The Centre for
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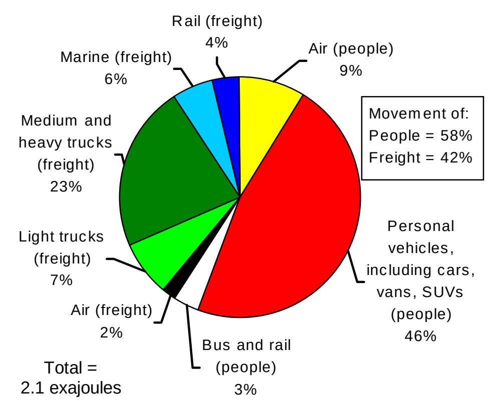
FREIGHT TRANSPORT

Introduction

One aim of the Centre's work program for 2000-2001 is "to propose a set of coordinated actions by which the freight transport industry … can move in more sustainable directions". Most of this issue of the *Monitor* is devoted to setting out many of the relevant issues.

Much is known about how *people* move in and between Canada's major cities. Little is known about freight movement, even though Canadians' high quality of life is almost completely dependent on freight transport. Concerns about freight transport are mostly confined to complaints about the number and size of trucks on the road, their safety, and the pollution they cause. Solutions focus mostly on moving the trucks or their freight elsewhere. The situation is much more complex, as is demonstrated here.

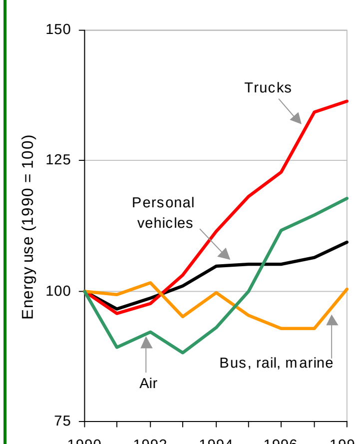
Box 1. Shares of transport energy use in Canada, 1998



Energy use for freight transport

Transport consumes about 29% of end-use energy in Canada.[1†] Freight's share of transport energy is about 40%, i.e., about 12% of all energy use. How transport energy is consumed is shown in Box 1.[2] Trends are shown in Box 2.[3] Energy use for personal vehicles, aviation, and especially trucks increased during the 1990s. For personal vehicles and aviation, this was in part due a decline in energy efficiency (trucks, rail, and marine showed increases in energy efficiency).[4]

Box 2. Use of petroleum products for transport, Canada, 1990 = 100

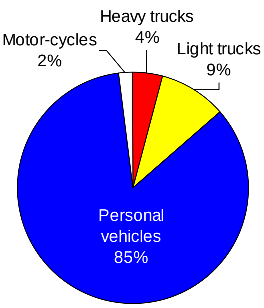


Energy use is just about the only basis for comparing different sectors and transport modes, but it presents a limited view of what is happening, especially on the roads. Box 3 provides a breakdown of Canada's road vehicle fleet;[5] personal vehicles and light trucks comprise well over 90% of all vehicles.

One way of comparing freight modes is to look at tonne-kilometres moved (tkm). Trends in all tkm in Canada by all carriers are shown in Box 4.[6]

 † The superscript numbers in the text refer to 39 reference notes that begin on Page 7.

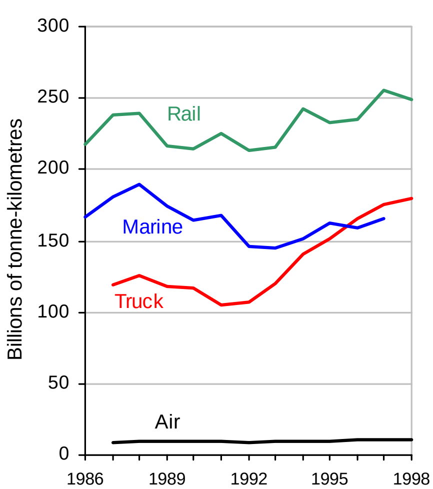
Box 3. Canadian road fleet in 1997



At first sight, a comparison of Box 1 and Box 4 suggests an overwhelming superiority of rail and marine modes over trucking in terms of energy efficiency (e.g., rail is responsible for 1.4 times as many tkm overall as trucks but uses only 0.12 times the energy, indicating a factor of over 10:1 in favour of rail). However, these are comparisons between apples and oranges. Rail and marine mostly moves large or bulk loads between distant destinations. Trucks do that and much more. If the energy efficiency of large fully loaded trucks moving long distances is compared with that of rail, the difference between the two modes could be much less. This is suggested in Box 5,[7] which summarizes European data and may not apply to North America. (A comparison of 1992 data indicates that the overall energy use per tkm of heavy-duty trucks was higher in Canada—and the U.S.—than in most European countries, e.g., 3.85 mj/tkm for Canada vs. 2.26 mj/tkm for Germany.[8])

If smaller trucks are used for longer journeys, rail can be far superior, as is suggested in Box 5. Any differences can be magnified substantially if trucks do not carry full loads, a matter addressed below.

