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Developing Indicators for Sustainable and Livable Transport Planning

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A world view taken in 1972 as Apollo 17 left Earth orbit for the Moon. (Courtesy of NASA).

Abstract

This report provides guidance on the use of indicators for sustainable and livable transportation planning. It defines *sustainability* and *livability*, discusses sustainable development and sustainable transport concepts, and how sustainability indicators can be applied in transport evaluation and planning. It describes factors to consider when selecting sustainable transportation indicators, identifies examples of indicators and indicator sets, and provides recommendations for selecting sustainable transport indicators for use in a particular situation.

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Preface

Our family's house was built more than a century ago. On the walls hang photographs of our ancestors born more than 150 years ago. Our shelves contain books more than 200 years old. We've visited ancient cities, roads, structurs and artwork more than two thousand years old. Our religion celebrates events that more than four thousand years ago. Many tools we use daily, such as knives, pottery and weaving, were first invented tens of thousands of years old.

Looking backward in time, we are directly affected by decisions made centuries and millennia ago, but our thinking about the future tends to be more limited. Households and communities generally only plan a few years or decades into the future; thirty or forty years is generally the limit.

Yet, most people share a basic human desire to leave a positive legacy for future generations, without it we would not invest in education, durable infrastructure, or environmental quality. Described differently, most people desire economic, social and environmental sustainability.

This is an important new concept because only recently have people been burdened with uncertainty about society's long-term future. Although technological progress has improved our quality of life in many ways, it can also exacerbate many problems, including war, oppression, resource depletion, environmental damages, and social alienation, which threaten the quality and very existence of future generations.

In the past, futurists debated whether the future would lead to *utopia* (an ideal world) or *dystopia* (a degraded world). Sustainable development reflects a more sophisticated understanding of our impacts: it recognizes that our future will result, in part, on our current decisions. We cannot simply predict the future, instead we create it.

Sustainability includes more than just long-term planning. If we are concerned with the quality of life and environment in distant *times*, we must also be concerned the quality of life in distant *places*, even if only because we care about our own descendants, since they will be affected by, and possibly descended from, people in other parts of the world.

Since economic, social and environmental activities interact in so many ways, most experts now agree that sustainability requires balancing these various realms. A basic principle of good planning is that individual, short-term decisions should reflect strategic, long-term objectives. Sustainability planning provides guidance to insure that individual decisions balance economic, social and environmental objectives, taking into account indirect, distant, and long-term impacts.

Sustainability and *sustainable development* are generally considered desirable, although some conditions should not be sustained, such as hate, poverty and ignorance, and these terms are sometimes used to promote a particular policy or project that may only vaguely reflect strategic planning objectives. As a result, there is potential for legitimate debate concerning what sustainability policies are truly desirable. None-the-less, sustainability principles properly applied can improve decision making, particularly for strategic policy making and planning.

Executive Summary

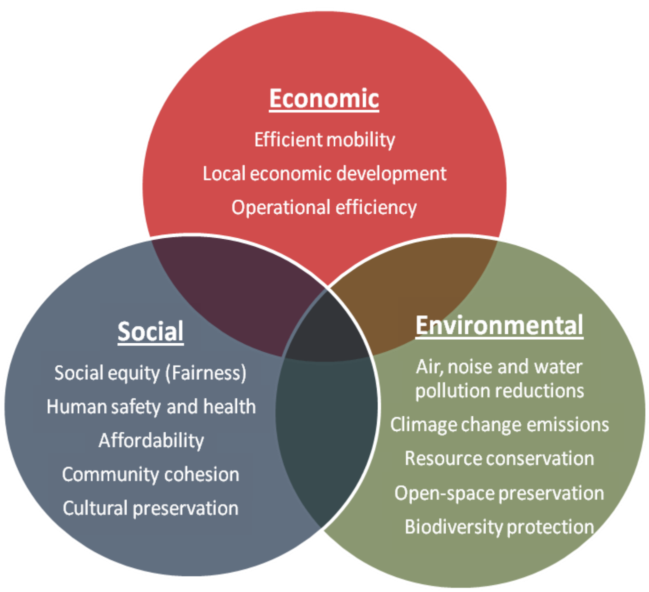
There is growing interest in the concepts of *sustainability, livability, sustainable development* and *sustainable transport*. *Sustainability* balances economic, social and environmental goals and objectives (*goals* are general desired outcomes, *objectives* are specific, measurable ways to achieve goals), including those that involve indirect and long-term impacts, as indicated in Table 1 and Figure 1. *Livability* refers to the subset of sustainability objectives that directly affect community members. They generally share the same objectives, but often with somewhat differing perspectives and priorities. For example, both justify efforts to reduce pollution, although sustainability often focuses on climate change emissions while livability focuses on local air and noise pollution.

Table ES-1 **Sustainability Goals**

Economic	Social	Environmental
Economic productivity	*Equity / Fairness*	Climate change prevention and *mitigation*
Local economic development	*Safety and security*	*Air, noise and water pollution prevention*
Resource efficiency	*Community development*	Non-Renewable Resource Conservation
Affordability	*Cultural heritage preservation*	*Openspace preservation*
Operational efficiency	*Public fitness and health*	Biodiversity protection
Good Governance and Planning		
Integrated, comprehensive and inclusive planning		
Efficient pricing		

Italics indicates livability objectives.

Figure ES-1 **Sustainable Transport Goals**



Sustainability emphasizes the integrated nature of human activities and therefore the need for coordinated planning among different sectors, groups and jurisdictions. It expands the objectives, impacts and options considered in a planning process. This helps insure that individual, short-term decisions are consistent with strategic, long-term goals.

Sustainable transport planning recognizes that transport decisions affect people in many ways, so a variety objectives and impacts should be considered in the planning process.

Various transport planning objectives support sustainability goals:

- *Transport system diversity*. Travelers can choose from various modes, location and pricing options, particularly ones that are affordable, healthy, efficient, and accommodate non-drivers.
- *System integration.* The various components of the transport system are well integrated, such as pedestrian and cycling access to transit, and integrated transport and land use planning.
- *Affordability.* Affordable transport options provide access to lower-income households.
- *Resource (energy and land) efficiency.* Policies encourage energy and land efficiency.
- *Efficient pricing and prioritization*. Road, parking, insurance and fuel are priced to encourage efficiency, and facilities are managed to favor higher value trips and more efficient modes.
- *Land use accessibility (smart growth).* Policies support compact, mixed, connected, multi-modal land use development in order to improve land use accessibility and transport options.
- *Operational efficiency.* Transport agencies, service providers and facilities are managed efficiently to minimize costs and maximize service quality.
- *Comprehensive and inclusive planning.* Planning is comprehensive (considers all significant objectives, impacts and options), integrated (decision-making is coordinated among different sectors, jurisdictions and agencies), and inclusive (all affected people are able to participate).

Table ES-2 indicates which objectives support which goals. Many help achieve multiple goals.

Table ES-2 **Sustainable Transport Goals and Objectives**

Sustainability Goals	Transport Planning Objectives							
	Transport Diversity	System Integration	Affordability	Resource (energy and land) Efficiency	Demand Management (efficient pricing & prioritization)	Land Use Accessibility (smart growth)	Cost Effective Operations	Comprehensive and Inclusive Planning
Economic productivity	✓	✓		✓	✓	✓	✓	
Economic development	✓	✓	✓	✓	✓	✓		✓
Energy efficiency	✓	✓		✓	✓	✓		
Affordability	✓	✓	✓	✓	✓	✓		
Operational efficiency					✓		✓	✓
Equity / Fairness	✓	✓	✓		✓	✓		
Safety, security and health	✓	✓	✓	✓	✓	✓		✓
Community development	✓	✓	✓	✓	✓	✓		✓
Heritage protection	✓			✓	✓	✓		✓
Climate stability	✓	✓	✓	✓	✓	✓		
Air pollution prevention	✓	✓	✓	✓	✓	✓		
Noise prevention	✓			✓				
Water pollution	✓	✓	✓	✓	✓	✓		✓
Openspace preservation	✓	✓	✓		✓	✓		✓
Good planning								✓
Efficient Pricing				✓	✓		✓	

This table indicates which planning objectives support various sustainability goals.

Table ES-3 summarizes sustainable transport goals, objectives and performance indicators.

Table ES-3 **Key Sustainable Transport Goals, Objectives and Indicators**

Sustainability Goals	Objectives	Performance Indicators
I. Economic		
Economic productivity	Transport system efficiency. Transport system integration. Maximize accessibility. Efficient pricing and incentives.	• Per capita GDP • Portion of budgets devoted to transport. • Per capita congestion delay. • Efficient pricing (road, parking, insurance, fuel, etc). • Efficient prioritization of facilities
Economic development	Economic and business development	• Access to education and employment opportunities. • Support for local industries.
Energy efficiency	Minimize energy costs, particularly petroleum imports.	• Per capita transport energy consumption • Per capita use of imported fuels.
Affordability	All residents can afford access to basic (essential) services and activities.	• Availability and quality of affordable modes (walking, cycling, ridesharing and public transport). • Portion of low-income households that spend more than 20% of budgets on transport.
Efficient transport operations	Efficient operations and asset management maximizes cost efficiency.	• Performance audit results. • Service delivery unit costs compared with peers. • Service quality.
II. Social		
Equity / fairness	Transport system accommodates all users, including those with disabilities, low incomes, and other constraints.	• Transport system diversity. • Portion of destinations accessible by people with disabilities and low incomes.
Safety, security and health	Minimize risk of crashes and assaults, and support physical fitness.	• Per capita traffic casualty (injury and death) rates. • Traveler assault (crime) rates. • Human exposure to harmful pollutants. • Portion of travel by walking and cycling.
Community development	Helps create inclusive and attractive communities.	• Land use mix. • Walkability and bikability • Quality of road and street environments.
Cultural heritage preservation	Respect and protect cultural heritage. Support cultural activities.	• Preservation of cultural resources and traditions. • Responsiveness to traditional communities.
III. Environmental		
Climate stability	Reduce global warming emissions Mitigate climate change impacts	• Per capita emissions of greenhouse gases (CO_2, CFCs, CH_4, etc.).
Prevent air pollution	Reduce air pollution emissions Reduce harmful pollutant exposure	• Per capita emissions (PM, VOCs, NOx, CO, etc.). • Air quality standards and management plans.
Minimize noise	Minimize traffic noise exposure	• Traffic noise levels
Protect water quality & hydrologic functions	Minimize water pollution. Minimize impervious surface area.	• Per capita fuel consumption. • Management of used oil, leaks and stormwater. • Per capita impervious surface area.
Openspace and biodiversity protection	Minimize transport facility land use. Encourage compact development. Preserve high quality habitat.	• Per capita land devoted to transport facilities. • Support for smart growth development. • Policies to protect high value farmlands and habitat.
IV. Good Governance and Planning		
Integrated, comprehensive and inclusive planning	Clearly defined planning process. Integrated and comprehensive analysis. Strong citizen engagement. Lease-cost planning.	• Clearly defined goals, objectives and indicators. • Availability of planning information and documents. • Portion of population engaged in planning decisions. • Range of objectives, impacts and options considered. • Efficient and equitable funding allocation

This table summarizes sustainability goals, objectives and performance indicators.

Introduction

"Sustainability is the next great game in transportation. The game becomes serious when you keep score" - Greenroads

There is growing interest in the concepts of *sustainability, livability, sustainable development* and *sustainable transportation*. *Sustainability* generally refers to a balance of economic, social and environmental goals, including those that involve long-term, indirect and non-market impacts. *Livability* refers to the subset of sustainability goals that directly affect community members. Sustainability reflects the fundamental human desire to protect and improve our earth. It emphasizes the integrated nature of human activities and therefore the need for coordinated decisions among different sectors, groups and jurisdictions. Sustainability planning (also called *comprehensive planning*) expands the objectives, impacts and options considered in a planning process, which helps insure that individual, short-term decisions are consistent with strategic, long-term goals.

Sustainability and livability are generally evaluated using *indicators*, which are specific variables suitable for quantification (measurement). Such indicators are useful for identifying trends, predicting problems, setting targets, evaluating solutions and measuring progress. Which indicators are selected can significantly influence analysis results. A particular policy may seem beneficial and desirable if evaluated using one set of indicators but harmful and undesirable according to others. It is therefore important that people involved in sustainability planning understand the assumptions and perspectives of the performance indicators they apply.

This paper explores concepts related to the definition of sustainable and livable transportation and the selection of indicators suitable for policy analysis and planning. It discusses various definitions of sustainability, livability, and sustainable transport, describes the role of indicators for policy making and planning, discusses factors to consider when selecting indicators, identifies potential problems with conventional transport planning indicators, describes examples of indicators and indicator sets, and provides recommendations for selecting indicators for use in a particular situation.

Key Definitions (based on Gudmundsson, 2001; USEPA, 2008)

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

Goal – what you ultimately want to achieve.

Objective – actions that help achieve goals.

Target – A specific, 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.

Defining Sustainability, Livability and Sustainable Transport

There are many definitions of sustainability, livability, sustainable development and sustainable transport (Beatley 1995; FHWA 2011; Schilleman and Gough 2012; NARC 2012). It is sometimes defined narrowly as simply *environmental sustainability*, concerned only with pollution reduction and habitat preservation, but is increasingly defined more broadly to include other goals. Below are examples of broad sustainability definitions:

Sustainable development *"meets the needs of the present without compromising the ability of future generations to meet their own needs."* (WCED 1987)

"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." (Mega and Pedersen 1998)

"The common aim [of sustainable development] must be to expand resources and improve the quality of life for as many people as heedless population growth forces upon the Earth, and do it with minimal prosthetic dependence. (Wilson 1998)

A sustainable transport system is one that is accessible, safe, environmentally-friendly, and affordable. (ECMT 2004)

"…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." (TRB 1997)

Sustainability is: *"the capacity for continuance into the long term future. Anything that can go on being done on an indefinite basis is sustainable. Anything that cannot go on being done indefinitely is unsustainable."* (Center for Sustainability 2004).

Environmentally Sustainable Transportation (EST) is: *Transportation that does not endanger public health or ecosystems and meets needs for access consistent with (a) use of renewable resources at below their rates of regeneration, and (b) use of non-renewable resources at below the rates of development of renewable substitutes.* (OECD 1998)

Concerns about sustainability and livability can be considered reaction to the tendency of decision-making to focus on easy-to-measure goals and impacts while undervaluing 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*.

"A sustainable community is one that is economically, environmentally, and socially healthy and resilient. It meets challenges through integrated solutions rather than through fragmented approaches that meet one of those goals at the expense of the others. And it takes a long-term perspective— one that's focused on both the present and future, well beyond the next budget or election cycle." - Institute for Sustainable Communities (ISC 1997)

Although sustainability planning often focuses on environmental goals, such as emission reductions and habitat preservation, a municipal government survey found that their sustainability policies are also based on economic goals such as infrastructure cost savings and economic development (Binghamton University 2016).

A sustainable transportation system is one that (CST 2005):

- 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.

Many experts (including the Transportation Research Board's Sustainable Transportation Indicators Subcommittee, the European Council of Ministers of Transport and the Centre for Sustainable Transportation) use this last definition because it is comprehensive and indicates that sustainable transport must balance economic, social and environmental goals, called a *triple bottom line*, as indicated in Table 1 and Figure 1. Although these imply that each goal fits into a specific category, they often overlap. For example, pollution is generally considered an environmental issue, but it also affects human health (a social issue), and fishing and tourism industries (economic issues).

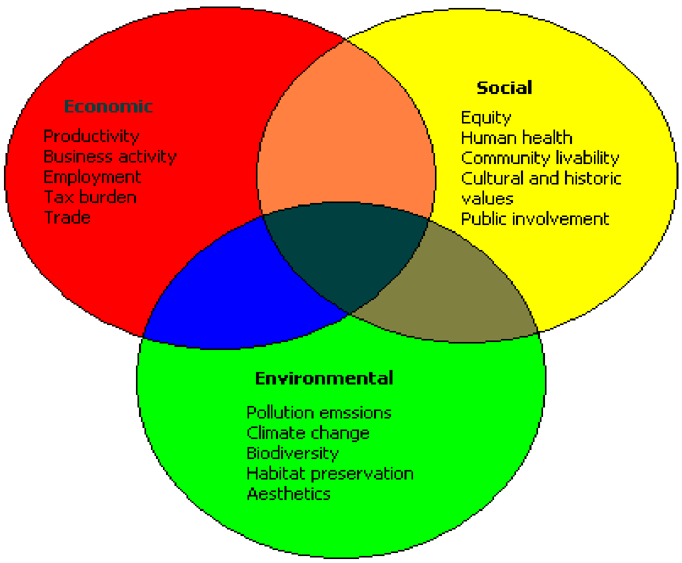
Table 1 **Sustainability Goals**

Economic	Social	Environmental
Economic productivity	*Equity / Fairness*	Climate change prevention and *mitigation*
Local economic development	*Safety and security*	*Air, noise and water pollution prevention*
Resource efficiency	*Community development*	Non-Renewable Resource Conservation
Affordability	*Cultural heritage preservation*	*Openspace preservation*
Operational efficiency	*Public fitness and health*	Biodiversity protection
Good Governance and Planning		
Integrated, comprehensive and inclusive planning		
Efficient pricing		

This table lists various sustainability goals. Italics indicates livability goals that directly affect residents ina community.

Livability refers to the subset of sustainability goals and impacts that directly affect community members, including local economic development and environmental quality, equity, affordability, basic mobility for non-drivers, public safety and health, and community cohesion. These mostly fall into the *social impacts* realm of sustainability.

Figure 1 **Sustainability Goals**



This figure illustrates various sustainability goals. Sustainability includes economic, social and environmental goals, which are often called the "triple bottom line."

Livability reflects sustainability impacts that directly affect people in a community, such as local economic development, affordability, public health and safety, and local environmental impacts.

The U.S. *Interagency Partnership for Sustainable Communities* defines the following livability principles (HUD-DOT-EPA 2010; NARC 2012):

- *Provide more transportation choices.* Develop safe, reliable, and economical transportation choices to decrease household transportation costs, reduce our nation's dependence on foreign oil, improve air quality, reduce greenhouse gas emissions, and promote public health.
- *Promote equitable, affordable housing.* Expand location- and energy-efficient housing choices for people of all ages, incomes, races, and ethnicities to increase mobility and lower the combined cost of housing and transportation.
- *Enhance economic competitiveness.* Improve economic competitiveness through reliable and timely access to employment centers, educational opportunities, services and other basic needs by workers, as well as expanded business access to markets.
- *Support existing communities.* Target federal funding toward existing communities—through strategies like transit oriented, mixed-use development, and land recycling—to increase community revitalization and the efficiency of public works investments and safeguard rural landscapes.
- *Coordinate and leverage federal policies and investment.* Align federal policies and funding to remove barriers to collaboration, leverage funding, and increase the accountability and effectiveness of all levels of government to plan for future growth, including making smart energy choices such as locally generated renewable energy

- *Value communities and neighborhoods.* Enhance the unique characteristics of all communities by investing in healthy, safe, and walkable neighborhoods—rural, urban, or suburban.

These principles (general guidelines for decision making) and *goals* (what people ultimately want) help define *objectives* (specific ways to achieve goals) and *targets* (specific, realistic, measurable objectives to be achieved). Common sustainable transport objectives include:

- *Improved transport system diversity.* This generally means improving walking, cycling, ridesharing, public transit, carsharing, telework and local delivery services, and creating more walkable and transit-oriented communities.
- *Smart growth land use development.* This includes land use policies that create more compact, mixed, connected, multi-modal development, and provide more affordable housing in accessible, multi-modal locations.
- *Energy conservation and emission reductions.* This may include more fuel efficient vehicles, shifts to alternative fuels, and reductions in total motor vehicle travel. This includes improving the quality of energy efficient modes including walking, cycling, ridesharing, public transit and telework, and increase land use accessibility.
- *Efficient transport pricing.* This includes more cost-based pricing of roads, parking, insurance, fuel and vehicles.

Sustainability and livability generally support similar planning objectives, although often for somewhat different reasons. For example, both support energy efficiency, sustainability primarily for global and long-term goals such as climate protection and resource conservation, and so tends to emphasize incentives to use more fuel efficient vehicles, while livability is primarily concerned with local and short-term goals, such as reducing local air pollution and improving affordability, and so tends to place more emphasis on improving affordable and fuel efficient modes. Similarly, both sustainability and livability justify increased transport system diversity, smart growth, and affordable-accessible housing, although their justifications may differ somewhat: sustainability emphasizes overall economic development, resource conservation and emission reductions, while livability emphasizes reduced traffic impacts, consumer savings and affordability, improved accessibility for non-drivers.

