadvantaged Human health impacts Community cohesion Community livability Aesthetics	Air pollution Climate change Noise and water pollution Habitat loss Hydrologic impacts DNRR

DNRR=Depletion of Non-Renewable Resources

These impacts can be defined in terms of goals, objectives, targets and thresholds. For example, a planning process may involve establishing traffic congestion *indicators* (defining how congestion will be measured), *goals* (the amount of congestion reduction desired, including factors such as whether reductions are particularly important for certain trips or vehicles, such as trucks and buses), *objectives* (shifts in travel time and mode to reduce congestion) and *targets* (specific, feasible changes in congestion impacts or travel behavior that should be achieved), and *thresholds* (levels beyond which additional actions will be taken to reduce congestion).

Different types of indicators reflect different perspectives and assumptions. Some focus on *vehicle travel* or *mobility*, but a better perspective considers *accessibility* (the ability to reach activities and destinations), taking into account travel options and land use patterns. For example, roadway level-of-service (LOS) primarily reflects automobile travel congestion. It indicates little about the quality of other modes or land use accessibility. A planning process that relies primarily on roadway LOS to evaluate transport system performance implicitly assumes that automobile travel is the most important mode and congestion is the most important problem. Two areas can have equal roadway LOS ratings but very different overall transport system performance due to differences in transport diversity and the distribution of destinations. Similarly, measuring impacts per vehicle-mile, per passenger-mile, per capita or per unit of economic activity reflect different perspectives and assumptions about what is important and desirable.

Indicators can reflect various levels, as illustrated in Table 2. For example, indicators may reflect the decision-making process (the quality of planning), responses (travel patterns), physical impacts (emission and accident rates), effects this has on people and the environment (injuries and deaths, and ecological damages), and their economic impacts (costs to society due to crashes and environmental degradation). The use of indicators is just one step in the overall planning process, which includes consulting stakeholders, defining problems, establishing goals and objectives; identifying and evaluating options, developing policies and plans, implementing programs, establishing performance targets and measuring impacts.

Table 2 **Levels of Impacts**

Level	Examples
External Trends ➜	Changes in population, income, economic activity, political pressures, etc.
Decision-Making ➜	Planning process, pricing policies, stakeholder involvement, etc.
Options and Incentives ➜	Facility design and operations, transport services, prices, user information, etc.
Response (Physical Changes) ➜	Changes in mobility, mode choice, pollution emissions, crashes, land development patterns, etc.
Cumulative Impacts ➜	Changes in ambient pollution, traffic risk levels, overall accessibility, transportation costs, etc.
Effects on People and the Environment ➜	Changes in pollution exposure, health, traffic injuries and fatalities, ecological productivity, etc.
Economic Effects ➜	Property damages and productivity losses due to crashes and environmental degradation; increased travel costs due to reduced accessibility.
Performance Evaluation	Ability to achieve specified standards and targets.

This table shows how indicators can measure various levels of impacts, from the planning process to travel behavior, impacts on people and the environment, and economic effects.

Many impacts are best evaluated using *relative* indicators, such as trends over time, comparisons between different groups or activities within the jurisdiction, or comparisons with other jurisdictions. Indicators can reflect whether trends are positive or negative with respect to objectives. Equity can be evaluated based on how disadvantaged groups (people with low incomes, physical disabilities or other disadvantages) compare with other groups in terms of their transport options and impacts. Communities and agencies can be evaluated by comparing their performance with peers.

Reference units are measurement units normalized to facilitate comparison of impacts, such as per-year, per-capita, per-mile, per-trip, per-vehicle-year and per dollar (4). The selection of reference units can affect how problems are defined and solutions prioritized. For example, measuring impacts such as emissions, crashes and costs per *vehicle-mile* ignores the effects of changes in vehicle mileage. Measuring these impacts *per capita* accounts for the effects of changes in total vehicle travel. Comparisons can be structured in various ways to reflect different perspectives, such as comparisons between different areas and groups, or trends over time.

