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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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Contents

Preface

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

Looking backward in time, we are directly affected by decisions that occurred centuries and millennia ago, but our thinking about the future tends to be much more limited. Households and communities generally only plan a few years or decades into the future; thirty or fourty 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 technololgical 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 must 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 have* become buzzwords for any desirable strategic policies. In truth, some conditions should not be sustained, such as hate, poverty and ignorance, and these terms are often used to promote a particular policy or project that may only vaguely reflect their true concept of integrated strategic planning. None-the-less, sustainability principles properly applied can lead to much better decision making, particularly for strategic policy making and planning.

Executive Summary

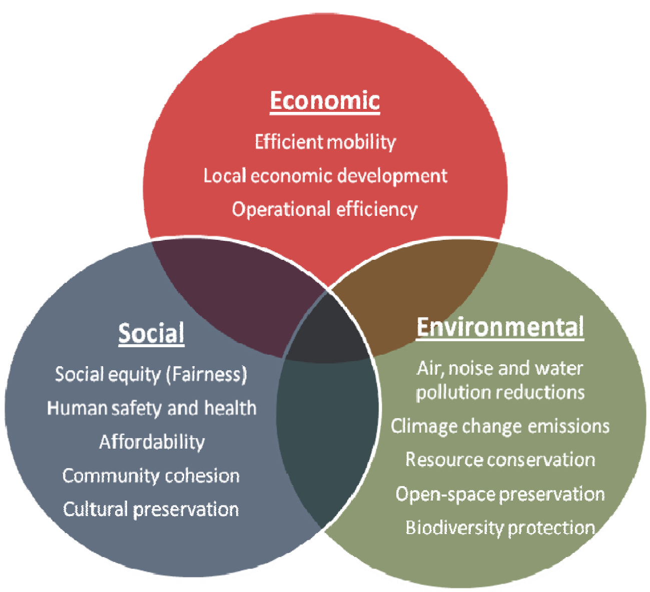
There is growing interest in the concepts of *sustainability*, *livability*, *sustainable development* and *sustainable transport*. *Sustainability* balances economic, social and environmental goals and objectives (*goals* are general desired outcomes, *objectives* are specific, measurable ways to achieve 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	*Human safety, security and health*	*Air, noise and water pollution prevention*
Resource efficiency	*Community development*	Non-Renewable Resource Conservation
Affordability	*Cultural heritage preservation*	*Openspace preservation*
Operational efficiency		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 those that are resource efficient, affordable, healthy, 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*. Transport services provide affordable options so lower-income households spend less than 20% of their budgets to access basic goods, services and activities.
- *Resource (energy and land) efficiency*. Transport planning encourages 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	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 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 exposure to harmful pollutants.	• Per capita emissions (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	Clearly defined planning process. Integrated and comprehensive analysis. Strong citizen engagement. Lease-cost planning (most beneficial solutions are selected and funded).	• 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.

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). 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)

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) prefer 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).

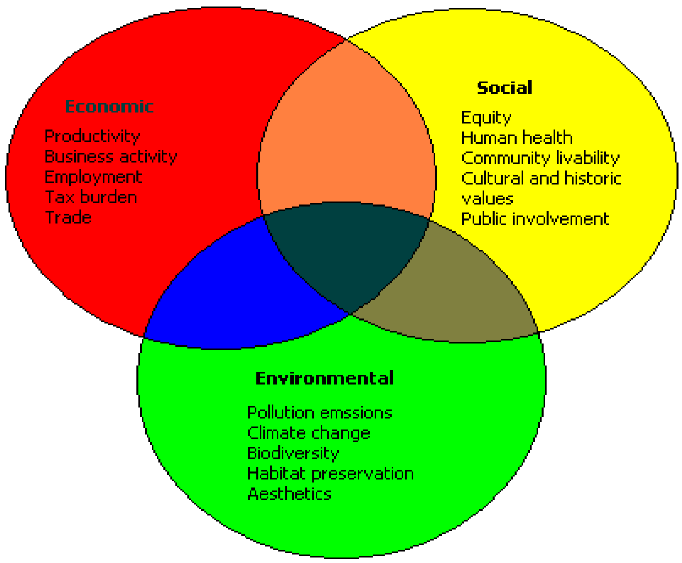
Table 1 **Sustainability Goals**

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

This table lists various sustainability goals.