Box 4. Freight movement in Canada by mode, 1986-1998



Shifting modes

A frequent consideration concerns whether there would be environmental and other advantages in moving loads from road to rail (or from road and rail to marine). For the most part, the only practicable shifts would concern inter-city or other long-distance freight movements.[9] As noted, energy savings may not provide such a strong reason as may be believed for such shifts. Where traction systems are comparable—as they are for trucks and trains, which both use diesel engines—respective air emissions are closely correlated with energy use. Thus there may not be much of a difference between the two modes in this respect. Rail's advantage in energy efficiency may be offset by trucks' more sophisticated emissions controls and higher quality fuel.[10]

The main advantages to be gained from shifts from trucking to rail lie in reduced congestion on inter-city roads, reduced need for road building, and in what may be the lesser impact of rail than road infrastructure on the local environment (e.g., smaller 'footprint', less interference with ecosystem integrity).

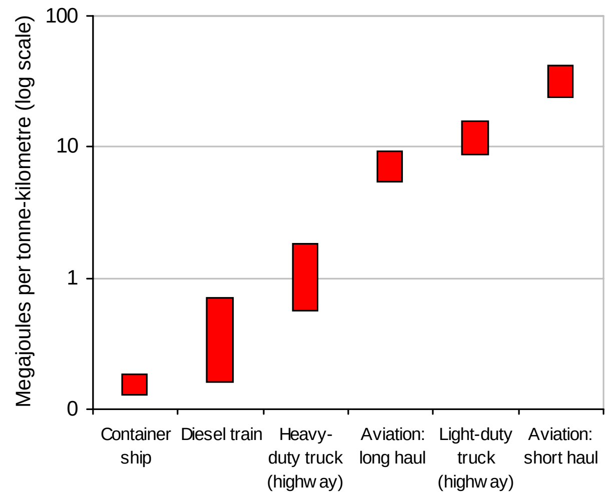
Marine may be the only declining freight mode (see Box 4). In the U.S., activity in this mode appears to be relatively constant.[11] Within Europe, the movement of freight by water has more than doubled over the last few decades.[12] Although moving freight by water is intrinsically the most energy-efficient mode, certain of its environmental impacts can be relatively large because of the use of fuel with high sulphur content.[13]

Local pollution: Particulates

All freight modes except aviation and light-duty trucks rely almost exclusively on diesel engines. They are 15-25% more fuel-efficient than gasoline engines per unit of fuel, but they also pollute more per unit of energy used in several respects. This is illustrated in Box 6, which shows on-the-road performance in the U.S.[14] (Canadian data would likely show a lower ratio for sulphur dioxide because the gasoline sold here tends to have a high sulphur content.) Of note in Box 6 is the particularly poor comparative performance of diesel engines in respect of particulates fine enough to be breathed deep into the lungs, i.e., less than 10 and certainly less than 2.5 micrometres (microns), known as PM-10 and PM-2.5.

Several agencies have or are about to identify diesel exhaust as a probable human carcinogen, mostly because it contains high levels of hazardous fine particulates.[15] Road vehicles are responsible for less than 1% of all PM-10 and less than 3% of PM-2.5 emitted into the air from human activity in the U.S., and perhaps in Canada,[16] but diesel exhaust from trucks is of special concern because large amounts of it can be produced in

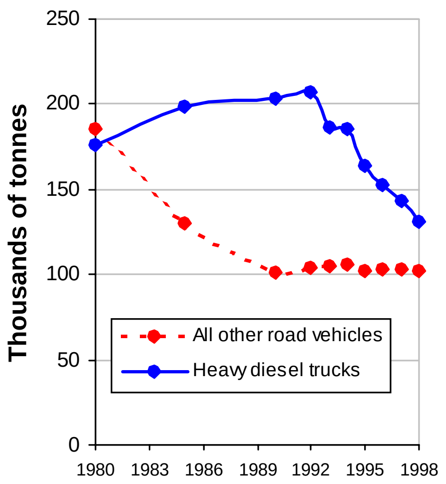
Box 5. Ranges of energy use per tonne-kilometre of fully loaded vehicles, Europe, late 1990s



Box 6. Diesel:gasoline ratios of emissions per energy unit (U.S., 1997)

Carbon monoxide	0.11
Volatile organics	0.17
Sulphur dioxide	1.24
Nitrogen oxides	1.32
Particulates (<10µm)	5.41
Particulates (<2.5µm)	7.96

Box 7. Total emissions of PM-10 from road vehicles in the U.S., 1980-1998



areas of high population concentration. Children, the elderly, and people with respiratory diseases are particularly vulnerable.

Trends in emissions of PM-10 from road vehicles in the U.S. are shown in Box 7.[17] Heavy diesel trucks, comprising less than 4% of vehicles on the road, were responsible for 56% of the PM-10 from road vehicles.[18] The improvement during the 1990s is evident, notwithstanding a large increase in truck traffic. Rail is another source of particulates, although not so often in proximity to people. In 1990, overall PM-10 emissions in the U.S. from rail were about 10% of those from heavy diesel trucks.

