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Well Measured

Developing Indicators for Comprehensive and Sustainable Transport Planning

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A whole world view showing Africa and Saudi Arabia taken Dec. 7, 1972 as Apollo 17 left Earth orbit for the Moon. (Courtesy of NASA).

Abstract
This paper provides guidance on 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 indicator sets, and provides recommendations for selecting indicators for use in a particular situation.

Contents

Introduction

What transportation policies can be considered sustainable and optimal? Would a transport system become sustainable if all vehicles are solar powered? Is an emission reduction strategy sustainable if it is costly and inequitable? What trends are unsustainable? Which communities are most sustainable? How much mobility is sustainable?

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. These indicators have many uses for planning and management regardless of whether or not a decision-making process is called "sustainability planning." This information 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 (based on Gudmundsson, 2001)

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.

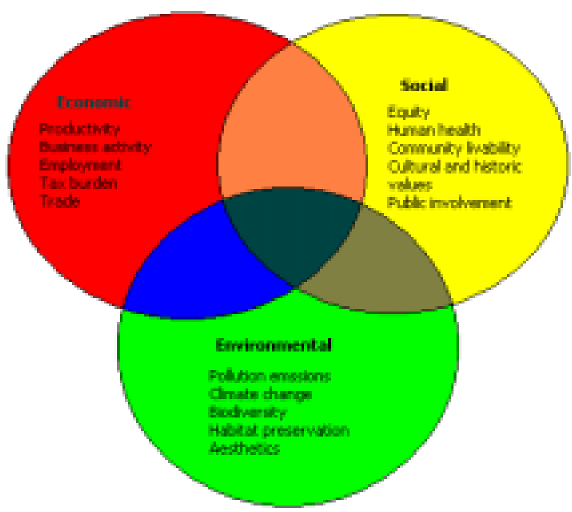
Indicator type – nature of data used by indicator (qualitative or quantitative, absolute or relative).

Sustainable Transportation

There is growing interest in *sustainability* and its implications for transport planning (Litman and Burwell, 2004). 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*[1]) considers society's overall, long-term goals.[2] This contrasts with *reductionist* planning, in which problems are assigned to a profession or organization with narrow responsibilities and goals, which often results in solutions to one problem that exacerbate other problems facing society, and undervalues strategies that provide modest but multiple benefits (Litman, 2003).

Sustainability is sometimes defined narrowly, focusing on resource depletion and air pollution problems, on the grounds that these impose significant long-term risks and are neglected by conventional planning (TRB, 1997). But it is increasingly defined broadly to include other issues (Figure 1). Narrowly defined sustainability can overlook connections between issues and opportunities for integrated solutions. For example, some air emission reduction strategies may exacerbate other economic, social and environmental problems. Comprehensive analysis takes these interactions into account, allowing decision-makers to identify strategies that help achieve multiple planning objectives, and so are truly optimal ("Win-Win Solutions," VTPI, 2005).

Figure 1 **Sustainability Issues**



This figure illustrates various sustainability issues.[3]

[1] *Sustainability* is a popular concept in some communities but not others, where it may be better to use the term *comprehensive planning*. The distinction is more ideological then functional.

[2] Sustainability originally reflected concerns about the long-term impacts of current resource consumption, for the sake of *intergenerational equity* (being fair to future generations). But if *future* equity and ecological quality are concerns, it makes little sense to ignore such impacts on this generation. Thus sustainability can be defined as planning that considers all impacts, including those distant in time and space.

[3] Although this figure implies that each issue fits into a specific category, there is actually considerable overlap. For example, pollution is an environmental concern, affects human health (a social concern) and fishing and tourism industries (economic concerns).

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.

If sustainability is defined primarily in terms of energy consumption and air pollution emissions, the best solution is more efficient and cleaner vehicles. Hybrid cars are now commercially available that are three times as fuel efficient as the fleet average and reduce emissions per vehicle-mile. But driving such a vehicle does not reduce congestion, road and parking facility costs, most consumer costs, accident costs, mobility problems facing non-drivers, or the environmental impacts of roads and sprawl; in fact, by reducing vehicle operating costs, it tends to increase these problems (Litman, 2004a). When all impacts are considered, strategies that improve travel options, create more accessible land use patterns, and reduce total automobile travel are generally most sustainable.

Table 1 **Comparing Benefits**

Impacts	Efficient Vehicles	Shift to Transit and Ridesharing	Shifts to Nonmotorized Modes
Energy and Emissions Reductions	Positive	Positive	Positive
Congestion Reduction		Positive	Positive
Road & Parking Cost Savings		Positive	Mixed
Crash Reductions		Positive	Positive
Improved mobility for non-drivers		Positive	Positive
Increased Public Fitness		No Change	Positive
Smart Growth Development		Positive	Positive

Shifting to more efficient vehicles helps achieve one or two planning objectives. Shifting modes and reducing total vehicle travel achieve many objectives.

Comprehensive analysis can also help determine *how* a particular strategy should be implemented to be considered sustainability. For example, some pricing reforms (increased fuel taxes, road and parking pricing, emission fees, etc.) are considered economically and environmentally beneficial, but regressive (they burden lower-income people more than higher-income people) and therefore socially inequitable. However, their overall equity impacts depend on how prices are structured, the quality of travel options available to lower-income people, and how revenues are used. For example, if higher prices are implemented with discounts for disadvantaged users, a community has good travel options, and revenues benefit disadvantaged people (improving walking facilities and transit services, or reducing other regressive taxes), such reforms can be equitable overall.

Described differently, when defined narrowly, sustainable planning is a specialized activity, but defined more broadly allows it to be integrated with other transport and land use planning activities (Nicolas, Pochet and Poimboeuf, 2003).

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 in activities and their scores on tests and projects in order to evaluate their overall learning progress. Motorist track their vehicle's fuel and oil consumption rates, engine and brake noise, and ease of acceleration to help determine when it requires servicing or replacement.