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* (HUD-DOT-EPA 2010) defines the following livability principles:

- *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**

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 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, including solutions that tend to be more efficient and beneficial overall. For example, with conventional, mobility-based planning which evaluates transport system performance based roadway level of service and average travel speeds, the primary problem is traffic congestion and the primary solution is roadway expansion. Comprehensive, accessibility-based planning considers more solutions (improving alternative modes, more efficient pricing, more accessible land use development, etc.) and considers a wider range of planning objectives (congestion reduction, improved mobility for non-drivers, energy conservation, improved safety, 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)

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 split, 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, but walkability, equity, environmental impacts and are more difficult to quantify, and so they often receive little 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.

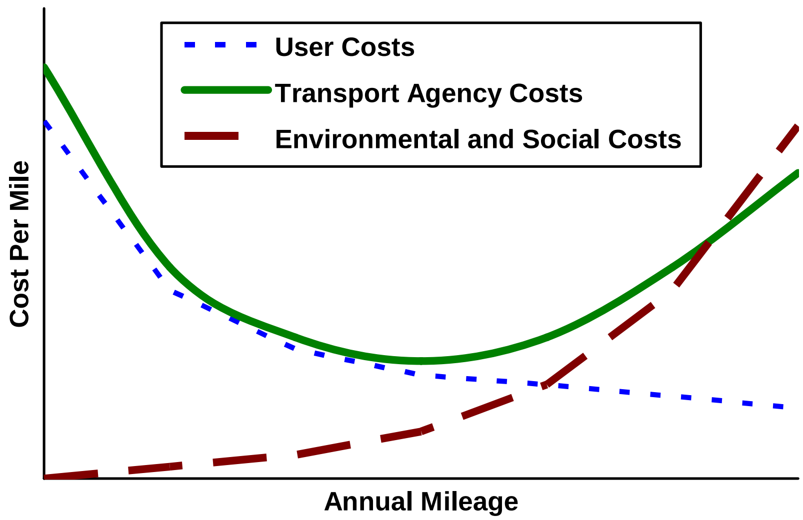
Specific planning decisions can be evaluated according to whether they increase or reduce market efficiency. For example, when evaluating potential congestion reduction strategies, those that increase automobile traffic and sprawl (e.g., roadway expansion) can be considered unsustainable, while those 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 has a downward sloping cost curve (economies of scale) when traffic is low, since increased driving allows costs to be divided among more miles of use, but once the system is congested average costs increase. Environmental, and social costs of driving are minimal when use is low, but slope upward.

- 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. *Welfare* (as used by economists) refers to total human wellbeing and happiness. Economic policies are generally intended to maximize welfare, although this is difficult to measure directly. Instead, monetary income, wealth and productivity (such as Gross Domestic Product [GDP]) are used as economic indicators. 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 one has greater wellbeing overall due to differences in how the wealth is created, distributed and used. There are many possible traps by which increased wealth can fail to increase welfare, for example, if a productive process harms the environment and makes people sick, if wealth distribution is severely unequal, if wealth is spent inefficiently, and if increased material wealth disrupts community cohesion, pride, freedom or other nonmarket goods.

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

Material wealth provides *declining marginal social welfare benefits*, which means that each additional unit of wealth provides less benefit than the last, because consumers purchase the most rewarding goods first, so additional wealth allows increasing less rewarding expenditures (Gilbert 2006, p. 239). For example, if a person only earns $10,000 annually, giving them another $10,000 makes them far better off. But the same $10,000 increase in income provides less benefit to somebody earning $50,000 annually, and less to somebody earning $100,000, and even less to somebody earning $500,000.

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

Transportation activities reflect these patterns. In accessible communities people can reach most destinations using low-cost modes such as walking, bicycle, wagon and public transit, but increased automobile dependency tends to reduce the performance of these modes ("Automobile Dependency," VTPI 2008). It makes nonmotorized travel difficult and dangerous. Low-cost modes receive less consideration in planning and investments. More dispersed land use patterns result in more trips beyond walking and cycling distances. As private vehicles become common, other modes lose status and consumers must own more costly vehicles to maintain prestige. As a result, motor vehicle ownership and use may increase with little net gain in accessibility or social welfare.

