The
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durable

SUSTAINABLE TRANSPORTATION PERFORMANCE INDICATORS PROJECT

BRIEF REVIEW OF SOME RELEVANT WORLDWIDE ACTIVITY

AND

DEVELOPMENT OF AN INITIAL LONG LIST OF INDICATORS

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1. INTRODUCTION

1.1. Background to the present project

Sustainable development is emerging as a guiding principle for human activity. It involves meeting the needs of the present in ways that do not compromise the ability of future generations to meet their needs. Much human activity is presently unsustainable. The particular predicament of transportation was captured well in an article by Greene and Wegnener[1]:

> *Near the end of the 20th century, the belief in the desirability of perpetual growth in mobility and transport has started to fade. … In metropolitan areas, the myth that rising travel demand will ever be satisfied by more motorways has been shattered by reappearing congestion. People have realized that the car has not only brought freedom of movement but also air pollution, traffic noise and accidents. It has become obvious that in the face of finite fossil fuel resources and the need to reduce greenhouse gas emissions the use of petroleum cannot grow forever. There is now broad agreement that present trends in transport are not sustainable, and many conclude that fundamental changes in the technology, design, operation, and financing of transport systems are needed.*

Decision-makers are becoming more aware of the need to implement solutions that promote the achievement of sustainable transportation. However, to date in Canada, no comprehensive tool has been developed to monitor the progress of Canadian transportation systems towards (or away from) sustainability. The present work on sustainable transportation performance indicators seeks to develop transportation indicators that will serve this purpose. Initial funding for this work has been provided by Transport Canada and Environment Canada.

The late John Hartman, Vice-Chair of the Board of the Centre for Sustainable Transportation, was the inspiration for the Centre's project on sustainable transportation performance indicators (STPI). He proposed the novel idea that will be made use of in this project; it is to link indicators to the Centre's definition of sustainable transportation, which had been developed by the Centre during 1997. This is the definition:

A sustainable transportation system is one that:

- *Allows the basic access needs of individuals and society to be met safely and in a manner consistent with human and ecosystem health, and within 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, reuses and recycles its components, and minimizes the use of land and the production of noise.*

John Hartman deconstructed the Centre's definition into 17 elements amenable to quantification, organized in three domains.[2] These elements will, in the course of the present work, form the ba-

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[1] Greene DL, and Wegener M (1997) Sustainable transport. *Journal of Transport Geography*, 5(3): 177-190.

[2] The 17 elements of the deconstructed definition are: Environmental domain: limits emissions, limits waste, minimizes consumption of non-renewable resources, reuses and recycles components, minimizes use of land, minimizes production of noise; Societal domain: meets access needs of individuals, meets access needs of society, access needs are met safely, access needs met consistent with ecosystem health, access needs met with equity within this generation, access needs met with equity within generations; Eco-

sis for the selection of indicators that can be used to monitor trends towards or away from sustainable transportation. Each selected indicator will quantify one or more the elements, directly or indirectly.

Indicators are statistics designed to allow significant trends to be monitored. The Centre's working definition of indicators is this: 'selected, targeted, and compressed variables that reflect public concerns and are of use to decision-makers'.[3] Indicators have two main uses: they can help with the comparison of different phenomena, and they can help with evaluating progress towards or away from a defined goal. The Centre's work on STPI falls primarily into the second category of interest.

1.2. Overview of the present project

The present project was conducted in two parts. The first part, reported in Sections 2 and 3, comprised a brief review of work done or in progress in Canada and elsewhere relevant to the development and use of STPI. The review was a useful prelude to our own development of STPI as it enabled a look at different concepts of sustainable transportation around the world, and generated ideas as to the quantification process and the uses of transportation indicators. It must be noted that *the review is limited to work relevant to the development and use of STPI as opposed to work on transportation indicators generally*. This distinction was made so as to narrow the review to a manageable and useful set of data.

The aim of the second part of the project—reported here is Sections 4, 5, and 6—was to draw on information gathered during the first part to develop a very preliminary long list of STPI that could be used in Canada. In doing this, the material developed during the review was assessed in terms of the 17 elements of the John Hartman's deconstructed definition of sustainable transportation. In proceeding with the development of the long list, there was reason to include potential indicators other than those detailed in the review, where gaps were noted or other considerations suggested their inclusion, as discussed in Section 6.

The resulting very preliminary long list of STPI for carrying forward to future work is set out here in Appendix C, which begins on Page 55.

Sections 7 and 8 provide some comments on the Centre's definition and a look ahead at possible future work.

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nomic domain: is affordable, operates efficiently, offers choice of transport mode, and support a vibrant economy.

[3] This definition is based on the work of Henrik Gudmundsson of the Danish Environment Agency (from a paper presented at a conference entitled Social Change and a Sustainable Transport, organized by the European Science Foundation and the U.S. National Research Foundation and held at the University of California, Berkeley, March 1999).

2. LITERATURE REVIEW

2.1. Overview and methodology

The purpose of this literature review is to look briefly at comparable work around the world on the development and use of STPI, and to present a synopsis of the best practices in other jurisdictions and development procedures in other agencies (TAC, OECD, etc.). This scan of what is being done elsewhere will provide a useful platform from which the construction of STPI for Canada will be addressed.

The review covers work accomplished in international agencies, universities, and other organizations, as well as all orders of government: local/regional, provincial/state, and national/supranational.

Given the amount of literature and the interest of many governments and international and local organizations in sustainable development and sustainable transportation in particular, it was necessary to narrow the scope of the literature review. Many organizations and governments had—prior to their interest in developing indicators of sustainable transportation—an established database and a way of reporting major trends in the sector. Good examples of these kinds of reporting documents are Transport Canada's *Annual Reports* and the Transport Association of Canada's annual publication *Transport in Canada*. These documents are useful in setting out major trends in the transportation sector, but they often do not report *development and deployment of sets of indicators* that can be used to monitor progress towards or away from sustainable transportation. The data contained in such documents will be taken into account in the second phase of the project when determining the availability of data to measure the proposed indicators, but they have *not* been included in the literature review.

The review presented here thus only includes work by governments and international and local organizations around the world that *define or attempt to define* sets of sustainable transportation indicators. In some cases, the transportation indicators that have been developed or proposed are part of a larger project on sustainable development. When this is the case, only the transportation indicators and the ones that could be relevant to the monitoring of transportation trends are presented.

The review of each document or document set is presented in three parts. In the first part, the work is introduced with account of the context within which the indicators were developed or proposed. A note is also made as to the vision of sustainable transportation that is articulated or implied. This enables the work reviewed to be placed into its original context and to relate it to other sustainable development initiatives.

The introduction is followed by a two-column table that lists each indicator and provides a description of it, relying in each case mostly on the wording in the respective reports. When a full description or quantification method for the indicator selected is not provided by the organization, or when the meaning of the indicators as it relates to sustainable transportation is not clear from the text, the description section has been left blank.

The third part of the review of each source presents information from the sources as to the availability of data and the extent to which the indicators have been used.

Following the reviews of the sources is a discussion of the approaches used in the reviews in relation to the approach proposed for the Centre's indicators work. This is followed by a very preliminary categorization of all of the indicators featured in the sources (see Appendix B on Page 49).

2.2. Overview of Canadian sources

Information from five Canadian sources is reviewed in the following five sub-sections. The sources are:

1. Environment Canada
2. National Round Table on the Environment and the Economy
3. Ontario Round Table on Environment and Economy
4. Transportation Association of Canada
5. Victoria Transport Policy Institute

Specific information about the sources is provided in the corresponding introductions.

2.3. Canada: Environment Canada

2.3.1. Introduction

Environment Canada's State of the Environment Directorate began focusing work on indicators in 1988-89. Impetus towards identifying and developing indicators was provided by the Group of Seven at the 1989 Economic Summit in Paris. This Group requested the Organization for Economic Co-operation and Development (OECD) to begin development of environmental indicators in the context of integrated environmental and economic decision-making. Canada took up the challenge and in the 1990 Green Plan set out a government-wide commitment to develop a preliminary national set of environmental indicators and initiate stakeholder consultations by mid-1991. A comprehensive set was to be developed with regular reporting beginning in 1993.

A report on Canada's Progress Towards a National Set of Environmental Indicators (State of the Environment Report 91-1), presenting 43 preliminary indicators in 18 issue areas, was released in April 1991 with widespread stakeholder and media interest. The preliminary environmental indicator set has served as the basis for ongoing consultations on indicator development with federal, provincial, and territorial departments and agencies, with environmental and other non-government organizations, and with private-sector stakeholders.

A current expression of this effort is the production by Environment Canada of a series of regularly updated *Bulletins* designed to provide a profile of the state of Canada's environment. They are also meant to help track progress in achieving environmental goals related to sustainable development. The bulletins are available at www3.ec.gc.ca/~ind/ english/TOC/toc_e.HTM.

The series uses a modified ‘Pressure–State–Response’ framework,[4] and also includes a fourth category related to the nature of human activity. The structure thus encompasses four sets of issues: ecological life support systems; natural resources sustainability; human health and well-being; and pervasive influencing factors. The main transport-related indicators found in the different issues of the *Bulletins* have been compiled and are presented below.

2.3.2. Indicators

Indicator (as named by the developer)	Description (based on information provided by the developer)
Urban Air Quality	
A1. Toxic substances in urban air: benzene	Benzene emissions are associated in part with the use of motor vehicles. Measuring the level of benzene in urban areas can help assess the effectiveness of vehicle emission controls. The adopted indicator represents the average concentration (ìg/m^3) of benzene in the air in urban areas for the period 1989 to 1997.
Energy Consumption	
A2. Fossil fuel consumption	Indicator of human activity in relation to motorized transport use. In the global as in the Canadian context, the indicator selected is a long-term trend in fossil fuel consumption: oil, coal, and natural gas (from 1950 to 1992).
Canadian Passenger Transportation	
A.3 How Canadians travel	Reflects human activity. Measures the trend in passenger-kilometres for each of the four most important modes of passenger transportation. Also relates the latter to the growth in GDP over the last 45 years.
A4. Fossil fuel use by automobiles	Considered as a stress factor as it causes depletion of natural resources. Expressed in billions of litres of gasoline used in automobiles in relation to billions of passenger-kilometres travelled, from 1950 to 1994. Shows that emissions control is being partially offset by the increase in the number of automobiles, the increase in the number of passenger-kilometres traveled, and the presence of poorly maintained and older vehicles on the road.
A5. Fuel efficiency of new automobiles.	Gives an indication of the choices made by consumers when buying new vehicles. Fuel efficiency is represented by litres/100 kilometres over the period 1965-1995 and assessed in relation to fuel cost (1986C$/litre) over the same period.
A6. Urban transit and automobile use	Indirect measure of the extent to which alternatives to travel by private automobile are adopted. Urban transit use (as measured in passenger-kilometres travelled) is assessed in relation to all motorized urban travel (also in passenger-kilometres) from 1950 to 1995.

[4] The Pressure–State–Response framework—developed in Canada and now used in a modified form by the by the OECD (see Section 2.10 below)—is based on a concept of causality. Human activities are said to exert *pressures* on the environment, therefore affecting its *state*. These changes in the state of the environment are addressed by society through the implementation of environmental, sectoral, and economic policies (the societal *response).*

Climate Change	
A7. Carbon dioxide emissions from fossil fuel use	Addresses human activity in terms of use of motorized transportation. Is measured both globally and in the Canadian context; globally by the megatonnes of CO_2 emissions in relation to the Gross World Product (GWP) for the years 1950 to 1994; in the Canadian context through the assessment of Canadian CO_2 emissions (megatonnes) in relation with to Canadian GDP for the years 1958 to 1994.
A8. Global atmospheric concentration of greenhouse gases	Indicator of stress on the environment resulting in part from transport activity. Expressed as concentration of carbon dioxide, shown yearly (in parts per million) from 1958 to 1996.

2.3.3. Use of indicators and data collection

All the indicators described in the *Bulletins* are widely used by Environment Canada and other government departments and agencies in various reporting mechanisms.

2.4. Canada: National Round Table on the Environment and the Economy

2.4.1. Introduction

The National Round Table on the Environment and the Economy (NRTEE) is an independent agency of the federal government committed to providing decision makers and opinion leaders with reliable information and objective views on the current state of the debate on the environment and the economy. Information about the NRTEE can be gained from this Web site: www.nrtee-trnee.ca.

The goal of the NTREE in regard to sustainable transportation is analyzing environmental and economic information to determine changes that will enhance sustainability in Canada. It has identified impacts and trends in transportation that are leading to increasing pollution, congestion and cost, as well as to declining quality of life for Canadians. The NRTEE also attempts to identify actions that will balance economic prosperity with environmental preservation.

The NRTEE has developed a draft set of sustainable transportation principles that concern access, equity, individual and community responsibility, health and safety, education and public participation, integrated planning, land and resource use, pollution prevention, and economic well-being. No indicators specifically constructed to assess movement towards or away from sustainable transportation have been adopted by the NRTEE, some indicators are presented to illustrate current trends associated with transportation.

2.4.2. Indicators

Indicator (as named by the developer)	Description (based on information provided by the developer)
B1. Worldwide major natural disasters	Illustrates the potential impact of climate variability. This indicator could be used to express possible links between natural disasters and millions of personal transportation-related decisions by consumers and businesses (such as the purchase of large vehicles, long distance vacation flights, etc). Such decisions can result in high consumption of transportation fuels and high levels of greenhouse gas emissions.
B2. Per-capita use of transportation energy	Reflects the transport energy per capita used (in gigajoules) by country.
B3. Total light-duty vehicles in Canada	Expressed in millions of vehicle registrations per year. Monitors the reliance on motor vehicles.
B4. Unit sales of cars and trucks	Used to monitor the trends toward the purchase of six-cylinder engines, which average higher fuel use than four-cylinder engines.
B5. Total kilometres driven in Canada	Provides an indication as to the reliance of the population on autombile use.
B6. Gas and diesel fuel prices at the pump	Provides an indication of motor-fuel energy consumption in relation to price changes.
B7. Per-capita gasoline consumption vs. urban density	Measure of accessibility to services by non-motorized modes of transport in urban areas.
B8. Greenhouse gas emissions from transportation	Measured in millions of tons of CO_2 equivalent (long term assessment); provide an indication of energy consumption from transportation.