Indicators must be carefully selected to provide useful information. In most situations, no single indicator is adequate, so a set of indicators should be selected. Such a set should reflect a broad range of planning goals and objectives. For example, it is desirable that indicators reflect all the impacts listed in Table 2, and possibly more. People using indicators should understand their perspectives and limitations. It is desirable that the data are suitable for comparison with other jurisdictions, times and organizations.

Table 2 **Sustainable Transportation Impacts**

Economic	Social	Environmental
Traffic congestion	Social equity	Air and water pollution
Mobility barriers	Impacts on mobility disadvantaged	Climate change
Accident damages	Human health impacts	Noise impacts
Facility costs	Community cohesion	Habitat loss
Consumer costs	Community livability	Hydrologic impacts
DNRR	Aesthetics	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* (identifying the type of congestion reduction desired, such as whether particular attention should be given to freight and public transit vehicle delays), *objectives* and *targets* (specific, feasible changes in congestion impacts 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 (Litman, 2003). 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 3. For example, indicators may reflect the 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 and lost productivity 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 ("Planning and Evaluation," VTPI, 2005).

Table 3 **Levels of Impacts**

External Trends ↓	Changes in population, income, economic activity, political pressures, etc.	Evaluation Indicators
Policy Or Planning Decisions ↓	Funding allocation, facility design decision, price reform, education program, etc.	
Options and Incentives ↓	New transport facilities and services, price changes, more 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 figure 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.

Quantitative data refers to numerically measured information. *Qualitative data* refers to other types of information. Qualitative data can be quantified using lettered or numbered rating systems such as Level-Of-Service (LOS). Similarly, the value people place on convenience, comfort and livability can be quantified using various economic evaluation techniques (Litman, 2004b). Quantitative data tends to be considered more objective and easier to analyze. This can create a problem: easier to measure impacts tend to receive more attention in a typical planning process than more difficult to measure impacts (which are often dismissed as "intangibles"). For example, vehicle traffic speeds and delays are easy to measure, and are quantified using Level-Of-Service ratings and congestion indices. Walkability, equity, and livability are more difficult to quantify, so they often receive less consideration than justified by their value to affected people. Sustainability indicators therefore require quantifying impacts as much as possible.

Table 4 **Quantitative and Qualitative Data**

Quantitative Data	Qualitative Data
Vehicle and person trips	Survey data
Vehicle and person miles of travel	User preferences
Traffic crashes and fatalities	Convenience and comfort
Expenditures, revenues and costs	Community livability
Property values	Aesthetic factors

This table compares examples of quantitative and qualitative transportation data.

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 help compare impacts, such as per mile, per trip, per vehicle-year, per capita, and per dollar (Litman, 2003). 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.

Individual indicators can be evaluated 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.

Transport and land use have interactive effects, and both affect sustainability. As a result, “smart growth” policies, which create more accessible and multi-modal land use, tend to support sustainability, while “sprawl” tends to reduce sustainability by increasing per capita land impacts and motor vehicle travel (“Smart Growth,” VTPI, 2004).

It may be helpful to prioritize indicators and develop different sets for particular situations. For example, it can be useful to identify some indicators that should always be collected, others that are desirable if data collection costs are acceptable, and some indicators to address specific planning objectives that may be important in certain cases. When developing indicators for a particular sector, jurisdiction or organization it is important to consider which impacts and objectives are within their responsibility.

Indicators By Category

This section describes the selection of sustainable transportation indicators by category.

Economic Indicators

Economic development refers to a community's progress toward economic objectives such as increased income, wealth, employment, productivity and social welfare. *Welfare* (as used by economists) refers to total human wellbeing and happiness. Economic policies are generally intended to maximize welfare, although this is difficult to measure directly. Instead, monetary income, wealth and productivity (such as Gross Domestic Product [GDP]) are often used as economic indicators. But these indicators can criticized on several grounds (Cobb, Halstead and Rowe, 1999; Dixon, 2004).

- They only measure material wealth that is traded in a market, and so overlook other factors that contribute to wellbeing such as health, self-reliance, love, community, pride, environmental resources, freedom, etc.
- These indicators give a positive value to destructive activities that reduce people's health and self-reliance, and therefore increase their use of market goods (medical services, purchased rather than home-grown or gathered foods and fuel).
- As they are typically used, these indicators do not reflect the distribution of wealth (although they can be used to compare wealth between different groups).

Two communities can have similar economic productivity, and two people can have similar wealth, yet one has greater wellbeing overall due to differences in how the wealth is created, distributed and used. There are many possible traps by which increased wealth can fail to increase welfare, for example, if a productive process harms the environment and makes people sick, if wealth distribution is severely unequal, if wealth is spent inefficiently, and if increased material wealth disrupts community cohesion, pride, freedom or other nonmarket goods.

Put differently, people often have significant *nonmarket* wealth ignored by conventional economic indicators, such clean air and water, health, public resources, self-reliance skills, the ability to farm and gather food, and social networks that provide security, education, entertainment, and other services. Market activities that degrade these free and low-cost resources make people poorer, forcing them to earn and spend more money for commercial replacements. Conventional economic indicators treat these shifts as entirely positive. More accurate indicators account for both the losses and gains of such changes.

Material wealth provides *declining marginal social welfare benefits*, which means that each additional unit of wealth provides less benefit than the last, because consumers purchase the most rewarding goods first, so additional wealth allows increasing less rewarding expenditures. For example, if a person only earns $10,000 annually, giving them another $10,000 makes them far better off. But the same $10,000 increase in income provides less benefit to somebody earning $50,000 annually, and less to somebody earning $100,000, and even less to somebody earning $500,000.

However, people seldom recognize these diminishing benefits, because as they become wealthier their financial expectations increase. As consumers become wealthier an increasing portion of their expenditures reflect status (also called *prestige* or *positional*) goods. Although such expenditures provide perceived benefits to individuals, they provide little or no net benefit to society since as one consumer displays more wealth, others must match it to maintain status. If you purchase a mansion, I feel obliged to purchase an equal size home, even if we both end up with larger houses than we can really use. In this way, a large increase in productivity and income may provide little gain in social welfare, particularly if it is directed at already wealthy consumers.