Particulates from diesel engines are mostly from incomplete combustion of diesel fuel. This can be remedied by raising the combustion temperature and by adding oxygen to the combustion mix.

Local pollution: nitrogen oxides

Both these strategies for reducing particulate emissions increase production of NO_x, which are a major pollutant in themselves and serve in many of the most populated areas of Canada and the U.S. as the major precursor of ozone, the chief constituent of ground-level smog, responsible for numerous respiratory diseases and for damage to plants. Road vehicles were responsible for about 32% of total NO_x emissions in the U.S. in 1998.[19]

Trends in emissions of NO_x from road vehicles in the U.S. are shown in Box 8.[20] Improvements in PM-10 emissions in the 1990s appear to have been achieved at the cost of overall increases in NO_x emissions (even though NO_x emissions per vehicle- and tonne-kilometre have declined). Rail is also a significant source of NO_x emissions, accounting in the U.S. in 1998 for just over a third of the overall emissions from heavy trucks.

Load factors and logistics

The most important determinant of environmental performance is load factor, i.e., how much of the capacity of a truck or train car is used or how fully a ship is loaded. A half-loaded truck uses more than 90% of the fuel used per kilometre by a fully loaded truck.[21] Thus the fuel use per tkm is almost twice as high for a half-loaded truck. Good data on the overall load factors of Canadian trucks appear to be unavailable, although it is believed that trucks on average operate well below capacity, with possible recent improvements.[22] U.S. data are equally sparse. They suggest a declining load factor, at least in the 1980s.[23]

Carrying less than a full load and empty backhauls are clearly not in the interest of the trucking industry. The responsibility for low loading efficiency likely lies with the demands of shippers or with a lack of coordination between shippers and truckers, or both. A major UK study indicated a wide range among truck fleets in the matter of energy use per tkm, mostly the result of different load factors, and the potential for major improvements in performance.[24]

A particular problem in analyzing Canadian road freight lies in relative lack of data concerning 'private' trucking, which comprises vehicles owned by shippers, as opposed to 'for hire' trucking. Insufficient data are available for for-hire trucking, but even less for private trucking. Data on trans-border traffic suggest that private trucks tend to be less fully loaded than for-hire trucks.[25] Japanese data suggest that the difference between private and for-hire trucks may be especially large for light-duty trucks.[26]

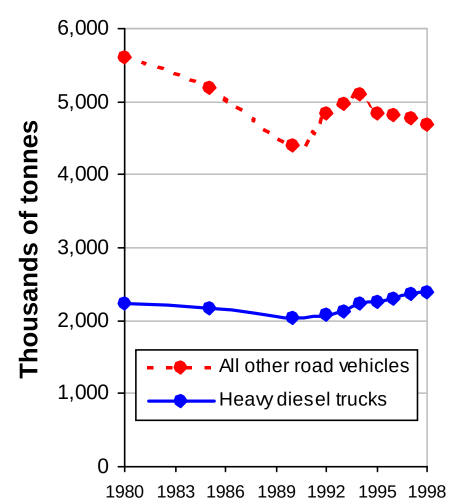
Load factors can be less of an issue for rail and marine, which operate at a slower overall tempo that allows for more efficient consolidation of loads. Rail load factors appear to have increased in both Canada and the U.S.[27] However, loading issues could emerge as rail operators strive to meet the demands of time-sensitive shippers by introducing guaranteed delivery times.

Load factors are just one of several aspects of freight logistics. Others include space utilization, scheduling, packaging and handling systems, and numerous other supply-chain factors.[28] Prominent is the widespread trend towards substitution of more frequent delivery for storage space (warehousing). One estimate suggests that 'just-in-time' delivery systems involve about twice the transport fuel use of what were described as "efficient non-JIT logistics".[29] This extra fuel use is offset to some degree by the energy savings from avoided construction and operation of warehouses.[30]

Urban freight movement

Among the greatest of all areas of ignorance about freight transport concerns what happens within Canada's urban regions. There is little understanding of the specific patterns of freight movement within these regions, especially the roles of light-duty commercial vehicles. Some data on heavy-duty vehicles can be gained from provincial surveys. For example, trips in, to, from or

Box 8. Total emissions of NO_x from road vehicles in the U.S., 1980-1998



across the Greater Toronto Area (GTA) comprised 42% of those included in a 1995 survey of commercial vehicle activity conducted for the Ontario government.[31] However, the findings of this survey—and others like it—say little about how goods are moved *within* the GTA. Survey locations reflected the primary intention of capturing inter-city trips. Light-duty vehicles were for the most part not covered; they may carry a significant share of what is moved around the GTA.