2.4.3. Use of indicators and data collection

The indicators presented are widely used in the transportation sector and do not require the development of new data sources.

2.5. Canada: Ontario Round Table on Environment and Economy

2.5.1. Introduction

Transportation provided a significant focus of the work of this Round Table, which completed its work in the mid-1990s. Its documents are on file at the York Centre for Applied Sustainability, York University, Toronto. Information is provided here from two documents:

> *Sustainability Indicators: The Transportation Sector. Prepared for the Ontario Roundtable on Environment and Economy, Sept. 1995.*
>
> *Development and Demonstration of Sustainability Indicators for the Ontario Transportation Sector, prepared by David Heeney, IndEco Consulting Inc., Toronto. [Available at http://www.web.net/ortee/transportation/report10/index.html.]*

These reports were prepared to help the Ontario Transportation Collaborative formulate a strategy for Ontario's transportation system. They represent a research effort on how the concept of sustainability and sustainability indicators may be introduced into the policy formulation and analysis process in Ontario. The reports develop and assess indicators for evaluating the impacts of possible actions or measures on the sustainability of the transportation system in Ontario.

The framework adopted was based on a 'Criterion–Influences–Actions–Measures' system.[5] The conceptual model adopted was a computerized revised version of the 'environment–economy linkages model' developed by Hickling Corporation and Econometric Research Limited, 1993.[6]

The vision of sustainable transportation was as follows: Achieving sustainability requires that the overall capital resources be not depleted (including manufacturing and natural capital). Thus a sustainable industrial system produces outputs at a level capable of being assimilated by the environment; has a low need for inputs of non-renewable resources; and has a structure that minimizes the use of resources.

A specific definition of sustainable transportation was not set out in the report. The concept of transport sustainability was referred to as encompassing three main criteria:

- *Produce outputs (emissions) at a level capable of being assimilated by the environment.*
- *Have a low need for inputs of non-renewable resources (where non-renewable are used, their use will be for non-consumptive investments and they will be recycled when no longer useful or needed).*
- *Minimizes disruption of ecological processes, land (and water area) use is also minimized as well as uses of sensitive habitats.*

2.5.2. Indicators

Indicators were set out under four main heads (environmental, economic, social, and system). Only indicators related to transportation have been included in the following table.

Indicator (as named by the developer)	Description (based on information provided by the developer)
Environmental	
C1. CO_2 loading	Quantifies the atmospheric concentration or total loadings of CO_2. This measure is said to be particularly useful when used as time series or looked at in relation to emissions from other sectors. Can give an idea as to the level of emissions in relation to the capacity level of the earth to assimilate them. No formula presented.

[5] The system is really a 'model' of the relationships among sustainability criteria, the output being the set of indicators. Hence a selected criterion (for example CO_2 emissions) can be deconstructed into a number of influences (e.g., persons per vehicle). These influences can trigger different actions by policy makers such as establishing new transit lines or a car pool database. These actions can, in turn, be facilitated by different policy measures.

[6] This model is complex. It connected environmental discharges and resource use, on a country basis, to a regionalized input-output model of the Ontario economy.

C2. Ecological footprint	Measures resource use. It is the measure of land that would be required to grow (on a sustained yield basis) substitutes for the non-renewable resources used. Particularly suited for resources like fossil fuels, for which biological material could be substituted. It provides an indicator high in symbolic relevance, integrative value and significance.
C3. Habitat disruption and land use	Refers to the amount of land used by the transportation system in different areas but does not give specific measurement criteria.
Economic	
C4. Employment	Is defined as a standard indicator used in economic models and being of a prime concern for decision-makers. It is not clear however how it can be applied to the measuring of sustainable transportation.
C5. Green GDP	Presents an overall picture of income, conventional or sustainable, in one number. Is said to be deemed significant by decision-makers as it integrates some environmental and sustainability considerations (contribution to quality of life). However, the measurement and applicability of the Green GDP as a measure of sustainability in transportation is not presented.
C6. Tax revenues	Gives an indication as to what extent the transportation sector is supportive of other societal initiatives (through tax revenues) by drawing on or contributing to public revenues. No specific measurement presented.
C7. Commute cost	Indication of accessibility/affordability of public transport.
Social	
C8. Population density (persons/ha). C9. Non-auto trips (% of urban trips not by automobile). C10. Commute time (population within 30 minutes commuting time of natural areas).	Refers to the enhanced opportunities for interactions (enhanced if shorter travel time is required to reach a destination). High density of population may be associated with availability of services within a distance that does not require the use—or at least the extensive use—of motorized transportation.
C11. Deaths and injuries	Measure of the number of deaths associated with the transportation sector.
C12. Crime	As it relates to motor vehicle theft and vandalism as a significant part of overall crime. Not obvious how it can help achieve sustainable transportation but relates to safety…
C13. Community disruption	Level of disruption from traffic and other related transportation activities. No measurement presented. Related to the need for traffic calming measures implementation.
C14. Distribution Inequality Index	Is based on the share of national income received by the poorest twenty percent of household each year. It is not obvious how this indicator applies to sustainable transportation.
C15. Demotechnic Index	The Demotechnic Index inter-relates population and consumption in order to obtain estimates that allow for comparisons of countries in terms of their contribution to global environmental stress. Essentially, the Index measures commercial energy use in units related to the average human metabolic requirement, and then expresses this as a population equivalent.

C16. E-index	The E-index measures specific projects relative to overall per capita energy use in various regions. Thus an E-index of 100% or 1 relative to Canada indicates that the project uses energy at the same rate per job created as the average for energy use per person in Canada.
C17. Vehicle access	Related to the concept of social interaction and equity issues. Measured as the vehicle ownership rate per household; and homes within 400 metres of a bus stop.
System Indicators	
C18. Non-fossil fuel use	The indicator measures the non-fossil share of total energy use in the transportation sector but no specific measurement data are proposed. Indicator of redundancy.
C19. Energy efficiency	Indicator of diversity and sustainability. Can be the number of transportation modes available to users; the overall energy-efficiency of the transport system (as measured in energy used per unit service, for example joule per passenger-kilometre or joule per ton-kilometre).
C20. Mixed land use C21. Trips with two or more modes	Both are indicators of integrity, which means that the transportation system enables better connections between various modes or transit and that land-use planning integrates various land uses and transportation services.

2.5.3. Use of indicators and data collection

Most indicators selected are in common use and the data needed for their measurement are for most part available from organizations in Canada or in the US. The document states however that there are particularly poor data linking environmental and social factors, making it difficult to quantify indicators such as 'community disruption' that would give an indication of the level of disruption from traffic and other related transportation activities. The Distribution Inequality Index, Demotechnic Index, and E-index are generally not widely used in the transportation sector.

2.6. Canada: Transportation Association of Canada

2.6.1. Introduction

The Transportation Association of Canada (TAC) is a non-profit association of government and industry members that acts as a neutral forum for the discussion of transportation issues and concerns and as a centre for technical excellence in surface transportation infrastructure. TAC is a national, multi-modal, multi-jurisdictional organization with a mission to promote the provision of safe, efficient, effective, and environmentally sustainable transportation services in support of Canada's social and economic goals.

In 1993, TAC's Urban Transportation Council (UTC) formulated a *New Vision for Urban Transportation*. It proposed 13 principles pointing to sustainable transportation systems and related urban land use in Canada. A survey to monitor trends towards attainment of the principles was first carried out in 1995. What is presented here is derived from the formulation of UTC's second survey, which involved 15 Canadian urban areas.

Survey questions can be considered as framing indicators or potential indicators to the extent that they provide appropriate *quantitative* responses. The UTC's survey has 35 questions that fall into this category.

2.6.2. Indicators

In the following table, with respect to an urban region, EUA refers to the Existing Urban Area of the region, CA refers to the region's Central Area, and CBD refers to the region's Central Business District. The two indicators marked with an asterisk (*) are considered by TAC's UTC to be of special significance for monitoring the extent to which sustainable transportation is being achieved in urban areas.

Indicator (as named by the developer)	Description (based on information provided by the developer)
Background data	
D1. Population in region	Population and employment densities are important direct indicators of urban structure and factors affecting travel intensity and behaviour.
D2. Employment in region	
D3. Population in EUA	
D4. Employment in EUA	
D5. EUA land area	
Land use characteristics	
D6. Population density in EUA	Population and employment densities are important direct indicators of urban structure and factors affecting travel intensity and behaviour.
D7. Employment density in EUA	
D8. Employment-to-population ratio in CA	
Transportation supply	
D9. Arterial lane-km per 1000 capita in EUA	
D10. Expressway lane-km per 1000 capita in EUA	
D11. High-occupancy-vehicle (HOV) lane-km per 100,000 capita in EUA	Expressed both per capita and as a percentage of the arterial and expressway lane-km. Gives an indication of the priority of bus transit and carpooling in the EUA.
D12. Automobiles per capita in EUA	Is an important factor in travel decisions and the ensuing gasoline-based carbon dioxide emissions.
D13. Morning peak period transit seat-km per capita in EUA	Provide good general indications of the amount of transit service supplied in the urban areas.
D14. 24-h transit seat-km per capita in EUA	
D15. Off-street parking spaces per employee in CBD	
Transportation demand	
D16. Morning peak period transit mode share to/from CBD	
D.17. Morning peak period auto mode share to/from CBD (drivers and passengers)	

D18. Morning peak period auto mode share for EUA (drivers and passengers)	
D19. Morning peak period auto occupancy to/from CBD	Measures of the efficiency vehicle trips in transporting people.
D20. Morning peak period auto occupancy for EUA	
D21. 24-h person trips per capita for EUA	
D22. Annual transit rides per capita for EUA*	True representation of the average ridership for the entire urban area.
D23. 24-h arterial auto vehicle-km per capita for EUA	
D24. Average-day vehicle-km per capita, calculated from fuel sales	
Transportation system performance	
D25. Average home-work trip distance in EUA	
D26. Annual injuries and fatalities per 1,000 capita in EUA	
D27. Road Utilization Index (RUI) in EUA	Expressed as vehicle-km/lane-km. Derived from foregoing information.
Transportation costs and finances	
D28. Total road expenditures per capita in region	
D29. Total transit expenditures per capita in region	
D30. Farebox revenue/operating and maintenance budget	
Environmental impacts of transportation	
D31. Fuel use per capita in EUA	
D32. Fuel use per person-trip in EUA	
D33. CO_2 emissions per capita in EUA*	
D34. CO_2 emissions per person-trip in EUA	

2.6.3. Use of indicators and data collection

Most of the indicators presented above are in common use and the data needed for their measurement are available without the need for extensive development of new databases.

2.7. Canada: Victoria Transport Policy Institute

2.7.1. Introduction

The Victoria Transport Policy Institute is an independent research organization dedicated to developing innovative and practical tools for solving transportation problems. The work of the Victoria Transport Institute has been included in this literature review for its different approach to its selection criteria for sustainable transportation indicators. It offers an alternative perspective on the selection of transport indicators by focusing on *access* (the ability to reach goods, services or destinations) rather than on the transportation system's ability to 'move vehicles' (by measuring traffic congestion for example). No information is provided by the Institute as to how to quantify the indicators proposed. Information on the Institute is available at its Web site: www.vtpi.org

2.7.2. Indicators

Indicator (as named by developer)	Description (based on information provided by developer)
E1. Average portion of household expenditures devoted to transportation	N/A
E2. Average amount of residents' time devoted to non-recreational travel	N/A
E3. Per-capita automobile use	N/A
E4. Ability of non-drivers to reach employment centres and services	N/A
E5. Quality of pedestrian and bicycle environment	N/A
E6. Per-capita land area paved for roads and parking facilities	N/A
E7. Quality of public transit service (hours of service, frequency, speed relative to auto, safety, comfort), integration with other modes	N/A
E8. Average number of major services within walking distance of residents and average distance (walking) between residences and public services.	N/A
E9. Land use mix (proximity of residential, community, and employment centres)	N/A
E10. Quality of delivery services	N/A
E11. Quality of mobility services for residents with special mobility needs.	N/A
E12. Affordability of public transit service by lower income residents	N/A
E13. Proportion of residents with public transit service within 500 metres	N/A
E14. Motor vehicle fatalities and accidents	N/A
E15. Per-capita energy consumption in respect of transportation	N/A
E16. Per-capita pollution in respect of transportation	N/A
E17. Medical costs attributed to transportation	N/A
E18. Portion of transportation-related costs paid by public funding	N/A
E19. Residents' participation in transportation and land-use decision-making.	N/A

2.7.3. Use of indicators and data collection

No information is provided

2.8. Baltic Region

2.8.1. Introduction

Baltic 21 is an international process of regional cooperation and environmental improvement involving countries with a Baltic Sea coastline. It has a strong emphasis on economic and social aspects of sustainable development. The work focuses on seven sectors of crucial importance in the region (agriculture, energy, fisheries, forestry, industry, tourism, and transportation). General information about Baltic 21 is available at this Web site: www.ee/baltic21/agenda/agenda.htm.

Sustainable transportation indicators have been developed as part of the monitoring effort towards meeting the objectives of sustainability set out the Baltic 21 agreement. The key document for our purposes is the following:

> *Baltic 21 Series No 13/98: Indicators on Sustainable Development in the Baltic Sea Region (An initial Set): Baltic 21 Transport Sector Report (no8/98). Annex 5: Indicators for Sustainable Transportation.*

The proposed indicator set is based on outcome-oriented indicators linked to goals. Because the document focuses on 'pathways' towards sustainable transportation rather than characterizing one 'right way', the indication of trends is deemed more important than relationship to specific targets. Therefore, most of the objectives presented (indicators) are not defined by concrete target values.

2.8.2. Indicators

The indicators selected in the Baltic 21 process are organized according to three different types of goals and measures:

- Indicators with regard to primary goals for sustainable transport (provide access to people, goods, and locations; reduce or mitigate pressure on health and environment; reduce or mitigate the use of non renewable resources; reduce casualties and environmental impacts by accidents);
- Indicators with regard to institutions, instruments, and measures (integrate environmental concerns into planning; apply the principles of sustainability in decision making on investment in infrastructure projects and transport planning; strengthen institutional capacity; apply the polluter pay principle; implement pollution control requirements) – *no indicators have yet been developed for this category*;
- Indicators with regard to the transport system and transportation activity (observe the development of the transport activities; observe its contribution to the overall problems in the Baltic Sea Region).