Transportation activities reflect these patterns. In accessible communities people can reach most destinations using low-cost modes such as walking, bicycle, wagon and public transit, but increased automobile dependency tends to reduce the performance of these modes ("Automobile Dependency," VTPI, 2005). It makes nonmotorized travel difficult and dangerous. Low-cost modes receive less consideration in planning and investments. More dispersed land use patterns result in more trips beyond walking and cycling distances. As private vehicles become common, other modes lose status and consumers must own more costly vehicles to maintain prestige. As a result, motor vehicle ownership and use may increase with little net gain in accessibility or social welfare.

Transportation can leverage other economic impacts ("Economic Development Impacts," VTPI, 2005). Vehicle and fuel expenditures tend to provide less business activity and employment than most other consumer expenditures, since they are mostly imported and capital rather than labor intensive. Such expenditures are particularly burdensome to the economies of developing countries that import petroleum. Increased motor vehicle ownership and use increase road and parking facility costs, reduce productivity due to congestion, and harm certain industries, particularly those that require clean environments such as tourism, agriculture and fisheries.

Sustainable transportation economic indicators should reflect both the benefits and costs of motor vehicle use, and the possibility that more motorized mobility reflects a reduction in overall accessibility and transport diversity, rather than a net gain in social welfare. Increased mobility that provides little or negative net benefits to society can be considered to reduce sustainability, while policies that increase the net benefits from each unit of mobility can be considered to increase sustainability.

Vehicle Travel As A Sustainability Indicator

Motor vehicle travel (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 reduces sustainability, 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.

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.) ("Market Principles," VTPI, 2005). Some analysis indicates that more than a third of all motor vehicle travel results from these distortions (Litman, 2005b).

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.

Table 5 lists possible economic indicators of sustainable transportation.

Table 5 **Economic Indicators of Sustainable Transportation**

Indicator	Description	Direction	Data Availability
User rating	Overall satisfaction rating of transport system by users.	More is better	3
Commute Time	Average door-to-door commute travel time.	Less is better	1
Employment Accessibility	Number of job opportunities and commercial services within 30-minute travel distance of residents.	More is better	3
Land Use Mix	Average number of basic services (schools, shops and government offices) within walking distance of homes.	More is better	3
Electronic communication	Portion of population with Internet service.	More is better	2
Vehicle Travel	Per capita motor vehicle-mileage, particularly in urban-peak conditions.	Less is better	1
Transport Diversity	Variety and quality of transport options available in a community.	More is better	3
Mode Split	Portion of travel made by non-automobile modes: walking, cycling, rideshare, public transit and telework.	More is better	2
Congestion delay	Per capita traffic congestion delay.	Less is better.	2
Travel costs	Portion of household expenditures devoted to transport.	Less is better.	2
Transport cost efficiency	Transportation costs as a portion of total economic activity, and per unit of GDP	Less is better.	2
Facility costs	Per capita expenditures on roads, parking and traffic services.	Less is better	1
Cost Efficiency	Portion of road and parking costs borne directly by users.	More is better	2
Freight efficiency	Speed and affordability of freight and commercial transport.	More is better	3
Delivery services	Quantity and quality of delivery services (international/intercity courier, and stores that offer delivery).	More is better	2
Commercial transport	Quality of transport services for commercial users (businesses, public agencies, tourists, convention attendees).	Higher is better	3
Crash costs	Per capita crash costs	Less is better	2
Planning Quality	Comprehensiveness of the planning process: whether it considers all significant impacts and uses best current evaluation practices.	More is better	2
Mobility management	Implementation of mobility management programs to address problems and increase transport system efficiency.	More is better	2
Pricing reforms	Implementation of pricing reforms such as congestion pricing, Parking Cash Out, tax reforms, etc.	More is better	2
Land use planning	Applies smart growth land use planning practices, resulting in more accessible, multi-modal communities.	More is better	2

Data availability: 1 = usually available in standardized form; 2 = often available but not standardized; 3 = limited, may require special data collection.

Social Indicators

Social impacts include equity, human health (which is also an economic impact if disease imposes financial costs or reduces productivity), community livability (the quality of the local environment as experienced by people in an area) and community cohesion (the quality of interactions among people living in a community), impacts on historic and cultural resources (such as historic sites and traditional community activities), and aesthetics. Various methods can be used to quantify these impacts (Forkenbrock and Weisbrod, 2001; Litman, 2004b; "TDM Evaluation," VTPI, 2005).

Transportation equity can be evaluated with a variety of perspectives and impacts (FHWA and FTA, 2002; Caubel, 2004; Litman, 2005a). It requires comparing differences in transport options, service quality, impacts and between different groups, particularly impacts on people who are economically, physically and socially disadvantaged.

Human health impacts of transportation include accident injuries, pollution illness, and health problems from inadequate physical activity. Policies that improve walking and cycling conditions and increase nonmotorized travel improve mobility for disadvantaged people and increase fitness and so tend to support sustainable transportation.

Community livability and cohesion can be measured using field surveys to see how transport facilities and activities impact the human environment, surveys of residents to determine how these impacts affects interactions among neighbors, and economic surveys to see how this affects property values and business activity. Historic and cultural resources can be evaluated using surveys which ascertain the value people place on them.

Table 6 lists examples of possible social indicators of sustainable transportation.