Traffic surveys in urban regions—whether of vehicle movements across screen cordons or of origins and destinations—are usually designed to provide information about the movement of people. What is needed is a comparable level of detail about the movement of freight. Only then will it be possible to make useful suggestions as to how urban freight transport could be rationalized.[32]

Energy availability

All freight modes face pressures to improve operating efficiency in an increasingly competitive environment. In spite of recent large increases in fuel prices, fuel costs remain a minor part of operating costs for all modes.[33] For the moment, improvements in fuel efficiency are secondary as a cost factor to improvements in other kinds of operating efficiency (notably better loading).

The energy scene is undergoing rapid change as the peak of world oil production is reached. Over the next decade or two, real oil prices could well rise to 5-10 times present levels, or even more.[34] Such increases could have major impacts on vehicle technology and logistics.

All modes can switch to other fuels, although for now trucks may be in the best position to do this. Natural gas could offer the best promise for the medium term, although use of this fuel also raises major questions about availability.[35]

Rail can make use of the widest range of fuels, but only if routes are electrified. With electrification, rail can operate with little use of fossil fuels, as it does already in parts of the world, notably France. Electrification has the potential to alter the balance of environmental impacts sharply in favour of rail, although for Canada this seems a distant dream.

In the longer term, road freight's dependence on fossil fuels could in theory be greatly reduced by the use of fuel cells relying on pumped hydrogen. Production, distribution, and storage problems for this fuel presently seem insuperable. Fuel cell systems involving in-vehicle production of hydrogen from a carbon based fuel (e.g., natural gas or methanol) do not presently seem to offer many advantages over advanced systems based on internal combustion engines.[36]

Air freight

Air is the fastest growing freight mode. Its total tkm remains small, but the total *value* of shipments may be more comparable to other modes. Energy use per tkm is much higher than for other modes except light trucks (Box 5), and the environmental impacts are much more global than local. Because a high proportion of air freight is carried in scheduled passenger aircraft, proper assignment of energy use and emissions can be difficult. There is no evident alternative to aviation's great reliance on refined petroleum. The longer term prospect for this mode is accordingly bleak, whether for freight or passengers.[37]

Concluding comments

Good freight transport facilities—and is often essential to—most current economic activity. Moreover, Canada's economic dependence on freight transport appears to grow each year. Also to be considered is the direct economic activity associated with freight transport; for example, truck driving is now the largest occupational category of males in Canada. Implementation of ill-thought-out proposals could have profound adverse effects. Great care is required to steer freight transport and associated matters in directions that reduce environmental impacts and accommodate changes in the availability of fuels, while maintaining an appropriate level of material prosperity. Progress in these matters is essential if transportation is to become more sustainable.

UNIVERSITY CURRICULUM PROJECT

The goal of this project being conducted by the Centre is to bring consideration of sustainability into university transportation programs across Canada, in a consistent and comprehensive way.

An initial survey of 52 universities identified 927 relevant courses, and a more detailed evaluation was made at three universities. Results showed that about three quarters of transportation courses at the three selected universities had no environmental content, confirming the need to continue the project.

The next phase, funded by Transport Canada and Environment Canada, involved development of three analytical resources: an instructor survey instrument; a database of transportation course syllabi; and an international survey of educational efforts in sustainable transportation. The report on this phase is available on request (see below).

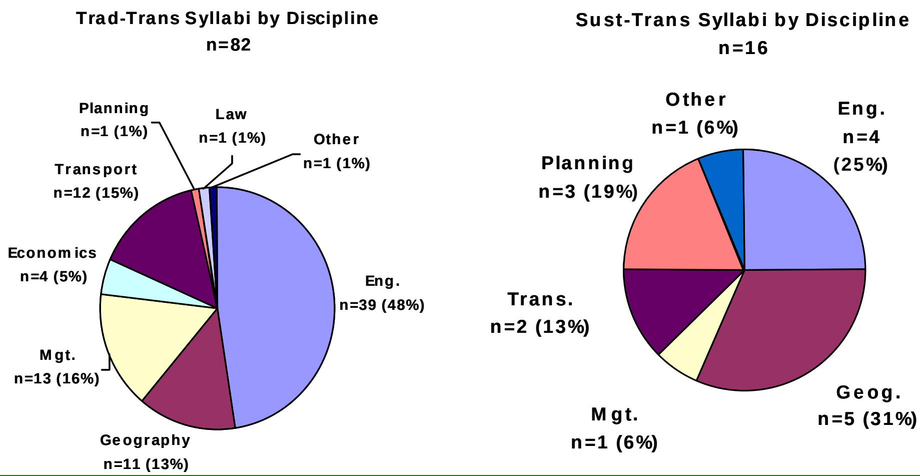
The current phase, being conducted over the period April 2000 to March 2001, is being funded by the federal government's Climate Change Action Fund under the title *Enabling Tomorrow's Transportation Professionals to Address Climate Change*. It is in three parts.