Indicator (as named by developer)	Description (based on information provided by developer)
Enable participation of individuals in society's life without social restrictions	
F1. Length of public transport network (rail and buses)	The public transport system provides mobility at reasonable quality to all people in a certain region.
F2. Number of food shops in a certain area	The basic services and goods are accessible in such distances that they do not demand motorized transportation.
Reduce or mitigate pressures on environment and health	
F3. NO_x emissions	Transport related NO_x emissions in the Region have been reduced to the extent, that the objectives for ambient NO_2 levels as well as for nitrogen deposition on the terrestrial and marine ecosystems are met. Monitor the level of emissions so that the objectives for ambient NO_2 levels as well as for nitrogen deposition on the terrestrial and marine ecosystems are met.
F4. Hourly average concentration of ozone in suburban areas and annual concentration (mean) of benzene in central urban areas	Emission of VOCs and NO_x have been reduced to the extent that excessive ozone levels are avoided and emission of carcinogenic VOCs from all movements of all vehicles have been reduced to meet acceptable risk levels (one case of cancer among ..... people).
F5. Mean annual concentration of particles in central urban areas	Emissions of particulate matter must be reduced to the extent that harmful ambient air levels are avoided.
F6. CO_2 emissions from fossil fuels by mode and transport sector	National per capita carbon dioxide emissions from transportation must be consistent with the global protection goals for the atmosphere.
F7. Length of railways and main roads; F8. Share of areas larger than 100 km^2 not separated by motorways	Land surface is used for the movement, maintenance, and storage of motorized vehicles (including public transport) such that the objectives for ecosystem protection are met
F9. Day and night time noise levels in residential, mixed, and industrial areas	Noise caused by transportation does not result in outdoor noise levels that present a health concern or serious nuisance.
Reduce or mitigate the consumption of non renewable resources (fossil fuels, metals)	
F10. Percentage of reused or recycled parts of different types of end-of-life vehicles	Resource consumption by the **production** of vehicles/ships is reduced or stabilized, for example by reusing or recycling material from end-of-life vehicles/ships at a level consistent with such goal.
F11. Final energy consumption by modes and fuel type	The consumption of fossil fuels by the transport sector has been stabilized or reduced to an extent that it is consistent with the global goals for the protection of the atmosphere.
Improve transport safety	
F12. Number of fatalities and injuries per year in transport	Number of casualties is reduced by ….. until ….

F13. Number of cases of serious pollution or health effects	The rate of large oil or chemicals spills on the Baltic Sea, at the harbors, on the roads and rail is reduced by …..% until …..
Extent of transport activity	
F14. Σ Length of main (all) roads and rail tracks	
F15. Σ Vehicle stock (different kinds)	
F16. Σ Traffic volumes of road, rail, air, sea (vehicle-kilometres)	
F17. Σ Total passenger and cargo turnover by air, ship, road, rail; mode shifts	
F18. Σ Total investment in maintenance costs with regard to road, rail, harbor and air infrastructure	
F19. Σ Investments dedicated to environmental protection	
Transport sector contribution to the overall regional problems	
F20. Σ Contribution to overall NO_x emissions in per cent	
F21. Σ Contribution to the overall nitrogen input to the Baltic Sea in percent	
F22. Σ Contribution to the overall emission of VOCs	
F23. Σ Contribution to the pollution of the Baltic Sea with hydrocarbons	
F24. Σ Contribution to overall CO_2 emissions (GHGs)	
F25. Σ Contribution to final energy consumption	

2.8.3. Use of indicators and data collection

The indicators selected are commonly used and the data needed can be gathered without extensive research.

2.9. New Zealand

2.9.1. Introduction

In 1996, the New Zealand Ministry for the Environment published a document entitled *National Environmental Indicators: Building a Framework for a Core Set* that proposed a program to establish a core set of nationally standardized indicators to help in the assessment of the state of the environment and in the monitoring of outcomes related to environmental policies and key legislation. In 1997, another document, *The State of the New Zealand Environment* was launched by the Ministry, stressing this time the need for better information about the effects of our activities on the environment. New Zealand's environmental indicators program initiated following the publication of this last document.

In June 1999, *Proposals for Indicators of the Environmental Effects of Transport* was published by the New Zealand Ministry of the Environment as a result of the environmental indicators program initiative. This document is the main one under review here. However some information from *The Indicator* (a project update newsletter produced by the Ministry) and the above-mentioned *National Environmental Indicators: Building a Framework for a Core Set* document were also given consideration.

The main purpose of the *Proposals* document was to provide the basis for agreement on the use of a core set of indicators to measure the environmental effects of transport.

The methodological framework for New Zealand's Environmental Performance Indicators (EPI) Program is the Pressure–State–Response model developed by Environment Canada and the OECD for identifying environmental indicators. According to the *Proposals* document, the components of the framework are these:

- **root causes of transport activity:** the way land is used, level of economic activity, state of transport technology, and national and local policies;
- **indirect pressures:** transport activity and the resulting construction, use, maintenance, and disposal of vehicles and infrastructure;
- **direct pressures:** emissions, resource use, noise, land use, etc.;
- **state or effects indicators:** outcomes such as the quality of land, air, and water in relation to their support of plant and animal health and biodiversity, including human health and welfare, amenity values, and social organization.

The indicators in the list below are divided into two main groups. First, there are two categories containing *priority indicators*, described as indirect pressure or transport activity indicators, and as direct pressure and state indicators. Second, there are what were described as *remaining candidate indicators*, grouped in several categories.

2.9.2. Indicators

Indicator (as named by developer)	Description (based on information provided by developer)
PRIORITY INDICATORS	
Indicators of transport activities (indirect)	
G1. Change in level of road congestion over time	Ratio of measured journey time to free-flow journey time over a sample of urban peak hour journeys, for cars, buses, and rail.
G2. Vehicle fleet composition	Indicator of the availability of private transport: vehicles per capita, both the total number and the numbers of cars and motorcycles (and possibly bicycles, private motor boats, and light aircraft).
G3. Overall urban density	Measure of ease of service by public transport; breakdown into inner and outer urban areas; urban area/head of population.
G4. Usual mode of transport for journey to work	Not specified.
G5. Vehicle-kilometres of travel by road users	Total vehicle-kilometres, and per capita and per vehicle, for all road vehicles, including cars and goods vehicles.
G6. Passenger-kilometres	By mode of transport: air, bus, rail, car, motorcycle, cycle, and walk, and also according to whether urban or inter-urban/rural.
G7. Freight tonne-kilometres	Revenue and availability by road, rail, coastal shipping, and air for urban and inter-urban transport.

Indicators of transport pressures (direct)	
G8. Residential population exposed to outside road traffic noise	Exposure to noise at levels greater than 55, 60, 65, and 70 dBA (24h L_{eq}) at the front property boundary; numbers and percentages of total population
G9. Residential population exposed to outside airport noise	Number of private dwellings and percentage of total private dwellings within 55, 65, 70, and 75 dBA (L_{dn}) airport noise contours at selected New Zealand airports.
G10. Total area of land under transport land use	Breakdown by mode; expressed as percentage of total land area for urban and on a per capita or per vehicle basis for the country; capable of breakdown by region and urban area.
G11. Percentage of arterial roads and state highways with appropriate levels of stormwater treatment	Defined as the percentage, by length, of major arterial roads and state highways that receives stormwater treatment through specifically designed treatment devices. (This is a response indicator that recognizes the high contribution of heavily trafficked roads to overall contaminant loads.)
G12. Sediment loads in streams (pressure indicator)	Sediment run-off from roads could be measured with end-of-pipe or in-stream sediment traps. The sediment could also be analyzed for toxics to provide further information on contaminant loading.
G13. Waahi tapu: location of transportation networks	A measure of transportation networks that are within 50 metres of waahi tapu within iwi rohe (tribal areas).
G14. Marae and papakainga: noise from transportation networks	Percentage of marae and papakainga exposed to outside road traffic noise levels greater than 55, 60, 65, and 70 dBA (24 th L_{eq}) at the property boundary.
REMAINING CANDIDATE INDICATORS	
Miscellaneous	
G15. Hours flown by New Zealand registered civil aircraft on domestic transport operations	By size of aircraft; total and per capita.
G16. Average trip length	By all modes of land transport.
Transport behaviour	
G17. Subsidized urban public transport journeys, available seats, and utilization	Total and per capita; subdivided into community (general) services and social (special mobility) services.
G18. Percentage of urban journeys by mode of transport (excluding cycle/walk)	No information provided.
G19. Percentage of short urban journeys by mode of transport	Includes cycle/walk; organized by distance: <1.5 km, 1.5-3.0 km, >3 km.
G20. Percentage of inter-urban passenger trips by mode of transport	No information provided.

Spatial Indicators	
G21. Public transport route length/highway route length	Measures of public transport coverage.
G22. Proportion of population within walking distance [200 m?] of a public transport boarding point	
G23. Proportion of traffic zones and trips served by a direct public transport connection; proportion of suburban traffic zones served by a direct public transport connection to the Central Business District (CBD)	
G24. Parking supply per worker: CBD and inner urban area	No information provided.
G25. Combined indicator that breaks down land transport use by type of use (information from GIS)	No information provided.
Congestion/cost indicators	
G26. Transport cost index	For car ownership (purchase and annual charges and per-km equivalent); car use (additional per-km costs); public transport costs (bus, rail, per km); parking costs per day (CBD).
Noise Indicators - roads	
G27. Residential population exposed to indoor road traffic noise	Levels greater than 45, 50, 55, and 60 dBA (24th L_{eq}) at the property facade; numbers and percentage of total population
G28. Change in vehicle fleet noise generation	Ratio of measured to modeled traffic noise normalized for traffic volume, heavy vehicle component and road surface effects, averaged over a set of indicator sites.
G29. Percentage of road system by road surface texture, subdivided into urban/rural and by traffic volume category	No information provided.
Land use change and land severance	
G30. Annual new road construction	In kilometres, or lane-kilometres, in total and as a percentage increase in the network.
G31. Area of arable land use converted to road or rail reserve	Could be part of an indicator for all urban land development; possible breakdown by land capability.
Air quality	
G32. Stage 1 indicator*: mobile source emissions, for CO, NO_x and PM_{10}	By main transport mode (road, rail, sea, and air) for New Zealand and for selected metropolitan urban areas. Total volumes, and per capita and per unit of GDP.

G33. Stage 2 indicator*: resident population exposure to local atmospheric concentrations of CO, NOx and PM_{10}	From road traffic sources at levels in relation to AAQG requiring 'Alert' (66-100% of guideline) or 'Action' (exceeding guideline), for selected urban areas, as proportion of total resident population.

* *Stage 1 indicators are those being implemented, or those capable of being implemented within two years. Stage 2 indicators require further development before implementation and are to be developed over the next three to five years. Stage 2 indicators generally address monitoring gaps in the Stage 1 indicator set.*

2.9.3. Use of indicators and data collection

Most of the indicators proposed are commonly used. However, data availability varies and for many indicators would have to come from a compilation of sources.

2.10. Organization for Economic Cooperation and Development (OECD)

2.10.1. Introduction

The OECD is the international organization of the industrialized, market-economy countries, mandated to support the economic growth of Member and non-Member countries through the exchange of information and the harmonization of government policies. The OECD is the major source of comparative data on market economies. Among the OECD's administrative components is its Environment Directorate whose functions include the collection and deployment of data pertaining to environmental issues, especially data relevant to economic concerns.

Two OECD documents from the OECD have been reviewed, as follows:

Indicators for the Integration of Environmental Concerns into Transport Policies, OECD Environment Monographs No:80, OECD/GD (93) 150, Paris 1993.

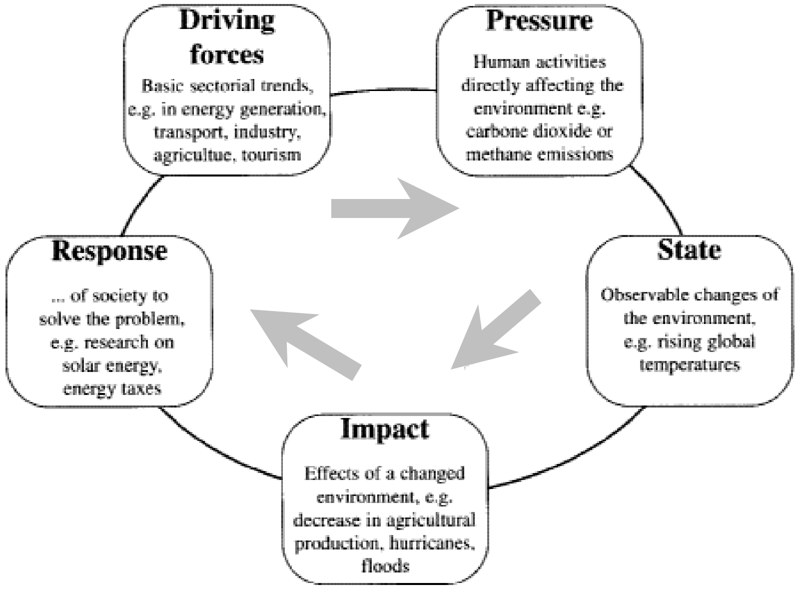
Toward Sustainable Transportation–Indicators to Measure Progress, OECD Workshop held in Rome, December 1999. (Session D: Transport-Environment Indicators, OECD Contribution).

These two documents pertain to the integration of environmental concerns into transport policies through the development and use of indicators. They speak to a common set of transport-environment indicators and the information below more or less represents the contents of each of the three documents.

The commonly agreed framework that forms the base of the OECD's indicator development is a version of the Pressure–State–Response model, adapted to take into account the specificities of the transport sector. The model has been modified to distinguish two categories of Pressures (Driving forces and Pressures) and two categories of State (State, Impact). The modified model is known by the acronym DPSIR. The five elements of the model are set out in the diagram on the next page.[7]

The DPSIR model has been adopted as the most appropriate way to structure environmental information by most Member states of the European Union and by international organizations deal-

[7] The diagram is taken from *Towards Environmental Pressure Indicators for the European Union.* European Union and Eurostat, Luxembourg, 1999.



ing with environmental information, including Eurostat and the European Environmental Agency, as well as the OECD.