Table 2 indicates the relationships between various sustainability and livability goals and planning objectives.

Table 2 **Sustainability And Livability Goals and Objectives**

	Transport Planning Objectives							
Sustainability Goals	Transport Diversity	System Integration	Affordability	Resource (energy and land) Efficiency	Demand Management (efficient pricing & prioritization)	Land Use Accessibility (smart growth)	Cost Effective Operations	Comprehensive and Inclusive Planning
Economic productivity	✓	✓		✓	✓	✓	✓	
Economic development	✓	✓	✓	✓	✓	✓		✓
Energy efficiency	✓	✓		✓	✓	✓		
Affordability	✓	✓	✓	✓	✓	✓		
Operational efficiency					✓		✓	✓
Equity / Fairness	✓	✓	✓		✓	✓		
Safety, security and health	✓	✓	✓	✓	✓	✓		✓
Community development	✓	✓	✓	✓	✓	✓		✓
Heritage protection	✓			✓	✓	✓		✓
Climate stability	✓	✓	✓	✓	✓	✓		
Air pollution prevention	✓	✓	✓	✓	✓	✓		
Noise prevention	✓			✓				
Water pollution	✓	✓	✓	✓	✓	✓		✓
Openspace preservation	✓	✓	✓		✓	✓		✓
Good planning								✓
Efficient Pricing				✓	✓		✓	

This table indicates which planning objectives support various sustainability and livability goals.

Both sustainability and livability support more comprehensive and integrated planning, which considers a broad range of objectives, impacts and options, and shifts from *mobility-based* to *accessibility-based* transport planning (see box below). This type of planning tends to expand the range of solutions that can be applied to transport problems. For example, conventional, mobility-based planning, which evaluates transport system performance based roadway level of service and average travel speeds, generally considers traffic congestion the primary transport problem and roadway expansion the primary solution. Comprehensive, accessibility-based planning tends to consider additional planning objectives (improved mobility for non-drivers, energy conservation, improved safety, etc.) and additional solutions (improving alternative modes, more efficient pricing, more accessible land use development, etc.).

Mobility-based Versus Accessibility-based Transport Planning (Litman 2003)
Accessibility (or just *access*) refers to people's ability to reach desired goods, services, activities and destinations (together called *opportunities*). For example, a stepladder provides access to a high shelf, a store provides access to goods, and a library or computer provides access to information. Access is the ultimate goal of most transportation, excepting the small portion of travel in which movement is an end in itself, (e.g., cruising, historic train rides, jogging, etc.).

Many factors can affect accessibility, including *mobility* (physical movement), road and path *connectivity*, *land use patterns* (the location of activities), and *mobility substitutes* (telecommunications and delivery services). The affordability, information availability, and even the social acceptability of transport options, can also affect overall accessibility.

Conventional planning often evaluates transport system performance based primarily on mobility (using indicators such as traffic speed and vehicle operating costs), ignoring other accessibility factors and improvement options. For example, with mobility-based planning, the only practical solution to traffic congestion is to expand roadway capacity. Accessibility-based planning allows other solutions to be considered, including improvements to alternative modes, more accessible land use patterns, and improvement to mobility substitutes. Accessibility-based transport planning tends to support sustainability by expanding the scope of analysis and supporting more resource-efficient solutions. As a result, as much as possible, sustainable transportation indicators should reflect accessibility-based planning.

Sustainability Planning Process

A sustainability planning process must be comprehensive and integrated, considering all significant objectives, impacts and options. It should begin by defining *goals* (what we ultimately want to achieve), which help define planning *objectives* (way to achieve goals), *targets* (specific, reasonable, measurable objective that we want to achieve), and *outcomes* (ultimate changes in activities and impacts, such as travel activity, consumer costs, accidents, pollution emissions, etc.).

Vision and Goals
(what we ultimately want to achieve)
↓
Objectives
(way to achieve goals)
↓
Targets
(specific, reasonable, measurable objective that we want to achieve)
↓
Outcomes
(ultimate changes in activities and impacts)
↓
Performance Indicators
(specific factors that are measured to indicate progress toward goals)

More comprehensive performance evaluation is an important component of sustainable transport planning (Strader 2012). Comprehensive sustainability analysis helps identify "win-win solutions," which are strategies that help achieve multiple objectives ("Win-Win Solutions," VTPI 2008). For example, comprehensive analysis allows planners to identify the congestion reduction strategies that also help achieve equity and environmental objectives. These integrated solutions can be considered the most sustainable. Narrowly-defined sustainability planning is a specialized activity, but broader analysis allows it to be incorporated into all planning activities (Nicolas, Pochet and Poimboeuf 2003).

Table 3 **Comparing Benefits**

Planning Objectives	Efficient Vehicles and Alt. Fuels	Alternative Modes	Pricing Reforms	Smart Growth Development
Vehicle travel impacts	*Increased*	*Reduced*	*Reduced*	*Reduced*
Energy conservation	✓	✓	✓	✓
Emission reductions	✓	✓	✓	✓
Congestion reduction	✗	✓	✓	✓
Facility cost savings	✗	✓	✓	✓
Traffic safety	✗	✓	✓	✓
Consumer savings		✓		
Improved mobility for non-drivers	✗	✓	✓	✓
Increased public fitness & health	✗	✓	✓	✓

More efficient and alternative fuel vehicles help conserve energy and reduce air pollution (✓), but by increasing total vehicle travel contradict others (✗). Vehicle travel reduction strategies help achieve more objectives and so can be considered more sustainable.

Factors to Consider When Selecting Indicators

Indicators are things that we measure to evaluate progress toward goals and objectives. Indicators should be carefully selected to provide useful information (USEPA 2008). In most situations, no single indicator is adequate, so an *index* (a set of indicators) that reflects various objectives and impacts should be used.

Indicators 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* (a desire for fast and efficient vehicle travel), *objectives* (changes in roadway supply or travel activity that reduces 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).

Indicators can reflect various levels of analysis, as illustrated in Table 4. For example, indicators may reflect the decision-making process (quality of planning), responses (travel patterns), physical impacts (emission and crash rates), human and environmental effects (injuries and deaths, and ecological damages), and their economic impacts (costs of crash and environmental damages). It is important to avoid double-counting impacts. For example, reductions in vehicle-mile emission rates can reduce ambient pollutants and human health damages; it may be useful to track each of these factors, but it would be wrong to add them up as if they reflect different types of impacts.

Table 4 **Levels of Analysis**

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.
Human and Environmental Effects ↓	Changes in pollution exposure, health, traffic injuries and fatalities, ecological productivity, etc.
Economic Impacts ↓	Property damages, medical expenses, productivity losses, mitigation and compensation costs.
Performance Evaluation	Ability to achieve specified 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.

Performance indicators can be categorized in the following way:

- *Process* – the types of policies and planning activities, such as whether the organization has a process for collecting and publishing performance data, and public involvement.
- *Inputs* – the resources that are invested in particular activities, such as the level of funding spent on various activities or modes.
- *Outputs* – direct results, such as the miles of sidewalks, paths and roads, and the amount of public transit service provided.
- *Outcomes* – ultimate results, such as the number of miles traveled and mode share, average travel speeds, congestion and crowding, number of accidents and casualties, energy consumption, pollution emissions, and user satisfaction.

It is often best to use some of each type of performance indicators. For example, when evaluating a government agency or jurisdiction it may be appropriate to develop an index that includes indicators of process, inputs, outputs and outcomes.

Quantitative data refers to easy-to-measure information. *Qualitative data* refers to other types of information. Qualitative data can be quantified using letter or number ratings such as Level-Of-Service (LOS). Various economic evaluation techniques can be used to quantify non-market values (Litman 2009). Quantitative data is easier to analyze and is often considered more objective than qualitative data, and so tends to receive more weight in a planning process (qualitative impacts are often dismissed as *intangibles*). For example, vehicle traffic speeds and delays are easy to measure, while walkability, equity, environmental impacts are more difficult to quantify, and so they tend to receive less consideration in conventional planning. Sustainability indicators therefore require quantifying impacts as much as possible.

Table 5 **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 or comparisons with peers (similar communities or agencies). Equity can be evaluated options and impacts of various groups. *Reference units* (also called *ratio indicators*) are measurement units normalized to facilitate comparisons, such as per-year, per-capita, per-mile, per-trip, per-vehicle-year and per dollar (Litman 2003; GRI 2006). 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* does account for changes in vehicle travel.

Choosing indicators often involves tradeoffs. A smaller set of indicators using 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. 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 is inexpensive, and some indicators to address specific planning objectives that may be important in certain cases, such as to address specific concerns about environmental or equity impacts.

Sustainability indicators can be integrated with other types of statistical analysis, such as financial accounting and performance evaluation, and existing data collection can be extended to support sustainability evaluation. Hart (1997) recommends asking the following questions about potential indicators:

- 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 consider local impacts at the expense of global impacts, for example, by encouraging negative impacts to be shifted to other locations?

Indicators is just one component of the overall planning process which also includes consulting stakeholders, defining problems, identifying goals and objectives, identifying and evaluating options, developing policies and plans, implementing programs, establishing performance targets, and measuring impacts.

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, although 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 (Dudson 1998).

However, there are several justifications for establishing vehicle travel reduction targets (Litman 2009): they help solve various problems and provide various benefits; they help insure that individual short-term planning decisions support strategic goals; they help prepare for future travel demands; and they help implement market reforms that create more efficient and equitable transport systems.

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 2008). 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.

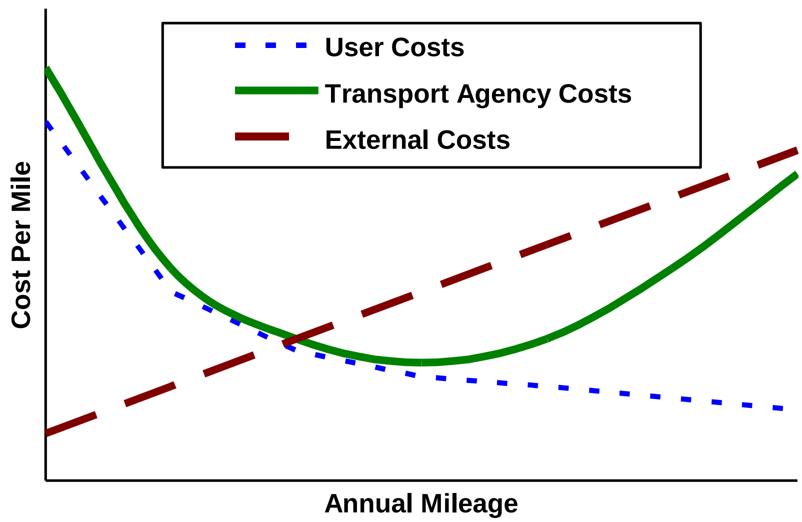
Specific planning decisions can be evaluated according to whether they increase or reduce market efficiency. For example, when evaluating potential congestion reduction strategies, those that increase automobile traffic and sprawl (e.g., roadway expansion) can be considered unsustainable, while those 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.

Trends Affecting Sustainability and Livability Planning

Several current trends tend to increase public support for more comprehensive and sustainable transport planning:

- The motor vehicle transportation system (including roads, parking facilities and support services) is now mature. It provides a high level of mobility for motorists under most conditions (excepting when roads are inadequately maintained or congested). The marginal benefits of roadway expansion and increased vehicle travel are declining, while marginal costs (traffic congestion, road and parking facility costs, consumer costs and inaffordability, accidents, sprawl, energy dependency, and pollution emissions) increase, as illustrated in Figure 2. This suggests that transport planning must consider more impacts and options (in other words, it must become more comprehensive and multi-modal) in order to identify the optimal solution to transport problems.

Figure 2 **Motor Vehicle Use Conflicting Cost Curves**



Since most motor vehicle costs are fixed, marginal costs decline with increased annual mileage, giving vehicle owners an incentive to maximize driving. Facility development cost initially decline due to economies of scale, but once roads are congested costs increase. External costs, such as parking costs, fuel production subsidies, accident and pollution damages, increase with vehicle travel.

- Various economic and demographic trends are increasing demands for alternative modes and more accessible land use, including aging population, rising fuel prices, increased urbanization, increasing traffic congestion, changing consumer preferences, and rising health and environmental concerns.
- Conventional economic analysis tends to evaluate progress only in terms of material wealth, assuming that society’s primary goal is to increase incomes and consumption. But as people become more affluent, the marginal benefit of increased consumption of material goods (more food, larger houses, more appliances, etc.) tends to decline, while the value of non-market goods (friendship, health, security, environmental quality, etc.) tends to increase.

Ecological Economics

Ecological economics (the discipline concerned with valuing ecological resources) defines sustainability in terms of *natural capital*, the value of natural systems to provide services such as clean air and water, and climatic stability (Jansson, et al. 1994). Ecological economics emphasizes the distinction between *growth* (increased quantity) and *development* (increased quality). It does not assume that material wealth necessarily reflects wellbeing (people's overall quality of life), and so attempts to measure social welfare outcomes rather than material wealth alone, and questions common economic indicators such as Gross Domestic Product (GDP), which measure the quantity but not the quality of market activities. It accounts for non-market costs of economic activities often ignored or even counted as positive outcomes by conventional economics (Daly and Cobb 1989). For example, GDP ignores the value of household gardening and fishing, but values food purchased to replace household production lost to environmental degradation.

Conventional economic analysis tends to equate material wealth with happiness, for example, evaluating policy decisions based on their economic productivity impacts. Sustainable economics recognizes that people have other values, such as dignity, generosity, equity, friendship, community, legacy (descendents and future reputation) and ecological integrity, and once peoples' basic physical needs are satisfied (they have adequate food, shelter and medical care) these non-market goods become increasingly important. Sustainable economics therefore strives for *sufficiency*, as opposed to conventional economics which generally assumes that continually increasing consumption is desirable.

Sustainability requires limiting resource consumption to ecological constraints (such as limiting land use to protect habitat and fossil fuel use to minimize climate change). Sustainability therefore supports a *conservation ethic*, which strives to maximize resource efficiency, in contrast to the conventional *consumption ethic*, which strives to maximize resource consumption, for example, by minimizing motor vehicle ownership and operating costs. Described differently, sustainability strives to maximize the amount of happiness people extract per unit of resource consumption, and sustainable transport strives to maximize the amount of happiness produced per unit of travel: more gladness per gallon and more smiles per mile.

Interest in sustainability originally reflected concerns about long-term risks of current resource consumption, reflecting the goals of *intergenerational equity* (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.

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. The term *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, so indicators such as income, wealth and productivity (such as Gross Domestic Product [GDP]) are used. These indicators can be criticized on several grounds (Cobb, Halstead and Rowe 1999; Dixon 2004; Schepelmann, Goossens and Makipaa 2010).

- They only measure market goods and so overlook other factors that contribute to wellbeing such as health, friendship, community, pride, environmental quality, etc.
- These indicators give a positive value to destructive activities that reduce people's health and self-reliance, and therefore increase consumption of medical services, purchased rather than home-produced foods, and motorized transport.
- 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 have very different levels of welfare due to differences in how the wealth is created, distributed and used. Various economic traps can increase the material wealth needed to maintain a given level of welfare, for example, if productive activities cause pollution that makes people sick, wealth is unequally distributed or spent inefficiently, and if increased material wealth disrupts community cohesion, pride, freedom or other nonmarket goods. Described differently, most people have significant *nonmarket* wealth ignored by conventional economic indicators, such clean air and water, public resources, household productivity (gardening, home cooking, maintenance skills), and social networks that provide security, education and entertainment without payment. Market activities that degrade 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 tends to provide declining marginal benefits (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 (Gilbert 2006, p. 239). For example, if a person only earns $10,000 annually, an additional $10,000 makes them far better off. But the same $10,000 increase provides less benefit to somebody earning $50,000 annually, and still less to somebody earning $100,000 or $500,000. However, people seldom recognize these diminishing benefits because as wealth increases so do financial expectations. 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. As a result, increased income by wealthy households may provide little incease in welfare.

Transportation activities reflect these patterns. In communities with good walking, cycling and public transit, people's transport demands can be satisfied relatively cheaply, but if a community becomes automobile dependent, transportation costs can may increase with little or no net gain in accessibility or individual's social welfare. Similarly, under some circumstances, increased vehicle travel and associated costs may provide little economic development benefits; in fact, some research indicates that beyond an optimal level, increased automobile travel reduces economic productivity (Zheng, et al. 2011) and transportation demand management strategies that reduce vehicle travel tend to support economic development (Litman 2010).

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.

Schepelmann, Goossens and Makipaa (2010) evaluate the problems with relying on GDP as an indicator of social welfare, and examine various alternatives. They conclude that the most realistic approach is to supplement GDP with additional environmental and/or social information. In order to make this kind of solution feasible the study recommends the establishment of an overarching and transparent indicator system for improving economic decision-making in support of sustainable development.

Zheng, et al. (2011) discuss ways to select economic indicators for sustainable performance evaluation. They recommend the following indicators:

1. *Affordability* – Transportation is affordable to individuals.
2. *Mobility* – Transportation provides efficient movement of people and goods for economic activity.
3. *Finance equity* – Transportation is financed in an equitable manner.
4. *Resilience* – Transportation is resilient to economic fluctuations.

Their analysis indicates that U.S. states that reflect these principles tend to have higher economic productivity (per capita GDP).

Table 6 lists possible economic indicators of sustainable transportation.

Table 6 **Economic Indicators of Sustainable Transportation**

Indicator	Description	Direction	Data Availability
User satisfaction	Overall transport system user satisfaction ratings.	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 share	Portion of travel made by efficient modes: walking, cycling, rideshare, public transit and telework.	More is better	2
Congestion delay	Per capita traffic congestion delay.	Less is better.	2
Affordability	Portion of household expenditures devoted to transport, particularly by lower-income households.	Less is better.	2
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	Portion of transport costs (roads, parking, insurance, fuel, etc.) that are efficiently priced (charged directly to users).	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, community livability (local environmental quality as experienced by residents and visitors) and community cohesion (the quality of interactions among community members), 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 2009; Mendes, Mochrie and Holden 2007), including:

- The United Nation Development Programme's *Human Development Index* (http://hdr.undp.org/en)
- Economist's *Quality-of-Life Index* (www.economist.com/media/pdf/QUALITY_OF_LIFE.pdf).
- The Legatum Institute's *Prosperity Index* (www.prosperity.org/ranking.aspx).
- Mercer *Quality of Living Survey* (www.mercer.com).

Transportation equity can be evaluated by comparing transport options, service quality, impacts and between different groups, particularly on economically, physically and socially disadvantaged people (FHWA and FTA 2002; Litman 2005a). Transportation health impacts include accident injuries, pollution illness, and inadequate physical activity. Policies that increase nonmotorized travel improve mobility for disadvantaged people and increase fitness tend to support sustainable transportation. Community livability and cohesion (Litman 2006a) can be measured using surveys that evaluate impacts on the human environment, including interactions among neighbors, and 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 7 lists examples of possible social indicators of sustainable transportation.

Table 7 **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 walks and cycles sufficient for fitness and health (15 minutes or more daily).	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 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 2009; FHWA 2004; Joumard and Gudmundsson 2010).

There may be considerable uncertainty about some monetized 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 environmental cost studies are incomplete, for example, many air pollution costs studies only include a portion of the types of harmful motor vehicle emissions, and many only consider human health impacts, ignoring ecological, agricultural and aesthetic damages (Litman 2009).

Table 8 lists possible environmental indicators of sustainable transportation. Joumard, Gudmundsson and Folkeson (2011) provided more extensive lists of environmental indicators.

Table 8 **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.

In practice, it is often infeasible to apply all the indicators described above, due to data collection and analysis costs. Later in this report these indicators are prioritized to indicate those that are most important and should usually be applied.

Accounting Indicators

Sustainable indicators can be incorporated into conventional statistics and accounting systems commonly used by public and private organizations to evaluate the value of assets and activities, such as censuses, national accounts and corporate reports, since they are based on similar principles and require similar data (Federal Statistical Office Germany 2005).