Table 6 **Social Indicators of Sustainable Transportation**

Indicator	Description	Direction	Data Availability
User rating	Overall satisfaction of transport system by disadvantaged users.	More is better	3
Safety	Per capita crash disabilities and fatalities.	Less is better	1
Fitness	Portion of population that regularly walks and cycles.	More is better	3
Community livability	Degree to which transport activities support community livability objectives (local environmental quality).	More is better	3
Cultural Preservation	Degree to which cultural and historic values are reflected and preserved in transport planning decisions.	More is better	3
Non-drivers	Quality of transport services and access for non-drivers.	More is better	3
Affordability	Portion of budgets spent on transport by lower income households.	Less is better	2
Disabilities	Quality of transport facilities and services for disabled people.	More is better	2
NMT transport	Quality of walking and cycling conditions.	More is better.	3
Children's Travel	Portion of children's travel to school and other local destinations by walking and cycling.	More is better	2
Inclusive Planning	Substantial involvement of affected people, with special efforts to insure that disadvantaged and vulnerable groups are involved	More is better	2

Data availability: 1 = usually available in standardized form; 2 = often available but not standardized; 3 = limited, may require special data collection.

Environmental Indicators

Environmental impacts include various types of air pollution (including gases that contribute to climate change), noise, water pollution, depletion of nonrenewable resources, landscape degradation (including pavement or damage to ecologically productive lands, habitat fragmentation, hydrologic disruptions due to pavement), heat island effects (increased ambient temperature resulting from pavement), and wildlife deaths from collisions. Various methods can be used to measure these impacts and quantify their ecological and human costs (EEA, 2001; Litman, 2004b; FHWA, 2004).

Of course there is considerable uncertainty about many of these costing methodologies and the resulting values. There are various ways of dealing with such uncertainty, including improved analysis methodologies, use of cost ranges rather than point values, and establishment of reference standards (such as acceptable levels of ambient air pollution and noise levels).

Many existing estimates of environmental impacts are partial analyses. For example, many monetized estimates of air pollution costs only include a portion of the types of harmful emissions produced by motor vehicles, and many only consider human health impacts, ignoring ecological, agricultural and aesthetic damages (Litman, 2004b).

Table 7 lists possible environmental indicators of sustainable transportation.

Table 7 **Environmental Indicators of Sustainable Transportation**

Indicator	Description	Direction	Data Availability
Environment			
Climate change emissions	Per capita fossil fuel consumption, and emissions of CO_2 and other climate change emissions.	Less is better	1
Other air pollution	Per capita emissions of “conventional” air pollutants (CO, VOC, NOx, particulates, etc.)	Less is better	2
Air pollution	Frequency of air pollution standard violations.	Less is better	1
Noise pollution	Portion of population exposed to high levels of traffic noise.	Less is better	2
Water pollution	Per capita vehicle fluid losses.	Less is better	3
Land use impacts	Per capita land devoted to transportation facilities.	Less is better	3
Habitat protection	Preservation of high-quality wildlife habitat (wetlands, old-growth forests, etc.)	More is better	3
Habitat fragmentation	Average size of roadless wildlife preserves.	More is better	3
Resource efficiency	Non-renewable resource consumption in the production and use of vehicles and transport facilities.	Less is better	2

Data availability: 1 = usually available in standardized form; 2 = often available but not standardized; 3 = limited, may require special data collection.

Conventional Transport Indicators

Conventional transport indicators mostly consider motor vehicles traffic conditions. Below are examples (ITE, 1999; Homberger, et al., 2001).

- Roadway level-of-service (LOS), which is an indicator of vehicle traffic speeds and congestion delay at a particular stretch of roadway or intersection. A higher rating is considered better.
- Average traffic speeds. Assumes higher is better.
- Average congestion delay, measured annually per capita. Lower is considered better.
- Parking convenience and price. Increased convenience and lower price is generally considered better.
- Crash rates per vehicle-mile. Lower crash rates are considered better.

Because they favor automobile travel, these indicators tend to increase motor vehicle travel. For example, they justify road and parking facility capacity expansion that tends to create more automobile-oriented transport and land use systems, increasing per capita vehicle travel and reducing the viability of walking, cycling and public transit. This tends to contradict sustainability objectives by increasing per capita resource consumption, traffic congestion, road and parking facility costs, traffic accidents, pollution emissions and land consumption, and reducing travel options for non-drivers, exacerbating inequity

By evaluating impacts per vehicle-mile rather than per capita, they do not consider increased vehicle mileage to be a risk factor and they ignore vehicle traffic reductions as possible solution to transport problems (Litman, 2003). For example, from this perspective an increase in per capita vehicle crashes is not a problem provided that there is a comparable increase in vehicle mileage. Increased vehicle travel can even be considered a traffic safety strategy if it occurs under relatively safe conditions, because more safe miles reduce per-mile crash and casualty rates.

A variety of methods are now available for evaluating the quality of alternative transport mode (walking, cycling, public transit, etc.), but they require additional data collection and are not yet widely used (FDOT, 2002; “Evaluating Transport Options, VTPI, 2005).

Examples of Sustainable Transportation Indicator Sets

Below are examples of sustainability and sustainable transport indicator sets. For more examples see Gudmundsson, 2001 and Mihyeon Jeon and Amekudzi, 2005.

Table 8 is an example of a *Genuine Progress Indicator* developed for Alberta, Canada, reflecting overall sustainability. Other regions, goals and analysis perspectives may require somewhat different indicators. These indicators can be applied to transport planning, by selecting those that are affected by transport facilities and activities, and using them to evaluate options.