The OECD indicators are structured according to three themes: sectoral trends of environmental significance; environmental impacts of the transport sector; and economic linkages between transport and the environment. Presented below, according to these topic heads, is the OECD's operational shortlist of transport-environment indicators.

2.10.2. Indicators

Indicator (as named by developer)	Description (based on information provided by developer)
Sectoral Trends of Environmental Significance	
H1. Transport intensity	The extent of passenger and freight transport—measured as passenger-kilometres/GDP unit and ton-kilometres/GDP unit, both by mode—gives an indication of a country's transport intensity..
H2. Vehicles	The operation of road vehicles accounts for four-fifths of transport-related energy consumption, and the vehicle-kilometres-travelled (vkt) per vehicle is fairly constant for a country from year to year, so the number of road vehicles acts as a good indicator of the extent of air emissions from transport. Moreover, because average vehicle occupancy tends to relatively constant too, the intensity of vehicle ownership (number of vehicles per capita) is an indirect indicator of passenger vehicle-kilometers traveled (pkt) by road.
H3. Fuels consumption	Fuel consumption by transport gives an indication of the energy intensity of the transport sector (gigwatt-hours/tonne freight; GWh/passenger-km) and the economy (GWh/unit GDP; GWh/capita). Can also give an indication of the importance of each mode in air emissions. When combined with vkt data, it can provide information as to the relative fuel efficiency of each mode. Data on consumption by fuel type can for their part help in assessing the importance of various air pollutants and/or the degree of implementation of fuel quality regulations.

H4. Infrastructure	The extent and density of transport infrastructure (km road/km^2, km road/capita; tonnage capacity of ports) is indicative of the state of development of transport services, as well as the relative importance of the various modes. The density of the network can also indicate the land fragmentation due to transport infrastructure. Measured in terms of road and rail network length and density.
Interactions with the environment	
H5. Air pollution	Air emissions (kilograms of emissions/vkt; kg emissions/capita) give an indication of the magnitude of the sector's environmental and related health risks. Locally, transport's contribution to air pollution can be measured by the level of NO_x emissions. Globally, CO_2 emissions levels can give an indication of the contribution of transport to air pollution. When compared to fuel consumption data, CO_2 emissions from transport can give an indication of efficiency of fuel use.
H6. Safety risks	Safety risk is an important indicator of the transport's sector's external social costs. The road accident rate (injuries or fatalities per vkt, per vehicle) gives for its part an indication of the magnitude of social costs associated with road traffic.
Economic and policy aspects	
H7. Pricing and taxation	The degree to which vehicle ownership versus operation is taxed has been shown to influence demand for personal mobility. Indicators can be growth/trend of gasoline prices (US$) and share of taxes in diesel fuel and gasoline prices (%).
H8. Subsidies	Can be used to promote and give an indication of sustainable transport development (in the short term). The indicator would be the percentage of costs subsidized, by mode.

2.10.3. Use of indicators and data collection

OECD indicators are being widely used and the data for their measurement are generally available without the need for extensive investment in data collection.

2.11. San Francisco

2.11.1. Introduction

The work reviewed is the section pertaining to transportation issues in the five-year *Sustainability Plan for the City of San Francisco.* The achievement of a sustainable transportation system is one of the 15 issues being given priority by the City. Seven major transportation and land-use goals have been identified by the City and a set of four transportation indicators has been developed to monitor progress towards these goals. The resource document is *Sustainable City: Working Toward a Sustainable Future for San Francisco*, available at www.sustainable-sf.org/Plan/Transit/intro.htm.

Information about the extensive community consultation process employed in the development of the Sustainability Plan—which involved some 400 volunteers—is available at www.sustainable-sf.org/Plan/Intro/intro.htm.

The particular framework used in the formulation of the transportation indicators is not specified. The formulation of the Sustainability Plan was dependent on work done for the European Union's Agenda 21 Implementation Plan—described as involving a 'general goals–specific objectives–actions' approach—and work by the organization Sustainable Seattle.

A *definition of a sustainable transportation system* is provided. It is *one in which people's needs and desires for access to jobs, commerce, recreation, culture, and home are accommodated using a minimum of resources.* The City of San Francisco has proposed that applying principles of sustainability to transportation will reduce pollution from the combustion of fossil fuels, noise, traffic congestion, land devaluation, urban sprawl, economic segregation and injury to drivers, pedestrians, and cyclists. In addition, the costs of commuting, shipping, housing, and goods will also be reduced.

Seven relevant goals have been set by the City:

1. To move people and goods with the most efficient use of resources
2. To have convenient regional transportation connections
3. To integrate transportation, land use, and economic development policies
4. To reduce transportation energy consumption and pollution generation
5. To reduce dependence on automobiles
6. To increase the reality and perception of safety and civility on transit to all
7. To provide a fair distribution of transportation resources to all users.

For each goal there is a five-year and a long-term objective. One of the first goal's five-year objectives is *to assess environmental impacts on transportation systems using performance measures in addition to vehicle "level of service"*.

2.11.2. Indicators

The achievement of the goals presented above will be monitored through four simple indicators that, sampled on a regular basis, will provide a bird's eye view of whether San Francisco is moving toward or away from sustainable transportation. Baselines for these indicators have yet to be established.

Indicator (as named by developer)	Description* (based on information provided by developer)
I1. Auto registration	↓
I2. Parking spot inventory	↓
I3. Transit ridership	↑
I4. Transit running time on key routes	↓

* An upward-pointing arrow indicates that the measurement should rise if the City is moving towards sustainable transportation. A downward-pointing arrow indicates that to attain sustainable transportation objectives, the measurement should fall.

2.11.3. Use of indicators and data collection

Not specified.

2.12. United Kingdom

2.12.1. Introduction

The Department of the Environment, Transport and the Regions of the UK has developed indicators of sustainable development, grouping them around 21 main issues. This review considers all of the “transport use” indicators as well as the transport-relevant “land use’ indicators. The source document is

> *Indicators of Sustainable Development for the United Kingdom, Department of the Environment, Transport and the Regions, UK (last updated in 1997).*

It can be viewed at www.environment.detr.gov.uk/epsim/indics/isd.htm

Following the commitment made at the Earth Summit of June 1992 in Rio, the UK Government published in 1994 its *Strategy for Sustainable Development*. One of the commitments made in Rio was the development of a set of indicators that would help considering whether the country’s development was becoming more sustainable, and also whether the UK Government is meeting its objectives as set out in the Sustainable Development Strategy. An Interdepartmental Working Group developed the document mentioned above, which contains a preliminary set of indicators relevant to the assessment of transport sustainability.

The UK has taken into account the ideas of other countries and organizations—with a final result that is similar to the OECD framework—but she has developed her own framework based on the key issues and objectives set out in the *Strategy for Sustainable Development*. This was done in an attempt to go beyond environmental indicators by also including indicators that explicitly link environmental impacts with socio-economic factors. The framework within which the UK indicators have been developed encompasses 21 ‘families’ of issues, one of them being ‘transport use’.

2.12.2. Indicators

Indicator (as named by developer)	Description (based on information provided by the developer)
Transport use	
J1. Car use and total passenger travel	Passenger-miles per head of the population: Great Britain (GB). Measures total miles traveled divided by population so that individuals can more readily relate to their own behavior. Shows the trends since 1970 in passenger-miles in GB per year per capita.
J2. Short journeys	Number of short journeys per person per year by mode (walk, cycle, bus, car) by length of journey (<1 mile, 1-2 miles, 2-5 miles). Show long-term trend.
J3. Real changes in the cost of transport	Shows the real change in price of passenger fares and motoring, in comparison with the growth in real personal disposable income, 1970-1994. Trends shown for gasoline/diesel, rail fares, bus fares, and all motoring costs.
J4. Freight traffic	Compares the annual trends in road and rail freight lifted (million tonnes) and moved (billion tonne-miles) since 1970.
Land use*	
J5. Road building	Land take for roads: England (in hectares, in rural and urban areas, for selected years)

J6. Regular journeys	Average journey length (in miles, for commuting, shopping and education, for selected years)
Air*	
J7. Carbon monoxide emissions	Road passenger transport CO emissions and road passenger-miles: UK. Index of road passenger CO emissions per passenger-mile (1970=100): UK.
J8. Black smoke emissions	Road freight transport black smoke emissions and road freight tonne-miles. Index of road freight black smoke emissions per freight tonne-mile (1970=100).
J9. Lead emissions	Lead emissions from gasoline-engined vehicles and share of unleaded fuel.
J10. Nitrogen dioxide concentrations	Accumulated hourly concentrations of NO_2 above 100 ppb
Climate change*	
J11. Emissions of greenhouse gases	CO_2, CH_4 and N_2O emissions (weighted by global warming potentials): UK. Index of weighted greenhouse gas emissions per GDP (1970=100): UK.

* Not included in the *transport use indicators* but referred to in other categories and relevant to transport sustainability.

2.12.3. Use of indicators and data collection

In some cases, the indicators can be easily calculated. In others the data needed to evaluate the preferred indicator are not available. Proxy measures have been suggested in such cases, and further work, including further methodological development and data collection, may be needed in the future. Overall however, the indicators proposed have been used for other purposes in the past.

2.13. World Bank

2.13.1. Introduction

The World Bank is the world's largest source of development assistance. It maintains a large knowledge base that includes environmental, economic, demographic, and other information. The Bank has an extensive range of activities involving the development of indicators for sustainability. Three of them are especially relevant to this review:

- **The Environmental Performance Indicator Project**: The Bank's Environmental Economic and Indicators Unit (EEI) has prepared a manual on environmental performance indicators (EPIs). This document was first issued in 1996 and updated in 1999.[8] It discusses indicator frameworks, selection criteria for environmental project indicators, and issues to consider for various environmental areas.

- **Indicators-on-the-Web.** Presently in progress, this World Bank project will provide managers with ideas for environmental performance indicators at the project and national level. The

[8] The present version of the document is Lisa Segnestam, *Environmental Performance Indicators* (second edition), Environmental Economics Series, Paper No. 71, October 1999 and is available from the World Bank Web site at www-esd.worldbank.org/eei/.

indicators will be presented in lists covering different sectors. This facility is still in development. It will contain a section on sustainable transportation indicators. Indicators-on-the-Web can be found at: www-esd.worldbank.org/eei/.

- **Development Goals**. The formulation of these is part of a project called "Entering the 21st Century", launched in 1996. The project aims to develop a set of indicators to measure progress towards sustainable development. This is a collaborative effort involving the World Bank, the OECD, the United Nations, and the World Resources Institute (another major source of relevant data). The aim is to propose a set of environmental indicators that should be monitored as part of the Bank's *International Development Strategy*. Information on these indicators as they pertain to transportation and environment is available at www.worldbank.org/data/dev/devgoals.html.

In the development of its list of indicators for sustainable development, the Bank indicator work follows the principles of the Pressure–State–Response framework developed by Environment Canada and the OECD.

2.13.2. Indicators

The indicators listed below have been compiled from the various World Bank sources:

Indicator (as named by the developer)	Description (based on information provided by the developer)
Energy efficiency and emissions	
K1. GDP per unit of energy use	1995 US$ of GDP per kg oil equivalent, per country (for 1980 and 1996)
K2. Traditional fuel use	Percentage of total energy use, per country (1980 and 1996)
K3. Carbon dioxide emissions	Total million tonnes of CO_2, per country (1980 and 1996); per capita tonnes, per country (1980 and 1996); kg of CO_2 per 1995 US$ of GDP, per country (1980 and 1996)
K4. Methane (CH_4) emissions; emissions of ozone-depleting substances	Measure ambient concentration levels. No other information provided.
Transport infrastructure	
K5. Paved roads	Percentage of all roads.
K6. Goods transported by road	Million tonne-kilometres.
K7. Passenger-kilometres per US$ million of GDP (purchasing parity)	For rail transport.
K8. Goods transported by railways	Tonne-kilometres per US$ million of GDP (purchasing parity).
K9. Diesel locomotives available	Per cent of all locomotives

K10. Aircraft departures	In thousands
K11. Passengers carried	For air, in thousands,
K12. Air freight	In million tonne-kilometres
Air pollution	
K13. Average monthly ambient air concentrations in capital/town	Nitrogen oxides (ppb); sulphur oxides (ppb); lead compounds (ppb); benzene (ppm); average monthly level of airborne particles. Average day traffic into capital/town. Green space as a percent of total capital/town area. Annual expenditure on air pollution abatement (US$). Market share of unleaded petrol.
Traffic and congestion (per country, for 1980 and 1997)	
K14. Motor vehicles	Per capita and per kilometre of road.
K15. Passenger cars	Per capita.
K16. Two-wheel vehicles	Per capita.
K17. Road traffic	Million vehicle-kilometres
K18. Traffic accidents	People injured or killed per 1000 vehicles

2.13.3. Use of indicators and data collection

The indicators included in the work of the World Bank have been extensively used. The database is built and could be of use to other organizations as needed.

3. DISCUSSION OF THE REVIEW

Aspects of the approaches used in the five Canadian and six other examples of indicator development reviewed above are summarized in the following table.

Source	**Uses definition/vision of sustainable transportation**	**Indicator development related to the definition/vision**	**Invokes PSR or similar framework**	**Indicators presented according to framework**	**Information as to use of indicators**
Canada: Environment Canada	✗	n.a.	✓	✗	✗
Canada: National Round Table	✗	n.a.	✗	n.a.	✗
Canada: Ontario Round Table	✓	✗	✓	✗	✗
Canada: TAC	✓	✓	✗	n.a.	✓
Canada: Victoria TPI	✗	n.a.	✗	n.a.	✗
Baltic Region	✓	✓	✗	n.a.	✗
New Zealand	✗	n.a.	✓	✓	✗
OECD	✗	n.a.	✓	✓	✗
San Francisco	✓	✗	✗	n.a.	✗
United Kingdom	✗	n.a.	✓	✗	✗
World Bank	✗	n.a.	✓	✗	✗

n.a. = not applicable (i.e., no explicit definition/vision or no explicit framework)

The table shows that indicator development has been associated with an explicit definition or vision of sustainable in only four of the eleven cases, and there was an evident link between the stated definition or vision in only two of these four (the Transportation Association of Canada and the Baltic Region). The Pressure–State–Response model or a similar model of environmental impacts and responses was referred to in six of the eleven cases, but in only two of these six (New Zealand and the OECD) were the selected indicators set out according to the model used. Only one case out of the eleven cases reviewed provided information as to how the indicators had been used.