Integrating these different systems requires the following:

- Accountants and statisticians be consulted concerning the developing of sustainability indicators so that, as much as possible, indicators are consistent with standard accounting principles and practices. For example, resource consumption data, such as energy and water use, can be collected and incorporated into annual reports in order to indicate the resource efficiency of production (energy and water consumed per unit of output).
- As much as possible, nonmarket impacts (such as environmental assets and human health damages) be measured and *monetized* (measured in monetary units) so that they can be incorporated into standard accounts. For example, corporate accounts can include *environmental accounting* and *environmental assets*, which reflect, for example, value of pollution emissions (including climate change emissions) produced by industrial activities, the value of emission reductions that result from energy conservation and emission reduction programs, and the value of brownfield site reclamation.
- Sustainability indicators include special analysis of long-term asset valuation and profitability. For example, strategic plans can be evaluated in terms of their impacts on corporate value a decade in the future.

There is a danger that efforts to integrate economic and sustainability indicators will end up focusing on factors that are easier to measure (such as quantified economic impacts) and overlook factors that are more difficult to measure (such as qualitative environmental and social impacts) and so perpetuate current biases. It is therefore important to identify impacts that may be important but excluded from a particular accounting system.

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 focus on motor vehicle travel quality and ignore other impacts, these indicators tend to justify policies and projects that increase motorized 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 2008).

Sustainable Transportation Principles

Principles are general organizing concepts which help define goals, objectives, practices and indicators. Below are examples of sustainable transport principles.

Sustainable Landscape: Guiding Principles of a Sustainable Site (ASLA 2009)

The American Society of Landscape Architects developed the following principles.

1. Do no harm

Make no changes to the site that will degrade the surrounding environment. Promote projects on sites where previous disturbance or development presents an opportunity to regenerate ecosystem services through sustainable design.

2. Precautionary principle

Be cautious in making decisions that could create risk to human and environmental health. Some actions can cause irreversible damage. Examine a full range of alternatives including no action and be open to contributions from all affected parties.

3. Design with nature and culture

Create and implement designs that are responsive to economic, environmental, and cultural conditions with respect to the local, regional, and global context.

4. Use a decision-making hierarchy of preservation, conservation, and regeneration

Maximize and mimic the benefits of ecosystem services by preserving existing environmental features, conserving resources in a sustainable manner, and regenerating lost or damaged ecosystem services.

5. Provide regenerative systems as intergenerational equity

Provide future generations with a sustainable environment supported by regenerative systems and endowed with regenerative resources.

6. Support a living process

Continuously re-evaluate assumptions and values and adapt to demographic and environmental change.

7. Use a systems thinking approach

Understand and value the relationships in an ecosystem and use an approach that reflects and sustains ecosystem services; re-establish the integral and essential relationship between natural processes and human activity.

8. Use a collaborative and ethical approach

Encourage direct and open communication among colleagues, clients, manufacturers, and users to link long-term sustainability with ethical responsibility.

9. Maintain integrity in leadership and research

Implement transparent and participatory leadership, develop research with technical rigor, and communicate new findings in a clear, consistent, and timely manner.

10. Foster environmental stewardship

In all aspects of land development and management, foster an ethic of environmental stewardship and understanding that responsible management of healthy ecosystems improves the quality of life for present and future generations.

National Round Table for Environment and Economy (NRTEE 1996)

Our aim is to develop transportation systems that maintain or improve human and ecosystem well-being together - not one at the expense of the other. Due to varying environmental, social and economic conditions between and within countries, there is no single best way to achieve sustainable transportation systems. A set of guiding principles can be described, however, upon which transition strategies should be built.

We recognize the fundamental importance of:

Access
Access to people, places, goods and services is important to the social and economic well being of communities. Transportation is a key means, but not the only means, through which access can be achieved.

Principle 1: Access
People are entitled to reasonable access to other people, places, goods and services.

People And Communities
Transportation systems are a critical element of a strong economy, but can also contribute directly to building community and enhancing quality of life.

Principle 2: Equity
Nation states and the transportation community must strive to ensure social, interregional and inter-generational equity, meeting the basic transportation-related needs of all people including women, the poor, the rural, and the disabled.

Principle 3: Health and Safety
Transportation systems should be designed and operated in a way that protects the health (physical, mental and social well-being) and safety of all people, and enhances the quality of life in communities.

Principle 4: Individual Responsibility
All individuals have a responsibility to act as stewards of the natural environment, undertaking to make sustainable choices with regard to personal movement and consumption.

Principle 5: Integrated Planning
Transportation decision makers have a responsibility to pursue more integrated approaches to planning.

Environmental Quality

Human activities can overload the environment's finite capacity to absorb waste, physically modify or destroy habitats, and use resources more rapidly than they can be regenerated or replaced. Efforts must be made to develop transportation systems that minimize physical and biological stress, staying within the assimilative and regenerative capacities of ecosystems, and respecting the habitat requirements of other species.

Principle 6: Pollution Prevention

Transportation needs must be met without generating emissions that threaten public health, global climate, biological diversity or the integrity of essential ecological processes.

Principle 7: Land and Resource Use

Transportation systems must make efficient use of land and other natural resources while ensuring the preservation of vital habitats and other requirements for maintaining biodiversity

Economic Viability

Sustainable transportation systems must be cost effective. If adjustment costs are incurred in the transition to more sustainable transportation systems they should be equitably shared, just as current costs should be more equitably shared.

Principle 8: Fuller Cost Accounting

Transportation decision makers must move as expeditiously as possible toward fuller cost accounting, reflecting the true social, economic and environmental costs, in order to ensure users pay an equitable share of costs.

Data, Information, Knowledge and Wisdom

The terms, data, information, knowledge and wisdom are sometimes used interchangeably, but thy differ in their level of abstraction and therefore their transferability and usefulness in decision-making.

- *Data* (also called *statistics* or *facts*) refers to specific, individual measurement results, such as the number of vehicle-miles-traveled (VMT), traffic speeds, and traffic fatalities.
- *Information* refers to data that is organized and integrated, and therefore suitable for research, such as analysis of the relationships between VMT, traffic speeds and traffic fatalities.
- *Knowledge* refers to information that organized, transferable and abstract, and therefore useful for decision-making, such as a model that can predict how specific transport policy and planning decisions will affect traffic accident risk.
- *Wisdom* is the most abstract level of understanding because it is comprehensive about context and values, such as a decision-makers ability to determine what transport policy and planning decisions are optimal, balancing traffic accident risk along with other planning objectives, and reflecting a community's needs and values.

These are connected and overlapping concepts. Wisdom requires knowledge, which requires information, which requires data.

Examples of Sustainable Transportation Indicator Sets

Below are examples of proposed or applied sustainability planning indicator sets. For more examples see Gudmundsson (2001), Mihyeon, Jeon and Amekudzi (2005), Jeon (2007) and FHWA (2011).

Sustainable Development Indicators (not specific to transportation)

City Property Initiative (www.unhabitat.org/tag/city-prosperity-intitiative)

UN-Habitat's *City Prosperity Initiative* (UN Habitat 2016) is an international program to collect standardized social, economic and environmental data, that has been implemented in more than 400 cities across the world, producing reliable, relevant and timely data for urban planning and research. These data cover the following themes:

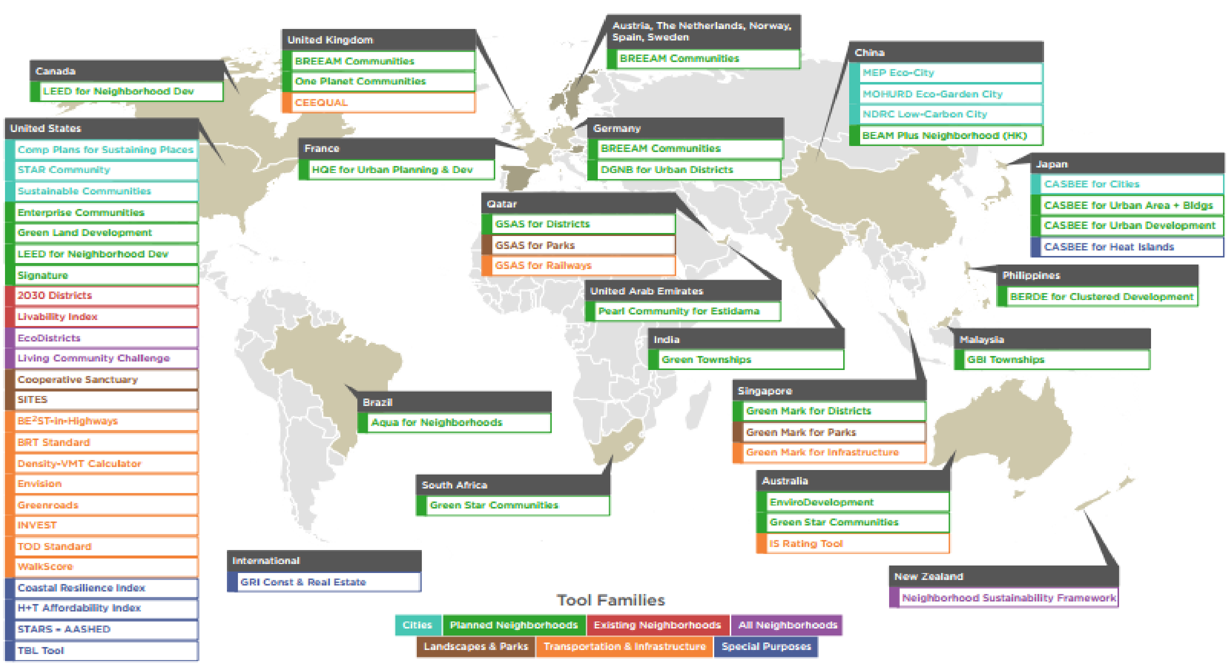
- Legislation
- Land
- Governance
- Planning & Design
- Economy
- Water & Sanitation
- Energy
- Mobility
- Safety
- Housing, Slum Upgrading
- Reconstruction
- Resilience
- Climate Change
- Gender
- Youth
- Human Rights

Urban Sustainability Rating Tools (Criterion Planners 2014)

A report presented at the *Global Symposium on Urban Sustainability Rating Tools*, identified and categorized approximatey fifty existing tools for rating urban sustainability, as indicated in Figure 3.

Figure 3 **Urban Sustainability Rating Tools**

22 countries and 54 tools



USEPA *Sustainability Concepts in Decision-Making (USEPA 2014)*

The U.S. Environmental Protection Agency (EPA) report, *Sustainability Concepts in Decision-Making: Tools and Approaches for the US Environmental Protection Agency*, identifies various analytic tools that government agencies can use to evaluate progress toward sustainability. Although the EPA focuses on environmental sustainability, many of these tools also account for economic and social impacts, and so can help consider multiple impacts, for example, identifying pollution reduction strategies that also help achieve economic, health and social equity objectives. These tools include:

- Economic assessment and lifecycle cost analysis.
- Ecosystem services evaluation and valuation.
- Risk and exposure assessments, and uncertainty analysis.
- Environmental footprint analysis.
- Social impact assessments
- Design charettees

Genuine Progress Indicator

The *Genuine Progress Indicator* (GPI) iadjusts Gross Domestic Product (GDP) to account for crime, environmental quality, leisure, income inequality, public infrastructure, volunteering and housework (Talberth, Cobb, and Slattery 2006). Table 9 summarizes GPI indicators.

Table 9 **Sustainability Indicators** (Pembina Institute 2001)

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

This table summarizes Genuine Progress Indicators used to evaluate sustainability.

Framework for Measuring Sustainable Regional Development (Kirk, et al., 2010)

A University of Minnesota study developed a framework for evaluating sustainable development in the Twin Cities metropolitan region. The proposed framework includes a set of six sustainability principles, and 38 indicators, each with specific definitions of how it can be measured and suitable data sources. Below are the six sustainability principles (similar to U.S. federal livability principles)

- Provide more transportation choices.
- Protect natural resources.
- Promote equitable, affordable housing.
- Value communities and neighborhoods.
- Enhance economic competitiveness and create positive fiscal impacts.
- Coordinate and leverage government policies and investment.

Below are the 38 indicators:

1. Proximity of Affordable Housing to Public Services and Facilities
2. Job Accessibility
3. Accessibility to Non-Work Opportunities
4. Access to Transit
5. Jobs-Housing Balance and Spatial Mismatch
6. Early Childhood development program participation
7. Education and Labor Force Skill Mismatch
8. Green Jobs
9. Housing and Transportation Affordability
10. Housing Mix
11. Infrastructure Preservation
12. Land Consumption
13. Infill Development and Redevelopment
14. Land Use Mix
15. Walkability
16. Impervious Surface
17. Employment Density
18. Composite Sprawl Index
19. Vehicle Miles Traveled (VMT) per Capita
20. Transportation Reliability
21. Transportation Safety
22. Commute Mode Choice
23. Carbon Footprint
24. Urban Greenness
25. Protection of Significant Ecological Areas
26. Surface Water Quality - Rivers
27. Surface Water Quality - Lakes
28. Impaired Waters
29. Ground Water
30. Air Quality
31. Exposure to Pollutants from Major Roadways
32. Proximity to Contaminated Sites
33. Children’s Lead Exposure
34. Asthma Prevalence
35. Diabetes Rate
36. Civic Engagement - voting participation
37. Civic Engagement - Community Vitality Index
38. Public Safety

Green Community Checklist

The Environmental Protection Agency (EPA 2003) proposes that *green* communities strive 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.

Ecological Footprint (www.footprintnetwork.org)

The *Ecological Footprint* measures the estimated land and water area required to produce the resources consumed and absorb wastes produced by a person, group or activity. This includes, for example, the amount of farmland needed to provide food and fibers, forests needed to provide wood and paper, watershed area needed to provide fresh water, land needed to produce energy, and land needed to absorb wastewater on a sustainable basis. Current consumption rates are estimated to exceed the Earth's long-term regeneration capacity, so the current consumption consumes ecological capital.

Neighborhood Sustainability

Bourdic, Salat and Nowacki (2012) developed a set of urban sustainability 60 indicators, with quantification methods, suitable for evaluing the energy, social and environmental consequences of different urban forms, and therefore policies and projects that affect urban development patterns. Some of these indicators have been quantified for real cities.

Happy Planet Index (www.happyplanetindex.org)

The Happy Plant Index (HPI) developed by the *New Economics Foundation* (www.neweconomics.org) is calculated by multiplying indicators of *Life Satisfaction* times *Life Expectancy*, and dividing the result by *Ecological Footprint* (resource consumption), which recognizes the value of longer, satisfying, resource efficient living (NEF 2009). Developing nations tend to rate relatively high by this index because they require fewer resources to achieve a given level of happiness, indicating greater ecological efficiency.

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* – Tonnes of carbon equivalent emissions from transport 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 facilities categorized as No Further Remedial Action Planned under Superfund Act.
- *Environmental Justice* – Environmental justice cases that remain unresolved over one year.

Vehicle Emission Analysis Data Requirments

An Asian Development Bank study identified the data required for evaluating transport climate change emission trends and management options, including information on vehicles, vehicle use, fuel type, and vehicle fuel intensity (Schipper, Fabian and Leather 2009).

Global City Indicators (www.cityindicators.org)

The *Global City Indicators* provides an established set of city indicators with a globally standardized methodology that allows for global comparability of city performance and knowledge sharing. Transportation indicators include:

Km of high capacity public transit system per 100,000 population
Number of two-wheel motorized vehicles per capita
Km of light passenger transit system per 100,000 population
Commercial Air Connectivity (number of nonstop commercial air destinations)
Number of personal automobiles per capita
Transportation fatalities per 100,000 population
Annual number of public transit trips per capita

Global Reporting Initiative (www.globalreporting.org)

The Global Reporting Initiative provides guidance for disclosure about their sustainability performance using a universally-applicable *Sustainability Reporting Framework* that allows consistent, understandable and comparable results. This effort supports a variety of reporting and accounting programs, including the UN Global Compact (UNGC) and ISO 14000.

SustainLane City Rankings (www.sustainlane.com)

SustainLane is a participatory, Internet-based guide to sustainable living. Its annual sustainability report rates and ranks the 50 largest U.S. cities based on these indicators:

Air & Water Quality
Ambient air quality (based on government data)
Tap water quality (based on government data)

Transportation
Commute mode share (portion of commuters who walk, bicycle or ride public transit)
Traffic congestion (based on Texas Transportation Institute reports)
Transit ridership (transit passenger-miles per square mile)

Built Environment
Green building (LEED certified buildings per capita)
Planning / Land use (portion of land devoted to parks, and a sprawl rating)

City Programs
City innovation (various special sustainability programs)
Energy / Climate change (support for energy conservation and emission reductions)
Knowledge / Communications (various indicators of municipal support for sustainability)

Green Biz & Economy
Green economy (various indicators of local efforts to promote green businesses)
Housing affordability (average housing prices relative to average local wages)
Local food / Agriculture (indicators of farmers markets and community gardens per capita)

Natural Disaster Risk
Natural disaster risk

Waste Management
Waste management (portion of waste diverted from landfills by recycling and composting)

Water Supply
Water supply (proximity and size of water supply, and per capita water consumption)

Critique

Some indicators overlap or duplicate. For example, farmers markets are counted in both "Green Economy" and "Local Food." LEED buildings are counted in both "Green Economy" and "Green Buildings." Transit ridership is counted in both "City Commuting" and "Transit Ridership." Although it claims to reflect community livability there are no indicators of community cohesion or social capital. The only equity indicator is "Housing Affordability." There are no service quality indicators, such as walking, cycling and public transit service quality, or home weatherization program effectiveness. Several indicators depend on special sustainability programs or incentives with no evaluation of their appropriateness or effectiveness, which may encourage cities to promote visible but ineffective initiatives.

Sustainable Transportation Indicator Sets

The following are indicator sets specific to sustainable transportation.

Current Transportation Performance Indicators

Transportation planners use various performance indicators for evaluating transportation conditions, prioritizing improvements, and day-to-day operations. Meyers (2005) describes and compares various performance indicators used by transportation planners in three countries. These include indicators related to roadway conditions (congestion, travel times, crashes), freight transport efficiency, pollution emissions, quality of various modes (including walking, cycling and public transit) and user satisfaction.

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 transport planning through the involvement of individuals and advocates in the planning process and special data collection.
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 transport 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 may be forced to use transit services in less secure times and locations).

Sustainable Transportation Indicators

Sustainable Transportation Performance Indicators

The Sustainable Transportation Performance Indicators (STPI) project by the Centre for Sustainable Transportation produced the indicators summarized in Table 10.

Table 10 **Sustainable Transportation Performance Indicators** (Gilbert, et al. 2003)

Framework	Initial STPI	Short-term Additions	Long-Term Additions
1. Environmental and Health Consequences of transport.	Total transport fossil fuel use. 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 people movement. Total motorized freight movement. 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 share 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 Environementally Sustainable Transport (EST).

- *CO_2* – Climate change is prevented by avoiding increased per-capita carbon-dioxide emissions.
- *NO_X* – Ambient NO_2, 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* – Ambient noise levels that present a health concern or serious nuisance (maximum 55-70 decibels during the day and 45 decibels at night and indoors).
- *Land use* – Transport facility land consumption 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.

Sustainable Infrastructure (www.asce.org/Sustainability/ISI-Rating-System)

The American Society of Civil Engineers (ASCE), the American Public Works Association (APWA) and the American Council of Engineering Companies (ACEC) have developed an Institute for Sustainable Infrastructure which is developing and implementing a web-based sustainable infrastructure project rating system (system). The overall goal of the system, and related training, is to enhance the sustainability of the nation's civil infrastructure, excluding occupied buildings. This rating system evaluates a project's:

- *Pathway Contribution* "Doing the right thing" with the community as the common denominator.
- *Performance Contribution* "Doing things right" or engineering high-performing projects.

World Business Council Sustainable Mobility Indicators

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

Table 11 **Sustainable Mobility Indicators** (Eads 2001)

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

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 12.

Table 12 **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.

Aviation Sustainability Indicators

Aviation presents unique sustainable transportation challenges (Upham and Mills 2003; Grimley 2006). Table 13 illustrates indicators for evaluating airport environmental and operational sustainability. This is an example of sustainability indicators developed for 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 peers and other modes.

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 people within noise contours (LAeq 50 and upward increments) relative to limits.
6. Terminal passengers	Number arriving at gates (Number departing gates)	Arrivals and departures relative to hourly maxima.
7. Surface access passengers	Number arriving at airport boundary. Number departing airport boundary.	Arrivals and departures relative to hourly maxima.
8. Water consumption & waste water emission	Monthly volume consumed. Effluent pollutant concentrations. Ambient pollutant concentrations.	Volume relative to maximum. Concentrations (effluent and ambient) relative to limits.
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	Paved area (square meters, within airport boundary and ownership, includes building footprints). Area of high and medium biodiversity (square meters, within airport boundary and ownership).	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.