Individual indicators should be selected based on their decision-making usefulness and ease of collection. There is tension between convenience and comprehensiveness when selecting indicators. A smaller set of indicators using easily available data is more convenient to collect and analyze, but may overlook important impacts. A larger set can be more comprehensive but have excessive data collection and analysis costs. By defining indicators early in a planning process and working with other organizations it is often possible to minimize data collection costs. For example, travel surveys can be modified to collect demographic data (such as income, age, disability status, driving ability, etc.) for equity evaluation, and land use modeling can incorporate more multi-modal factors.

Sustainability indicators can be integrated with other types of accounting statistics (12). Indicator sets should be derived as much as possible from existing accounting data sets, while existing accounting data should be extended towards sustainable development requirements.

Hart recommends asking the following questions about potential indicators (13):

- Is it relevant to the community's definition of sustainability? Sustainability in an urban or suburban area can be quite different from sustainability in a rural town. How well does the direction the indicator is pointing match the community's vision of sustainability?
- Is it understandable to the community at large? If it is understood only by experts, it will only be used by experts.
- Is it developed, accepted, and used by the community? How much do people really think about the indicator? We all know how much money we make every year. How many people really know how much water they use in a day?
- Does it provide a long-term view of the community? Is there information about where the community has been as well as where the community should be in 20, 30, or 50 years?
- Does it link the different areas of the community? The areas to link are: culture/social, economy, education, environment, health, housing, quality of life, politics, population, public safety, recreation, resource consumption/use, and transportation.
- Is it based on information that is reliable, accessible, timely and accurate?
- Does the indicator focus on local sustainability that is at the expense of global sustainability? Any indicator that says "we are going to be better off by making someone else worse off" should not generally be used. This does not mean that one community cannot be better than another community. There will always be communities that succeed while others fail; it just means that a community should not try to achieve sustainability at the expense of another community.

Vehicle Travel As A Sustainability Indicator

Motor vehicle travel (measured as *Vehicle Miles Traveled* [*VMT*] or *Vehicle Kilometers Traveled* [*VKT*], and *Passenger Miles Traveled* [*PMT*] or *Passenger Kilometers Traveled* [*PKT*]) is sometimes used as a sustainability indicator, assuming that motorized travel is unsustainable because it is resource intensive and environmentally harmful. But this is controversial because motorized travel also provides economic and consumer benefits. Some people argue that high levels of motorized travel can be sustainable with technological improvements in vehicle and roadway designs (14).

This issue can be viewed from an economic efficiency perspective. Current transport markets are distorted in ways that result in economically excessive motor vehicle travel, including various forms of road and parking underpricing, uncompensated environmental impacts, biased transport planning practices (e.g., dedicated highway funding, modeling that overlooks generated traffic effect, etc.), and land use planning practices that favor lower-density, automobile-oriented development (e.g., restrictions on density and multi-family housing, minimum parking supply, pricing that favors urban-fringe locations, etc.) Some analysis indicates that more than a third of all motor vehicle travel results from these distortions (15).

To the degree that market distortions increase vehicle travel beyond what is economically optimal (beyond what consumers would choose in an efficient market), the additional vehicle travel can be considered unsustainable and policies that correct these distortions increase sustainability. In this context, vehicle mileage and shifts to non-automobile modes can be considered sustainability indicators. This may not apply in some situations, such as in developing countries when vehicle ownership is growing from low to medium levels, and where transportation markets are efficient.

Specific planning decisions can be evaluated according to whether they increase or reduce market efficiency. For example, when evaluating potential congestion reduction strategies, those that increase automobile traffic and sprawl (e.g., roadway expansion) can be considered unsustainable, while those that correct underpricing (e.g. road and parking pricing), increase transport system diversity (e.g., walking, cycling, rideshare and transit improvements), and encourage more efficient travel behavior (e.g., commute trip reduction programs) can be considered to increase sustainability. In situations where a significant portion of vehicle travel is excessive (such as urban peak conditions) blunter incentives may be justified, such as regulations that limit automobile travel and favor alternative modes.