Transportation can leverage other economic impacts ("Economic Development Impacts," VTPI 2008). Vehicle and fuel expenditures tend to provide less business activity and employment than most other consumer expenditures, since they are mostly imported and capital rather than labor intensive. Such expenditures are particularly burdensome to the economies of developing countries that import petroleum. Increased motor vehicle ownership and use increase road and parking facility costs, reduce productivity due to congestion, and harm certain industries, particularly those that require clean environments such as tourism, agriculture and fisheries.

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

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.

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 Split	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; Caubel 2004; 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).

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

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.

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 following guiding principles for sustainable landscapes were developed by the American Society of Landscape Architects.

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.

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)

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

This major 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

Genuine Progress Indicator

The *Genuine Progress Indicator* (GPI) is an economic performance indicator that adjusts 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	Free time	
Expenditures, Disposable Income	Volunteerism	*Forests*
and Savings		Timber sustainability
Disposable income	*Human Health and Wellness*	Forest fragmentation
Personal expenditures	Life expectancy	
Taxes	Premature mortality	*Parks and Wilderness*
Savings rate	Infant mortality	Parks and wilderness
	Obesity	Wetlands and peatlands
Money, Debt, Assets and Net		
Worth	*Suicide*	*Fish and Wildlife*
Household Debt	Suicide	Fish and wildlife
Income Inequality, Wealth,	*Alcohol, Drug and Tobacco Abuse*	*Water Resource and Quality*
Poverty and Living Wages	Drug use (youth)	Water quality
Income distribution		
Poverty	*Auto Crashes and Injuries*	*Energy Use and Air Quality*
	Auto crashes	Energy use intensity
Public and Household		Air quality-related emissions
Infrastructure	*Family Breakdown*	Greenhouse gas emissions
Public infrastructure	Divorce	
Household infrastructure	Problem gambling	*Carbon Budget*
		Carbon budget deficit
Employment	*Crime*	
Weekly wage rate	Crime	*Municipal and Hazardous Waste*
Unemployment rate		Hazardous waste
Underemployment	*Democracy*	Landfill waste
	Voter participation	
Transportation		*Ecological Footprint*
Transportation expenditures	*Intellectual & Knowledge Capital*	Ecological footprint
	Educational attainment	

This table summarizes Genuine Progress Indicators used to evaluate sustainability.

Green Community Checklist

The US 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 amount of land and water area required to produce the resources people consume and absorb wastes people produce. This includes, for example, the amount of farmland needed to provide food and fibers, the amount of forest needed to provide wood and paper, the amount of watershed needed to provide water, the amount of land needed to produce energy, and the amount of land needed to absorb wastewater on a sustainable basis for person's consumption pattern. Current consumption rates are estimated to exceed the Earth's long-term regeneration capacity, so the current consumption consumes ecological capital.

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

Vehicle Emission Analysis Data Requirments

In a study sponsored by the Asian Development Bank, Schipper, Fabian and Leather (2009) identify the types of data required for evaluating transportation climate change emission trends and management options. This includes information on vehicles, vehicle use, fuel type, and vehicle fuel intensity.

Global Reporting Initiative (www.globalreporting.org)