Non-Motorized Transport Performance Indicators (Roughton, et al. 2012)

The report, *Creating Walkable and Bikeable Communities: A User Guide to Developing Pedestrian and Bicycle Master Plans*, identifies the following non-motorized transport performance indicators.

Infrastructure

- Total miles of bikeways
- Miles of bikeways catering to each type of bicyclist (i.e. Strong and Fearless, Enthusiastic and Confident, and Interested but Concerned)
- Percent of households within one quarter mile of a bicycle facility
- Percent of buses equipped with bicycle racks
- Percent of transit stops with bicycle parking or secure bicycle parking
- Percent of new developments that include secure bicycle parking or other end-of-trip facilities
- Number of bicycle parking spaces
- Percent of roadways with sidewalks
- Number of miles of sidewalk infill per year
- Percent of intersections up to current ADA standards
- Number of transit stops with pedestrian amenities
- Percent of new developments meeting pedestrian standards
- Number of bridges with dedicated bicycle and pedestrian facilities
- Number of miles of trails/multi-use paths

Programs

- Percent of schools served by Safe Routes to Schools program
- Number of safety trainings offered per year
- Number of enforcement efforts per year
- Attendance at Ciclovia or Open Streets events
- Number of households participating in individualized marketing programs
- Mode shift resulting from individualized marketing programs

Use and Safety

- Mode share for work trips
- Mode share for all trips
- Number of walking and bicycling trips per day along key corridors
- Bicycle and pedestrian crash rates
- Percent of bicyclists that are women, youth or seniors
- Average trip distance across all modes
- Number of trips made by bike share

Public Opinion

- Percent of residents satisfied with the safety and comfort of existing bicycle and/or pedestrian facilities
- Percent of residents interested in walking and bicycling more frequently

GPI Sustainable Transportation Objectives and Indicators (GPI 2008)

The *GPI Transportation Accounts: Sustainable Transportation in Halifax Regional Municipality* (HRM) are intended to provide transportation indicators and full cost accounting of passenger transportation for assessing the current transportation system and monitoring its progress towards sustainability. A data set and baseline estimate was constructed using the best data presently available for measuring regional passenger road transportation. Table 14 summarizes the objectives and indicators chosen. This study also developed estimates of the full economic costs of road passenger travel, based on previous research that quantifies and monetizes transportation costs.

Table 14 **GPI Sustainable Transportation Objectives and Indicators** (GPI 2008)

Objective	Indicator
Transport Activity	
1. Decrease economically excessive motor vehicle transport, and increase use of more sustainable modes	1. Motorized movement of people: - Vehicle-km - Passenger-km - Vehicle-km per capita
2. Decrease energy consumption	2. Transport-related energy consumption - Total and per capita energy consumption devoted to transportation, by mode and fuel
3. Decrease greenhouse gas (GHG) emissions	Transport-related GHG emissions by mode and per capita
4. Decrease emissions of air pollutants	Total transport emissions of air pollutants by mode and per capita
5. Decrease space taken by transport facilities	Land Use - Distribution of population and dwellings in HRM - Total land area consumed by cars and per capita
Social	
Increase access to basic services	Access to basic services - Percentage of population commuting to work, by mode - Trip origin and destination
7. Increase access to public transportation	Access to public transit - Percentage of population who live within 500m of transit station - Percentage of population living within Metro Transit's service area - Number of Metro Transit passengers on ferries and conventional buses
Economic	
8. Decrease cost of household transportation expenditure	Expenditure on personal mobility - Percentage of household expenditures dedicated to transportation

This table summarizes the objectives and indicators used to evaluate transportation system performance in the Halifax region.

PacScore Local Accessibility Indicator (Dock, Greenberg and Yamarone 2012)

The city of Pasadena, California developed the *PacScore* metric which evaluates local transport system performance based on accessibility, sustainability, livability and user experience. It uses geographic information systems to quantify walkability (the number of destinations accessible within a quarter-mile walk), multi-modal level of service indicators (the convenience and speed of walking, cycling, public transport and automobile travel), and per capita vehicle-travel.

Strategic Urban Transport Assessment

In the article, "New Approaches to Strategic Urban Transport Assessment," Hale (2011) argues that conventional transport project assessment primarily reflects the incremental impacts of individual projects, and so fails to account for broader, strategic planning objectives and long-term impacts. He argues that more comprehensive impact analysis is particularly important for evaluating walking, cycling and public transit project benefits. He emphasizes the need for a broader indictor set for more comprehensive evaluation of metropolitan region transport outcomes related to society, environment and economy, as summarized in Table 15.

Table 15 **Comprehensive Evaluation Metrics for Consideration (Hale 2011)**

Category	Performance Indicators	
1. Metropolitan multimodal travel and transport characteristics	Mode share Sustainable mode use (walking, cycling and public transport) Vehicle km per capita Household transport expenditures Daily commute time Mode share shares for journey types	Trip generation rates Transport capital investment Per capita vehicle ownership Fuel and annual car ownership taxes Average travel speeds by mode (transit/car) Length dedicated protected bike paths
2. Mass transit system indicators and metrics	Operating ratio (expenses to revenues) System capacity System patronage Rail system length System networking Peak/off-peak ratio Cost per passenger served Average peak period passenger loadings Rail station access mode shares	Annual capital investment Cost per passenger km Standard service frequencies Operating hours/span Annual maintenance expenditure Provision of real time information Fleet maturity Provision of regional smart card
3. Land use	Urban density Regional population Portion of population within 800m of transit Suburbanisation	Location efficiency Housing stress (proportion of households with housing costs that exceed 30% of household budgets). Transit real estate strategy
4. Transit accessibility to key amenities	CBD access Higher Education access	Public health access
5. Qualitatively-oriented review categories	Multi-destination network? Transit investment linked to local land use planning changes? Fully-developed TOD policy framework?	Number of proposed TOD locations Travel Demand Management (TDM) Bike and pedestrian network quality
6. Analyses particular to the corridor, sub-regional and precinct scales	Transit service-levels Transit usage Pedestrian and cycling infrastructure Walking and cycling performance Station access mode shares	Jobs/housing balance Residents/jobs within station catchment Project and precinct-level densities Car ownership Multi-modality
7. Transit project and investment economics	BCR (benefit cost ratio) Net Present Value (NPV)	Full identification and monetisation of sustainable transport benefits

Hale (2011) proposed these regional tranpsort performance indicators.

STAR*Community Index*

STAR Community Index (www.icleiusa.org/sustainability/star-community-index) is a strategic planning and performance management system that offers local governments guidance for improving community sustainability. The table below summarizes their list of possible community sustainability goals.

Environment		
Natural Systems	Planning and Design	Energy & Climate
Natural Resource Planning & Inventory Green Infrastructure Land Use in Watersheds Water Quality & Supply Agriculture & Aquaculture Resource Lands Biodiversity & Invasive Species Ambient Noise & Light Waste Minimization	Comprehensive Planning Excellence in Design Interconnected Land Use Compact & Complete Communities Design for People Housing Public Spaces Transportation & Mobility Land Conservation Historic Preservation & Cultural Heritage Code Barriers Public Engagement & Participation	Greenhouse Gas Mitigation Climate Adaptation Energy Supply Energy Use Resource Efficient Buildings Alternative Fuels & Infrastructure Industrial Sector Energy Use Agricultural Climate Impacts
Economy		
Economic Prosperity	Employment & Workforce Training	
Enterprise Support Industry Sector Development & Revitalization Market Development Community-Based Economic Development Economic Localization Land Redevelopment & Revitalization Food System	Employment Opportunity Employment Benefits Labor Rights Living Wages Supportive Workplaces Workplace Learning & Career Paths Workforce Development Comprehensive Plan Workforce Training Resources for Success	
Society		
Education, Arts & Community	Health & Safety	Affordability & Social Equity
Education Opportunities Education Environments School-Community Engagement Ecological Literacy Arts & Culture Arts & Cultural Civic Support Social & Cultural Diversity Neighborhood Vitality Civic Literacy + Engagement Financial Literacy	Health System Health & Safety Literacy Workplace Health & Safety Food Access & Nutrition Drinking Water Quality Outdoor Air Quality Indoor Air Quality Toxics Reduction Natural & Human Hazards Emergency Prevention & Response Safe Communities Active Living & Recreation	Government Transparency Revenue Generation Public Expenditures & Financial Investment Infrastructure Investment Social Cohesion Human Services Poverty Prevention & Alleviation Civil & Human Rights Cultural Practices Environmental Justice Equity Literacy Adjudication & Restorative Justice Community Empowerment Equity Assessment & Planning

Lyons Regional Indicators

Nicolas, Pochet and Poimboeuf (2003) describe how local travel survey data and other available information are 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 16 summarizes these indicators

Table 16 **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 share 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.

Sustainable Assessment Indicators

Jeon, Amekudzi and Guensler (2008) developed a multiple sustainability dimensional indexes to evaluate transportation planning options in a multicriteria environment, using the performance indicators in Table 17. These performance measures are quantified and the resulting values used to calculate a Composite Sustainability Index (CSI) for specific project scenarios. This methodology is applied to Atlanta-area transportation projects.

Table 17 **Sustainability Assessment Indicators** (Jeon, Amekudzi and Guensler 2008)

Sustainability Dimension	Goals and Objectives	Performance Measures
Transportation System Effectiveness	A1. Improve Mobility	A11. Freeway/arterial congestion
	A2. Improve System Performance	A21. Total vehicle-miles traveled A22. Freight ton-miles A23. Transit passenger miles traveled A24. Public transit share
Environmental Sustainability	B1. Minimize Greenhouse Effect	B11. CO_2 emissions B12. Ozone emissions
	B2. Minimize Air Pollution	B21. VOC emissions B22. CO emissions B23. NO_x emissions
	B3. Minimize Noise Pollution	B31. Traffic noise level
	B4. Minimize Resource Use	B41. Fuel consumption B42. Land consumption
Economic Sustainability	C1. Maximize Economic efficiency	C11. User welfare changes C12. Total time spent in traffic
	C2. Maximize Affordability	C21. Point-to-point travel cost
	C3. Promote Economic development	C31. Improved accessibility C32. Increased employment C33. Land consumed by retail/service
Social Sustainability	D1. Maximize Equity	D11. Equity of welfare changes D12. Equity of exposure to emissions D13. Equity of exposure to noise
	D2. Improve Public Health	D21. Exposure to emissions D22. Exposure to noise
	D3. Increase Safety and Security	D31. Accidents per VMT D32. Crash disabilities D33. Crash fatalities
	D4. Increase Accessibility	D41. Access to activity centers D42. Access to major services D43. Access to open space

These performance measures are quantified and used to calculate a Composite Sustainability Index.

Table 18 summarizes performance measures (PMs) used by U.S. states to evaluate the quality of transportation and land use planning coordination, based on a literature review and survey of 25 states. These are consistent with many sustainable transportation planning indicators.

Table 18 **State DOT Land Use Performance Indicators** (Miller 2008)

Goal	Performance Measures
Increased transportation options	Percentage of commuters driving alone to work
	Number of spaces used at park and ride facilities
	Vehicle miles traveled per capita
	Travel time and distance to work
Increased transportation options	Ability to get from one destination to another readily, where destinations include jobs, retail and tourist stops, and transit services
	Percentage of housing units built by location type (e.g., rural growth center, developing area, remaining rural area, or developed area)
	Percentage jobs/population located close to transit or other efficient modes
	Miles of bike/ped facilities constructed
	Number of routes designated as bicycle facilities
	Number of attractions within a threshold travel time
	Ratio of non-auto to auto travel costs, including travel time and money
	Access to centers
	Ratio of jobs to housing
Improved quality of existing transport options	Satisfaction with transportation options
	Person-hours of delay
	Average delay per trip; percentage of person-miles by LOS; real intercity travel time minus (straight-line distance divided by the speed limit).
Improved public services or economic growth	Response time for fire, police, and rescue and travel time for Schools
	Cost of above municipal services (fire, police, rescue, and schools)
	Reduction in consumer costs attributable to better transport
	Ratio of actual corridor travel time to free flow travel time
Protects or manages corridors	Number of jurisdictions that protect land adjacent to airports from development
	Miles of roadway with agreements between state DOT and local government
	Alignment of strategic highway corridors and land use overlay
	Arterials where an access management plan has been established.
	Percent interregional corridor miles with corridor management/land use plans
	Agreements between state and local plans
Aligns state and local efforts	Locations where state and integrated transportation studies are undertaken
	Jurisdictions with current active local plans
	Customer satisfaction with coordination
	Customer/Stakeholder satisfaction rating
	Transportation projects are listed in the regional transportation plan
Reduced land consumption (and other environmental measures)	Percent of jobs or population in urban centers
	Population density
	Geographical expansion of the urbanized area
	Conversion of undeveloped land
	Loss of farmland, open space, habitat, forest land acreage or loss of historic resources or of specified/designated visual assets.
	Loss of wetlands
	Measured O_3, NO_x, CO and estimated (or measured) CO_2

These performance measures are used by U.S. states to evaluate transport and land use coordination.

Texas DOT Sustainable Transportation Indicators

The Texas Department of Transportation commissioned the Transportation Institute to develop sustainable transportation performance measures for TXDOT's strategic plan. Table 19 summarizes the objectives. Specific performance measures were defined for each objective.

Table 19 **Sustainability-Related Objectives** (Ramani, et al. 2009)

Strategic Goal	Sustainability Related Objective
Reduce Congestion	Improve mobility on highways
	Improve reliability of highway travel
Enhance Safety	Reduce crash rates and crash risk
	Improve traffic incident detection and response
Expand Economic Opportunity	Optimize land-use mix for development potential
	Improve road-based freight movement
Increase Value of Transportation Assets	Maintain existing highway system quality
	Reduce cost and impact of highway capacity expansion
	Leverage non-traditional funding sources for highways
	Increase use of alternatives to single-occupant automobile travel
Improve Air Quality	Reduce adverse human health impacts
	Reduce greenhouse gas emissions
	Conform to emissions exposure standards

Critique

This set of objectives ignores social objectives such as improved mobility for non-drivers, increased affordability, and improved public fitness and health from increased walking and cycling. The objecitves also ignore other environmental impacts such as loss of open space (directly, by highway facilities and indirectly, by stimulating sprawl), habitat loss and water quality impacts. There is apparently no consideration of user costs and indirect costs, such as the costs of providing parking facilities and potential savings from reduced vehicle ownership and use.

The objectives are based on *mobility* rather than *accessibility*, which assumes that mobility is an end in itself and ignore strategies that improve accessibility without increasing mobility such as more accessible land use development. Improved road-based freight movement appears to ignore shifts to rail and water transport as possible freight improvement strategies although they are more resource efficient.

The objectives and indicators are distance-based (such as crash and emission rates per vehicle-mile), and so does not recognize increased mileage as a risk factor and mileage reduction strategies as potential ways to achieve sustainability.

Multi-Criteria Evaluation

Sambert, Bassok and Holman (2011) advocate using multi-criteria evaluation (MCE) to evaluate the sustainability of transport projects and programs. This approach uses a scoring system to rate the project according to various criteria (they identify 49), which allows consideration of both quantitative and qualitative factors.

Comprehensive Highway Capacity Project Evaluation

The study, *A Systems-Based Performance Measurement Framework for Highway Capacity Decision Making* (Cambridge Sysemtatics 2009) developed a state-of-the-art performance measurement framework that individual transportation agencies and other public agencies can adapt for evaluating major transportation capacity projects.

Table 20 **Transport Capacity Performance Factors** (Cambridge Systematics 2009)

Transportation	Environment	Economics	Community	Costs
Mobility Reliability Accessibility Safety	Ecosystems, Habitat, and Biodiversity Water Quality Wetlands Air Quality Climate Change Environmental Health	Economic Impact Economic Development	Land Use Archaeological and Cultural Resources Social Environmental Justice	Cost Cost-Effectiveness

This table indicates major factors that should be considered transporat system capacity evaluation, such as highway expansion projects.

The report provides more detailed definitions and information about these performance indicators. It makes the following recommendations for selecting performance indicators:

- Performance measures should be driven by strategically aligned goals and objectives.
- Input, output, and outcome measures should all be included in performance measurement.
- Performance measurement efforts should concentrate on the "vital few."
- Early attempts at performance measurement should emphasize process as well as results.
- Performance measurement programs are most effective when integrated throughout an organization.
- Performance measurement reporting should be appropriately tailored to intended audiences.
- Successful performance measurement programs require high-level buy-in.
- Practitioners should strive for consistency of performance measurement terms and definitions.

Regional Sustainable Transporation Principles and Indicators (York Region 2009)
The York, Ontario region's Transportation Master Plan is based on eleven sustainability principles, their goals and performance indicators, summarized below.

Table 21 **Transport System Indicators** (York Region 2009)

Sustainability Principles	Goals	Key Performance Indicators
I. Healthy Communities		
Put pedestrians and transit first	Recognizes that every trip begins and ends with pedestrian links. Design transport systems to promote and active living and community wellbeing.	• Mode share (portion of trips by each mode) • Pedestrian mode share compared with peer communities. • Jobs within walking distance of homes (jobs/housing balance)
Provide access and mobility for everyone	Ensure that all residents (especially those with lower incomes, disabilities, recent immigrants, youth and the elderly) have barrier-free, reliable and affordable access.	• Change in per capita transit ridership • Per capita transit trips by income, disability, immigrant status, age, etc.
Integrate transportation and land use planning	Integrate transport planning with other urban development practices to create an urban form that is compact, mixed and supports a sense of community.	• Self-containment (portion of trips that start and end within the region). • Mean auto and transit trip length. • Mean auto and transit trips travel times.
Encourage communication, consultation and public engagement	Transport decision-making is open, transparent and accountable, based on strong consultation, citizen engagement and communication.	N/A – this principle is unsuited for measurement.
II. Sustainable Natural Environment		
Protect and enhance our environment and cultural heritage	Protect, restore and enhance the natural environment through integrated planning and advanced construction and operations practices. Respect and protect cultural heritage.	• Vehicle air pollution emissions (including greenhouse gases). • Protection of openspace.
Energy efficiency	Design a transport system that is energy efficient and responds to climate change	Auto vehicle-kilometers of travel. Total GHG emissions.
Implement and support transportation demand management initiatives	Improve the convenience and reliability of alternative modes to encourage their use and reduce single-occupant vehicle travel.	Average vehicle occupancy (a proxy for use of high-occupancy vehicles).
III. Economic Vitality		
Support economic wellbeing	Ensure that the transport system supports economic development	• Roadway congestion. • Jobs accessible by public transit.
Ensure fiscal sustainability and equitable funding	Provide full cost accounting for all transport projects and services.	Compare total costs to society of alternatives, including road expansion, alternative mode improvements, pricing reforms, smart growth policies, etc.
Implement and support transportation supply management initiatives	Mange transport system in an efficient and cost-effective, socially and environmentally responsible manner.	• Transit service costs per capita • Transit service cost recovery. • New roadway required per additional resident.
Conduct performance evaluation	Monitor and report sustainable transport performance indicators	N/A – this principle is unsuited for measurement.

Summarizes sustainability principles, goals and performance indicators were developed by York Region.

Transport For Sustainable Development In The European Region (ENECE 2011)

The United Nations Economic Commission for Europe (UNECE) report, *Transport For Sustainable Development In The ECE Region*, describes ways that the UNECE is working to help acheive various sustainability objectives including basic mobility, cost efficiency, traffic safety, environmental sustainability, and sustainable development. Includes definitions and indicatores of sustainable development and sustainable transportation, and applies these to evaluate current conditions and trends. Tables 22 and 23 summarize the UNECE's sustainable development approach.

Table 22 **Three Pillars Of Sustainable Development** (ENECE 2011)

	Social	Economic	Environmental
Accessibility	Social inclusion through access to social services.	Competitiveness through access to markets.	Congestion in urban areas and border crossing inefficiencies has negative environmental consequences.
Affordability	Social inclusion through affordable mobility.	Social affordability of infrastructure and transportation. Ensuring a competitive business environment	Maintenance backlogs reduce the environmental efficiency of the transport system.
Safety	Safe transport ensures that mobility is not a health risk.	Cost for the society for a loss of human life and crashes.	Safe transport of dangerous goods.
Security	A secure transport system ensures that individuals can travel without risk of terrorist attacks or other criminal offences.	Cost for the society of loss of goods, infrastructure and especially human life.	Secure transport of dangerous goods.
Environmental	Minimise local air pollution and noise from transport which is a risk for human health.	The impact of transport on the environment has economic costs.	Minimize impact of transport on natural capital by reducing negative impact on biodiversity, natural habitat, air pollution, greenhouse gas emission, generation of waste and noise.