The first part comprised analysis of the 297 items held in the project's database of Canadian transportation course syllabi. As shown in Box 9, only 16 of these courses were found to combine a high level of transportation content and a high level of environmental content. Box 10 shows the variation by discipline of

Box 9. Results of assessment of 297 courses according to transport and environment content

Environmental content	Transport content: High	Transport content: Low
High	Group 1 (Sust-Trans) 16 courses (5%)	Group 2 (Enviro) 98 courses (33%)
Low	Group 3 (Trad-Trans) 82 courses (28%)	Group 4 (Misc) 101 courses (34%)

Box 10. Variation by discipline of ‘traditional transportation’ (Trad-Trans) courses and ‘sustainable transportation’ (Sust-Trans) courses



the 16 courses with syllabi showing high transport and environment content and the 82 courses with syllabi showing high transport content but low environmental content.

Among the 16 courses, there was no evidence of convergence in course content or method. Unlike typically ‘mature’ academic subjects, including many aspects of transportation (e.g., road design, demand modelling) and environmental studies (e.g., impact assessment), there is no textbook—or ‘canon’ of common articles, book chapters, and reports—that constitutes an intellectual core of learning materials.

The second part involved administration of a bilingual survey questionnaire to 119 instructors of transport courses, approximately distributed across Canada according to the general population, with slight under-representation from Quebec. The survey addressed teaching practices and attitudes concerning transportation and the environment.[38]

Two results from the second part of the work are illustrated in Box 11. The left-hand panel shows the good news: a majority of respondents agreed that the environmental content of courses out to be expanded. The right-hand panel shows the bad news: a majority believed that someone else should be doing it.

The third part of the current phase comprises three workshops being held in Vancouver and Toronto in February 2001, and in Quebec City in March. The overall aims of the workshops are to begin a process of curriculum development for sustainable transportation and to help build a network that can support this development. The outcomes of these workshops will be reported in a later *Monitor*.

SUSTAINABLE TRANSPORTATION PERFORMANCE INDICATORS (STPI)

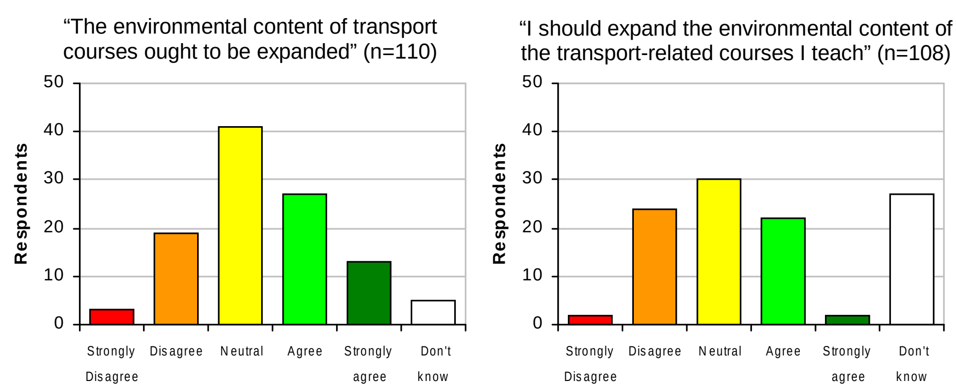
The Centre’s STPI project aims to help with the assessment of progress towards sustainable transportation in Canada by developing three levels of performance indicator. One would be a composite indicator that attempts to reflect in a single number the condition of transportation in Canada in relation to sustainability. The second would comprise 5-10 indicators that reflect the components of the single indicator. The third would consist of 10-30 indicators that enhance understanding of transport activity and its impacts.

Phase 1 was supported by Environment Canada and Transport Canada and was completed in June 2000. It comprised a a brief review of some relevant world-wide activity and development of a list of 84 potential STPI to carry forward for further analysis and refinement.[39]

Phase 2 of the STPI project, completed in December 2000, was supported by four federal government departments: Environment Canada, Industry Canada, Natural Resources Canada, and Transport Canada. **Phase 2 was in essence a reality check**. It sought to confirm whether or not the project was moving in the right direction, and to secure information about potential users of STPI and how the STPI might be used. As well, Phase 2 continued the process of moving towards identification of the final sets of STPI. It was structured around a workshop held in November 2000.

Two surveys were conducted by the IBI Group in September and October 2000 in preparation for the workshop. One was a follow-up of respondents to the Urban Transportation Indicators surveys initiated by the Urban Transportation Council of the Transportation Association of Canada and conducted in 1994-5 and 1999. The other survey sought information from govern-

Box 11. Faculty attitudes towards including environmental content in transport courses, and as to who should do it



ment officials and others as to potential users and uses of STPI.

Several lessons were learned from the surveys and the workshop, including the following:

- The demand for STPI among persons interested in transportation indicators is strong. They would be used for a wide variety of purposes.
- The ranges of potential users and uses are broad, and so, correspondingly, is the range of topics for which there should be STPI.
- There are nevertheless skeptics as to the feasibility of developing STPI, because of the data challenges, and as to the value of any result, because of the controversy it could provoke. The lessons for the development of STPI are that everything should be carefully justified, and nothing should be taken for granted.
- There is strong support for having STPI that are linked to clear objectives or targets including those set or implied in government policies.
- The STPI should concern economic, social, and environmental aspects of moving towards sustainable transportation. However, all three aspects need not be represented in the proposed single composite indicator.