The Global Reporting Initiative provides guidance for organizations to use 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 split (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-oriented indicator is "Housing Affordability." There are no service quality indicators, such as the quality of walking, cycling and public transit services, 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.	Use of fossil fuel energy for all transport. Greenhouse gas emissions for all transport. Index of emissions of air pollutants from road transport. Index of incidence of road injuries and fatalities.	Air quality. Waste from road transport. Discharges into water. Land use for transport. Proximity of infrastructure to sensitive areas and ecosystem fragmentation.	Noise Effects on human health. Effects on ecosystem health.
2. Transport activity	Total motorized movement of people. Total motorized movement of freight. Share of passenger travel *not* by land-based public transport. Movement of light-duty passenger vehicles.	Utilization of passenger vehicles. Urban automobile vehicle-kilometers. Travel by non-motorized modes in urban areas. Journey-to-work mode shares.	Urban and intercity person-kilometers. Freight modal participation. Utilization of freight vehicles.
3. Land use, urban form and accessibility	Urban land use per capita.	Urban land use by class size and zone. Employment density by urban size, class and zone. Mixed use (percent walking to work, ratio of jobs to employed labour force.	Share of urban population and employment served by transit. Share of population and employment growth on already urbanized lands. Travel and modal split by urban zone.
4. Supply of transport infrastructure and services.	Length of paved roads.	Length of sustainable infrastructure. Transit seat-kilometers per capita.	Congestion index.
5. Transport expenditures and pricing.	Index of relative household transport costs. Index of relative cost of urban transport.	Percent of net government transport expenditures spent on ground-based public transport.	Transport related user charges. Expenditures by businesses on transportation.
6. Technology adoption.	Index of energy intensity of cars and trucks. Index of emissions intensity of the road-vehicle fleet.	Percent of alternative fuel vehicles in the fleet.	Percent of passenger-kms and tonne-kms fuelled by renewable energy. Percent of labour force regularly telecommuting.
7. Implementation and monitoring.		Number of sustainable transport indicators regularly updated and widely reported. Public support for initiatives to achieve sustainable transport.	Number of urban regions where planning and delivery of transport and related land use matters have a single authority.

Environmentally Sustainable Transport

The Organization for Economic Cooperation and Development (OECD 2001) developed the following indicators of Environemental ly 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
Ease of access to means of mobility Financial outlay required of user Average door-to-door time required Reliability, measured as variability in average door-to-door time Safety (chance of death or serious injury befalling the user) Security (chance of the user being subjected to robbery, assault, etc.)	Impacts on the environment and on public health and safety Greenhouse gas emissions (CO_2 equivalent) "Conventional" emissions – NOx, CO, SO_2, VOC, particulates Safety (number of deaths and serious injuries) Security Noise Land use Resource use (including recycling) Impacts on public revenues and expenditures "Launching aid" Publicly-provided infrastructure Required operating subsidies Potential for reducing public expenditures Potential for generating government revenues Equity impacts	Profitability (ability to earn at least a competitive return on investment) Total market size Conditions determining market acceptance Required competences Private investment required Necessity/possibility of "launching aid" and payback conditions Investment net of publicly-provided infrastructure Cash flow generation Potential cash flow from operations Gap between likely actual and required cash flow; potential for public subsidies Policy barriers/incentives

Eliminating overlaps resulted in the following set

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

TERM

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

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 13 lists the credits and their default wegiths used in this tool.

Table 13 **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.

Aviation Sustainability Indicators

Aviation presents unique sustainable transportation challenges (Upham and Mills 2003; Grimley 2006). Table 15 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 15 **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.

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 16 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 16 **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.

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 17 summarizes these indicators

Table 17 **Lyons Indicators** (Nicolas, Pochet and Poimboeuf 2003)

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

This table summarizes sustainable transportation indicators used in Lyons.

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 18. 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 18 **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 19 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 19 **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 within particular distance of transit or other 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 compared to the population growth rate
	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 O3, NOx, CO and estimated (or measured) CO2

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 20 summarizes the objectives. Specific performance measures were defined for each objective.

Table 20 **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.

Comprehensive Highway Capacity Project Evaluation (Cambridge Sysemtatics 2009)

The study, *A Systems-Based Performance Measurement Framework for Highway Capacity Decision Making*, 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 21 **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 22 **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 split (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 23 and 24 summarize the UNECE's sustainable development approach.

Table 23 **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 24 **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.

Incremental Improvements To Conventional Transport Evaluaton

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

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

The report, *Measuring Transportation Investments: The Road To Results*, evaluates how well U.S. states define and consider various performance goals in transport investment planning. The research examines the following 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 from transportation-related incidents across all modes of transportation .
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, activities and destinations for both work and leisure, and to meet the transportation needs of different populations. Performance measures include availability and use of multimodal transportation options—including public and private transit and pedestrian and bicycle access—for the general public and populations with specific needs, such as elderly, disabled and low-income individuals .
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 transportation 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.