It should be stressed that the above synthesis of approaches relies on information uncovered during the rather quick review of readily available information. It may well be that there has been more reliance on definitions or visions of sustainable transportation than is suggested by the above table. It may be too that the indicated frameworks have played a larger role in the identification and organization of indicators than the table suggests. Finally, although the accounts of indicator development that have been reviewed have not provided information as to the use of the indicators, such information may be available elsewhere in the reports of the respective organizations; as well, the indicators proposed by one organization could well have been used by another organization.

The eleven cases were selected for review because in each of them the indicator development was conducted within a general effort concerning attainment of sustainable development. Numerous other potential sources were not included in the review because there was no sustainability component. However, even in the cases reviewed, it is not always evident that *sustainable transportation indicators* were being developed, as opposed to *transportation indicators*.

Possible confusion between what may be two kinds of indicator was evident at a meeting of the UN-ECE's[9] Task Force on Sustainable Urban Transport Indicators held in Barcelona, Spain, at the end of March 2000, and attended by one of the present authors (RG). Much of the meeting involved discussion of transportation indicators that had no clear relationship to sustainable transportation. This was a valuable exercise towards fulfillment of the UN-ECE's responsibility for assisting with harmonization of data gathering and presentation—for example, with respect to how data concerning the use of public transport are to be collected and represented—but for a large part of the meeting the question as to how such information could be used to contribute towards attainment of sustainable transportation was left begging.

On the second day of the Task Force meeting, discussion turned to the distinction between general transport indicators and sustainable transport indicators. There was some agreement with the proposition that the hallmark of the latter kind of indicator is that it is developed within the context of a clear statement as to the nature of sustainable transportation and clear quantitatively expressed criteria as to what constitutes attainment.

The distinction between general transportation indicators and sustainable transportation indicators my best be illustrated by a few examples, each of which features once or more often in the above review.

The indicator 'total passenger-kilometres per unit of GDP' has value as an expression of the economic efficiency. An increasing trend could suggest that transportation is being provided more efficiently; a decreasing trend could suggest that GDP growth is becoming less dependent on transport. These are useful things to know. However, such an indicator has no clear relevance to the *sustainability* of transportation, which is largely—although not entirely—a matter of intergenerational equity, i.e., whether present practices are reducing opportunities for future generations. Indeed, a declining trend could provide false comfort in that it could present the appearance of greater intergenerational equity while obscuring an absolute increase in transport activity and consequent environmental impacts.

The indicator 'total passenger-kilometres by public transport' is again a useful presentation of data about transport activity, for some purposes. An increasing trend suggests growing viability of transit operations, and vice versa. However, if the energy intensity of public transport is higher

[9] The United Nations Economic Commission for Europe (UN-ECE), based in Geneva, served from the 1940s to the 1980s as the main instrument of dialogue and cooperation between the market economies of Western Europe and North America and the command economies of Eastern Europe. Now it is a forum for economic cooperation among the countries of North America, Europe, and Central Asia. Its main purpose is to harmonize the policies and practices of its 55 member countries. Canada has been a member of the UN-ECE since November 1945.

than that of alternative modes, as it is for example in the United States,[10] then an increasing trend in the indicator does not necessarily represent progress towards sustainability.

A key focus of the work during the second day of the Barcelona meeting was the development of a list of policy objectives of the kind that could be used to frame a set of sustainable transport indicators. These objectives are attached here as Appendix A.

There seemed to general agreement at the Barcelona meeting that the most appropriate route towards development of sustainable transportation indicators involves taking the following three basic steps:

1. define what is meant by sustainable transportation;
2. quantify the elements of the definition in terms of criteria for attainment of sustainable transportation;
3. construct indicators that allow assessment of progress towards meeting the criteria.

This is essentially the strategy that guides the present indicators work of the Centre for Sustainable Transportation.

Use of such a strategy does not mean for a moment that indicators work done according to other strategies is without value. Previous and ongoing work has made important contributions to understanding both the features of transport systems and the relationships between these features and economic, demographic, and other variables. Work done within the framework of Pressure–State–Response model and its derivatives have been of particular value in contributing to understanding of the dynamics of transport systems.

[10] See *National Transportation Statistics*, Bureau of Transportation Statistics, U.S. Department of Transportation, Washington D.C., 1999 (available at www.bts.gov/ntda/nts).

4. TOWARDS DEVELOPMENT OF A LONG LIST OF INDICATORS

4.1. Preliminary categorization of indicators

Development of the initial long list of indicators developed during the second part of the present project drew heavily on the numerous indicators identified in the review in Section 2. As a step towards this development, the indicators noted in the review were sorted into three main categories, each with several sub-categories.

The sorted indicators are set out in the left-hand column of Appendix B (see Page 49). The number of each indicator indicates its source, e.g., Indicator A1 is the first-mentioned indicator in the review of Environment Canada's work in Section 2.3. Repetition of similar indicators has been avoided, with the dropped indicators shown as in the second and third indicators listed in Appendix B.

The three main categories used in Appendix B correspond to the main domains of sustainability: environmental, economic, and social. The assignment of each indicator to a specific domain was based on the description provided by the developer. In some cases this description was inadequate and the assignment was done according to what appear to be the surface nature of the indicator. Indicators that fitted under more than one domain were sometimes duplicated to reflect their multiple applicability.

Environmental domain: This is the most extensive domain in terms of the number of indicators it includes. Three sub-categories were used: emissions and concentrations; resource use including use of land; and noise.

Economic domain: The economic domain is the least extensive in terms of the number of indicators it includes. Three sub-categories were used: pricing and taxation; expenditures and subsidies; and others (including, for example, employment and GDP per unit of energy use).

Social domain: The indicators in the social domain were also allocated to three sub-categories: health and safety; accessibility; and miscellaneous (including green GDP and participation in decision-making).

Some indicators were difficult to classify. For example, are indicators concerning employment better located in the economic domain or in the social domain? In Appendix B such indicators can be found in both domains.

It was difficult to assign indicators of **transport activity** to one of the above domains. These appear in a separate category in Appendix B.

4.2. Classification of indicators in relation to definition elements

The initial step in developing a long list of indicators for carrying forward to further work was to link the 160 purported indicators of sustainable transportation compiled during the review—and listed in the left-hand column of Appendix B, which begins on Page 49—to the Centre's definition of sustainable transportation, and in particular to its 17 elements (see Section 1.1). The indicators were assessed in terms of their appropriateness to an element of the using the following rating scale:

'A' rating: the indicator provides a potentially strong, quantified indication as to progress towards or away from the aspect of sustainable transportation portrayed by the respective element;

'B' rating: the indicator provides for quantified assessment that is relevant to the respective aspect of sustainable transportation without being able to indicate the degree of progress;

'C' rating: the indicator is only loosely related to the respective element and generally does not provide for quantification

Where an indicator seemed unrelated to a particular element it was given no rating.

Section 5.1 sets out the 17 elements of the definition each with a brief commentary and associated rating criteria. (Criteria could not be developed for one of the 17 elements.) The actual ratings applied are set out in Appendix B. Section 5.2 provides some analysis of the results of the rating process.

5. ASSESSING INDICATORS IN RELATION TO THE ELEMENTS OF THE DEFINITION

5.1. Criteria for assessment

This section lists the 17 elements of the Centre's definition of sustainable transportation,[11] provides comments on each element, and sets out criteria for relating each indicator to the elements. The detailed results of the classification of indicators appear in Appendix B (see Page 49). The classification is summarized in Section 5.2 beginning on Page 40.

1. Limits emissions within the planet's ability to absorb them.

Comment: Such limitation occurs when the system produces emissions into air, water, and land within the defined notion of what might be the natural absorption capacity of the ecosystems into which they are emitted (in some cases—e.g., globally acting gases—the planet as a whole). The key notion here is that almost anything released within an ecosystem can be metabolized, but the rate of metabolism can be exceeded with resulting accumulation of what may be toxic matter. It is often useful to distinguish between globally and locally acting emissions, with emissions transported over distances—such as nitrogen oxides in air and liquid effluents running into oceans—providing a possible intermediate category of regionally acting emissions. Locally and regionally acting emissions of concern are those that have direct toxic effects on animals and plants; globally acting emissions are more likely to affect atmospheric phenomena such as radiating forcing (global warming) and depletion of the stratospheric ozone layer. Emissions occur chiefly during the operation of the system but can also occur during production, transmission, and disposal of the vehicles, infrastructure, and fuels.

Suggested classification:

A: Relates specified transport emissions to defined absorption capacity.

B: Involves quantification of transport emissions without reference to defined absorption capacity.

C: Mentions emissions but does not specify transport's share, or does not quantify them.

2. Limits wastes within the planet's ability to absorb them.

Comment: 'Wastes' is a more generic term than 'emissions'. It more usually refers to solid and liquid materials as opposed to gaseous materials (which are more likely to be called 'emissions'). As well, it more usually refers to unusable materials remaining at the end of the useful life of vehicles and infrastructure, and to unusable materials replaced during use, e.g., tires and crankcase oil, rather than to 'wastes' produced during operation. Reuse and recycling (see Element 4 below) is applicable to such solid and liquid wastes. The present element could be combined with Element 1.

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[11] For convenience, Footnote 2 containing the 17 elements ordered by domain is repeated here: The 17 elements of the deconstructed definition are: Environmental domain: limits emissions, limits waste, minimizes consumption of non-renewable resources, reuses and recycles components, minimizes use of land, minimizes production of noise; Societal domain: meets access needs of individuals, meets access needs of society, access needs are met safely, access needs met consistent with ecosystem health, access needs met with equity within this generation, access needs met with equity within generations; Economic domain: is affordable, operates efficiently, offers choice of transport mode, and support a vibrant economy.

Suggested classification:

A: Relates specified transport wastes other than emissions to defined absorption capacity.

B: Involves quantification of such transport wastes without reference to absorption capacity.

C: Mentions such waste but does not specify them as arising from transport, or does not quantify them.

3. Minimizes consumption of non-renewable resources.

Comment: This element chiefly concerns the use of petroleum as fuel and feedstock for plastic production, but also concerns the use of certain minerals (e.g., copper ore) and may concern water use in production processes. The relevant sustainability principles are that non-renewable resources should be used at rates at below the rates of development of renewable substitutes and that use of renewable resources should be used at rates below their rates of regeneration (or else they are not, in practice, renewable).

Suggested classification:

A: Relates use of non-renewable resources in transport to rates of development of renewable replacements.

B: Involves quantification of use of non-renewable resources in transport without reference to replacement.

C: Mentions use of non-renewable resources but does not specify transport's share, or does not quantify them.

4. Reuses and recycles components.

Comment: This element is of a different nature from those above in that it refers more to *methods* of achieving sustainability rather than to a basic sustainability objective. Reuse and recycling are chiefly methods of limiting the kind of wastes covered in Element 2, but also play a role in minimizing consumption of non-renewable resources for production, the concern of Element 3.

Suggested classification:

A: Relates amounts of material reused or recycled, or both, to amounts of potential waste from production and operation of transport; may also reference energy and other savings during production.

B: Quantifies reuse or recycling of materials, or both, remaining from production and operation of transport, but not in relation to amounts of potential waste.

C: Makes a general reference to the value of reuse and recycling in relation to transport, but without quantification.

5. Minimizes the use of land.

Comment: This element has somewhat different characteristics as it applies to urban and rural land. In urban areas, the use of large amounts of land for transport purposes (also known as 'land take'), including the storage of vehicles, displaces other uses and thus contributes to urban sprawl. Such use of land also has specific adverse effects, including interference with ecosystems through alteration of land—e.g., changing its albedo and changing drainage patterns—and by presenting barriers to migration and other movement. There are also adverse esthetic effects. Much but not all of the adverse effects can be reduced by minimizing land take, particularly in urbanized areas. Remaining adverse effects—e.g., barriers to migration—can be minimized by design, but in ways that are difficult to quantify.

Suggested classification:

A: Quantifies land use for all transport purposes; for urban areas this should be in relation to the total urbanized area. May quantify albedo, barrier, and drainage impacts of land used for transport.

B: Quantifies land use for transport purposes but not in relation to the amount of land in the urban area, or in relation to potential adverse impacts.

C: Makes a general reference to land take for transport, but without any quantification.

6. Minimizes production of noise.

Comment: Noise is a human health hazard and an irritant. High levels damage the auditory system. Lower levels disrupt sleep and have less specific effects. There are fairly well established critical levels for health impacts, usually different for nighttime noise and daytime noise. Because it refers to a specific health hazard, this element might be subsumed under Element 10. (However, some of the emissions referred to in Element 1 are health hazards and are not suggested for inclusion under Element 10.)

Suggested classification:

A: Accounts for noise from transport in relation to acceptable levels for human health.

B: Quantifies noise from transport but not in relation to critical levels.

C: Makes only a general reference to noise from transport.

7. Meets the basic access needs of individuals.

Comment: This element could be clearer if it referred to 'transport' needs or to 'mobility' needs rather than to 'access' needs. It refers to the extent to which a transport system makes possible the necessary movements of people in their everyday lives: to go to work, meet friends and relatives, buy goods, receive services, visit parks and natural areas, and so on. 'Access' is used in the definition to make two points. One is that 'mobility' is a need for the most part only to the extent that it enables a more basic need to be met (such as those indicated above). The other is the basic needs can often be met without mobility, as when goods are delivered, or with less mobility, as when a workplace is nearby rather than distant. Better mobility—i.e., more or better transport—can be replaced by better access, i.e., closer proximity or other better availability to what is required. For a transport system to be sustainable, the needs of individuals have to be met with a minimum of motorized mobility, particularly motorized mobility that makes use of non-renewable resources, notably fossil fuels. Thus sustainable transportation requires an emphasis on avoiding the need for journeys of more than a few kilometres, and providing that such long journeys as occur are made using systems based on renewable energy. There are two main aspects to the quantification of meeting access needs sustainably. One is that people's needs are met. The other is that little transport energy is used to meet them. The present element is concerned with the first aspect only, specifically whether the transport system is a facilitator or constraint to the meeting of needs. In terms of securing data, people may be more likely to respond to what constrains them rather than what facilitates them. The term 'basic' in the definition is problematic in that it introduces a more subjective aspect, although the idea of 'need' itself is also somewhat subjective.