Table 8 **Sustainability Indicators** (Pembina Institute, 2001)

Economic	Social	Environmental
Economy, GDP and Trade	Time Use	Energy
Economic growth (GDP)	Paid work time	Oil and gas reserve life
Economic diversity	Household work	
Trade	Parenting and eldercare	Agriculture
	Free time	Agricultural sustainability
Personal Consumption	Volunteerism	
Expenditures, Disposable Income and Savings	Commuting time	Forests
		Timber sustainability
Disposable income	Human Health and Wellness	Forest fragmentation
Personal expenditures	Life expectancy	
Taxes	Premature mortality	Parks and Wilderness
Savings rate	Infant mortality	Parks and wilderness
	Obesity	
Money, Debt, Assets and Net Worth		Fish and Wildlife
	Suicide	Fish and wildlife
Household Debt	Suicide	
		Wetlands and Peatlands
Income Inequality, Wealth, Poverty and Living Wages	Substance Abuse: Alcohol, Drugs and Tobacco	Wetlands
		Peatlands
Income distribution	Drug use (youth)	
Poverty		Water Resource and Quality
	Auto Crashes and Injuries	Water quality
Public and Household Infrastructure	Auto crashes	
		Energy Use Intensity and Air Quality
Public infrastructure	Family Breakdown	
Household infrastructure	Divorce	Energy use intensity
		Air quality-related emissions
Employment	Crime	Greenhouse gas emissions
Weekly wage rate	Crime	
Unemployment rate		Carbon Budget
Underemployment	Gambling	Carbon budget deficit
	Problem gambling	
Transportation		Municipal and Hazardous Waste
Transportation expenditures	Democracy	Hazardous waste
	Voter participation	Landfill waste
	Intellectual & Knowledge Capital	Ecological Footprint
	Educational attainment	Ecological footprint

This table summarizes Genuine Progress Indicators used to evaluate sustainability.

Green Community Checklist

The US Environmental Protection Agency (EPA, 2003) proposes that a "green" community strives to:

Environment

- Comply with environmental regulations.
- Practice waste minimization and pollution prevention.
- Conserve natural resources through sustainable land use.

Economic

- Promote diverse, locally-owned and operated sustainable businesses.
- Provide adequate affordable housing.
- Promote mixed-use residential areas which provide for open space.
- Promote economic equity.

Social

- Actively involve citizens from all sectors of the community through open, inclusive public outreach.
- Ensure that public actions are sustainable, while incorporating local values and historical and cultural considerations.
- Create and maintain safe, clean neighborhoods and recreational facilities for *all*.
- Provide adequate and efficient infrastructure (water, sewer, etc.) that minimizes human health and environmental harm, and transportation systems that accommodate broad public access, bike and pedestrian paths.
- Ensure equitable and effective educational and health-care systems.

USDOT Environmental Performance Measures

The US Departement of Transportation uses the following environmental performance indicators (FHWA, 2002).

> *Emissions* – Tons of mobile source emissions from on-road motor vehicles
>
> *Greenhouse Gas Emissions* – Metric tons of carbon equivalent emissions from transportation sources.
>
> *Energy* – Transportation-related petroleum consumption per gross domestic product.
>
> *Wetlands Protection* – Acres of wetlands replaced for every acre affected by Federal-aid Highway projects.
>
> *Livable Communities/Transit Service* – Percent urban population living within 1-mile of transit stop with service of 15 mintues or less.
>
> *Airport Noise Exposure* – Number of people in US exposed to significant aircraft noise levels.
>
> *Maritime Oil Spills* – Gallons of oil spilled per million gallons shipped by maratime sources.
>
> *Fisheries Protection* – Compliance with Federal fisheries regulations.
>
> *Toxic Materials* – Tonns of hazardous liquid materials spilled per millon ton-miles shipped; and gallons of hazardous liquid spilled per serious transportation incident.
>
> *Hazardous Waste* – Percent DOT faciliteis categorized as No Further Remedial Action Planned under Superfund Act.
>
> *Environmental Justice* – Environmental justice cases that remain unresolved over one year.

Sustainable Transportation Performance Indicators

The Sustainable Transportation Performance Indicators (STPI) project by the Centre for Sustainable Transportation produced the indicators summarized in Table 9.

Table 9 **Sustainable Transportation Performance Indicators** (Gilbert, et al, 2003)

Framework	Initial STPI	Short-term Additions	Long-Term Additions
1. Environmental and Health Consequences of transport.	Use of fossil fuel energy for all transport. Greenhouse gas emissions for all transport. Index of emissions of air pollutants from road transport. Index of incidence of road injuries and fatalities.	Air quality. Waste from road transport. Discharges into water. Land use for transport. Proximity of infrastructure to sensitive areas and ecosystem fragmentation.	Noise Effects on human health. Effects on ecosystem health.
2. Transport activity	Total motorized movement of people. Total motorized movement of freight. Share of passenger travel *not* by land-based public transport. Movement of light-duty passenger vehicles.	Utilization of passenger vehicles. Urban automobile vehicle-kilometers. Travel by non-motorized modes in urban areas. Journey-to-work mode shares.	Urban and intercity person-kilometers. Freight modal participation. Utilization of freight vehicles.
3. Land use, urban form and accessibility	Urban land use per capita.	Urban land use by class size and zone. Employment density by urban size, class and zone. Mixed use (percent walking to work, ratio of jobs to employed labour force.	Share of urban population and employment served by transit. Share of population and employment growth on already urbanized lands. Travel and modal split by urban zone.
4. Supply of transport infrastructure and services.	Length of paved roads.	Length of sustainable infrastructure. Transit seat-kilometers per capita.	Congestion index.
5. Transport expenditures and pricing.	Index of relative household transport costs. Index of relative cost of urban transport.	Percent of net government transport expenditures spent on ground-based public transport.	Transport related user charges. Expenditures by businesses on transportation.
6. Technology adoption.	Index of energy intensity of cars and trucks. Index of emissions intensity of the road-vehicle fleet.	Percent of alternative fuel vehicles in the fleet.	Percent of passenger-kms and tonne-kms fuelled by renewable energy. Percent of labour force regularly telecommuting.
7. Implementation and monitoring.		Number of sustainable transport indicators regularly updated and widely reported. Public support for initiatives to achieve sustainable transport.	Number of urban regions where planning and delivery of transport and related land use matters have a single authority.

Environmentally Sustainable Transport

The Organization for Economic Cooperation and Development (OECD, 2001) developed the following indicators of Environemementally Sustainable Transport (EST).