Best Practices

The following principles should be applied when selecting transportation performance indicators (13, 16):

> *Comprehensive* – Indicators should reflect various economic, social and environmental impacts, and various transport activities (such as both personal and freight transport).
>
> *Data quality* – Data collection practices should reflect high standards to insure that information is accurate and consistent.
>
> *Comparable* – Data collection should be standardized so the results are suitable for comparison between various jurisdictions, times and groups. Indicators should be clearly defined. For example, "Number of people with good access to food shopping" should specify 'good access' and 'food shopping.'
>
> *Easy to understand* – Indicators must useful to decision-makers and understandable to the general public. The more information condensed into a single index the less meaning it has for specific policy targets (for example, *Ecological Footprint* analysis incorporates many factors) and the greater the likelihood of double counting.
>
> *Accessible and Transparent* – Indicators (and the data they are based on) and analysis details should be available to all stakeholders.
>
> *Cost effective* – The suite of indicators should be cost effective to collect. The decision-making worth of the indicators must outweigh the cost of collecting them.
>
> *Net Effects* – Indicators should differentiate between net (total) impacts and shifts of impacts to different locations and times.
>
> *Performance targets* – select indicators that are suitable for establishing usable performance targets.

Table 3 lists recommended indicator sets grouped into *Most Important* (should usually be used), *Helpful* (should be used if possible) and *Specialized* (should be used to reflect particular needs or objectives).

Much of the data required for these indicators may be available through existing sources, such as censuses and consumer surveys, travel surveys and other reports. Some data can be collected during regular planning activities. For example, travel surveys and traffic counts can be modified to better account for alternative modes, and to allow comparisons between different groups (e.g., surveys can include questions to categorize respondents). Some indicators require special data that may require additional resources to collect.

Some of these indicators overlap. For example, there are several indicators of transport diversity (quality and quantity of travel options, mode split, quality of nonmotorized transport, amount of non-motorized transport, etc.), and cost-based pricing (the degree to which prices reflect full costs) is considered an indicator of both economic efficiency and equity/fairness. It may be most appropriate to use just one such indicator, or if several similar indicators are used, give each a smaller weight.

Table 3 **Recommended Indicator Sets (1)**

	Economic	Social	Environmental
Most Important (Should usually be used)	Per capita mobility (daily or annual person-miles or trips). Mode split (*personal travel:* nonmotorized, automobile and public transport; *freight:* truck, rail, ship and air). Average commute travel time and reliability. Average freight transport speed and reliability. Per capita congestion costs. Total per capita transport expenditures (vehicles, parking, roads and transit services).	Per capita traffic crashes and fatalities. Quality of transport for disadvantaged people (disabled, low incomes, children, etc.). Affordability (portion of household budgets devoted to transport). Overall satisfaction rating of transport system (based on objective user surveys). Universal design (consideration of disabled people's needs in transport planning)	Per capita energy consumption, disaggregated by mode. Energy consumption per freight ton-mile. Per capita air pollution emissions (various types), disaggregated by mode. Per capita land devoted to transport facilities (roads, parking, ports and airports). Air and noise pollution exposure and health damages. Impervious surface coverage and stormwater management practices.
Helpful (Should be used if possible)	Relative quality (availability, speed, reliability, safety and prestige) of non-automobile modes (walking, cycling, ridesharing and public transit) relative to automobile travel. Number of public services within 10-minute walk and job opportunities within 30-minute commute of residents.	Portion of residents who walk or bicycle sufficiently for health (15 minutes or more daily). Portion of children walking or cycling to school. Community cohesion (quality of interactions among neighbors). Degree cultural resources are considered in transport planning.	Community livability ratings. Water pollution emissions. Habitat preservation. Use of renewable fuels. Transport facility resource efficiency (such as use of renewable materials and energy efficient lighting).
Specialized (Use to address particular needs or objectives)	Portion of households with internet access. Change in property values.	Transit affordability. Housing affordability in accessible locations.	Impacts on special habitats and environmental resources. Heat island effects.
Planning Process	Comprehensive (takes into account all significant impacts, using best current evaluation practices). Inclusive (substantial involvement of affected people, with special efforts to insure that disadvantaged and vulnerable groups are involved). Based on *accessibility* rather than *mobility*. Application of smart growth land use policies.		
Market Efficiency	Portion of total transportation costs that are efficiently priced. Neutrality (public policies do not arbitrarily favor a particular mode or group) in transport pricing, taxes, planning, investment, etc. Applies *least cost planning*.		

This table identifies various sustainable transport indicators ranked by importance and type. For equity analysis, indicators can be disaggregated by demographic factors, so impacts on disadvantaged groups (people with disabilities, low incomes, children, etc.) are compared with overall averages.