This table links the UNECE's five working areas to the three dimensions of sustainability.

Table 23 **Indicator Set: Transport For Sustainable Development** (ENECE 2011)

	Access	Affordability	Safety	Security	Environment
Impact on Capital	*Economic capital* Access to markets and employment *Social capital* Access to basic social services	*Economic capital* Affordable access to education and employment opportunities. Long-term sustainable economically Investment. *Social capital* Affordable access to basic services.	*Economic capital* Safe transport to avoid costs of traffic crashes. *Social capital* Safe transport to avoid individual tragedies and loss of human and cultural capital.	*Economic capital* Secure transport to avoid loss of infrastructure, goods and human lives. *Social capital* Secure transport to avoid individual tragedies and loss of human and cultural capital.	*Natural capital* Transport that is sustainable with respect to energy use, emissions and land use to maintain the natural capital of the world.
Indicators	*Indicator 1* Infrastructure density *Indicator 2* Infrastructure quality *Indicator 3* International transport *Indicator 4* Burden of border crossings	*Indicator 1* Household spending on transport. *Indicator 2* Price of transport *Indicator 3* Public investment in transport *Indicator 4* Private investment in transport	*Indicator 1* Road fatalities *Indicator 2* Seatbelt use, impaired driving and speeding *Indicator 3* Active level crossings	*Indicator 1* Terror threats *Indicator 2* Criminal activities	*Indicator 1* Energy consumption in transport *Indicator 2* Emissions of greenhouse gases and local pollutants *Indicator 3* Local pollutants from transport *Indicator 4* Noise pollution
Sustainability Targets	Infrastructure density is linked to social development perforamance. Minimize share of population without access to all-wealther road or rail. Strategic international links, particularly for landlocked countries. Efficient border crossings	Affordable transport independent of income. Long-term investment plans. Thorought pre-investment analysis	Minimize road fatalities and injuries. Minimize rail and IWT fatalities and injuries. Minimize accidents involving dangerous goods	Prevent terrorist threats and attacks. Prevent criminal activities.	Reduce dependence on non-renewable energy sources in transport. Minimize emissions of greenhouse gases and local pollutants. Minimize noise impacts from transport. Minimzie waste from transport and improve degree of recycling.

This table provides an overview of the working areas of the UNECE Transport Division with respect to sustainable development.

Key Performance Indicators for Smart Sustainable Cities (UNECE 2016)
The United Nations has established *Sustainable Development Goals*; the UN Habitat program has established the *City Prosperity Index*; the ITU and UNECE launched a *Smart Sustainable Cities* program; and the International Standards Organization has established *Indicators for City Services and Quality of Life*. In order to help operationalize these goals and programs, these organizations established a *Focus Group on Smart sustainable Cities* to develop key performance indicators (KPIs) that can help stakeholders measure the performance of various smart sustainable city ventures once they are initiated.

This program produced a series of *Technical Specifications and Reports* on SSC KPIs:

- *Technical Specifications On Overview Of Key Performance Indicators In Smart Sustainable Cities*, October 2014.
- *Technical Specifications On KPIs Related To The Use Of Information And Communication Technology In Smart Sustainable Cities*, March 2015.
- *Technical Specifications On Key Performance Indicators Related To The Sustainability Impacts Of Information And Communication Technology In Smart Sustainable Cities*, March 2015.
- *Technical Report On Key Performance Indicators Definitions For Smart Sustainable Cities*, March 2015.
- *Key Performance Indicators For Smart Sustainable Cities To Assess The Achievement Of Sustainable Development Goals* (UNECE 2016).

Sustainable Transportation Performance Measures (USEPA 2011)
The U.S. Environmental Protection Agency's *Guide To Sustainable Transportation Performance Measures* describes sustainable transportation performance measures (indicators) suitable for local, regional and state planning. It discusses the application of sustainability indicators in transportation decision-making, and provides specific examples of how metropolitan planning organizations have used such indicators for various types of strategic and project planning, investment decisions, and performance evaluation.

It identifies twelve suitable indicators. For each, the guidebook presents possible metrics, summarizes the relevant analytical methods and data sources, and illustrates the use of each measure by one or more transportation agencies.

The profiled measures are:

- Transit accessibility
- Bicycle and pedestrian mode share
- Vehicle miles traveled per capita
- Carbon intensity
- Mixed land uses
- Transportation affordability
- Distribution of benefits by income group
- Land consumption
- Bicycle and pedestrian activity and safety
- Bicycle and pedestrian level of service
- Average vehicle occupancy
- Transit productivity

Sustainable Infrastructure

Some indicators rate the sustainability of infrastructure, including roadways.

Envision (http://terralogicss.com/_blog/Sustainable_Transportation/post/The_New_Sustainability-Based_Rating_System_for_Infrastructure_Projects_Called_Envision)

Envision is a sustainability rating system developed by the *Institute for a Sustainable Infrastructure* (www.sustainableinfrastructure.org) with support of the American Society of Civil Engineers (ASCE), American Council of Engineering Consultants (ACEC) and the American Public Water Association (APWA) to evaluate infrastructure projects including roads, bridges, pipelines, railways, airports, dams, levees, landfills, water treatment systems and other civil works. It is intended to evaluate, grade and give recognition to infrastructure projects that make exemplary contributions to a more sustainable future. Projects are graded not only on individual performance, but also on their contribution to the performance and long-term sustainability of the community they serve. It stretches traditional design boundaries to include infrasture durability, flexibility and utility.

Greenroads (www.greenroads.org)

Greenroads is a sustainability rating system for roadway design and construction, suitable new, reconstruction and rehabilitation and bridge projects. It is a collection of sustainability best practices, called *credits*. Achieving credits earns points toward an overall project score that indicates the roadway's sustainability. It was developed by the University of Washington's *Transportation Northwest* institutue, with support from a coalition of state and federal agencies.

Sustainable Highways (www.sustainablehighways.org)
The U.S. Federal Highway Administration's *Sustainable Highways Self-Evaluation Tool* identifies sustainable highways characteristics, and provides procedures and techniques to help organizations apply sustainability best practices to roadway programs and projects. Table 24 lists the credits and their default wegiths used in this tool.

Table 24 **Proposed TERM Indicator List** (EEA 2002)

Credits	Points
System Planning & Processes	
SP-1 Comprehensive and Integrated Planning Incorporate environmental, economic, and social sustainability goals into long-range transport plans.	10
SP-2 Environmental Management System Improve environmental stewardship by having an environmental management system.	10
SP-3 Context Sensitive Solutions Ensure that a system-wide context sensitive solutions (CSS) approach is integrated.	10
SP-4 Equity Analysis Provide a transportation system that fairly benefits affected geographic or demographic groups.	10
SP-5 Land Use Planning Integration Ensure integration of transportation system plan with local and/or regional land use planning.	10
SP-6 Multimodal Transportation - INTERIM Agency has a plan for meeting ser needs for access and mobility through convenient choices.	10
SP-7 Professional Development Educate personnel to identify environmental issues, minimize impacts and apply sustainable solutions.	10
SP-8 Travel Demand Management Reduce travel demand or redistribute demand in space and time.	10
SP-9 Safety Management - INTERIM Agency has a data-driven Strategic Highway Safety Plan (SHSP).	10
SP-10 Air Quality Ensure air quality issues are addressed in transportation system plan.	10
SP-11 Greenhouse Gas Emissions Integrate climate change mitigation considerations into the transportation planning process.	10
SP-12 Climate Change Effects Long Range Transportation Plan (statewide or metropolitan) considers potential climate change impacts.	10
SP-13 Noise Reduction Management Plan Protect human health by reducing overall highway traffic noise.	10
SP-14 Financial Sustainability Finance plan provides a tool for prioritizing, planning and programming sustainability investments.	10
Project Development	
PD-1 Cost Benefit Analysis Using the principles of cost benefit analysis, ensure that users benefit.	1
PD-2 Highway and Traffic Safety - INTERIM Improve human health by implementing projects that reduce serious injuries and fatalities.	10
PD-3 Context Sensitive Solutions Deliver projects that synthesize transportation requirements and community values.	5
PD-4 Lifecycle Assessment Incorporate energy and emissions information into the decision-making process.	2
PD-5 Lifecycle Cost Analysis Determine the project lifecycle cost to aid in project decision-making.	2
PD-6 Freight Mobility Increase freight mobility and decrease freight environmental impact.	5
PD-7 Educational Outreach Increase public, agency and stakeholder awareness of roadway sustainability activities.	2

Credits	Points
PD-8 Habitat Restoration Offset the destruction and deterioration of natural habitat caused by road construction.	3
PD-9 Runoff Flow Control Mimic predevelopment hydrological conditions in the right of way (ROW).	3
PD-10 Runoff Quality Improve water quality of stormwater runoff leaving the roadway Right-of-Way (ROW)	3
PD-11 Ecological Connectivity Provide wildlife access across roadway facility boundaries and reduce vehicle-wildlife collisions.	3
PD-12 Low Impact Development Use decentralized stormwater management controls to preserve, emulate, and improve hydrologic flow.	3
PD-13 Recycled Materials Reduce lifecycle impacts from extraction and production of virgin materials.	5
PD-14 Renewable Energy Offset total operational energy use through autonomous renewable energy sources.	5
PD-15 Site Vegetation Promote sustainable site vegetation that does not require irrigation.	2
PD-16 Pedestrian Access Promote walkable communities by providing sidewalk facilities within the roadway Right-of-Way.	2
PD-17 Bicycle Access Promote bicycling in communities by providing dedicated cycling facilities within project right of way.	2
PD-18 Transit and HOV Access Promote use of public transit and carpools in communities by providing new transit and HOV facilities.	5
PD-19 Historical, Archaeological, and Cultural Preservation Respect and preserve cultural and historic assets, and feature National Scenic Byways Program (NSBP).	2
PD-20 Scenic, Natural, or Recreational Qualities Feature National Scenic Byways Program scenic, natural, or recreational intrinsic qualities in a roadway.	2
PD-21 Low-Emitting Materials Reduce human exposure to hazardous airborne compounds from construction materials.	2
PD-22 Energy Efficiency Reduce lifetime energy consumption of lighting systems for roadways.	5
PD-23 Traffic Systems, Management and Operations Meet economic and social needs and improve mobility without adding capacity.	5
PD-24 Long-Life Pavement Minimize life cycle costs by promoting design of long-lasting pavement structures.	5
PD-25 Pavement and Structure Reuse Reuse existing pavement and structural materials.	5
PD-26 Stormwater Cost Analysis Determine lifecycle costs and savings associated with best management practices for stormwater.	1
PD-27 Thermal Pavement Use pavement thermal properties to enhance sustainability.	3
PD-28 Contractor Warranty Incorporate construction quality into the public low-bid process through the use of warranties.	3
PD-29 Stormwater Pollution Prevention Plan Reduce pollution and associated effects from construction activities.	3
PD-30 Environmental Training Provide construction personnel with the knowledge to identify environmental issues and best practices.	1
PD-31 Equipment Emission Reduction Reduce construction equipment emissions by encouraging application of EPA Tier 4 standard.	2
PD-32 Fossil Fuel Reduction Reduce the overall consumption of fossil fuels by nonroad construction equipment.	2

Credit	Points
PD-33 Construction Noise Mitigation Reduce or eliminate disturbance from road construction noise and improve human.	1
PD-34 Quality Control Plan The contractor will establish, implement, and maintain a construction Quality Control Plan (QCP).	5
PD-35 Reduced Energy Materials Reduce fossil fuels use and emissions at the hot mix asphalt or cement plants.	3
PD-36 Waste Management Utilize a management plan for to minimize the amount of construction-related waste.	1
PD-37 Earthwork Balance Reduce need for transport of earthen materials by balancing cut and fill quantities.	3
PD-38 Environmental Management System Long Range Transportation Plan (statewide or metropolitan) considers potential climate change effects.	3
PD-39 Tracking Environmental Commitments Assure that environmental obligations are identified, communicated, completed, and documented.	3
Transportation Systems Management, Operations & Maintenance	
OM-1 Pollution Prevention Plan Reduce water pollution produced during operation and maintenance activities within the right of way.	10
OM-2 Pavement Management System Make pavements last longer and perform better by preserving and maintaining them.	10
OM-3 Bridge Management System Make bridges last longer and perform better by preserving and maintaining them.	10
OM-4 Paved Surfaces Management System Increase paved surfaces durability and performance with maintenance and preservation activities.	10
OM-5 Traffic Control Infrastructure Maintenance Increase safety and operational efficiency by maintaining roadway traffic controls.	10
OM-6 Cleaning and Litter Prevent pollution and maintain aesthetic quality through roadway cleaning and litter removal.	10
OM-7 Roadside Infrastructure Maintenance Maintain road functionality through upkeep of supporting infrastructure and operations.	10
OM-8 Snow and Ice Control Reduce environmental impacts of snow and ice control methods and materials.	10
OM-9 Mobility Maximize the utility of the existing roadway network through use of technology and management.	10
OM-10 Safety - INTERIM Maximize the safety of the existing roadway network through use of technology and management.	10
OM-11 Renewable Energy Use Reduce the consumption of fossil fuels during operation and maintenance of facilities.	10
OM-12 Sustainable Purchasing Address resource and energy use, pollution generation, climate change.	10
OM-13 Alternative Fuel Fleet Reduce fossil fuel use and emissions in vehicles used for operations and maintenance.	10
OM-14 Recycle and Re-use Create and pursue a formal recycling and reuse plan for maintenance and operations activities.	10
OM-15 Ecological Connectivity Improve wildlife access across roadway facility boundaries and reduce vehicle-wildlife collisions.	10

This table summarizes credits and weights used in the Sustainable Highways Evaluation Tool.

Transport Agency Sustainability Evaluation

Some sustainability evaluation processes are designed for use by transportation agencies.

National Cooperative Highway Research Program Project 08-74, *Sustainability Performance Measures for State Departments of Transportation and Other Transportation Agencies* (Zietsman and Ramani 2011; Ramani, et al. 2011) developed a sustainability performance measurement framework, suitable for transport agency planning, programming, project development, construction, maintenance and systems operations. The framework includes guiding principles, goals relevant to transportation agencies' functions, guidance for applying sustainability performance evaluation. They also developed a spreadsheet to facilitate this analysis. The framework is based on the following recommended goals.

1. *Safety*—Provide a safe transportation system for users and the general public.
2. *Basic accessibility*—Provide a transportation system that offers accessibility that allows people to fulfill at least their basic needs.
3. *Equity/equal mobility*—Provide options that allow affordable and equitable transportation opportunities for all sections of society.
4. *System efficiency*—Ensure the transportation system's functionality and efficiency are maintained and enhanced.
5. *Security*—Ensure the transportation system is secure from, ready for, and resilient to threats from all hazards.
6. *Prosperity*—Ensure the transportation system's development and operation support economic development and prosperity.
7. *Economic viability*—Ensure the economic feasibility of transportation investments over time.
8. *Ecosystems*—Protect and enhance environmental and ecological systems while developing and operating transportation systems.
9. *Waste generation*—Reduce waste generated by transportation-related activities.
10. *Resource consumption*—Reduce the use of non-renewable resources and promote the use of renewable replacements.
11. *Emissions and air quality*—Reduce transportation-related emissions of air pollutants and greenhouse gases.

Fabish and Haas (2011) recommend the following livability program performance indicators:

- Program commitment delivery (did the program accomplish what was intended?)
- Portion of regional development in targeted areas (did the program encourage developed where desired?)
- Leveraged funding (did the program close the financing gap?)
- Transportation targets (did it increase transit ridership, improve pedestrian and bicycle access, achieve intended cost efficiencies, etc.).

Livability for Montana State Transport Planning (WTI 2012)

The report, Livability for Montana Transportation investigates the meaning of livability for use by the Montana Department of Transportation. Based on research and community outreach it developed the following definition: *"Provide a transportation system that emphasizes a safe, maintained road network; allows for multimodal transportation opportunities; and considers local community values."* Although the research found that *livability* definitions vary, it identified several common themes related to transport:

- Transportation systems should include all modes (air, automobile, public transit, bicycle, pedestrian, and other local modes).
- Land use and transportation clearly influence each other. Transportation plans and projects should result in a transportation system that integrates with and supports local land use plans, affordable housing projects, and similar efforts that encourage a livable community structure.
- Transportation systems in dense and developing areas should be highly connected. Cul-de-sacs and streets designed around specific land development limit connectivity. A well-designed grid system promotes connectivity.
- Transportation projects should incorporate local values in the planning/design process. Such values may include aesthetically pleasing transportation corridors and pedestrian safety.
- Safety and capacity for the automobile mode should not be ignored.
- Transportation systems should seek to reduce fossil fuel use and greenhouse gases.
- Transportation systems should provide access to jobs, education, health care, and services.
- Transportation projects should be coordinated with other projects to leverage funding and accomplish livability goals.

Cross-Country Review of Transport Agency Indicators (Karlaftis and Kepaptsoglou 2012)

A study for the International Transport Forum analyzed the performance indicators used by transport agencies in various countries. They find that most agencies use indicators that reflect infrastructure quality and preservation, mobility and accessibility, support for economic development, safety and security, environmental sustainability. Few indicators are multi-modal (for example, there is little consideration of non-motorized transport), and few indicators reflect social equity objectives such as improved accessibility for non-drives or accommodation of people with disabilities. They conclude that standardizing performance indicators and targets among different agencies worldwide would be difficult but useful for benchmarking and resource allocation.

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Incremental Improvements To Conventional Transport Evaluation

There are sometimes opportunities to incrementally improve conventional transport planning practices to better evaluate sustainability goals (FDOT 2012). Examples are described below.

Transport Model Performance Evaluation (Rodier and Spiller 2012)

The report, *Model-based Transportation Performance: A Comparative Framework and Literature Synthesis*, incorporates various performance indicators into transport modeling to evaluate the effectiveness of various land-use, transit, and automobile pricing policies. The results indicate the direction and relative magnitude of change resulting from these policies, as well as potential biases that result in analyses that overlook some of these impacts. Table 25 summarizes the indicators used.

Table 25 **Performance Indicator Framework** (Rodier and Spiller 2012)

	Performance Indicator	Required Model Data
Travel	Access	Travel time/cost by origin/destination location, mode, area (corridor, subarea, region), time of day (peak and off-peak), and/or activity type (work, school, shop)
	Proximity	Quantity of land consumed; redevelopment and/or infill by type, area, and/or location; total jobs by total households by area
	Choice	Transit, pedestrian, and bicycle mode share by area
	Congestion	Vehicle speed/distance by mode (including trucks), activity type, area (key corridors or economic destinations)
Equity	Access	Access by socioeconomic group and location
	Spatial	Clustering of socioeconomic groups by location
	Housing	Home location change attributed to rent increase by socioeconomic group
	Housing	Supply and cost (rent/own) by type and location
Economic	Financial/land use	Built-form input to service cost, tax, and/or infrastructure cost model
	Financial/transport	Use and revenue relative to capital and operation and maintenance (O&M) costs
	Surplus	Spatial economic effects (producer and consumer surplus)
Environmental	Energy/climate/air	Vehicle activity in fuel use, climate change, and emissions models
	Noise	Residential location and vehicle facilities in noise models
	Habitat/ecosystem/ water	Land consumed by type and location input to habitat, ecosystem, and water models

This table summarizes performance indicators incorporated in transport models for more comprehensive analysis of impacts of various policy and planning options.

Measuring Transportation Investments: The Road To Results (PCT 2011)

The report, *Measuring Transportation Investments: The Road To Results*, evaluates how well U.S. states consider various performance goals in transport investment planning. It examines these six policy areas:

1. *Safety.* The ability of the transportation system to allow people and goods to move freely without harm. Performance measures include fatalities and injuries for all modes.
2. *Jobs and commerce.* How well the transportation system facilitates or supports business development and employment. Performance measures include job creation, the movement of freight and estimates of the economic return from policies and investments.
3. *Mobility.* The efficient movement of people between destinations by automobile, pedestrian, bicycle and transit modes. Performance measures include congestion levels, travel times, travel speed and volume, time lost to traffic delays and on-time transit performance.
4. *Access.* The ability of the transportation system to connect people to desired goods, services and activities, and to meet the needs of different populations. Performance measures include availability and use of multimodal transport options—including walking, cycling, public and private transport—for the general public and people with special needs (disabled and low-income).
5. *Environmental stewardship.* The effect of the transportation system on energy use and the natural environment. Performance measures include fuel usage, transportation-related emissions, climate change indicators, and preservation of and impact on ecological systems.
6. *Infrastructure preservation.* The condition of the transport system's assets. Performance measures include the physical condition of roads, bridges, pavements, signs, culverts and rail systems

The analysis rates weather each state considers these goals but does not evaluate how well this is done or the degree it affects investment decisions. The report recommends federal, state and local policy reforms to improve government agency's ability to evaluate investments and incorporate this information into transport planning and investment decisions.