Phase 3 will concern the actual development of the proposed three levels of indicator. Subject to funding, it will be conducted between July 2000 and June 2001. A related proposal by the Centre concerns development of the initial version of an online *Canadian Transportation Data Book* that will pull together much available information about transportation in Canada from federal, provincial, municipal, private-sector, and other sources.

THE CENTRE FOR SUSTAINABLE TRANSPORTATION

The Centre is a federally chartered, non-profit organization.

It began work in 1996 with start-up funds from Environment Canada and Transport Canada. These departments of the Government of Canada continue to contribute support.

The Centre's mission is to provide leadership in achieving sustainable transportation in Canada by facilitating cooperative actions, and thus contributing to Canadian and global sustainability.

To achieve its mission the Centre provides reliable information, fills knowledge gaps through research, educates stakeholders and raises awareness among them, and offers strategic policy advice in selected areas.

The Centre's first publication was its *Definition and Vision of Sustainable Transportation*, published in mid 1997. You are reading the fourth issue of the *Sustainable Transportation Monitor*, published annually from 1998 to 2000 and now more frequently. All issues of the *Monitor* are available at the Centre's Web site, as are the Centre's other publications (visit www.cstctd.org). The *Monitor* provides evaluation of progress towards or away from sustainable transportation and discussion of related matters.

Comments on this issue of the *Monitor* and proposals as to what should be covered in coming issues are much appreciated. E-mail is the preferred mode of communication but feedback by any mode is welcome. **Please see Page 1 for our e-mail address, fax and phone number, and mailing address**. Contact the Centre as well if you would like to find out how to become a corporate or individual member of the Centre.

REFERENCE NOTES

1. The estimate of transport's share of all end-use energy is taken from Natural Resources Canada, *Energy Efficiency Trends in Canada 1990 to 1998*, October 2000, p. xv.
2. Box 1 is derived from the database supporting the source detailed in Note 1, available at <oee1.nrcan.gc.ca/dpa/data_e/database_e.cfm>. Note that in this database all aviation has been assigned to passenger transport. For Box 1, air freight has been separated out by assuming that freight accounts for approximately 20% of aviation energy (following Table 5-21a of the report entitled "Assessment of Freight forecasts and Greenhouse Gas Emissions" by Delcan Corp., prepared for the Transportation Table of Canada's Climate Change Process, June 1999).
3. Box 2 is based on the same source as Box 1 (see Note 2).
4. The table below shows annual rates of change in energy use, activity (person- or tonne-kilometres), and efficiency (activity per unit of energy) by transport mode, 1990-1998:

	Average annual rate of change in:		
	Activity	**Energy use**	**Efficiency**
Air	1.8%	2.1%	-0.3%
Marine	0.1%	-0.9%	1.0%
PVs*	1.0%	1.1%	-0.1%
Rail	1.9%	-1.8%	3.8%
Trucks	5.6%	4.0%	1.5%

*PVs (personal vehicles) are cars, minivans, SUVs, etc

Energy use data in the table are from the source in Note 2. Activity data are from Transport Canada's T-Facts files, available at <www.tc.gc.ca/pol/en/t-facts_e/Statistical_Data_Menu.htm>.