Suggested classification:

A: Quantifies the extent to which lack of transport constrains (or availability of transport facilitates) the meeting of defined everyday needs, such as employment and food shopping.

B: Quantifies availability of transport facilities or services to individuals but not in relation to their particular needs, or quantifies an aspect of a need (e.g., distance between home and workplace) but not in relation to the availability of transport.

C: Makes only a general reference to the availability of transport facilities or services to individuals.

8. Meets the basic access needs of society.

Comment: There are two considerations here. The first—which is more or less important for different societies—is that the society can trade, and has the transport means to effect the trade. Tradable goods and services can be accessed at various distances and by various modes, and can be replaced by local products. The second consideration is that the internal workings of society essential for its collective needs—which may be more than the sum of the individual needs addressed in Element 7—are not impeded by insufficient transport. These internal workings may require more or less actual transport. Much business, for example, can be transacted electronically without the movement of people or even paper. As in the case of individuals, for a transport system to be sustainable, the collective needs of society would have to be met with a minimum of motorized mobility, particularly motorized mobility that makes use of non-renewable resources, notably fossil fuels. Thus sustainable transportation requires an emphasis on avoiding to the extent possible the need for movement of people and goods by more than a few kilometres, and providing that such long movements as occur are made using systems based on renewable energy. The basic question here is whether the collective needs of society are impeded by lack of transport. The challenge is that of defining and quantifying collective needs. There is also the matter of addressing for societies, as for individuals, what is meant by a '*basic* need'.

Suggested classification:

A: Quantifies the extent to which lack of transport constrains trade and the other collective needs of the society, such as for efficient government, business, and education.

B: Quantifies society-wide availability of transport but not in relation to particular needs.

C: Makes only a general reference to the society-wide availability of transport.

9. Consistent with human health.

Comment: The transport system could be responsible for levels of emissions and waste within 'natural absorption capacity' (Elements 1 and 2) and still cause problems for human health. Thus, if human health is considered to be an important attribute of sustainability then appropriate indicators are required. (See Element 11 below for a discussion of how health and safety might relate to sustainability.) The most direct kind of indicator would address such matters as the prevalence of transport-related diseases. However, the relationships between transport activity and disease are often not clear, and the best available indicators may concern only the *conditions* for disease—e.g., high atmospheric concentrations of certain pollutants—rather than the diseases themselves. The difference should be noted between *emissions* of pollutants or their precursors, covered by Element 1, and *atmospheric concentrations* of pollutants, which are part of the present concern. Acceptable levels of most transport-related pollutants in relation to human health have been established by bodies such as the World Health Organization.

Suggested classification:

A: Quantifies the prevalence of transport-related diseases in humans.

B: Quantifies the incidence of transport-related conditions for the occurrence of human ill-health, e.g., exceedences of WHO standards for carbon monoxide.

C: Makes only a general reference to transport and human health.

10. Consistent with ecosystem health.

Comment: This element is redundant to a degree with Elements 1 and 2 in that those elements refer to maintaining transport's emissions and waste within ecosystems' natural absorptive capacities. This is perhaps the most important requirement for the health of an ecosystem: that it is not affected by toxins to the degree that they can accumulate. There are other requirements. For example, ecosystems need enough nutrients (which may include water and sunlight) and enough space for proper functioning. A challenge for indicators development is that, unlike human health and ill-health (see Element 9), the concepts of ecosystem health and ill-health are not well developed.[12] For the moment, in the absence of something better, the classifications suggested in relation to the present element are based on those provided for Element 9.

Suggested classification:

A: Quantifies the prevalence of transport-related diseases in ecosystems.

B: Quantifies the incidence of transport-related conditions for the occurrence of ecosystem ill-health, e.g., extent of eutrophication.

C: Makes only a general reference to transport and ecosystem health.

11. Access needs are met safely.

Comment: The key question here may be the relation between safety and sustainability. It is similar to a question that can be raised about human health and sustainability (Element 9). Almost nobody wants transport to be unsafe, and thus to the extent that 'sustainable' means 'desirable' or 'good' it follows that collisions etc. are unsustainable. However, it is evident that a certain level of harm from transport activities is considered sustainable, or at least acceptable. Moreover, collisions create economic activity in hospitals and body shops and can thus contribute to economic sustainability. Obviously a level of harm could be reached at which a transport system would be essentially dysfunctional, but tolerable harm is far from that level. The basic question is whether sustainability in any way implies avoidance or harm or distress to humans. The answer depends on the degree of ethnocentricity of the concept of sustainability that is employed. If the defining feature of sustainability is maintaining the conditions whereby future generations [of humans] can meet their needs—as it is taken to be here—transport must be safe enough to avoid harm or distress that might reduce later opportunities. If sustainability means maintaining the habitability of the planet for the largest number of species, then the record suggests that reducing

[12] "Ecosystem health is defined as a systematic approach to the preventive, diagnostic, and prognostic aspects of ecosystem management, and to the understanding of relationships between ecosystem health and human health." International Society for Ecosystem Health (www.oac.uoguelph.ca/ISEH/). "Ecosystem health refers to the vigour and resilience of ecosystems and landscapes. The ability of a given ecosystem to provide necessities of life for human and non-human populations—such as production of food, raw materials, nutrient cycling—is dependent upon that ecosystem's health. Ecosystem health is fundamental to the well-being of all living things on the planet." Saskatchewan Ministry of Environment and Resource Management (www.serm.gov.sk.ca/ecosystem/monitoringconference/index.php3).

the human population and its endeavours could be more sustainable. The similarity of the considerations of the present element to those of Element 9 suggests that the two might be combined. The suggested classification is based on that for Element 9.

Suggested classification:

A: Quantifies the prevalence of deaths and injuries related to transport activity.

B: Quantifies the incidence of transport-related conditions for the occurrence of deaths and injuries, e.g., high speed limits and lack of separation of facilities for non-motorized modes.

C: Makes only a general reference to transport safety.

12. Access needs are met consistent with equity within the present generation

Comment: This element responds to the part of the most accepted definition of sustainability that concerns meeting the needs of the present generation. [13] It goes further in suggesting that moving towards equity among the current human inhabitants of the planet is desirable. Equity involves moderating the divisions in society, or at least not accentuating them. Thus the relevant indicators should speak to the extent to which the transport system increases or reduces social polarization. This is usually thought of in terms of income, but may be considered also in terms of opportunity. For example, that where the automobile is the only form of passenger transport, the very old, young teenagers, and other non-drivers can be at a greater disadvantage than when public transit is available, because transit can be used independently by a wider ranger of people. To the extent that equity within generations is a societal need, the present element could be subsumed under Element 8.

Suggested classification:

A: Quantifies the extent to which transport facilitates or impedes social polarization.

B: Quantifies social polarization but without specific reference to transport.

C: Makes only a general reference to social polarization.

13. Access needs are met consistent with equity across generations

Comment: This element responds to the central part of the most accepted definition of sustainability, the part that concerns no compromising the ability of future generations to meet their own needs.[14] Intergenerational equity is the defining feature of sustainability, and provides the main basis for inclusion of Elements 1-3. Devising an indicator that would embrace the whole of the rich notion of intergenerational equity would be difficult. The indicator would speak to somewhat unquantifiable matters such as loss of opportunity. Strong elements of the notion are contained in Elements 1-3. However, the maintenance of opportunities across generations includes such aspects as education, culture, and social structure. These aspects are not included in Elements 1-3 and comprise for the most part the unquantifiable aspects of the concept. No classification is offered either because the present element is redundant in relation to Elements 1-3 or because it refers to matters that are unquantifiable.

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[13] In the final report of the World Commission on Environment and Development (1987), sustainable development is defined as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs.” (p. 43)

[14] See Footnote 13.

14. Is affordable

Comment: The affordability of transport can be absolute or perceived. In the former case a person or society may be without the means to pay for transport or transport facilities (including vehicle ownership and operation, and the installation and maintenance of infrastructure). In the latter case there are funds available but the cost is considered excessive in relation to other uses of the funds. Thus affordability can relate both to the cost of transport and to its perceived or relative cost in relation to such matters as disposable income or capacity for investment. This element may be covered entirely by Elements 7 or 8, or both.

Suggested classification:

A: Relates the cost of transport use or services to available funds, whether for individuals or society as a whole.

B: Quantifies the cost of transport use or services, but not in relation to available funds.

C: Makes only a general reference to the cost of transport use or transport services.

15. Operates efficiently

Comment: Efficiency in relation to the operation of transport operation can have several senses: efficient use of fuel and materials, and efficient use of labour and equipment. Efficiency can also refer to such matters as reliability and predictability, and the degree to which the transport system expedites timely movement from one place to another. The classification used here embraces the last kind of sense by focusing on the quality of the transport system, for the movement of people or goods. As in the case of affordability (Element 14), the present element may be covered largely by Elements 7 or 9, or both. Some parts of the present element (e.g., fuel efficiency) may be covered by Element 3.

Suggested classification:

A: Quantifies the actual or perceived quality of the transport system against an accepted benchmark.

B: Quantifies the actual or perceived quality of the system without reference to a benchmark.

C: Makes only a general reference to the quality of the transport system.

16. Offers a choice of transport modes

Comment: Part of the sense of this element is contained in aspects of Element 15, and thus in Elements 7 and 8, in that an attribute of quality in that a feature of efficiency/quality is that choices are available in the event of malfunction. There is a more fundamental sense in which choice may relate to sustainability. Human society is an evolving, adapting system and variety can contribute greatly to adaptability. If the only way of crossing the Atlantic involves large expenditures of fuel and strong contributions to climate change, there will be more pressure to retain this method in spite of its unsustainable nature. However, if there are several ways of making the crossing, some more sustainable than others, reducing use of the most unsustainable mode could be less painful and thus more likely to occur.

Suggested classification:

A: Quantifies the number of practicable alternative ways of making several specific journeys or types of journey, for passengers or freight.

B: Quantifies the number of transport modes available without relating them to particular movements or people or freight.

C: Makes only a general reference to the availability of choices of transport mode.

17. Supports a vibrant economy

Comment: Transport is a paradox. The manufacture, use, reuse, and disposal of vehicles, fuels, and infrastructure comprise major sectors of modern economies. The more transport there is available, and the more spent on transport, the greater the contribution to Gross Domestic Product and perhaps to other indices of general economic well-being. On the other hand, individual businesses are profitable to the extent they keep transport costs low, and thus avoid the use of transport to the extent consistent with efficient operation. The second factor is given less prominence in economic discourse, in part because of preoccupation with GDP as an indicator of economic progress. Because of these two largely contradictory factors, it may be difficult to devise a single indicator of the extent to which transport contributes to a vibrant economy. A complex indicator could provide some kind of trade-off between the two kinds of factor. The classification proposed here gives more weight to the second factor.

Suggested classification:

A: Quantifies the factor cost of transport in the production and distribution of goods and services.

B: Quantifies the economic value of the transport sectors.

C: Makes only a general reference to the economic impacts of transport.

5.2. Classification of indicators

The table in Appendix B (Page 49) shows how the indicators were classified in relation to the elements. Of the total of 160 indicators subjected to classification, 11 were not assigned to any element, 101 were assigned to one element only, 37 were assigned to two elements, and 11 were assigned to three elements.

The numbers of A, B, and C classifications assigned to each element are shown in the table on the next page. Several things are apparent from this table.

- The first is that only three of the elements have ‘A’ class indicators assigned to them (#11, #12, and #14). This suggests that the indicators examined in Part 1 of this work were for the most part *not* appropriate for use as indicators of progress towards or away from sustainable transportation. The usual basis for the inappropriateness is that the indicators are not quantified or quantifiable in relation to particular values considered here to be consistent with sustainable transportation. Numerous gaps remain to be filled. This task is begun here in Section 6.1.

- Two elements have neither an ‘A’ nor a ‘B’ class indicator assigned to them (#9 and #13). One of these (#13) had no assignments because appropriate criteria could not be developed. Developing indicators for these two elements will present special difficulties, probably on account of the complexity of the elements.

Assignment of indicators to elements by classification

ELEMENT	Number of indicators classified in relation to element as: A	B	C	Total
1. Limits emissions (within planet's ability to absorb them)	0	15	3	18
2. Limits waste (within planet's ability to absorb them)	0	1	0	1
3. Min. consumption of non-renewable resources	0	6	9	15
4. Reuses and recycles components	0	1	0	1
5. Minimizes the use of land	0	14	9	23
6. Minimizes production of noise	0	2	5	7
7. Meet the basic access needs of individuals	0	35	16	51
8. Meets the basic access needs of society	0	9	5	14
9. Consistent with ecosystem health	0	0	23	23
10. Consistent with human health	0	1	8	9
11. Access needs are met safely	1	0	4	5
12. Access needs are met consistent with equity within the present generation	1	1	3	5
13. Access needs met with equity across generations	0	0	0	0
14. Is affordable	3	6	4	13
15. Operates efficiently	0	4	7	11
16. Offers a choice of transport modes	0	5	1	6
17. Supports a vibrant economy	0	1	5	6
Totals	**5**	**101**	**102**	**208**

- A total of nine elements, including the two just mentioned, had fewer than three class ‘A’ or ‘B’ indicators assigned to them (#2, #4, #6, #10, #11, #12, and #17—as well as #9 and #13). These elements may also present difficulties, although this may depend on the quality of the indicators that do correspond to them.

- Three elements have numerous class ‘B’ indicators assigned to them, notably #7 but also #1 and #14. The challenge here will be of a different kind: to fashion one or two indicators when there may be so many potential indicators to work with.