- *CO_2* – Climate change is prevented by avoiding an increase in per-capita carbon-dioxide emissions from transport.
- *NO_X* – Damage from ambient NO_2 and ozone levels and nitrogen deposition is greatly reduced.
- *VOC* – Damage from carcinogenic VOCs and ozone is greatly reduced.
- *Particulates* – Harmful ambient air levels are avoided by reducing emissions of fine particulates (particularly those less than 10 microns in size).
- *Noise* caused by transport no long results in outdoor noise levels which present a health concern or serious nuisance (maximum 55-70 decibels during the day and 45 decibels at night and indoors).
- *Land use* for the movement, maintenance and storage of all transport vehicles is reduced to the extent that local and regional objectives for ecosystem protection are met.

The OECD concludes that environmentally sustainable transport will require:

- Significant reduction in car ownership and use, and shifts to more efficient vehicles.
- Reduced long-distance passenger and freight travel, particularly air travel, and increased non-motorized short-distance travel.
- Energy-efficient, electric powered, high-speed rail.
- Energy-efficient, less polluting shipping.
- More accessible development patterns.
- Increased use of telecommunications to substitute for physical travel.
- More efficient production to reduce long-distance freight transport.

Mobility For People With Special Needs and Disadvantages

Special consideration should be given to evaluating the ability of a transportation system to serve people who face the greatest mobility constraints, such as wheelchair users and people with very low incomes (Litman and Richert, 2005; Litman, 2005a). Special effort may be made to identify these users in transportation surveys and ridership profiles, evaluation of transportation system features in terms of their ability to accommodate people with disabilities. The following are possible performance indicators.

1. Surveys of disadvantaged people to determine the degree to which they are constrained in meeting their basic mobility needs (travel to medical services, school, work, basic shopping, etc.) due to inadequate facilities and services.

2. Travel surveys that identify the degree of mobility by disadvantaged people, and how this compares with the mobility of able-bodied and higher-income people.

3. The degree to which various transportation modes and services accommodate disadvantaged people, including the ability of walking facilities and transit vehicles to accommodate wheelchair users and users with other disabilities, and transportation service discounts and subsidies for people with low incomes.

4. Degree to which disadvantaged people are considered in transportation planning through the involvement of individuals and advocates in the planning process, special data collection, and special programs.

5. The portion of pedestrian facilities that accommodate wheelchair users, and the number of barriers within the system.

6. The frequency of failures, such as excessive waiting times, inaccurate user information and passups of disadvantaged people by transportation services.

7. User surveys to determine the problems, barriers and costs disadvantaged people face using transportation services.

8. The portion of time and financial budgets devoted to transportation by disadvantaged people.

9. Indicators of the physical risks facing people with disabilities using the transportation system, such as the number of pedestrians with disabilities who are injured or killed by motor vehicles, and the frequency of assault on transit users, particularly those with disabilities and lower incomes (who are often forced to use transit services in less secure times and locations, due to fewer transportation options).

World Business Council Sustainable Mobility Indicators

The table below summarizes sustainable mobility indicators developed for the World Business Council's Sustainable Mobility project.

Table 10 **Sustainable Mobility Indicators** (Eads, 2001)

User Concerns	Societal Concerns	Business Concerns
Ease of access to means of mobility Financial outlay required of user Average door-to-door time required Reliability, measured as variability in average door-to-door time Safety (chance of death or serious injury befalling the user) Security (chance of the user being subjected to robbery, assault, etc.)	Impacts on the environment and on public health and safety Greenhouse gas emissions (CO_2 equivalent) "Conventional" emissions – NOx, CO, SO_2, VOC, particulates Safety (number of deaths and serious injuries) Security Noise Land use Resource use (including recycling) Impacts on public revenues and expenditures "Launching aid" Publicly-provided infrastructure Required operating subsidies Potential for reducing public expenditures Potential for generating government revenues Equity impacts	Profitability (ability to earn at least a competitive return on investment) Total market size Conditions determining market acceptance Required competences Private investment required Necessity/possibility of "launching aid" and payback conditions Investment net of publicly-provided infrastructure Cash flow generation Potential cash flow from operations Gap between likely actual and required cash flow; potential for public subsidies Policy barriers/incentives

Eliminating overlaps resulted in the following set

- Ease of accessibility to means of mobility.
- Financial outlay required.
- Average required door-to-door time.
- Reliability (variability in required average door-to-door time).
- Safety (risk of death or serious injury befalling the user).
- Security (risk of the user being subjected to robbery, assault, etc.).
- Transport-related GHG emissions.
- Impact on environment, public health and safety (with associated sub-indicators).
- Impact on public revenues and expenditures (with associated sub-indicators).
- Equity implications (with associated sub-indicators).
- Prospective rate of return (with associated sub-indicators).

TERM

The European Union's *Transport and Environment Reporting Mechanism* (TERM) identifies the sustainable transportation indicators summarized in Table 11.

Table 11 **Proposed TERM Indicator List** (EEA, 2002)