Multi-Modal Urban Transportation Performance Indicators

The study, *Traffic & Transportation Policies and Strategies in Urban Areas in India* (Wilbur Smith 2008) 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 Moving 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).

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).

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 25, 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 25 **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 26 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 26 **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 27 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 27 **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 (http://smartercities.nrdc.org/rankings/scoring-criteria). 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 28 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 28 **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.

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

Table 29 lists recommended indicator sets grouped into *Most Important* (should usually be used), *Helpful* (should be used if possible) and *Specialized* (should be used to reflect particular needs or objectives).

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

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

Table 29 **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 split (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 performance standards for evaluation. For example, there may be no suitable performance standards for stormwater management or universal design. In that case, they may be evaluated based on 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, compare the portion of household income devoted to transport, and satisfaction with the transport system, between people with and without disabilities, the lowest and the average income quintile, and young adults with other age groups. Similarly, special consideration can be applied to the quality of “basic access” (transport with high social value, such as access to for emergency and service vehicles, medical services, education, employment, etc.), by measuring how often people are unable to make such trips.

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

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

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

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

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

Data Quality and Availability

An important consideration in selecting indicators is the cost and quality 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 split
- 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. Data refers to the following features:

- *Accuracy*. The methods used to collect statistics must be suitably accurate.
- *Transparency*. The methods used to collect statistics must be accessible for review.
- *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.
- *Frequency*. Data should be collected regularly, which may be quarterly, annually, or ever several years, depending on type.
- *Consistency*. The range of statistics, their definitions and collection methodologies should be suitably consistent between different jurisdictions, modes and time periods.
- *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 30 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 30 **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 split (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 little 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

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 (http://www.oregon.gov/ODOT/SUS)

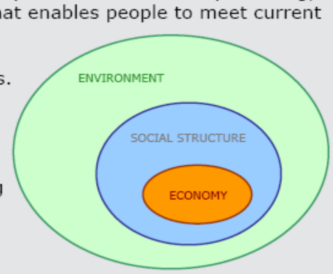
In 2000, Oregon Governor Kitzhaber enacted an Executive Order that promoted sustainability in state government operations. In 2001, the state legislature passed the Oregon Sustainability Act, which set objectives for state agencies in conducting their internal operations and external missions and created 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.

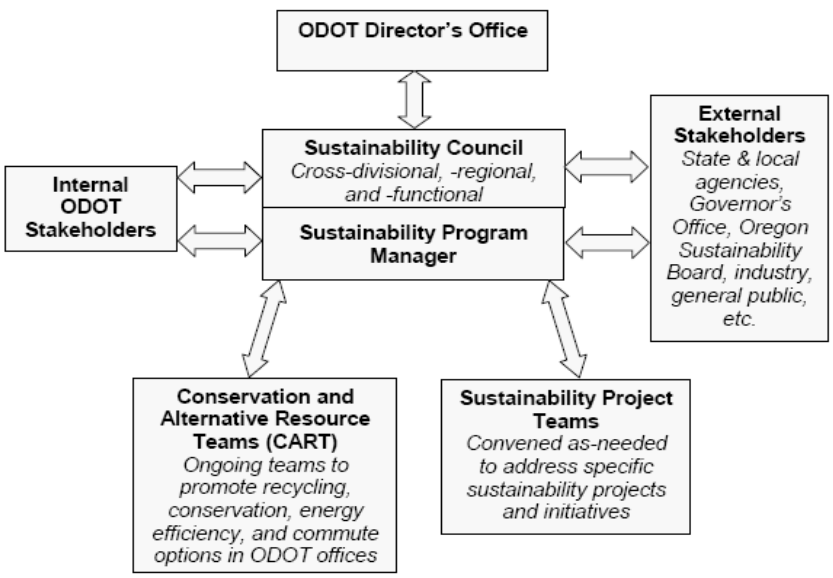
Sustainability, then, can be viewed as a uniquely broad and long-term concept that addresses quality of life and efficiency concerns. It is a global concept addressed at the local level, and it applies a timeframe that considers costs and benefits over lifetimes rather than one- or two-year cycles.