In all, 85 of the initial list of 160 indicators were involved in one or more ‘A’ or ‘B’ designations (65 indicators were associated with one element, 19 with two elements, and one with three elements). These elements were considered to be useful for carrying forward to a subsequent stage of indicator development. However, the approximate number of potential indicators we wanted to carry forward was 75, and room had to be created for the identification of potential indicators to fill the identified gaps. Accordingly, these 85 potential indicators were reduced in number to 69 by further consolidation of similar items and by elimination of items specific to places outside Canada. These 69 potential indicators are listed in Appendix C on Page 55, which shows the final list to be carried forward for further consideration.

6. FILLING THE GAPS

6.1. Providing Class A indicators for as many elements as possible

The analysis conducted in Section 5.2 showed that close matches could not be found for most of the elements of the Centre's definition among the indicators identified in Part 1 of the project. Accordingly, the list in the table below was developed, based on the Class A criteria set out in Section 5.1. The issues addressed by each element are complex, and thus in each case an *index* is proposed, i.e., a carefully constructed composite of several variables.[15]

Development of further indicators

Element and *proposed indicator*	Comment
1. Limits emissions within the planet's ability to absorb them. *Index of specified transport emissions in relation to defined absorption capacity.*	Ways would have to be found of aggregating diverse emissions and diverse capacities. Capacities would be set in terms of established standards for public and ecosystem health. Numerous Class B indicators for specific emissions are being carried forward for consideration.
2. Limits wastes within the planet's ability to absorb them. *Index of specified transport wastes in relation to defined absorption capacity.*	Ways would have to be found of aggregating diverse wastes and diverse capacities. Capacities would be set in terms of established standards for public and ecosystem health. With difficulty, this indicator could be combined with the indicator for Element #1.
3. Minimizes consumption of non-renewable resources. *Index describing the rates of use of non-renewable materials in relation to the rates of growth of production of renewable replacements.*	Presently fossil fuel use is the main problem; as these are replaced other non-renewable materials will assume importance. May also be considered a *method* of achieving sustainability. Several Class B indicators of fuel and energy use are being carried forward for further consideration.
4. Reuses and recycles components. *Index of the degree of reuse and recycling in relation to amounts of potential waste from production and use.*	This is a *method* of achieving a sustainability objective (that implied in Element #2) and is also considered in Section 6.2.
5. Minimizes the use of land. *Index of the amount of land used for all transport purposes in relation to total urbanized land area.*	As stated, this indicator would concern amount of land only and not the adverse effects of land use for transport: e.g., on albedo and drainage. Several Class B indicators of land use are being carried forward for further consideration.
6. Minimizes production of noise. *Index of transport noise in relation to established critical levels for health impacts.*	This might be considered in relation to Element #9 as serious noise effects are health effects. However, because of the importance of noise and its tendency to increase with some measures to reduce pollution, there is justification in considering a separate indicator.

[15] What is meant by an index can be gained by the following *hypothetical* example, based on the first potential index listed in the table below. Investigation may suggest that carbon dioxide and fine particulate matter are the only emissions that need be represented in the index because other transport emissions vary with one of the other of these two. Moreover, the base (say 2000) levels could be set at, respectively 80 and 20, reflecting the relative harm done, with the target levels in each case set at zero. Movement of the index towards zero would indicate movement towards sustainability.

7. Meets the basic access needs of individuals. *Index of the extent to which lack of transport constrains the meeting of defined everyday needs.*	This is a critical indicator that poses several questions of definition and conceptualization. The proposed indicator is phrased in terms of *constraints*— because that is the matter on which the key data might be collected—but could equally be phrased in terms of facilitation. Very many Class B indicators of availability of transport facilities are being carried forward for further consideration, but none on the extent to which needs are met.
8. Meets the basic access needs of society. *Index of the extent to which lack of transport constrains the meeting of the collective needs of society.*	The issues here are similar to but more complex than those concerning Element #7. In considering collective needs, the temptation will be to focus on economic imperatives. There are importation but determine only some of society's basic access needs. A key matter will be distinguishing societal from individual needs. Some Class B indicators of transport activity and availability of transport facilities are being carried forward for further consideration.
9. Consistent with human health. *Index of the prevalence of transport-related diseases in humans.*	One issue is assessing the contribution of transport to disease. Another, even more difficult issue, is considering the broadest definition of health, which goes beyond the avoidance of disease to include other aspects of well-being.
10. Consistent with ecosystem health.	No index is proposed here as the main requirements for ecosystem health are covered by Elements #1 and #2. However, this could be regarded as a serious omission to the extent that ecosystem health is considered to be the defining feature of sustainability.
11. Access needs are met safely.	This is one of the few elements to have assigned to it a Class A indicator (see Indicator F12 in Appendices A and B). As well, because of the element's questionable relation to sustainability, and its close relation to Element #9, no new indicator is proposed.
12. Access needs are met consistent with equity with the present generation. *Index of the extent to which transport contributes to social polarization.*	Equity is taken to mean the opposite of social polarization, which is a slippery and politically charged concept that may be difficult to quantify. A more narrow interpretation could refer only to equity of access, which would make this element an aspect of Element #7 or #8. A Class A indicator that captures the more narrow sense (see Indicator E1 in Appendices A and B) has already been associated with this element.
13. Access needs are met consistent with equity across generations.	It is difficult to conceive of relevant quantification that would not be covered by Elements #1, #2 or #3, and thus no indicator is proposed. However, as with Element #10, this element points to what many regard as a defining feature of sustainability. Thus, the lack of a specific indicator could be regarded as a serious omission.
14. Is affordable.	This element has been associated with the largest number of Class A indicators (see Indicators E1, E12, and E18 in Appendices A and B). However, it is likely entirely covered by Elements #7 or #8, or both. For these reasons, no further indicator is proposed.
15. Operates efficiently. *Index of the actual or perceived quality of the transport system in relation to an accepted benchmark.*	Only one of the several senses of 'efficiency' is addressed here. Constructing the necessary variable and establishing the quality benchmark could present profound difficulties. As in the case of Element #14, this element may be covered entirely by Elements #7 or #8, or both.

16. Offers a choice of transport modes. *Index of the availability of transport opportunities for moving people and freight.*	This element is considered to go beyond matters of quality and address a fundamental requirement for a successfully evolving system—that of variety—and thus what may be a essential component of sustainability.
17. Supports a vibrant economy. *Index of the factor cost of transport in the production and distribution of goods and services.*	As noted earlier, there are two, somewhat contradictory senses in which transport can contribute to the economy. The sense focused on here refers to its economic efficiency. It may readily be subsumed under Element #8.

The 13 indicators proposed in the above table are included in Appendix C on Page 55, which presents the list of indicators that could receive further consideration.

6.2. Two further potential indicators

The indicators reviewed in Part 1 of this project for the most part did not address the matter of monitoring *actions* taken to modify transport behaviour and otherwise move Canada's transport systems towards sustainability. One of the elements of the definition speaks to such an action or method—#4. Reuses and recycles components—but addresses only a small part of the total effort that will be required. In tracking progress towards sustainable transportation, it could be useful to have at least one indicator that speaks to the totality of the effort being undertaken to achieve this end.

The indicator proposed for this purpose is as follows:

> *Index of the number and intensity of the actions undertaken to change the trajectory of Canada's transport system from 'business as usual' to one consistent with attainment of sustainability.*

This would a different kind of indicator or index from most of the others in that it refers to the behaviour of government officials and others rather than to features of the transportation system. It will likely be especially difficult to construct and analyze. For these reasons, it may well be given a low priority in a subsequent analysis.

Consideration of the Centre's definition of a sustainable transportation system in the course of the work reported here suggested that it lacks an important element. The present definition does not speak to the need to use renewable resources sustainably, for example, to use fresh water within the rate of natural regeneration or to engage in artificial regeneration that maintains the stock of fresh water.[16] The following new element, with a suitable amendment to the third bullet point of the Centre's definition (see Page 1), would remedy the omission: *uses renewable resources at below their rates of regeneration*.

A potential index for this new element could be the following, which is based on the index for Element #3 in the table in Section 6.1:

[16] This notion is given prominence in the brief definition used within the OECD's EST project: *An environmentally sustainable transport system is one 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.*

Index describing the rates of use of renewable resources in relation to the rates of their regeneration.

These two potential indicators, together with the 13 developed in Section 6.2 and the 69 indicators identified in Section 6.1, form the list of 84 indicators to be carried forward for further consideration. This list is provided in Appendix C on Page 55

7. RATIONALIZATION OF THE ELEMENTS OF THE CENTRE'S DEFINITION

The development of indicators in relation to a definition is essentially an exercise in operationalization of the definition that calls into question its integrity, coherence, redundancy, and utility.

The detailed examination of the Centre's definition allows the conclusion that it could be reduced to the following (comprised elements of the Centre's definition are in brackets after each of the new elements, numbered as in the table in Section 6.1):

A. Limits emissions and other wastes from transport within natural absorption capacity (#1, #2, #10, #13)
B. Minimizes consumption of non-renewable resources including land (#3, #4, #5, #14)
C. Meets the basic access needs of individuals (#7, #8, #11)
D. Meets the basic access needs of societies (#8, #12, #14, #15, #17)
E. Meets the needs safely and in a manner consistent with human health (#6, #9, #11)
F. Provides a choice of transport mode (#16)

As well account could be taken of the new element proposed in Section 6.2. This would be added to the above list in the following way, and would not comprise elements of the Centre's definition:

G. Uses renewable resources at below their rates of regeneration

This refined list is proposed for guidance during subject work on development of STPI rather than as a recommendation to change the Centre's definition. The Centre's definition contains many redundancies that they help convey meaning and flavour. However, consideration could be given to changing the Centre's definition to include the newly identified element.

8. FUTURE WORK

Proposed future work, subject to the availability of funding, is to involve refinement of the preliminary long list of STPI indicators in Appendix C to a short list of about ten indicators, and a very short list of about four indicators. The short list is to be designed for use by transport professionals and the very short list for use in communicating to the general public. Policy-makes could make use of both lists.

Factors to be taken into account in developing the short lists include the following:

Availability of data: An indicator is only as valid and reliable as the data on which it is based. Lack of good data precludes the use of an indicator; although the potential utility of an indicator may stimulate data development.

Ease of understanding: For an indicator to be useful, especially for the general public, it must be understandable, both in what it describes and in what changes in the indicator mean. For professionals, there must also be ease of comprehension as to how the indicator is constructed.

Comprehensiveness: Transportation is an enormously complex activity involving numerous modes with wide ranges of environmental, social, and economic impacts at many levels of societal organization across many geographical circumstances. To the extent possible, the indicator sets should capture this complexity (without sacrificing ease of comprehension).

Usefulness: The exercise of indicator development is justified only to the extent that the resulting indicators will be used. In particular, they should signal the need for remedial action, the kinds of changes required—e.g., whether in technology or transport activity—and even the nature of the remedies to be applied.

In proceeding towards the difficult work of developing the short lists of indicators, it is proposed to hold a workshop at an early date involving potential users of the indicators. The actual development would be strongly guided by the outcome of this workshop.

APPENDIX A

POLICY OBJECTIVES FOR SUSTAINABLE TRANSPORTATION DEVELOPED AT THE BARCELONA UN-ECE TASK FORCE MEETING

(see Page 30)

Overall Policy Objectives (ranked, except for #4):

1. There should be good and safe access for all to people, goods, and services throughout the urban area.

2. The transport system (in all cases referring to the movement of both people and freight) should be responsible for a sustainable level of resource use, including land.

3. The transport system should be responsible for a sustainable level of emissions into air, water, and land, including noise.

4. In matters concerning the transport system, directly and indirectly, there should be a high level of citizen satisfaction and a high quality of life.

Supporting policy objectives (not ranked):

5. The transport system should be economically efficient and affordable for the community.

6. The transport system should be affordable for all social groups.

7. All aspects of the transport system should be suitable for people of limited mobility.

8. All parts of the transport system should be well integrated, especially as regards non-motorized modes.

9. Public transport should be agreeable, convenient, and punctual.

10. Generally speaking, the highest priority should be given to non-motorized modes.

11. Freight logistics throughout the urban area require high-priority attention.

APPENDIX B

INDICATORS IDENTIFIED DURING THE REVIEW AND THEIR APPROPRIATENESS TO THE DEFINITION ELEMENTS

Element number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
Element **INDICATORS IDENTIFIED DURING THE REVIEW** (see Section 2 of this report)	Limits emissions (within planet's ability to absorb them)	Limits waste (within planet's ability to absorb them)	Min. consumption of non-renewable resources	Reuses and recycles components	Minimizes the use of land	Minimizes production of noise	Meet the basic access needs of individuals	Meets the basic access needs of society	Consistent with ecosystem health	Consistent with human health	Access needs are met safely	Access needs are met consistent with equity within the present generation	Access needs met with equity across generations	Is affordable	Operates efficiently	Offers a choice of transport modes	Supports a vibrant economy	NUMBER OF ELEMENTS TOUCHED
ENVIRONMENTAL																		
EMISSIONS AND CONCENTRATIONS																		
A1. Toxic substances in urban air: benzene	B								C	C								3
A8. Global atmospheric concentration of greenhouse gases (see also C1)	B								C									2
B8. Greenhouse gas emissions from transportation (see also A7, D33, D34, F6, F24, J11, K3)	B								C									2
F3. NO_x emissions	B								C									2
F4. Hourly average concentration of ozone in suburban areas and annual concentration (mean) of benzene in central urban areas	B								C	C								3
F5. Mean annual concentration of particulates in central urban areas	B								C									2
F20. Contribution to overall NO_x emissions in per cent	B								C									2
F21. Contribution to the overall nitrogen input to the Baltic Sea in percent	B								C									2
F22. Contribution to the overall emission of VOCs	B								C									2
F23. Contribution to the pollution of the Baltic Sea with hydrocarbons	B								C									2
F25. Contribution to final energy consumption			B															1