Indicators can be disaggregated by demographic (income, employment, gender, age, physical ability, minority status, etc.) and geographic factors (urban, suburban, rural, etc.), time (peak and off-peak, day and night), and by mode (walking, cycling, transit, etc.) and trip (commercial, commuting, tourism, shopping, etc.). For equity analysis, special consideration should be given to transport service quality and cost burdens for disadvantaged people (people with disabilities, low incomes, children, etc.). For example, compare the portion of household income devoted to transport, and satisfaction with the transport system, between people with and without disabilities, the lowest and the average income quintile, and young adults with other age groups. Similarly, special consideration can be applied to the quality of "basic access" (transport with high social value, such as access to for emergency and service vehicles, medical services, education, employment, etc.), by measuring how often people are unable to make such trips.

Comprehensive, lifecycle analysis should be used, taking into account all costs and resources used, including production, distribution and disposal. The analysis should indicate if costs are shifted to other locations, times and groups.

These data can be presented in various ways to show trends, differences between groups and areas, comparison with peer jurisdictions or agencies, and levels compared with recognized standards. Overall impacts should generally be evaluated *per capita*, rather than per unit of travel (e.g., per vehicle-mile) in order to take into account the effects of changes in the amount of travel that occurs.

These indicators can be used to establish specific performance targets and contingency-based plans (for example, a particularly emission reduction policy or program is to be implemented if pollution levels reach a specific threshold, or a community will receive a reward for achieving a particular rating or award if it achieves a particular mode shift).

It may be appropriate to use a limited set of indicators which reflect the scale, resources and responsibilities of a particular sector, jurisdiction or agency. For example, a transportation agency might only measure transportation impacts involving the modes, clients and geographic area it serves. Special sustainability analysis and indicators may be applied to freight or aviation sectors.

It is important that users understand the perspectives, assumptions and limitations in different types of indicators and indicator data. Indicators should reflect different levels of impacts, from the decision-making processes; travel effects; intermediate impacts; and ultimate outcomes that affect people and the environment.

Conclusions

Indicators are things we measure to evaluate progress toward goals and objectives. Such indicators have many uses: they can help identify trends, predict problems, assess options, set performance targets, and evaluate a particular jurisdiction or organization. Indicators are equivalent to senses (sight, hearing, touch, smell, taste) – they determine how things are perceived and what receives attention. Which indicators are used can significantly affect planning decisions. An activity or option may seem good and desirable when evaluated using one set of indicators, but harmful when evaluated using another. It is therefore important to carefully select indicators that reflects overall goals. It is also important to be realistic when selecting indicators, taking into account data availability, understandability and usefulness in decision-making.

For comprehensive and sustainable transportation planning it is usually best to choose a balanced set of indicators reflecting a combination of economic, social and environmental objectives. An indicator set that focuses too much on one type of impact or overlooks others can result in decisions that are not overall optimal. It is important that users understand the perspectives, assumptions and limitations of each indicator. Indicators can apply at several levels:

- *Planning process* – whether planning and investment practices are comprehensive, unbiased, inclusive, etc.
- *Options and incentives* – whether consumers have adequate options (such as quality alternative modes) and markets are efficient (such as cost-based pricing).
- *Travel behavior* – Vehicle ownership, vehicle travel, mode split, etc.
- *Physical impacts* – pollution emission and crash rates, land consumption, etc.
- *Effects on people and the environment* – rates of illnesses and deaths, reduced productivity, environmental degradation, etc.
- *Economic effects* – monetized estimates of economic costs, reduced productivity, property values, etc.
- *Performance targets* – degree to which desired standards and targets are achieved.

There is tension between convenience and comprehensiveness when selecting indicators. A smaller index using easily available data is more convenient to use, but may overlook important impacts and therefore distort planning decisions. A larger set can be more comprehensive but have unreasonable data collection costs and be difficult to interpret.

There are currently no standardized indicator sets for comprehensive and sustainable transport planning. Each jurisdiction or organization must develop its own set based on needs and abilities. It would be useful for major planning and professional organizations to establish recommended sustainable transportation indicator sets, data collection standards, and evaluation best practices in order to improve sustainability planning and facilitate comparisons between jurisdictions, organizations and time periods.

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