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 the figure below:



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

Hypothetical Example

A public transit agency interested in developing comprehensive performance indicators starts by defining the following objectives that transit is intended to help achieve:

- Improved transit service quality
- Reduced traffic congestion
- Reduced road and parking facility costs
- Energy conservation
- Pollution emission reductions
- Increased safety
- Improved mobility for transportation disadvantaged people
- Consumer cost savings, increased affordability
- Support for strategic planning objectives (reduced sprawl, urban redevelopment, etc.)
- Cost effective operation
- Planning effectiveness

Performance indicators are selected to reflect these objectives. Below are examples. The exact set of indicators will depend on priorities and the cost of collecting data.

- Service quality is indicated by transit service accessibility (portion of homes, businesses and public institutions with some minimal level of transit service, such as 30-minute or less headways), frequency, transit travel speeds relative to driving, reliability (indicated by the portion of trips that are on schedule), frequency of pass-ups, portion of passengers that must stand, waiting area comfort (portion with shelters), seat comfort, vehicle and waiting area cleanliness, and ease of obtaining user information.

- Congestion reduction, road and parking cost savings, energy conservation and pollution reductions result from automobile to transit mode shifts and the tendency of transit to reduce per capita automobile travel. Suitable indicators include per capita transit trips, transit passenger-miles, per capita vehicle ownership and mileage, and mode split. Congestion is particularly affected by peak-period trips, so commute mode split is a good indicator, but total trips is important for evaluating other impacts.

- Safety is indicated by crashes and injuries per million passenger-kilometers, and total traffic injuries and fatalities per 100,000 population for all residents in a community. Similarly, personal security is indicated by the frequency of security incidents.

- Mobility for transportation disadvantaged people is indicated by the quality of walking and cycling conditions, transit service accessibility, land use mix (proximity of public services to residential neighborhoods), quality of taxi services, and Internet service, with special attention to lower-income households and neighborhoods.

- Consumer costs are indicated by the portion of household expenditures devoted to transportation and housing. Affordability is indicated by the availability of transit service to lower-income residents, fares relative to average income (particularly for lower-income households, taking into account special need-based discounts, such as concession fares and free transit passes for seniors, people with disabilities, children, etc.).

- Support for strategic land use objectives may include factors such as whether compact infill development is occurring along transit lines and near transit stations, and the portion of employment located near high quality transit.

- Cost effective operation is indicated by performance data, such as cost per revenue-mile and passenger-trip, and cost recovery rates.

- Planning effectiveness is indicated by factors such as the success at establishing strategic plans, the degree to which individual short-term planning decisions are consistent with strategic planning goals, the degree to which transportation and land use planning is coordinated, and the quality of public involvement and support of plans. This may be evaluated qualitatively rather than quantitatively.

Each of these indicators should be reported separately for each mode (bus, train and demand response), service area, time period (peak and off-peak, day of week, month of year), year (to indicate trends over time), and comparing the study system or community with peers. As much as possible, this information should be presented in graphs to help readers see trends. It may be appropriate to establish a semi-independent transportation evaluation agency which is in charge of data collection, evaluation and reporting.

There are often conflicts between different objectives and goals. For example, improving basic mobility for non-drivers (which requires providing service even where and when demand is low) can conflict with efforts to improve productivity (which requires that transit service only be provided where and when demand is high). If possible, analysis should investigate and report on the cause of changes, and indicate whether these support overall goals. For example, lower vehicle operating costs per passenger-mile may reflect desirable influences, such as increased vehicle fuel efficiency, or it could indicate undesirable influences such as reduced service in outlying areas. Similarly, increases in transit ridership may reflect desirable influences, such as improved service that attracts discretionary travelers, or undesirable influences such as increased poverty.

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 split, 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 31 summarizes sustainable transport goals, objectives and performance indicators.

Table 31 **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	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 stability	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	Clearly defined planning process. Integrated and comprehensive analysis. Strong citizen engagement. Lease-cost planning and funding (the most overall beneficial solutions are selected and funded).	• 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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