Group	Indicators	
Transport and Environment Performance		
Environmental consequences of transport	Transport final energy consumption and primary energy consumption, and share in total (fossil, nuclear, renewable) by mode.	
	Transport emissions and share in total emissions for CO_2, NO_x, NM, VOCs, PM_{10}, SO_x, by mode.	
	Exceedances of air quality objectives.	
	Exposure to and annoyance by traffic noise.	
	Infrastructure influence on ecosystems and habitats ("fragmentation") and proximity of transport infrastructure to designated sites.	
	Land take by transport infrastructures.	
	Number of transport accidents, fatalities, injured, polluting accidents (land, air and maritime).	
Transport volume and intensity	*Passenger transport (by mode and purpose):* total passengers total passenger-kilometers passenger-kilometers per capita passenger-kilometers per GDP	*Freight transport (by mode and group of goods):* total tonnes total tonne-kilometers tonne-kilometers per capita tonne-kilometers per GDP
Determinants of the Transport/environment System		
Spatial planning and Accessibility	Average passenger journey time and length per mode, purpose (commuting, shopping, leisure) and territory (urban/rural).	
	Access to transport services e.g.: motor vehicles per household, portion of households located within 500m of public transport.	
Transport supply	Capacity of transport infrastructure networks, by mode and by type of infrastructure (e.g. motorway, national road, municipal road etc.).	
	Investments in transport infrastructure/capita and by mode.	
Price signals	Real passenger and freight transport price by mode.	
	Fuel price.	
	Taxes.	
	Subsidies.	
	Expenditure for personal mobility per person by income group.	
	Proportion of infrastructure and environmental costs (including congestion costs) covered by price.	
Technology and utilization efficiency	Energy efficiency for passenger and freight transport (per pass-km and per tonne-km and by mode).	
	Emissions per pass-km and emissions per tonne-km for CO_2, NO_x, NM, VOCs, PM_{10}, SO_x by mode.	
	Occupancy rates of passenger vehicles.	
	Load factors for road freight transport (LDV, HDV).	
	Uptake of cleaner (unleaded petrol, electric, alternative fuels) and alternative fuelled vehicles.	
	Vehicle fleet size and average age.	
	Proportion of vehicle fleet meeting certain air and noise emission standards (by mode).	
Management integration	Number of Member States that implement an integrated transport strategy.	
	Number of Member States with national transport and environment monitoring system.	
	Uptake of strategic environmental assessment in the transport sector.	
	Uptake of environmental management systems by transport companies.	
	Public awareness and behaviour.	

This table summarizes indicators used to evaluate transport sustainability in the TERM project.

SUMMA

SUMMA (SUstainable Mobility Measures and Assessment) is a European Commission sponsored project to define and operationalize sustainable mobility, develop indicators, assess the scale of sustainability problems associated with transport, and identify policy measures to promote sustainable transport (www.SUMMA-EU.org). Table 12 shows the scope of its analysis.

Table 12 **SUMMA Outcomes of Interest**

Economic	Environmental	Social
EC1: Accessibility Economic accessibility has two aspects: (1) local access of goods and people to services, work, industrial plants, etc., and (2) long distance links among regions.	*EN1: Resource use* The use of materials, energy and other resources by the transport sector.	*SO1: Accessibility and affordability* The time and cost required to reach basic services. Lower income individuals generally have poorer accessibility to basic services than those well off.
EC2: Transport operating costs The costs to the user of the transport system, both direct user costs (fuel, ticket prices, transport equipment), and indirect costs, such as the costs of congestion.	*EN2: Direct ecological intrusion* The impacts of transport on flora and fauna that are not caused by emissions or pollution, but rather by transport infrastructure (building, using, and maintaining).	*SO2: Safety and security* Safety implies freedom from danger. Security concerns freedom from fear (of crime or other undesired actions).
EC3: Productivity/Efficiency Providing conditions for an expanding, productive and efficient economy, and therefore for more individual and public welfare. Inefficiencies increase the resources needed to produce benefits.	*EN3: Emissions to air* Emissions of pollutants, etc. into the air, which affect health and harm buildings. Also the emission of greenhouse gasses, which contributes to global warming.	*SO3: Fitness and health* The trend to perform short trips by car decreases fitness and increases the threat to health (through increased pollution).
EC4: Costs to economy All costs of transport (except for the individual user), i.e. infrastructure investments, maintenance, public subsidies, final energy consumption and external costs of transport.	*EN4: Emissions to soil and water* Emissions of pollutants to soil and water, wastewater from manufacture and maintenance, runoff from roads, discharges of oil and wastewater by ships, etc.	*SO4: Livability and amenity* Transport influences our *quality of life*. It concerns an individual's direct surroundings and the impact transport has on it. It concerns not only measurable aspects (noise, pollution) but also perceptions and attitudes.
EC5: Benefits to economy The gross value added generated by the transport sector, national revenues from taxes and traffic system charging, and economic growth induced by transport.	*EN5: Noise* Transport is one of the most significant sources of noise in urban areas. There is evidence that noise is related to human and animal health and wellbeing.	*SO5: Equity* This concerns the fair distribution of costs and benefits among different groups in society, among income classes, among regions, and among generations.
	EN6: Waste Transport vehicles and infrastructure create large amounts of waste during their life cycle, which can partly be recycled or reused, but is otherwise disposed of by incineration and in landfills.	*SO6: Social cohesion* The ongoing process of developing a community of shared values, challenges and opportunities based on trust, hope and reciprocity. It is related to *social capital*, which refers to features of social organisation such as networks, norms, and social trust that facilitate co-operation for mutual benefit.

This table summarizes analysis used in the SUMMA project.

Aviation Sustainability Indicators

Table 13 illustrates indicators developed for evaluating airport environmental and operational sustainability. This is an example of sustainability indicators developed for evaluating a particular transport sector or facility. Such indicators can be converted into reference values, such as impacts per passenger-trip (arrivals and departures), for tracking performance over time and comparing performance with peer airports and other interregional travel modes. Threshold indicators are used to evaluate performance with respect to established limits and targets.