5. The estimates in Box 3 were derived from Transport Canada's 1998 *Annual Report*. The total number of vehicles on the road was estimated as having been being close to 17 million in 1997, including about 17,000 buses that are not shown in Box 3. Fully loaded 'heavy trucks' weigh more than 4.5 tonnes. 'Light trucks' are other road vehicles used for moving goods rather than people. Most light trucks are in the 'personal vehicles' category, along with SUVs, minivans, and regular automobiles. Of the 'heavy trucks' and 'light trucks', roughly half—in terms of the dollar value of the goods movement—are 'private', i.e., they are owned by shippers. The others are 'for-hire' trucks. Private trucking is more prominent in urban freight movement than in longer-distance movement (*Profile of Private Trucking in Canada*, Industry Canada, 1998, Exhibit 3.1). Of the heavy trucks, 47% have a registered weight (maximum with load) of 4.5-11 tonnes; 11% are rated at 11-15 tonnes, and 42% are rated at 15-63.5 tonnes (*Trucking in Canada: A Profile*, Industry Canada, 1998).
6. Box 4 is derived from Transport Canada's T-Facts files (see Note 4). Several assumptions have been made to include in Box 4 just about all tonne-kilometres (tkm) moved *within Canada's land and marine limits*. They include the following. **Air**: Air freight comprises 20% of passenger weight at 0.1 tonne per passenger. The numbers of transborder and international flights by Canadian and foreign airlines are equal. On average, for transborder flights a distance equal to a quarter of the average domestic journey length is over Canada; for international flights, the distance over Canada is half the average domestic journey length. **Marine**: The length of transborder and international shipping trips in Canadian waters is one quarter of the transborder trip length. **Rail**: Only one quarter of transborder tkm occurs in Canada. **Truck**: Only one quarter of transborder tkm occurs in Canada. Half of transborder tkm is performed by U.S. carriers. Private carriers are responsible for half the tkm of for-hire carriers. (The last assumption is based on the greater prominence of for-hire trucking in longer-distance carriage, discussed in Note 5.) Box 4 does not present a complete picture of the movement of materials in Canada. Significant omissions are goods carried in personal vehicles, oil and other materials moved by pipeline, and much of the movement of materials in connection with agriculture and resource extraction, including fishing, forestry, and mining. Many more tkm are performed for Canadians *outside Canada* than within Canadian limits. These include approximately 1.7 *trillion* marine tkm (estimate based on T-Fact files, see Note 4) and uncounted other tkm associated with Canada's trading activity.
7. Box 5 is based on data in Fig. 6.1 of Eurostat, *Transport and Environment: Statistics for the Transport and Environment Reporting Mechanism (TERM) for the European Union*, 2000, with a separate estimate concerning light-duty trucks based on a February 2000 presentation to the Annex 1 Expert Group on the United Nations Framework Convention on Climate Change, February 2000 held at the OECD, Paris (Crist P, McGlynn G, *Freight Transport Trends and their impacts on greenhouse gas emissions*). The well-established increase in fuel efficiency with truck size formed the basis of one of the recommendations of the Transportation Table of the National Climate Change Process, to the effect that tractor-trailer combinations exceeding 25 metres in length should be permitted on roads throughout Canada. (See the Table's *Options Paper*, available at <www.nccp.ca>.)
8. Schipper L et al., Energy use and carbon emissions from freight in ten industrialized countries: an analysis of trends from 1973 to 1992, *Transport Research, Part D: Transport and the Environment*, 1997. The data represented in Box 1 and Box 4 allow crude estimates of the energy intensities of the different freight modes in Canada, in megajoules per tkm as follows: Air = 3.9; Truck (all weights) = 3.5; Marine = 0.6; Rail = 0.3. The discrepancies between these estimates and those in Box 5 require resolution. (The present estimate of aviation tkm may be too high, or—less likely—that of aviation energy use may be too low, or both.)
9. The Transportation Table of the National Climate Change Process concluded that shifting freight modes (e.g., truck to rail, rail to marine) did not warrant early consideration due to its high cost and limited potential to reduce emissions. (See the last source detailed in Note 7.) Although shifting modes is usually thought of as shifting to potentially less energy intensive modes for environmental or cost reasons, there may well be counter-trends in the form of shifts from road and rail to air, even over short distances, to provide for earlier delivery times or to avoid surface congestion, notwithstanding the higher costs of air freight. A recent well-publicized example concerned the UK Post Office, which almost doubled its dedicated night-time flights during the pre-Christmas period (to 67 per night) to avoid rail congestion. (*Financial Times*, London UK, December 1, 2000).
10. Rapid and in some cases dramatic changes in emissions control technology and regulations—for all freight modes—make comparisons among the current performances of modes particularly difficult. See, for example, the proposal of the U.S. EPA described in Note 15.
11. See U.S. Bureau of Transportation Statistics, *National Transportation Statistics, 1999*, p. 432.
12. See Fig. 3.14 of the first source detailed in Note 7. In the 15 Euro-

pean Union countries from 1970-1995, tkm by road transport increased 2.9 times; by water transport the increase was 2.1 times, almost all the result of an increase in short-sea shipping by 2.4 times. Rail freight activity declined slightly over this period.