UK Transport Analysis Guidance – WebTAG (www.dft.gov.uk/webtag)

The Department for Transport's WebTAG website provides comprehensive guidance on the conduct of transport studies, inlcuding guidance on how to:

- Set objectives and identify problems.
- Develop potential solutions.
- Create a transport model for the appraisal of the alternative solutions.
- Conduct an appraisal which meets the Department's requirements.

This is a guide to best practices and a requirement for all projects/studies that require government approval. It includes specific instuctions and detailed documents for evaluating accessibility (i.e. overall transport system effectiveness), safety, environmental and economic development impacts, plus the integration among different types of transort, transport and land use development, transport and the environment, and between various planning objectives.

Multi-Modal Level-Of-Service Indicators

The 2010 *Highway Capacity Manual* (TRB 2010) includes multi-modal performance indicators based on an extensive research program that developed Level-of-Service (LOS) ratings which measure how various facility design factors affects walking, cycling, automobile and public transit travel (Dowling Associates 2008). These include:

- *Cycling LOS* takes into account the availability of parallel bicycle paths, the number of unsignalized intersections and driveways (because they create conflicts between cyclists and other vehicles), width of outside through lane or bicycle lane (the degree of separation between bicyclists and motor vehicle traffic), motor vehicle traffic volumes and speeds, portion of heavy vehicles (large trucks and buses), the presences of parallel parked cars, grades (hills), and special conflicts such as freeway off-ramps.

- *Pedestrian LOS* takes into account pedestrian facility crowding, the presence of sidewalks and paths, vehicle traffic speeds and volumes, perceived separation between pedestrians and motor vehicle traffic (including barriers such as parked cars and trees), street crossing widths, extra walking required to reach crosswalks, average pedestrian crossing delay (time needed to wait for a gap in traffic or a crosswalk signal), and special conflicts such as multiple free right-turn lanes (which tend to be difficult for pedestrians to cross).

Sustainable Transportation Economic Evaluation (www.transpotohealthlink.com/index.html)

The HDR *Sustainable Return on Investment (SROI)* process assesses the economic, social and envioronmental benefits of a transportation infrastructure project. It includes four phases:

I. Development of a structured and logical plan (assessment of "how" all the variables and assumptions interact to determine the impact of a project).
II. Quantifying the input data and assumptions (statistical probability/uncertainty analysis of the project elements).
III. Risk assessment session with stakeholders (step 2 elements).
IV. Model Simulation and forecasting results (data modeling of various project scenarios and statistically based probability distributions).

The SROI model promotes transparency, accountability, and efficient use of all social resources necessary to maximize the "triple bottom line" of economic, social and environmental value. In addition, the SROI methodology builds on best practices in Cost-Benefit Analysis and Financial Analysis methodologies, complemented by state-of-the-art Risk Analysis and Stakeholder Elicitation techniques.The SROI process identifies the significant impacts of a project and values these impacts in monetary terms, while accounting for non-monetary benefits and external costs and benefits. The SROI is essentially a feasibility study in conjunction with the monetized value of non-cash costs of environment, community variables and external benefits.

SROI originated from a Commitment to Action to develop a new generation of public decision support metrics for the Clinton Global Initiative (CGI). SROI was developed with, and peer-reviewed, by Columbia University's Graduate School of International Public Affairs and launched at the 2009 CGI annual meeting. The SROI process has been used by HDR to evaluate the monetary value of sustainability programs and projects valued at over $10 Billion.

Korean Green Growth Index (KOTI 2011)

The *Green Growth Index* is designed to evaluate sustainable development. In includes three transport sector indices, including low-carbon ecofriendliness, energy efficiency and economic activity. These include:

Low Carbon Eco-Friendliness

- Climate change emission rates (per person, vehicle-km, GDP)
- Air pollution emission rates (per person, vehicle-km, GDP, by mode)
- Traffic safety (accident and fatality rates per capita and vehicle)
- Number of people exposed to traffic noise.
- Amount of land devoted to tranpsort facilities (total and per capita)
- Environmental-related law suits.

Energy Efficiency Index

- Total energy consumption rates (total, per capita, by mode and travel activity)
- Fossil fuel consumption rates (total, per capita, by mode and travel activity)
- Renewable fuel consumption (total, per capita, by mode and travel activity)
- Non-motorized travel (per capita and commute mode share)

Economic Activity Index

- Travel activity (person and tonne-kilometers per capita and per GDP)
- Vehicle travel activity (person and tonne-kilometers per capita and per GDP)
- Public transport (seat-kms and passenger-kms)
- Commute duration and distance.
- Average travel speed (by mode and location)
- Average total weekly travel distance (activity range)/person and household
- Congestion delay
- Mode share
- Transport expenses (portion of household budgets and GDP)
- Percentage of household expenditures on road use, parking, transport services, etc.
- GDP/passenger-km, ton-km
- Expenses spent on non-business activities a week per household
- Expenses per non-mandatory activity (won/activity)
- Expenses per trip by transport mode (nonbusiness)
- Change in expenses spent on non-business activities per unit travel distance increase

Index values were calculated for seven Korean cities and ten OECD countries. The summary results rate Sweden top, the U.S. lowest, and Korea eighth. In addition to these current indicators, KOTI is considering additional indicators, including public investments in research and resource-efficient modes and transport safety programs, total social costs of transport, length of road and railroads, number of intermodal terminals, land use accessibility (number of jobs, services and recreational facilities within 30 minutes travel time, and portion of people and jobs within 500 meters of transit stations).

Multi-Modal Urban Transportation Performance Indicators (Wilbur Smith 2008)

The study, *Traffic & Transportation Policies and Strategies in Urban Areas in India* developed a *Transport Performance Index* for evaluating urban transport systems and prioritizing improvements in Indian cities. It consists of the following factors:

- *Public Transport Accessibility Index* (the inverse of the average distance (in km) to the nearest bus stop/railway station (suburban/metro).
- *Service Accessibility Index* (% of Work trips accessible in 15 minutes time).
- *Congestion Index* (average peak-period journey speed relative to a target journey speed).
- *Walkability Index* (quantity and quality of walkways relative to roadway lengths).
- *City Bus Transport Supply Index* (bus service supply per capita).
- *Para-Transit Supply Index* (para-transit vehicle supply per capita).
- *Safety Index* (1/traffic fatalities per 100,000 residents).
- *Slow Vehicle (Cycling) Index* (availability of cycling facilities and cycling mode share).
- *On-street Parking Interference Index* (1/(portion of major road length used for on-street parking + on-street parking demand).

Good Examples Of Bad Indicators

Sustainability performance indicators may fail in the following ways.

- *Narrow scope fails to reflect true sustainability.* For example, they may measure only fossil fuel consumption and climate change emissions, without considering other economic, social and environmental impacts.[1]
- *Inadequate indicators to reflect intended goals.* For example, *availability of public transit service* is just one indicator of the quality of accessibility for disadvantaged populations; others include the quality of walking and cycling conditions, the affordability of bus fares and housing in areas serviced by public transit, and the availability of internet and delivery services to lower-income households.
- *Lack a logical structure.* For example, some indicator sets include both *policies* (incentives to choose fuel efficient vehicles) and *outcomes* (increased fleet fuel efficiency, reduced per capita energy consumption and pollution emissions). Although this may sometimes be appropriate, it is important that the indicator structure recognize these differences and avoid double-counting impacts.
- *Considers intermediate objectives rather than outcomes.* For example, “miles of bikeways” is an intermediary indicator which may fail to achieve the ultimate goal of increasing nonmotorized transport activity, since it may result in bikepaths and lanes constructed where they are cheapest to build rather than where they would provide the greatest benefits, and it overlooks the importance of other strategies that may do more to increase walking and cycling activity, such as more accessible land use development, school transport management programs, and more efficient transport pricing.
- *Based on inappropriate reference units.* For example, measuring impacts per vehicle-mile or lane-mile can justify increased vehicle travel or road construction, increasing total transportation problems.
- *Fail to clearly define how the indicators are to be interpreted.* For example, increased transit ridership may be good if it results from improved service and efficient pricing, but is not necessarily good if it reflects poverty.
- *Fail to reflect total and lifecycle impacts.* For example, some biofuels increase total climate change emissions (depending on feedstocks), and efforts to reduce traffic congestion by expanding highway capacity may reduce delays and emissions in the short-run but by stimulating sprawl may increase total vehicle travel and emissions over the long-run.

[1] For example, sustainability indicators that focus only on fossil fuel consumption and climate change emissions implies that the transportation system becomes sustainable if motorists shift to biofuels or nuclear-powered electric cars, although this fails to achieve other sustainability objectives such as reduced congestion, accidents and land use sprawl, or improved opportunity for disadvantaged people.

An Enviornmental Organization

An unnamed environmental organization proposed the following sustainable transport indicators:

1. Air quality index ratings and frequency of air pollution standard violations.
2. Number of asthma cases.
3. Number of privately owned hybrid and Alterative Fuel Vehicles (AFVs).
4. City vehicles that are hybrid or AFV.
5. Number of hybrids or AFV taxis.
6. Policies to promote purchase and use of hybrid and AFVs, such as parking incentives, tax incentives or permission to use HOV lanes.
7. Number of public transit users.
8. Trips by foot or bicycle per capita.
9. Number of conventional vehicles.
10. Carpooling/car sharing program in the city.
11. High Occupancy Vehicle (HOV) lanes: percentage of road network.
12. Subway or trolley lines or streetcars.
13. Per capita vehicle fuel consumption.
14. Availability of alternative fuel in the city.
15. Availability of transportation to assist disabled people (handydarts etc.)
16. Ratio of annual investment in public transport versus private transport infrastructure.
17. Ratio of public versus private transport energy use per passenger kilometer.
18. Number of school buses.

Critique

Some of these indicators are appropriate, but others may actually promote unsustainable policies. For example, allowing hybrids to use HOV lanes can cause those lanes to become congested so they no longer encourage transit and rideshare use, increasing total energy consumption, pollution emissions, and other transportation problems. Similarly, "Number of school buses" assumes that busing is desirable; while school busing may be better than parents chauffeuring children individually, walking and biking to school is more sustainable overall. High rates of school busing may be an indication of poor land use planning and bad walking and cycling conditions, both of which are unsustainable.

Texas Deparment of Transportation

The Texas Department of Transportation developed a set of sustainable transportation performance measures for evaluating transportation projects (Zietsman, et al., 2008). But the resulting performance measures, summarized in Table 26, reflect a narrow, highway agency perspective. For example, the Travel Rate Index implies that congestion declines if off-peak vehicle mileage increases. Similarly, safety and pollution impacts are based on rates per lane-mile, rather than total or per capita, which implies that crash and pollution problems decline if total lane-miles increase. The goal of expanding economic opportunity only reflects highway project funding and local commercial and industrial land development, it does not reflect broader community economic development objectives such as improving economic opportunity for disadvantaged groups, increased energy efficiency, or more efficient land use development. Although these may be appropriate highway agency performance measures, they fail to reflect the broader perspective and scope required to develop a truly sustainable transportation system.

Table 26 **TxDOT Sustainable Transport Performance Measures** (Zietsman, et al. 2008)

Goal	Performance Measures
Reduce Congestion	Travel rate index; Buffer index
Enhance Safety	Annual number of crashes per lane mile; Percentage of lane-miles under Traffic Management Center (TMC) surveillance
Expand Economic Opportunity	Percentage of project funding from alternative sources; Percentage of land within ½-mile of corridor that is zoned as commercial or industrial
Improve Air Quality	Daily oxides of nitrogen (NOx), carbon monoxide (CO), and volatile organic compounds (VOC) emissions in grams per lane mile
Increase Value of Transportation Assets	TxDOT's Pavement Condition Rating (on scale of 1-100); Percentage of lane-miles that can be added in median; Whether toll-eligible project is being tolled

The sustainable transportation performance measures developed by the Texas DOT reflect a narrow perspective and scope.

National Transportation Performance Evaluation (Litman 2008)

Hartgen, Chadwick and Field's 2008 report, *Transportation Performance of the Canadian Provinces*, by uses the unique set of 21 indicators in Table 27 to evaluate and compare Canadian provinces' transport system performance. Although some are appropriate and commonly used, others are ambiguous, and a few are illogical (Litman, 2008). For example, their safety (*fatality rate per billion vehicle km*) and congestion indicators (*annual hours of delay per capita*) are widely used, but their roadway indicator (*vehicle kilometers of travel per two-lane kilometer of road*) is ambiguous (a higher value could indicate cost efficiency or inadequate roadway supply and congestion) and inherently favors more urbanized provinces over more rural provinces.

Their highway cost efficiency indicator (*provincial expenditures per kilometer of major road*) favors provinces with relatively inexpensive, low-quality, low-volume roads, although the results would be reversed if the study used a more logical indicator, *provincial expenditures per vehicle-kilometer*, which would recognize that the economic value of roads results from their use. Aviation performance indicators (*passengers* and *tonnes of cargo per flight*) favor provinces with major airports over those with smaller airports. The road freight efficiency indicator (*Total employment per truck border crossing*) is ambiguous and rail and marine indicators (*Origin tonnes per km of first line track*, and *Port operator expenditures per tonne handled*) ignore differences in the costs of handling different types of freight. For example, it implies that a province that ships more bulk goods (such as aggregates and potash) has a more productive transport system than one that ships higher value manufactured goods.

Table 27 **Performance Indicators** (Hartgen, Chadwick and Fields 2008)

Mode	Dimension	Measure	Measure weight	Modal weight (trips or tonnes)	Grand weight (trips & tonnes)
Passenger					**90%**
Highway	Traffic Vehicle	km of travel per two-lane km of road	1/8	96.50%	
	Cost	Provincial expenditures per km, major road	1/8		
	Condition	Percent of major roads in fair or poor condition	1/8		
	Access	Travel time to Ottawa	1/8		
	Access	Travel time to US border	1/8		
	Safety	Fatality rate per billion veh-km	1/8		
	Congestion	Annual hours of delay per capita	1/8		
	Access	Avg. round trip commute time	1/8		
Transit	Traffic	Ridership per capita served	1/2	3.24%	
	Cost	Operating cost per trip	1/2		
Air	Traffic	Passengers per flight	1/2	0.17%	
	Safety	Accidents per million passengers	1/2		
Rail		Not evaluated		0.01%	
Marine	Traffic	Government operating cost per passenger	1/2	0.08%	
	Safety	Accidents per million passengers	1/2		
Freight					**10%**
Highway	Traffic	Tonnes of truck traffic per km of road	1/3	23.80%	
	Safety	Fatal collisions per million tonnes	1/3		
	Trade	Total employment per truck border crossing	1/3		
Air	Traffic	Tonne of cargo per flight	1.0	0.10%	
Rail	Traffic	Origin tonnes per km of first line track	1/2	27.20%	
	Safety	Rail accidents per million originating tonnes			
Marine	Traffic	Port operator expenditures per tonne handled	1/3	48.90	
	Safety	Port expense/revenue ratio	1/3		
	Trade	Shipping accidents per mill. tonnes	1/3		

This table summarizes the performance indicators used by Hartgen, Chadwick and Fields.

Table 28 critiques these indicators. Their results are useless for planning and management. They imply that increasing motor vehicle travel and freight transport volumes are inherently beneficial in terms of transport system effectiveness and productivity. If applied they would bias decisions to favor mobility over accessibility and automobile travel over other modes. They provide no guidance on public transit service quality, nonmotorized transportation, or factors such as fuel efficiency.

Table 28 **Performance Indicator Critique** (Litman 2008)

Indicator	Critique	Direction of Bias	Grade
Kilometers of vehicle travel per two-lane km of road	Ambiguous. Could indicate inadequate road supply.	Favors urban conditions and increased vehicle traffic.	D
Provincial expenditures per major road kilometer	Inappropriate. Ignores cost differences due to geographic factors and traffic volumes.	Favors rural conditions, and cheap, inferior roads.	C
Percent of major roads in fair or poor condition	Appropriate		A
Roadway travel time to Ottawa	Inappropriate. Miss-represents the concept of access.	Favors central provinces, particularly Ontario and Quebec.	F
Roadway travel time to US border	Inappropriate. Miss-represents the concept of access.	Favors southern provinces.	F
Traffic fatality rate per billion vehicle-kms	Mobility-based.	Favors increased motor vehicle travel.	C
Annual hours of congestion delay per capita	Appropriate, but data are limited to a few cities.	Favors provinces with few large cities.	B
Average round trip commuting time	Inappropriate as a road indicator; should apply to all modes.	Favors smaller cities and rural areas.	B
Transit ridership per capita served	Appropriate if one of several transit quality indicators.	Favors larger cities.	B
Transit operating cost per trip	Appropriate.	Favors larger cities.	B
Aviation passengers per flight	Inappropriate. Miss-represents the concept of load factor.	Favors cities with major airports.	D
Aviation accidents per million passengers	Appropriate.		A
Government operating cost per ferry passenger	Inappropriate. Ignores differences in costs.	Provinces with shorter and cheaper ferry services.	D
Accidents per million ferry passengers	Appropriate.		A
Tonnes of truck traffic per km of road	Ambiguous. Could indicate inadequate roads.	Favors urban conditions and increased truck shipping volumes.	D
Fatal collisions per million tonnes	Mobility-based.	Favors increased motor vehicle travel.	B
Total employment per truck border crossing	Inappropriate. Provides meaningless information.	Favors provinces with fewer border crossings.	F
Tonne of cargo per flight	Inappropriate. Miss-represents the concept of load factor.	Favors cities with major airports.	D
Origin tonnes per km of first line track	Ambiguous. Indicates little about true cost efficiency.	Favors provinces that generate high rail freight volumes.	C
Rail accidents per million originating tonnes	Appropriate.		A
Port operator expenditures per tonne handled	Ambiguous. Indicates little about true cost efficiency.	Favors provinces with cheaper to handle marine freight.	D
Port expense/revenue ratio	Appropriate, but fails to account for factors such as investment.	Favors provinces that are not currently improving facilities.	B
Shipping accidents per million tonnes	Fails to account for different types of freight	Favors provinces with safer to handle marine freight.	B

This table critiques performance indicators used by Hartgen, Chadwick and Fields. Some are appropriate and commonly used, others are ambiguous, and a few are illogical.

Smarter Cities and Flawed Rankings
Alex Steffen, *World Changing*, July 16, 2009 (www.worldchanging.com/archives/010154.html)

Smarter Cities is an NRDC project designed to support urban sustainability. It's a good project:

> *"When thinking about the urban environment, more often than not problems come first to mind. Less commonly thought about is the potential presented by cities, potential to rethink and reshape their environments responsibly. Today urban leaders — mayors, businesses and community organizations — are in the environmental vanguard, making upgrades to transportation infrastructure, zoning, building codes, and waste management programs as well as improving access to open space, green jobs, affordable efficient housing and more. If they succeed in making their cities more efficient, responsible and sustainable, what will result will be smarter places for business and healthier places to live."*

The project ranks cities based on criteria such as green buildings, green space and recycling rates. But there's a problem: what's measured tends not to be a good set of indicators of whether these cities are actually improving in any meaningful way. Smarter Cities in particular seems to have gotten the wires crossed between its excellent mission and its flawed measurements.

Seattle, for instance, ranks #1. Living in Seattle, I feel no qualms about probing into how a city with profound sustainability problems managed to make it to the top of a "smart cities" ranking. I can tell you it ain't pretty. Though sustainability itself is a somewhat slippery concept, there are absolutely standards by which we can judge progress, as they mean the same things everywhere, and are pretty good measurements of overall impact. What, for instance, are a city's per capita greenhouse emissions? How many miles do citizens drive? How much water do they use? How much energy? How much waste do they generate? These sorts of numbers actually tell us something about how the people live and their overall impact.

But Smarter Cities counts more easily-measured, but sort of pointless data. For instance, the green building ranking rated the number of Energy Star and LEED buildings in a city, rather than quality of the general building code: so a city like Seattle, where building codes are far behind those of the U.K and Northern Europe, still comes off looking good because it has a few more individual green buildings than other cities. Similarly, "energy production and conservation" was rated by solely by the percentage of green power sources for its electricity, not total direct energy usage (much less total embedded energy usage). This means that a city like Seattle looks great, because of the region's abundance of hydropower, while in fact not being particularly ahead of the curve in any other way.