Table 13 **Indicators Of Airport Sustainability** (Upham and Mills, 2003)

Indicators	Absolute Measures	Threshold-Related Measures
1. Number of surface access vehicles: cars, light goods vehicles, heavy goods vehicles, buses, motorcycles, rail.	Number arriving at airport boundary (monthly, annually) Number departing airport boundary (monthly, annually)	- Movement number relative to hourly maxima
2. Aircraft Movements	Arrivals (hourly, monthly, yearly). Departures (hourly, monthly, yearly).	- Movement number relative to hourly maximum
3. Static power consumption	Fossil-fuelled electricity consumption. Fossil-fuelled gas consumption. Wind, solar or bio-generated electricity consumption.	- Consumption relative to any relevant hourly maxima
4. Gaseous pollutant emissions (from surface vehicles, static power, aircraft)	NOx, CO2, N_2O, CO_2, CO, NMVOC, and PM_{10} (g) per source. Ambient concentrations.	- Ambient concentrations relative to statutory EU limits
5. Aircraft noise emissions	Day, evening and night LAeq (dB) and LA max (A-weighted long-term average and peak sound level)	Land area and numbers of people within noise contours (LAeq 50 and upward increments) relative to regulated limits.
6. Terminal passengers	Number arriving at gates (Number departing gates)	- Arrivals relative to hourly maxima. - Departures relative to hourly maxima.
7. Surface access passengers	Number arriving at airport boundary. Number departing airport boundary.	- Arrivals relative to hourly maxima. - Departures relative to hourly maxima.
8. Water consumption & waste water emission	Monthly volume consumed. Effluent concentrations. Ambient concentrations of water pollutants.	- Volume consumed relative to hourly maximum. - Pollutant concentrations (effluent and ambient) relative to permitted maxima.
9. Solid waste	Monthly volume arising. Monthly volume recycled or re-used Monthly volume of hazardous waste.	Set targets for absolute volumes and relate performance to these.
10. Land take & biodiversity	Area paved (m2, within airport boundary and ownership, includes building footprints). Area of high and medium biodiversity (m2, within airport boundary and ownership, includes building footprints).	Set target for absolute areas and relate performance to these.

This table summarizes airport sustainability indicators. Threshold indicators indicate performance relative to standards and stated limits.

Lyons Regional Indicators

Nicolas, Pochet and Poimboeuf (2003) describe how local travel survey data and other available information is used to evaluate transport system sustainability in Lyons, France. This region has 1.2 million inhabitants with a relatively centralized, urban development pattern.

Indicators were organized to reflect economic, social and environmental impacts. Economic indicators reflect transport cost-efficiency, that is, the economic costs per unit of travel, including costs to residents, businesses, and governments. Social indicators reflect the relative mobility and transportation cost burdens for people in different income classes. Environmental indicators reflect various transport pollution emissions and land requirements. These impacts were disaggregated by mode (automobile, public transit, walking), geographic location (central, middle and outer urban areas) and household demographics. Table 14 summarizes these indicators

Table 14 **Lyons Indicators** (Nicolas, Pochet and Poimboeuf, 2003)

Dimension	Indicator	Level of Analysis
Mobility		
Service provided	Daily number of trips Trip purposes Average daily travel time	Overall and by geographic location
Organization of urban mobility	Mode split Daily average distance traveled Average travel speed	Overall and by travel mode
Economic		
Cost for the community	Annual transportation costs (total, per resident and per passenger-km) • Households • Businesses • Local government	Overall and per mode
Social		
	Household vehicle ownership Personal travel distance Household transportation expenditures (total and as a portion of income)	Overall, by income and geographic location
Environmental		
Air pollution - global	Annual energy consumption and CO2 emissions (total and per resident)	Overall, by mode, by location of emission, and location of resident.
Air pollution - local	CO, NOx, hydrocarbons and particulates (total and per resident)	Overall, by mode, by location of emission, and location of resident.
Space consumption	Daily individual consumption of public space for transport and parking. Space required for transport infrastructure.	Overall, by mode and place of residence.
Other	Noise Accident risk	Overall, by mode and place of residence.

This table summarizes sustainable transportation indicators used in Lyons.

Best Practices

Below are recommendations for selecting and applying sustainable transport indicators.

- *Diversity* – choose a set of indicators that reflect all relevant economic, social and environmental planning objectives.
- *Usefulness* – choose indicators that can be applied to planning decisions.
- *Ease of understanding* – choose indicators understandable to experts and the general public.
- *Data availability and collection costs* – choose indicators that rely on data that are available or can be collected with available resources.
- *Comparability* – if possible, choose indicators and data that are suitable for comparison with other jurisdictions, times and organizations.
- *Performance targets* – select indicators that are suitable for establishing usable performance targets.

Table 15 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).

Table 15 **Recommended Indicator Sets**

	Economic	Social	Environmental
Most Important (Should usually be used)	Per capita mobility (person-miles or trips). Mode split. Average commute travel time. Per capita congestion costs. Portion of household budgets devoted to transport. Public/external costs of transport per capita.	Quality of accessibility for disadvantaged people. Per capita traffic crashes and fatalities. Community impacts. Portion of low-income household budgets devoted to transport. Inclusiveness of planning process.	Per capita energy consumption. Per capita air pollution emissions (various types). Per capita land devoted to transportation facilities. Air and noise pollution exposure and health damages. Quality of environmental analysis and planning.
Helpful (Should be used if possible)	Degree to which transport planning decision reflect market principles. Relative quality of non-automobile modes (walking, cycling, ridesharing, public transit). Job opportunities and public services within 30-minute commute distance of residents.	Portion of residents who regularly walk or bicycle. Portion of children walking or cycling to school. Consideration of cultural resources in transport planning. Residents' overall satisfaction rating of transport system. Universal design (consideration of disabled people's needs in transport planning)	Community livability ratings. Water pollution emissions.
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.
Planning Process	Comprehensive (takes into account all significant impacts, using best current evaluation practices). Unbiased (applies objective, least-cost planning and investment practices). Inclusive (substantial involvement of affected people, with special efforts to insure that disadvantaged and vulnerable groups are involved). Application of smart growth land use policies.		
Market Efficiency	Portion of total roadway and parking costs borne directly by road users. Implementation of pricing reforms such as congestion pricing, distance-based vehicle insurance and registration fees, Parking Cash Out, unbundled parking, tax reforms, etc.		

This table indicates indicators ranked by importance and type.

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.

Most 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.). Special consideration should be given to “basic access” (transport that society considers of high value, such as access to for emergency and service vehicles, medical services, education, employment, etc.), and to the quality of transport for disadvantaged people.

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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International Society for Ecological Economics (http://kabir.umd.edu/ISEE/ISEEhome.html) is a professional organization.

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