Element number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
G12. Sediment loads in streams (pressure indicator)	C								C									2
G32. Mobile source emissions, for CO, NO_x and PM_{10} (see also J7)	B								C									2
G33. Resident population exposure to local atmospheric concentrations of CO, NO_x and PM_{10}										B								1
H5. Air pollution (see also E16)	C								C	C								3
J8. Black smoke emissions	B								C	C								3
J9. Lead emissions	B								C	C								3
J10. Nitrogen dioxide concentrations	B								C									2
K4. Methane (CH_4) emissions; emissions of ozone-depleting substances	B								C	C								3
K13. Average monthly ambient air concentrations in capital/town	C								C									2
RESOURCE USE (INCLUDING LAND USE)																		
A2. Fossil fuel consumption (see also A4, K2)			C															1
A5. Fuel efficiency of new automobiles.			C															1
B2. Per-capita use of transportation energy			B															1
B4. Unit sales of cars and trucks							B											1
B7. Per-capita gasoline consumption vs. urban density			B															1
C2. Ecological footprint			C															1
C3. Habitat disruption and land use					C				C									2
C15. Demotechnic Index			C															1
C16. E-index			C															1
C18. Non-fossil fuel use			C															1
C19. Energy efficiency			C															1
D5. EUA land area					C													1
D9. Arterial lane-km per 1000 capita in EUA					B													1
D10. Expressway lane-km per 1000 capita in EUA					B													1
D15. Off-street parking spaces per employee in CBD					B		B											2
D31. Fuel use per capita in EUA			C															1
D32. Fuel use per person-trip in EUA			B															1
E3. Per-capita automobile use							B											1
E6. Per-capita land area paved for roads and parking facilities					B													1
E9. Land use mix (proximity of residential, community, and employment centres) (see also C20)					C													1
F7. Length of railways and main roads (see also F14)					B		B		C									3
F8. Share of areas larger than 100 km2 not separated by motorways					B													1
F10. Percentage of reused or recycled parts of different types of end-of-life vehicles		B		B														2
F11. Final energy consumption by modes and fuel type			B															1
G3. Overall urban density																		0

Element number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
G10. Total area of land under transport land use					B				C									2
G25. Combined indicator that breaks down land transport use by type of use (information from GIS)					C													1
G29. Percentage of road system by road surface texture, subdivided into urban/rural and by traffic volume category (see also K5)															C			1
G30. Annual new road construction (see also J5)					B		B		C									3
G31. Area of arable land use converted to road or rail reserve					B		B		C									3
H3. Fuels consumption			C															1
H4. Infrastructure					C		C											2
I2. Parking spot inventory					B		B											2
NOISE																		
F9. Day and night time noise levels in residential, mixed, and industrial areas						B												1
G8. Residential population exposed to outside road traffic noise						C												1
G9. Residential population exposed to outside airport noise						C												1
G14. Marae and papakainga: noise from transportation networks						C												1
G27. Residential population exposed to indoor road traffic noise						C												1
G28. Change in vehicle fleet noise generation						B												1
ECONOMIC																		
PRICING AND TAXATION																		
B6. Gas and diesel fuel prices at the pump														B				1
D30. Farebox revenue/operating and maintenance budget														B				1
G26. Transport cost index												C		B				2
H7. Pricing and taxation														B				1
J3. Real changes in the cost of transport												C		B				2
EXPENDITURES AND SUBSIDIES																		
D28. Total road expenditures per capita in region														C				1
D29. Total transit expenditures per capita in region														C				1
E1. Average portion of household expenditures devoted to transportation												A		A				2
E18. Portion of transportation-related costs paid by public funding (see also H8)														A				1
F18.Total investment in maintenance costs with regard to road, rail, harbor and air infrastructure														C				1
F19. Investments dedicated to environmental protection																	C	1
G17. Subsidized urban public transport journeys, available seats, and utilization														C				1
OTHERS																		
C4. Employment																	C	1
C14. Distribution Inequality Index												C						1
E17. Medical costs attributed to transportation										C	C							2
K1. GDP per unit of energy use																	B	1

Element number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
SOCIAL																		
HEALTH AND SAFETY																		
C11. Deaths and injuries											C							1
C12. Crime											C							1
F12. Number of fatalities and injuries per year in transport (see also E14 and K18)											A							1
F13. Number of cases of serious pollution or health effects										C								1
H6. Safety risks											C							1
ACCESSIBILITY																		
C7. Commute cost												B		B				2
C8. Population density (persons/ha).																		0
C10. Commute time (population within 30 minutes commuting time of natural areas).															C			1
C17. Vehicle access (see also B3, B4, D12, E3, F15, G2, I1, K14, K15, K16)							C											1
C20. Mixed land use					C													1
C21. Trips with two or more modes																B		1
D7. Employment density in EUA					C													1
D8. Employment-to-population ratio in CA					C													1
D25. Average home-work trip distance in EUA							B											1
E2. Average amount of residents' time devoted to non-recreational travel															C			1
E4. Ability of non-drivers to reach employment centres and services							C								C			2
E5. Quality of pedestrian and bicycle environment															B			1
E7. Quality of public transit service (hours of service, frequency, speed relative to auto, safety, comfort), integration with other modes															B			1
E8. Average number of major services within walking distance of residents and average distance (walking) between residences and public services.							B											1
E10. Quality of delivery services															B			1
E11. Quality of mobility services for residents with special mobility needs.															B			1
E12. Affordability of public transit service by lower income residents														A				1
E13. Proportion of residents with public transit service within 500 metres (see also G22)					B		B											2
F1. Length of public transport network (rail and buses)					B		B	B										3
F2. Number of food shops in a certain area																		0
G1. Change in level of road congestion over time																		0
G13. Waahi tapu: location of transportation networks					C		C	C										3
G23. Proportion of traffic zones and trips served by a direct public transport connection; proportion of suburban traffic zones served by a direct public transport connection to the Central Business District (CBD)					B		B											2
G24. Parking supply per worker: CBD and inner urban area					B		B											2
I4. Transit running time on key routes															C			1

Element number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
MISCELLANEOUS																		
C5. Green GDP																	C	1
C13. Community disruption						C												1
D1. Population in region																		0
D2. Employment in region																		0
D3. Population in EUA																		0
D6. Population density in EUA																		0
E19. Residents' participation in transportation and land-use decision-making.																		0
TRANSPORTATION ACTIVITY																		
A3. How Canadians travel																		0
A6. Urban transit and automobile use							B											1
B5. Total kilometres driven in Canada							C											1
C9. Non-auto trips (% of urban trip not by automobile).							B									C		2
D11. High-occupancy-vehicle (HOV) lane-km per 100,000 capita in EUA							B											1
D12. Automobiles per capita in EUA							B											1
D13. Morning peak period transit seat-km per capita in EUA							B											1
D14. 24-h transit seat-km per capita in EUA							B											1
D16. Morning peak period transit mode share to/from CBD							B									B		1
D17. Morning peak period auto mode share to/from CBD (drivers and passengers)							B											1
D18. Morning peak period auto mode share for EUA (drivers and passengers)							B											1
D19. Morning peak period auto occupancy to/from CBD							C											1
D20. Morning peak period auto occupancy for EUA							C											1
D21. 24-h person trips per capita for EUA							B											1
D22. Annual transit rides per capita for EUA*							B											1
D23. 24-h arterial auto vehicle-km per capita for EUA							C											1
D24. Average-day vehicle-km per capita, calculated from fuel sales							C											1
D27. Road Utilization Index (RUI) in EUA							C											1
E15. Per-capita energy consumption in respect of transportation			B															1
F16. S Traffic volumes of road, rail, air, sea (vehicle-kilometres)								B										1
F17. S Total passenger and cargo turnover by air, ship, road, rail; mode shifts							B	B										2
G4. Usual mode of transport for journey to work							C											1
G5. Vehicle-kilometres of travel by road users							C											1
G6. Passenger-kilometres							C											1
G7. Freight tonne-kilometres								C										1
G15. Hours flown by New Zealand registered civil aircraft on domestic transport operations							B	B										2

Element number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
G16. Average trip length															C			1
G18. Percentage of urban journeys by mode of transport (excluding cycle/walk)							B									B		2
G19. Percentage of short urban journeys by mode of transport							B									B		2
G20. Percentage of inter-urban passenger trips by mode of transport							B									B		2
G21. Public transport route length/highway route length							B	B										2
H1. Transport intensity																	C	1
H2. Vehicles							B											1
I3. Transit ridership							B											1
J1. Car use and total passenger travel							B											1
J2. Short journeys							C											1
J4. Freight traffic								B										1
J6. Regular journeys							C											1
K6. Goods transported by road								C										1
K7. Passenger-kilometres per US$ million of GDP (purchasing parity)																	C	1
K8. Goods transported by railways								C										1
K9. Diesel locomotives available								B										1
K10. Aircraft departures							B	B										2
K11. Air passengers carried							B											1
K12. Air freight carried								B										1
K17. Road traffic							C	C										2
NOT READILY CLASSIFIABLE																		
B1. Worldwide major natural disasters																		0
G11. Percentage of arterial roads and state highways with appropriate levels of stormwater treatment															C			1

APPENDIX C

LONG LIST OF POTENTIAL INDICATORS FOR CARRYING FORWARD TO FURTHER WORK

INDICATORS	Associated element(s)
Indicators carried forward from the review in Section 2	
A1. Toxic substances in urban air: benzene	1
A8. Global atmospheric concentration of greenhouse gases	1
B8. Greenhouse gas emissions from transportation	1
F4. Hourly average concentration of ozone in suburban areas and annual concentration (mean) of benzene in central urban areas	1
F5. Mean annual concentration of particulates in central urban areas	1
F20. Contribution to overall NO_x emissions in per cent	1
F22. Contribution to the overall emission of VOCs	1
F25. Contribution to final energy consumption	3
G32. Mobile source emissions, for CO, NO_x and PM_{10}	1
G33. Resident population exposure to local atmospheric concentrations of CO, NO_x and PM_{10}	10
J8. Black smoke emissions	1
J9. Lead emissions	1
J10. Nitrogen dioxide concentrations	1
K4. Methane (CH_4) emissions; emissions of ozone-depleting substances	1
B2. Per-capita use of transportation energy	3
B4. Unit sales of cars and trucks	7
B7. Per-capita gasoline consumption vs. urban density	3
D9. Arterial and expressway lane-km per 1000 capita in EUA	5
D15. Off-street parking spaces per employee in CBD	5,7
D32. Fuel use per person-trip in EUA	3
E3. Per-capita automobile use	7
E6. Per-capita land area paved for roads and parking facilities	5
F7. Length of railways and main roads	5,7
F8. Share of areas larger than 100 km^2 not separated by motorways	5
F10. Percentage of reused or recycled parts of different types of end-of-life vehicles	3,5
G30. Annual new road construction	5,7
G31. Area of arable land use converted to road or rail reserve	5,7
F9. Day and night time noise levels in residential, mixed, and industrial areas	6
G28. Change in vehicle fleet noise generation	6
B6. Gas and diesel fuel prices at the pump	14
D30. Farebox revenue/operating and maintenance budget	14
G26. Transport cost index	14
H7. Pricing and taxation	14
J3. Real changes in the cost of transport	14
E18. Portion of transportation-related costs paid by public funding	14
K1. GDP per unit of energy use	17
F12. Number of fatalities and injuries per year in transport	11
C21. Trips with two or more modes	16

D25. Average home-work trip distance in EUA	7
E5. Quality of pedestrian and bicycle environment	15
E7. Quality of public transit service (hours of service, frequency, speed relative to auto, safety, comfort), integration with other modes	15
E8. Average number of major services within walking distance of residents and average distance (walking) between residences and public services.	7
E10. Quality of delivery services	14
E11. Quality of mobility services for residents with special mobility needs.	14
E12. Affordability of public transit service by lower income residents	13
F1. Length of public transport network (rail and buses)	5,7,8
G23. Proportion of traffic zones and trips served by a direct public transport connection; proportion of suburban traffic zones served by a direct public transport connection to the CBD	5,7
C9. Non-auto trips (% of urban trip not by automobile).	7
D11. High-occupancy-vehicle (HOV) lane-km per 100,000 capita in EUA	7
D12. Automobiles per capita in EUA	7
D13. Morning peak period transit seat-km per capita in EUA	7
D14. 24-h transit seat-km per capita in EUA	7
D17. Morning peak period auto mode share to/from CBD (drivers and passengers)	7
D18. Morning peak period auto mode share for EUA (drivers and passengers)	7
D21. 24-h person trips per capita for EUA	7
D22. Annual transit rides per capita for EUA*	7
F16. S Traffic volumes of road, rail, air, sea (vehicle-kilometres)	8
F17. S Total passenger and cargo turnover by air, ship, road, rail; mode shifts	7,8
G18. Percentage of urban journeys by mode of transport (excluding cycle/walk)	7
G19. Percentage of short urban journeys by mode of transport	7
G20. Percentage of inter-urban passenger trips by mode of transport	7
G21. Public transport route length/highway route length	7,8
H2. Vehicles	7
J1. Car use and total passenger travel	7
J4. Freight traffic	8
K9. Diesel locomotives available	8
K10. Aircraft departures	7,8
K11. Air passengers carried	7
K12. Air freight carried	8
Indicators developed to fill gaps (Section 6)	
Index of specified transport emissions in relation to defined absorption capacity.	1
Index of specified transport wastes in relation to defined absorption capacity.	2
Index describing the rates of use of non-renewable materials in relation to the rates of growth of production of renewable replacements.	3
Index of the degree of reuse and recycling in relation to the amounts of potential waste from production and use.	4
Index of the amount of land used for all transport purposes in relation to the total urbanized land area.	5
Index of transport noise in relation to established critical levels for health impacts.	6
Index of the extent to which lack of transport constrains the meeting of defined everyday needs.	7
Index of the extent to which lack of transport constrains the meeting of the collective needs of society.	8
Index of the prevalence of transport-related diseases in humans.	9
Index of the extent to which transport contributes to social polarization.	12
Index of the actual or perceived quality of the transport system in relation to an accepted benchmark.	15

Index of the availability of transport opportunities for moving people and freight.	16
Index of the factor cost of transport in the production and distribution of goods and services.	17
Index of the number and intensity of the actions undertaken to change the trajectory of Canada's transport system from 'business as usual' to one consistent with attainment of sustainability.	All
Index describing the rates of use of renewable resources in relation to the rates of their regeneration	None (new element)