Or take transportation, which the rankings defined by the percentage of people who use public transport and the number of transportation choices available to the average citizen. Better would have been to compare vehicle miles traveled per capita, which actually measures what's most important, which is how many trips people take in their cars (which drops rapidly with density). The bizarre ranking criteria produced the effect of having Los Angeles come in as greener than New York City, despite the fact that New Yorkers drive far less and produce fewer transportation-related emissions.

For "standard of living," they employ in part the National Association of Home Builders *Housing Opportunity Index*, a flat measurement of the cost of housing compared to wages -- a figure often use to argue for sprawl -- rather than incorporating better understandings of the true cost of living in given communities, such as the Housing and Transportation Affordability Index. Cheap homes don't necessarily mean affordable lives.

The point here is not to pick on Smarter Cities (or Seattle). The point here is that unless we start defining real success (and measuring our progress in light of it), comparative measurements are worse than useless: they can even become a form of greenwashing. I look forward to a city ranking that makes it easier for individuals to measure their own efforts, easier for citizens to judge progress, and easier for cities to set goals that might in fact make them truly bright green place to live.

Livability Objectives and Indicators

As previously described, livability refers to the subset of sustainability goals, objectives and impacts that directly affect community members. Table 29 defines various livability goals and objectives, describes their relationships to livability, and indicates various documents that provide guidance for evaluating them available from the *Victoria Transport Policy Institute* website. Also see the Online TDM Encyclopedia for additional information for evaluating and implementing livability objectives and strategies.

Table 29 **Livability Objectives and Indicators**

Goal or Objective	Relationship To Livability	Evaluation Documents
Accessibility – people's overall ability to access desired goods, services and activities.	Can help achieve economic development and equity goals.	Evaluating Accessibility for Transportation Planning
Active transport – the quality of walking and cycling conditions and the amount of nonmotorized travel activity.	Can help achieve affordability, equity, public fitness and health, and community cohesion goals.	Evaluating Nonmotorized Transport, (Online TDM Encyclopaedia chapter)
Affordability –transport and housing expenses as a portion of household budgets.	Can help achieve economic development and equity goals.	Transportation Affordability: Evaluation and Improvement Strategies
Affordable-accessible housing – lower-priced housing located in accessible areas.	Can help achieve economic development and equity goals.	Affordable-Accessible Housing In A Dynamic City
Community cohesion – the quantity of positive interactions among people in a community	Can help achieve quality of life and public safety goals.	Community Cohesion As A Transport Planning Objective
Environmental quality – local air, noise and water pollution	Can help achieve local quality of life and public health goals.	Transportation Cost and Benefit Analysis
Equity – transport benefits and costs are distributed fairly.	A livability goal.	Evaluating Transportation Equity
Local economic development – progress toward a community's economic goals.	A livability goal.	Evaluating Transportation Economic Development Impacts
Public health and safety –support for improved health and safety	A livability goal.	If Health Matters: Integrating Public Health Objectives in Transportation Decision-Making
Smart growth – compact, mixed, multi-modal land use development	Can help achieve equity, economic development, health and environmental quality goals.	Evaluating Transportation Land Use Impacts
Transport diversity – the quantity and quality of transport options.	Can help achieve economic development and equity goals.	You *CAN* Get There From Here; Evaluating Transportation Diversity

This table lists various livability goals and objectives, describes how they relate to livability, and identifies VTPI documents that provide guidance for evaluating them.

The report, *Places In The Making: How Placemaking Builds Places And Communities* identifies various indicators that can be used to evaluate community livability and the success of placemaking efforts, as summarized in Table 30.

Table 30 **Placemaking Indicators** (Silberberg, et al. 2013)

Use and Activity	Economic Impacts	Public Health and Healthy Living	Social Capital
Mixed-use index Daytime use Evening use Weekend use Number of 'indicator' users such as families, older people, or racial or ethnic mix Transit usage stats (bike and transit) Occupied buildings Number of public events Behavior mapping Timelapse photography Population Walkscore Building conditions (e.g. façade scores) How much mentioned in the press? Online reputation, hashtags, Flickr keywords Sale and retail adds naming public place as amenity ("proximity to…") Security perception survey User satisfaction survey	Employment rate / gross jobs Indicator businesses (e.g. concentrations of consumption/socializing-oriented businesses such as Restaurants and bars, as well as independent businesses) Direct (salaries), indirect (eg chair vendors), Induced (general raise in spending based on increase in local HH income) spending Property values Increased tax revenue Change in adjacent business retail sales Number of businesses Increase in premium in property sales (what people are willing to pay over the typical in the area) Commercial and residential occupancy rates Increase in median area wages Tax liens on buildings or properties in adjudication	Crime statistics Sanitation rating Air quality Decibel levels Traffic speed Traffic counts Baseline public health data: asthma rates, life expectancy, etc. Living crashes/injury data for pedestrians cars, bikes	Social network mapping Rates of volunteerism Number of community meetings related to placemaking project Number and diversity of community partners involved Number and diversity of people who show up to community meetings (how many repeat attendees?) Value of in-kind donations Diversity and geographic range of financial supporters Diversity and geographic range of users of public place Mental maps of residents' perceived "territory" Number of friends on the streets Number of congregation points on the streets Most significant change technique Changes in legislation Surveys - do you know neighbors name, neighbors pet, how comfortable do you feel disciplining a neighborhood child, etc

This table lists various indicators that can be used to evaluate placemaking.

Best Practices

The following principles should be applied when selecting transportation performance indicators (Hart 1997; Jeon 2007; Marsden, et al. 2007; Renne 2009; FHWA 2011):

- *Comprehensive* – Indicators should reflect various economic, social and environmental impacts, and various transport activities (such as both personal and freight transport).
- *Quality* – Data collection practices should reflect high standards to insure that information is accurate and consistent.
- *Comparable* – Data collection should be clearly defined and standardized to facilitate comparisons between various jurisdictions, times and groups. For example, "Number of people with good access to food shopping" should specify 'good access' and 'food shopping.'
- *Understandable* – Indicators must understandable to decision-makers and the general public. The more information condensed into an index the less meaning it has for specific decisions.
- *Accessible and transparent* – Indicators (and the raw data they are based on) and analysis details should be available to all stakeholders.
- *Cost effective* – Indicators should be cost effective to collect.
- *Net effects* – Indicators should differentiate between net (total) impacts and shifts of impacts to different locations and times.
- *Functional* – select indicators suitable for establishing usable performance targets.

Indicators should be designed to promote behavior and results that are consistent with the desired outcomes. Outcome indicators (travel activity, emissions, health, etc.) are generally better than input or process indicators (expenditures or program development). Avoid indicators that may be biased or manipulated. For example, indicators should generally be reported per capita to avoid favoring larger, smaller, growing or contracting jurisdictions.

Table 31 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 indicators may overlap. For example, several may indicate transport diversity (quality and quantity of travel options, mode share, quality of nonmotorized transport, amount of non-motorized transport, etc.), and cost-based pricing (the degree to which prices reflect full costs) is considered both an economic efficiency and equity/fairness indicator. It may be best to use just one such indicator, or if several similar indicators are used, give each a smaller weight.

Table 31 **Recommended Indicator Sets**

	Economic	Social	Environmental
Most Important *(Should usually be used)*	Personal mobility (annual person-kilometers and trips) and vehicle travel (annual vehicle-kilometers), by mode (nonmotorized, automobile and public transport). Freight mobility (annual tonne-kilometers) by mode (truck, rail, ship and air). Land use density (people and jobs per unit of land area). Average commute travel time and reliability. Average freight transport speed and reliability. Per capita congestion costs. Total transport expenditures (vehicles, parking, roads and transit services).	Trip-to-school mode share (nonmotorized travel is desirable) Per capita traffic crash and fatality rates. Quality of transport for disadvantaged people (disabled, low incomes, children, etc.). Affordability (portion of household budgets devoted to transport, or combined transport and housing). Overall transport system satisfaction rating (based on objective user surveys). Universal design (transport system quality for people with disabilities and other special needs).	Per capita energy consumption, by fuel and mode. Energy consumption per freight ton-mile. Climate change emissions. Air pollution emissions (various types), by mode. Air and noise pollution exposure and health impacts. Land paved for transport facilities (roads, parking, ports and airports). Stormwater management practices.
Helpful *(Should be used if possible)*	Quality (availability, speed, reliability, safety and prestige) of non-automobile modes (walking, cycling, ridesharing and public transit). Number of public services within 10-minute walk, and job opportunities within 30-minute commute of residents. Portion of households with internet access.	Portion of residents who walk or bicycle sufficiently for health (15 minutes or more daily). Portion of children walking or cycling to school. Degree cultural resources are considered in transport planning. Housing affordability in accessible locations. Transit affordability.	Community livability ratings. Water pollution emissions. Habitat preservation in transport planning. Use of renewable fuels. Transport facility resource efficiency (such as use of renewable materials and energy efficient lighting). Impacts on special habitats and environmental resources.
Planning Process	Comprehensive (considers all significant impacts, using best current evaluation practices, and all suitable options, including alternative modes and demand management strategies). Inclusive (substantial involvement of affected people, with special efforts to insure that disadvantaged and vulnerable groups are involved). Based on *accessibility* rather than *mobility* (considers land use and other accessibility factors).		
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 these indicators can be disaggregated by demographic group and geographic location.

Some indicators lack specific performance standards for evaluation. For example, there may be no suitable performance standards for stormwater management or universal design. In that case, input or process indicators may be used which measure how well best stormwater management and universal design practices are included in the planning process.

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, transport system affordability, user satisfaction, safety and pollution exposure can be compared between people with and without disabilities, lower and higher income quintiles, and various age groups. Similarly, special analysis can be applied to *basic access* (transport that society considers high value, such as access to 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.

Data Quality and Availability

An important consideration in selecting performance indicators is the quality and cost of data. Currently, most jurisdictions collect some transportation-related statistics, such as:

- Person travel (by distance, demographic group and travel type)
- Vehicle ownership (by type)
- Vehicle travel (by type, purpose and location)
- Mode share
- Crashes and casualties (by type)
- Travel speeds and congestion delay
- Land use factors (development density and mix)
- Roadway length and condition
- Railroad length and condition
- Airports
- Transport facility expenditures
- Public transit service quality
- Walking & cycling facility length and condition
- Transport system connectivity (transferability between modes)
- Energy consumption
- Pollution emissions
- Traffic and aircraft noise exposure
- Household transport expenditures
- Mobility options for non-drivers

There is currently little consistency or quality control of these statistics (STI 2008; Bullock 2006). To be useful, jurisdictions should collect the same statistics, using consistent definitions, and meet minimum data quality standards, so results can be compared between jurisdictions and over time. High quality data reflects the following features:

- *Comprehensiveness.* An adequate range of statistics should be collected to allow various types of analysis. This should be disaggregated in various ways, including by geographic area (particularly by urban region), mode and vehicle type and demographic group.
- *Consistency.* The range of statistics, their definitions and collection methodologies should be suitably consistent between different jurisdictions, modes and time periods.
- *Accuracy.* The methods used to collect statistics are suitably accurate.
- *Transparency.* The methods used to collect statistics must be accessible for review.
- *Frequency.* Data should be collected regularly, which may be quarterly, annually, or ever several years, depending on type.
- *Availability.* Statistics should be readily available to users. As much as possible, data sets should be available free on the Internet in spreadsheet or database format.

Table 32 indicates U.S. indicator data sources. Here is the key to table references:

APTA = American Public Transportation Association *Transit Statistics* (www.apta.com/research/stats)

BLS = Bureau of Labor Statistics, *Consumer Expenditure Survey* (www.bls.gov)

BTS = Bureau of Labor Statistics, *Transportation Statistics Annual Report* (www.bts.gov)

Census = U.S. Census Bureau (www.census.gov)

FHWA = *Highway Statistics* (www.fhwa.dot.gov/ohim)

HTAI = Housing and Transportation Affordability Index (http://htaindex.cnt.org)

LTS = Local Travel Surveys (www.surveyarchive.org)

NHTSA = National Highway Traffic Safety Administration (www.nhtsa-tsis.net)

NTIA = National Telecommunications and Information Administration (www.ntia.doc.gov)

ORNL = Oak Ridge National Laboratories, *Transportation Energy Book* (www-cta.ornl.gov/data)

TTI = Texas Transportation Institute's *Urban Mobility Report* (http://mobility.tamu.edu/ums)

Walkscore (www.walkscore.com).

Table 32 **Data Sources**

Indicator	Data Sources
Economic	
Personal mobility (annual person-kilometers and trips) and vehicle travel (annual vehicle-kilometers), by mode (nonmotorized, automobile and public transport).	BTS, FHWA and LTS.
Freight mobility (annual tonne-kilometers) by mode (truck, rail, ship and air).	BTS, FHWA and LTS.
Land use density (people and jobs per unit of land area).	Census
Average commute travel time and reliability.	Census, LTS and TTI
Average freight transport speed and reliability.	BTS, FHWA and LTS. See FHWA, 2006 for more discussion of freight performance indicators.
Per capita congestion costs.	TTI. (Per capita costs should be used rather than the Congestion Index)
Total transport expenditures (vehicles, parking, roads and transit services).	BLS (vehicle and transit expenditures), APTA (transit expenditures). Other sources needed for tolls, parking and other expenditures.
Quality (availability, speed, reliability, safety and prestige) of non-automobile modes (walking, cycling, ridesharing and public transit).	LTS and APTA. Other sources needed to improve multi-modal performance indicators, particularly for non-motorized modes (walking and cycling).
Number of services within 10-minute walk, and job opportunities within 30-minute commute of residents.	Walkscore, Census, LTS and regional GIS analysis.
Portion of households with internet access.	Census, NTIA
Social	
Trip-to-school mode share (nonmotorized preferred)	LTS. This may require special survey questions.
Per capita traffic crash and fatality rates.	FHWA, NHTSA, APTA
Quality of transport for disadvantaged people (disabled, low incomes, children, etc.).	LTS. This generally requires special survey questions.
Affordability (portion of household budgets devoted to transport, or combined transport and housing).	BLS, HTAI, LTS
Overall transport system satisfaction rating (based on objective user surveys).	LTS. This generally requires special survey questions.
Universal design (transport system quality for people with disabilities and other special needs).	LTS. This generally requires special survey questions.
Portion of residents who walk or bicycle sufficiently for health (15 minutes or more daily).	LTS. This generally requires special survey questions.
Portion of children walking or cycling to school.	LTS. This generally requires special survey questions.
Degree cultural resources are considered in transport planning.	Requires special analysis of planning process.
Housing affordability in accessible locations.	HTAI, Local GIS analysis
Transit affordability.	APTA, LTS

Environmental	
Per capita energy consumption, by fuel and mode.	FHWA, LTS. Requires special analysis of fares.
Energy consumption per freight ton-mile.	ORNL, FHWA
Climate change emissions.	ORNL, LTS, local, regional or state energy data.
Air pollution emissions (various types), by mode.	LTS, with local, regional or state emission data.
Air and noise pollution exposure and health impacts.	Local, regional or state air quality data.
Land paved for transport facilities (roads, parking, ports and airports).	Special GIS Analysis. See Woudsma, Litman and Weisbrod (2006) for methodology.
Stormwater management practices.	Requires special analysis.
Community livability ratings.	Requires special analysis. See examples of community livability and quality ratings in this report.
Water pollution emissions.	Local, regional or state water quality data.
Habitat preservation in transport planning.	Requires special analysis of planning process.
Use of renewable fuels.	ORNL, LTS, local, regional or state fuel data.
Transport facility resource efficiency (such as use of renewable materials and energy efficient lighting).	Requires special analysis.
Impacts on special habitats and environmental resources.	Requires special analysis.

This table indicates potential sources of sustainable transportation indicators data in the U.S.

This indicates that data are available for most sustainable transportation indicators. Some indicators require special questions to be incorporated into local travel surveys (LTS), data at new geographic scales (such as more local or regional reporting), or special analysis of available data, but only a few indicators require totally new data collection. This indicates that with improved planning and coordination (for example, establishing standardized definitions and survey questions, and making data available at a finer geographic scale), sustainable transportation performance evaluation will require few additional costs, and can help improve the overall quality of transportation related statistics, that is, it will provide value to many types of transportation and land use planning, regardless of whether it is intended for sustainable transport planning.

Outside the U.S., transport-related statistics are generally more limited and less standardized ("Transportation Statistics," VTPI 2008). Some international data sets are listed below, but none are as comprehensive, consistent, frequent or available as those in the U.S.

International Road Federation (www.irfnet.org)
Millennium Cities and Mobility In Cities Database (www.uitp.org/publications/MCD2-order)
National Transit Database (www.ntdprogram.gov)
OECD Transport Statistics (www.oecd.org)
International Transport Forum (www.internationaltransportforum.org)
International Association of Public Transport (www.uitp.org).

Some organizations, such as the *OECD* (www.sourceoecd.org/factbook) and the European Union (http://ec.europa.eu/energy/publications/statistics/statistics_en.htm) provide international transportation-related data, and a few countries, particularly the United Kingdom (www.dft.gov.uk/transtat) and Australia (www.btre.gov.au) collect and make available data sets, but they are often unsuited to comparisons between different jurisdictions and countries.

Examples

Best Walking and Cycling Communities

Various organizations publish rankings such as the "Ten Most Walkable Cities" or "Ten Most Bikable Cities." Such rankings can be useful if they stimulate discussion about why and how to improve walking and cycling conditions, and motivates communities to compete on these terms. However, such rating systems are often incomplete or biased, based on some set of available information, and sometimes recent media coverage that highlights the good walking and cycling conditions in a particular area. They can also be counter-productive – for example, if the list of Most Walkable U.S. Cities leads with New York and San Franciso, many people will think, "Our community will never be very successful in this competition," and give up.

Rather than identifying "best" communities it is often better to rate "most improved," recognizing that even relatively disadvantaged areas are often able to improve significantly, which often provides the greatest benefits. Ratings should generally be based on comparisons with peer communities; for example, large cities compared with large cities, college towns with other college towns, and suburbs with suburbs.

A balanced index includes some *inputs* (e.g., the quality of pedestrian and bicycle planning); some *outputs* (the degree to which the plans are implemented), and some *outcomes* (per capita walking and cycling trips, growth in the use of these modes, reductions in VMT, changes in pedestrian and cycling casualty rates, etc.). It is also useful to include a *leadership* category which recognizes innovative policies and programs.

Table 33 **Walkable and Bikeable Community Indicators**

Indicator	How Measured
Pedestrian Plan	Does the jurisdiction have a plan? What quality? How well is it being implemented?
Bike Plan	Does the jurisdiction have a plan? What quality? How well is it being implemented?
Multi-Modal transport planning	Does the jurisdiction apply multi-modal evaluation to all transport planning decisions? Does it use multi-modal level-of-service ratings?
Active transport funding	How does pedestrian and bicycle program funding compare with active transport mode share targets, for example, if the target is 15% of trips by walking and cycling, is 15% of the total transport budget devoted to improving these modes?
Complete streets policies	Does the jurisdiction have complete streets policies which insure that walking and cycling are considered in all roadway planning? How well are they being implemented?
Smart growth policies	Does the jurisdiction have complete streets policies which encourages more compact, walkable development? How well are they being implemented?
Affordable-accessible housing	Does the jurisdiction encourage the development of affordable housing in walkable, bikeable, transit-oriented neighborhoods?
Active transport mode share	What portion of total trips in the region are by walking and cycling, and is this growing.
Active transport safety	What portion of crash casualties are pedestrians and cyclists, and is this declining?
Active transport leadership	What innovative policies and programs is the jurisdiction implementing.

Various indicators should be used to rate and compare a community for walkability and bikability.

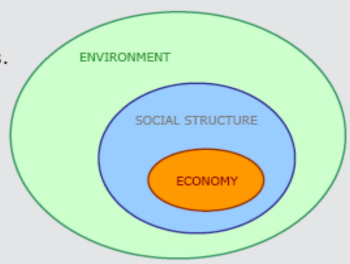
Growing GreenLITES (www.nysdot.gov/programs/greenlites)
Greenlites (Green Leadership In Transportation Environmental Sustainability) is a self-certification program developed by the New York State Department of Transportation that distinguishes transportation projects and operations based on the extent to which they incorporate sustainability and livability objectives. NYSDOT project designs and operations are evaluated for sustainable practices and based on the total credits received, an appropriate certification level is assigned. The rating system recognizes varying certification levels, with the highest level going to designs and operational groups that clearly advance the state of sustainable transportation solutions. It uses a detailed spreadsheet that rates individual projects according to a wide variety of best practices.

Oregon Sustainability Plan (www.oregon.gov/ODOT/SUS)
In 2000, Oregon Governor Kitzhaber enacted an Executive Order that promoted sustainability in state government operations. In 2001, the state legislature passed the Oregon Sustainability Act, which set objectives for state agencies in conducting their internal operations and external missions and created the Oregon Sustainability Board to provide oversight to sustainability efforts in the state. Subsequent executive orders have expanded the scope of state agency sustainability planning and initiatives and encouraged sustainability practices in universities, local governments and the private sector.

As a result, the Oregon Department of Transportation developed a Sustainability Plan which responds to these mandates and to the challenges facing ODOT's internal operations and Oregon's transportation system. It includes short-term goals to be achieved by 2012 and long-term goals to be achieved by 2030.

What does "sustainability" mean?
The term "sustainable development" emerged in the 1980s as researchers began studying the systematic relationships between human societies and their effect on nature. The Brundtland Report, published in 1987 by the World Commission on Environment and Development, was the first major intergovernmental report codifying the term "sustainable development" as a strategy for linking societal development with protection of the environment. The concept of sustainable development has now broadened and often is referred to with one word, "sustainability."

The Oregon Sustainability Act of 2001 (ORS 184.421) defines sustainability as using, developing and protecting resources in a manner that enables people to meet current needs while providing for future generations to meet their needs, from the joint perspective of environmental, economic and community objectives.



Within this three-part definition of sustainability, there is an implicit hierarchy. The resources provided by the earth's natural systems (the environment) are critical for the smooth functioning of our social systems (adequate water supplies, safe transportation systems, other reliable infrastructure). Without well-functioning social systems, our economic systems cannot be productive. The sustainability hierarchy, then, starts with the natural and physical systems of the earth providing the critical support for our social systems, followed by a healthy, functioning social system allowing our economic systems to thrive.

Sustainability, then, can be viewed as a uniquely broad and long-term concept that addresses quality of life and efficiency concerns. It is a global concept addressed at the local level, and it applies a timeframe that considers costs and benefits over lifetimes rather than one- or two-year cycles.

This box summarizes the Oregon DOT's definition of sustainability.

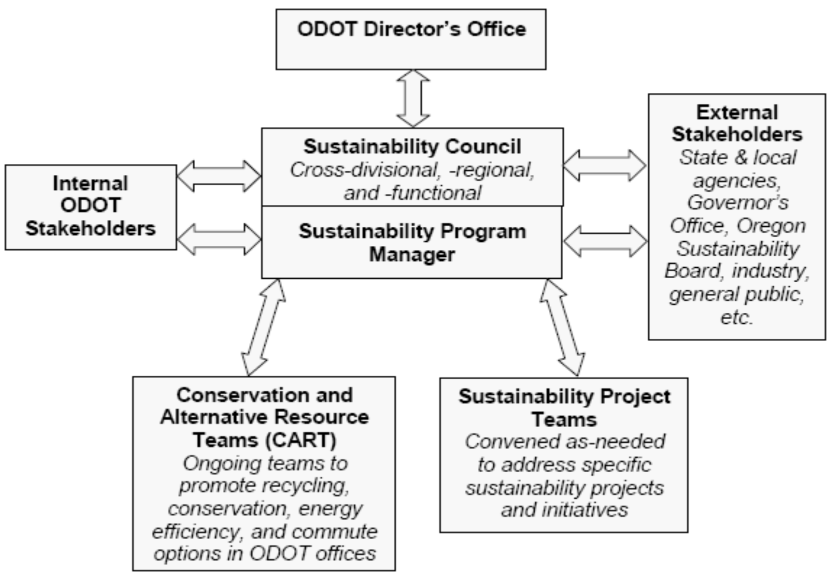
Based on this analysis framework, the Plan concludes that:

> The state's primary opportunity to sustain and improve access to goods, services, activities, and destinations is in strategically developing the multimodal transportation system while at the same time optimizing the highway system and supporting clean, efficient, alternative-

> fueled vehicles to use it. The emphasis should be on meeting people's and businesses' needs in the most efficient way. The state should improve ways to achieve accessibility and ensure that when travel is necessary, it is as efficient and sustainable as possible.
>
> As the state agency responsible for providing a safe, efficient transportation system in the state, ODOT has a key role in responding to the transportation challenges and in considering sustainable transportation solutions. ODOT directly controls some solutions such as traffic signal timing and access management on state highways, and funds some projects that meet sustainable transportation objectives such as bicycle and pedestrian facilities and public transportation for the elderly and disabled. Other projects require partnering with other state agencies, regional and local governments or the private sector. For example, ODOT partners with local governments to support public transportation, bicycle and pedestrian facilities intercity passenger bus and rail services.

ODOT has developed internal policies and practices to operationalize sustainability planning, as indicated in Figure 4.

Figure 4 **Oregon DOT Sustainable Evaluation Process**



This figure illustrates how sustainability is incorporated into the Oregon Department of Transportation organization.

Based on these sustainability goals, ODOT developed specific focus areas and objectives:

- Health and Safety
- Social Responsibility/Workforce Well-Being and Development
- Environmental Stewardship
- Land Use and Infrastructure
- Energy/Fuel Use and Climate Change
- Material Resource Flows
- Economic Health

CalTrans Strategic Management Plan 2015-2020

The CalTrans Strategic Management Plan 2015-2020 (CalTrans 2015) includes detailed performance indicators in the following categories:

- *Safety and Health:* Provide a safe transportation system for workers and users and promote health through active transportation and reduced pollution in communities. The safety of our workers and the users of California's transportation system is our number one priority. The most important attribute of a transportation system is that it is safe for users and can be planned, designed, built, maintain and operated safely. Our transportation system has measurable effects on the health of Californians. This is manifest by the impact of emissions from the transportation system, and the health benefits of active transportation programs.
- *Stewardship and Efficiency:* Money counts. Responsibly manage California's transportation-related assets. As stewards of a transportation system that is vital to the economy and livability of our state, Caltrans is committed to the most effective and efficient use of every transportation dollar. Caltrans will keep California's transportation system in the best condition possible and advocate for adequate resources.
- *Sustainability, Livability and Economy:* Make long-lasting, smart mobility decisions that improve the environment, support a vibrant economy, and build communities, not sprawl. Sustainability is a central element of our new Mission. Caltrans has chosen to define sustainability as the consideration of these three areas:
    - People− fostering community health and vitality,
    - Planet − preserving and restoring environmental and ecological systems,
    - Prosperity − promoting economic development. Over time, sustainability elements will be incorporated into all Caltrans programs, policies, processes, projects, plans, and procedures.
- *System Performance:* Utilize leadership, collaboration, and strategic partnerships to develop an integrated transportation system that provides reliable and accessible mobility for travelers. A transportation system must be safe, well-maintained, and high-performing. System Performance is managed on a regional and corridor basis. We must work with our partners to ensure the State's transportation system is contributing to an efficient and interconnected network.
- *Organizational Excellence:* Be a national leader in delivering quality service through excellent employee performance, public communication, and accountability. A world-class transportation system requires a worldclass staff to plan, design, build, maintain, operate, and manage it. Significant achievements can, and will, be accomplished with a capable, educated, welltrained, and motivated workforce equipped with the right tools and resources. Caltrans is committed to providing its staff with these tools and resources.

Table 34 summarizes the Plan's sustainability, livability and economy performance indicators.

Table 34 **Sustainability, Livability and Economy Performance Indicators**

Strategic Objectives	Performance Measures	Targets
PEOPLE: Improve the quality of life for all Californians by providing mobility choice, increasing accessibility to all modes of transportation and creating transportation corridors not only for conveyance of people, goods, and services, but also as livable public spaces.	Percentage increase of non-auto modes for: • Bicycle • Pedestrian • Transit	By 2020, increase non-auto modes: • Triple bicycle; • Double pedestrian; and • Double transit. (2010-12 California Household Travel survey is baseline.)
	Accessibility Score. (To be determined considering e.g., multimodal transportation proximity to jobs, disadvantaged communities, housing services, transit-oriented communities, etc.)	By December 2016, develop and adopt Caltrans Accessibility Score.
	Livability Score. (To be determined considering, e.g., quality of life, noise, safety, localized emissions, environmental justice, etc.)	By December 2016, develop and adopt Caltrans Livability Score.
	Percentage of top 25 priority corridor system master plans completed to enhance sustainability of transportation system. (Priority corridors to be determined considering: mobility, freight, highways, transit, rail, bike, pedestrian, aviation, etc.)	By 2017, complete corridor system plans for all State routes. By 2020, complete top 25 corridor system management plans.
PLANET: Reduce environmental impacts from the transportation system with emphasis on supporting a statewide reduction of greenhouse gas emissions to achieve 80% below 1990 levels by 2050.	Per capita vehicle miles traveled. (Reported statewide by District.)	By 2020, achieve 15% reduction (3% per year) of statewide per capita VMT relative to 2010 levels reported by District.
	Percent reduction of transportation system-related air pollution for: • Greenhouse gas (GHG) emissions • Criteria pollutant emissions	15% reduction (from 2010 levels) of GHG to achieve 1990 levels by 2020. 85% reduction (from 2000 levels) in diesel particulate matter emissions statewide by 2020. 80% reduction (from 2010 levels) in NOx emissions in South Coast Air Basin by 2023.
	Percent reduction of pollutants from Caltrans design, construction, operation, and maintenance of transportation infrastructure and building for: • Greenhouse gas (GHG) emissions • Criteria air emissions • Water pollution	By 2020, reduce Caltrans' internal operational pollutants by District from 2010 levels (from planning, project delivery, construction, operations, maintenance, equipment, and buildings) including: • 15% reduction by 2015 and 20% reduction by 2020 of Caltrans' GHG emissions per EO-B-18-12. • 10% reduction in water pollutants. By 2020, 85% reduction (from 2000 levels) in diesel particulate matter emissions statewide. By 2023, 80% reduction (from 2010 levels) in NOx emissions in South Coast Air Basin.
	Percent increase in transportation projects that include green infrastructure. Weighting mechanism to be developed.	By 2020, increase by 20% (5% per year) incorporating green infrastructure into transportation projects relative to 2010 levels.

PROSPERITY: Improve economic prosperity of the State and local communities through a resilient and integrated transportation system	Prosperity score. Score to be determined considering, e.g., gross State/ regional product, freight system competitiveness, transportation system efficiency, return on transportation investment, etc	By 2016, develop and adopt Caltrans prosperity score.
	Freight System Efficiency. Improve freight system efficiency to enhance freight competitiveness and support a sustainable, low emissions freight system.	By 2020, 10% increase in freight system efficiency.
	Resiliency Score for: • Climate change resiliency (e.g., vulnerability to flood, sea level rise, etc.) • System resiliency (e.g., adaptability from emergencies, disasters, etc.) • Financial resiliency (e.g., ensure funding considering maintenance, operations, modernization, disasters, financial stability, etc.) Resiliency Score to be determined considering, e.g., asset management, emergency and risk management, climate change, sea level rise, vulnerability, adaptation, etc.)	By December 2017, develop and adopt Caltrans Resiliency Score.
	Reduction of resource consumption by: • Reduction of materials taken to landfills (reduction of virgin materials used, reuse of existing materials for construction, recycling of building, construction, and roadside trash) • Reduction of potable water use	By 2020, reduce resource consumption from 2010 levels by District: • 15% reduction of materials taken to landfills • 15% reduction of potable water use

The CalTrans Strategic Management Plan 2015-2020 includes these sustainability, livability and economy performance indicators

Bicycling and Walking in the U.S.: Benchmarking Reports (AWB 2014)

The U.S. Alliance for Biking & Walking recognized the inadequacy of comprehensive and accessible data on active transportation (walking and cycling) activity and conditions. In response it has produced bi-annual Bicycling and Walking in the U.S.: Benchmarking Reports which include detailed information on the amount of walking and cycling that occurs in various geographic areas (cities, states, for the U.S. overall, plus some international data for comparision), government planning and funding practices, costs and benefits, and examples of successful active transportation development programs.

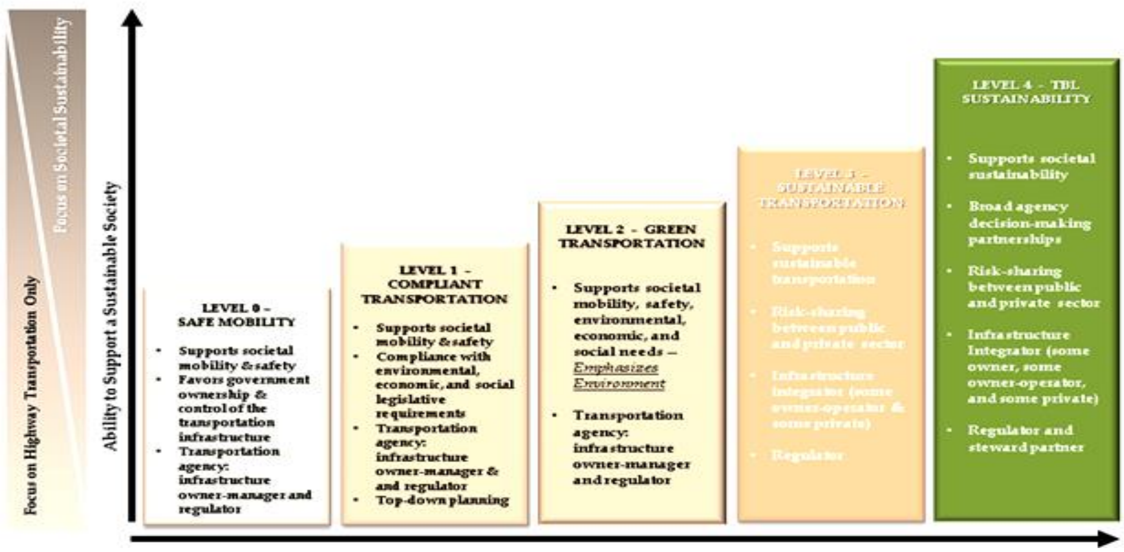
State Highway Corridor Planning (Zhang 2013)

The Maryland State Highway Administration developed a Model Of Sustainability and Integrated Corridors (MOSAIC) to evaluate the mobility, safety, socioeconomic and environmental stewardship impacts of various highway improvement options (adding general purpose lanes, converting at grade intersections to grade separated interchanges, high occupancy vehicle lane, high occupancy toll lane, bus rapid transit/bus-only lane, light rail transit, truck-only lane, express toll lane, and lane removal) on U.S. 29. The analysis quantified various impacts which were aggregated into scores for mobility, safety, socioeconomics, natural resources, energy and fuel, and implementation costs.

Transportation Agency Practices (Booz Allen Hamilton 2014)

The report, *Sustainability as an Organizing Principle for Transportation Agencies*, describes how sustainability can be incorporated into transportation agency practices. It discusses various definitions of sustainability, trends in sustainable transportation analysis, and their implications for transport planning. The figure below summarizes various levels of transportation evaluation which culminate in comprehensive sustainability planning.

Figure 5 **Scope of Sustainability Analysis**



According to this analsyis, transportation agencies must expand their goals and scope of analysis in order to help support a more sustainable society.

Transport Emission Evaluation (Robertson, Jägerbrand and Tschan (2015)

This report investigate the needs and gaps in developing country's ability to measure, report and verify the emission reductions of transportation policies and projects. The study reviewed the general and transportation-specific data availability, requirements and methodologies used by national and international organizations for evaluating the emission impacts of transportation policies and projects in developing countries.

The study concludes that traffic and transportation impact evaluation is a complex and demanding process, and the potential for misinterpretation of results is significant. Furthermore, it seems the project-based evaluations often apply excessively short analysis periods. Other challenges relate to institutional roles and responsibilities, the availability of personal and financial resources, and the knowledge and perspectives applied. Based on these findings the report recommends further development of transport-related climate mechanisms towards a more sectoral and transformational perspective.

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 can help determine how problems are defined and which impacts receive attention. 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 reflect overall goals. It is also important to be realistic when selecting indicators, taking into account data availability, understandability and usefulness in decision-making.

Although there are many possible definitions of sustainability, sustainable development and sustainable transport, experts increasingly agree that these refer to balancing economic, social and environmental goals. Comprehensive and sustainable transport planning therefore requires a set of indicators that reflects appropriate economic, social and environmental goals and impacts. An indicator set that focuses too much on one impact category can result in suboptimal decisions. It is important that users understand the perspectives, assumptions and limitations of each indicator. Sustainable transportation indicators can include:

- *Planning process* – the quality of analysis used in planning decisions.
- *Options and incentives* – whether consumers have adequate travel options and incentives to use the most efficient option for each trip.
- *Travel behavior* – Vehicle ownership, vehicle travel, mode share, etc.
- *Physical impacts* – pollution emission and crash rates, land consumption, etc.
- *Human and environmental impacts* – illnesses and deaths, environmental degradation, etc.
- *Economic effects* – monetized estimates of economic costs, reduced productivity, etc.
- *Performance targets* – degree to which stated 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.

Although there are currently no standardized sustainable transport data or indicator sets, considerable progress is being made in defining how indicators should be defined and selected. Individual jurisdiction and organization should choose indicators based on their specific needs and abilities. It will be useful for major planning and professional organizations to standardize transportation data collection practices and established recommended sustainable transport indicator sets suitable for various planning applications.

Table 34 summarizes sustainable transport goals, objectives and performance indicators.

Table 34 **Key Sustainable Transport Goals, Objectives and Indicators**

Sustainability Goals	Objectives	Performance Indicators
I. Economic		
Economic productivity	Transport system efficiency. Transport system integration. Maximize accessibility. Efficient pricing and incentives.	• Per capita GDP and income. • Portion of budgets devoted to transport. • Per capita congestion delay. • Efficient pricing (road, parking, insurance, fuel, etc). • Efficient prioritization of facilities (roads and parking).
Economic development	Economic and business development	• Access to education and employment opportunities. • Support for local industries.
Energy efficiency	Minimize energy costs, particularly petroleum imports.	• Per capita transport energy consumption • Per capita use of imported fuels.
Affordability	All residents can afford access to basic (essential) services and activities.	• Availability and quality of affordable modes (walking, cycling, ridesharing and public transport). • Portion of low-income households that spend more than 20% of budgets on transport.
Efficient transport operations	Efficient operations and asset management maximizes cost efficiency.	• Performance audit results. • Service delivery unit costs compared with peers. • Service quality.
II. Social		
Equity / fairness	Transport system accommodates all users, including those with disabilities, low incomes, and other constraints.	• Transport system diversity. • Portion of destinations accessible by people with disabilities and low incomes.
Safety, security and health	Minimize risk of crashes and assaults, and support physical fitness.	• Per capita traffic casualty (injury and death) rates. • Traveler crime and assault rates. • Human exposure to harmful pollutants. • Portion of travel by walking and cycling.
Community development	Help create inclusive and attractive communities. Support community cohesion.	• Land use mix. • Walkability and bikability • Quality of road and street environments.
Cultural heritage preservation	Respect and protect cultural heritage. Support cultural activities.	• Preservation of cultural resources and traditions. • Responsiveness to traditional communities.
III. Environmental		
Climate protectin	Reduce global warming emissions Mitigate climate change impacts	• Per capita emissions of global air pollutants (CO_2, CFCs, CH_4, etc.).
Prevent air pollution	Reduce air pollution emissions Reduce exposure to harmful pollutants.	• Per capita emissions of local air pollutants (PM, VOCs, NOx, CO, etc.). • Air quality standards and management plans.
Prevent noise pollution	Minimize traffic noise exposure	• Traffic noise levels
Protect water quality and minimize hydrological damages	Minimize water pollution. Minimize impervious surface area.	• Per capita fuel consumption. • Management of used oil, leaks and stormwater. • Per capita impervious surface area.
Openspace and biodiversity protection	Minimize transport facility land use. Encourage more compact development. Preserve high quality habitat.	• Per capita land devoted to transport facilities. • Support for smart growth development. • Policies to protect high value farmlands and habitat.
IV. Good Governance and Planning		
Integrated, comprehensive and inclusive planning	Planning process efficiency. Integrated and comprehensive analysis Strong citizen engagement. Lease-cost planning (the most overall beneficial policies and projects are implemented).	• Clearly defined goals, objectives and indicators. • Availability of planning information and documents. • Portion of population engaged in planning decisions. • Range of objectives, impacts and options considered. • Transport funds can be spent on alternative modes and demand management if most beneficial overall.

This table summarizes sustainability goals, objectives and performance indicators.

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