13. No North American data on ships' emissions seem to be readily available. Data on pp. 155-157 of the first source detailed in Note 7 suggest that marine emissions per tkm are at or below those of other modes except for emissions of sulphur dioxide, which are about a factor of ten higher (not including aviation).
14. The table in Box 6 is based on data in the source detailed in Note 11 and on information from the U.S. Environmental Protection Agency.
15. Agencies classifying diesel exhaust as a probable human carcinogen include the International Agency for Research on Cancer, the U.S. National Toxicology Program, the California Air Resources Board, and the German Environmental Agency (Umweltbundesamt). Environment Canada has proposed that fine particulate matter be declared toxic under the *Canada Environmental Protection Act*, a proposal that is being challenged as premature by the Canadian Trucking Association (fax to Environment Canada dated August 8, 2000) The U.S. Environmental Protection Agency has proposed that over the period 2007-2010 diesel particulate emissions from new vehicles be reduced by 90%.
16. Davis SC, *Transport Energy Data Book*, Oak Ridge National Laboratory, Oak Ridge, Tennessee, October 2000, Tables 4.8 and 4.10. According to Environment Canada's 1995 Criteria Air Contaminant Emissions Inventory the Canadian proportions attributable to road diesel engines are lower if so-called 'open sources' (e.g., forest fires, dust from unpaved roads) are included in the total, but higher if they are not. (The Inventory is available at <www.ec.gc.ca/pdb/cac/cacdoc/1995e/main95.html>.)
17. Box 7 is based on Table 4.9 of the source detailed in Note 16.
18. According to Environment Canada's 1995 Criteria Air Contaminant Emissions Inventory (see Note 16), heavy diesel trucks were responsible for 77% of PM-10 from road vehicles. They comprised less than 4% of vehicles on the road (see Box 3).
19. See Table 4.4 of the source detailed in Note 16. According to Environment Canada's 1995 Criteria Air Contaminant Emissions Inventory (see Note 16), road vehicles were also responsible for about 32% of total NO_x emissions in Canada, 35% if 'open sources' are not included in the total.
20. Box 8 is based on Table 4.5 of the source detailed in Note 16.
21. Data on the relation between truck loading and energy consumption come from <www.trucktires.com/gentech/w-F.htm>. The comparisons here are by weight. For many loads, volume is the limiting factor, thus comparisons of load factors based on weight can be relatively meaningless. What may be the only study of utilization of cubic capacity found it to average only 28% (Samuelson A, Tilanus B, A framework efficiency model for goods transportation, with an application to regional less-than-truckload distribution. *Transport Logistics*, 1997.)
22. See, for example, the load data set out in Note 31.
23. Greene D, Fan Y, *Transportation Energy Intensity Trends, 1972-1992*. Transportation Research Board (TE7.H5 #1475), Washington DC, 1995
24. The study of fleets' freight logistics was conducted by Alan McKinnon of Herriot-Watt University, Edinburgh, UK, and is cited in the second source detailed in Note 7. It found that energy savings in the order of 25% could be gained if the lowest-performing two thirds of 113 UK truck fleets were to achieve the mean performance of the highest third.
25. See Exhibit 5.7 in *Profile of Private Trucking in Canada*, Industry Canada, 1998.
26. Presentation by Shinji Nakagawa at the event detailed in Note 7.
27. Information about U.S. rail load factors is from the source in Note 23. The more recent information about Canadian rail load factors comes from the Railway Association of Canada's *Railway Trends 2000*. Rail load factors may have increased as a result of relaxations of government restrictions on train length and weight.
28. See McKinnon A, *A logistical perspective on the fuel efficiency of road transport*, OECD-ECMT-IEA workshop "Improving fuel efficiency in road freight: the role of information technology", Paris, February 1999.
29. Royal Commission on Environmental Pollution, *Transport and the Environment*, HMSO, London, UK, 1994, p. 164.
30. The energy costs of construction and operation of warehouses have not been well established, and thus the extent to which these costs offset the increased transport costs from JIT practices is not known. Energy use in warehouses appears to be low compared with other types of building (U.S. Energy Information Administration, *A Look at Commercial Buildings in 1995: Characteristics, Energy Consumption, and Energy Expenditures*, October 1998, p. 218). Low transport costs and high product value seem to be the main factors determining the extent of JIT vs. warehousing. (See McKinnon AC,. Logistical Restructuring, Road Freight Traffic, Growth and the Environment. In Banister D, ed., *Transport Policy and the Environment*, Spon, London, 1998.)
31. *Ontario Commercial Vehicle Survey, 1995*, reported in Ontario Ministry of Transportation, *Strategic Overview of Goods Movement in the GTA: Appendix*, August 1997. Almost half of the surveyed trips that involved the GTA were from one point in the GTA to another (48%); the others were inter-city trips passing through the GTA (about 11%) or with a GTA origin or destination (about 41%). Only 37% of the heavy trucks involved in GTA-related trips had a full load; 34% had a partial load and 29% were empty. One in ten trips involved more than one stop in the GTA.
32. Ignorance about freight transport in urban areas is not confined to Canada. See, for example, Short J, *Freight transport in cities*, ECMT workshop "Freight Transport in Towns: Recent International Developments", Amsterdam, The Netherlands, Nov. 1988.
33. Fuel costs as a proportion of all trucking costs is not well known. A U.S. owner-operator represented his breakdown as follows: income, 47%; fuel, 25%; truck payment, 16%; other costs, 12% ("Looking at tough times through a windshield", *New York Times*, January 16, 2001).
34. For a fuller discussion of energy availability see *Sustainable Transportion Monitor*, No.2, Centre for Sustainable Transportation, Toronto, 1999. See also *Monthly Indicators*, CIBC World Markets, Toronto, October 2000.
35. See, for example, Woronuk RH, *Canadian gas supply: going up? or down?* Paper presented at a meeting of the Ontario Petroleum Institute, Niagara Falls, Ontario, 1999.
36. See, for example, Keller M, Zbinden R, *EST-Alpine: feasibility of the technological changes*. OECD, Paris, February 2000.
37. For a fuller discussion of aviation prospects see *Sustainable Transportion Monitor*, No.3, Centre for Sustainable Transportation, Toronto, 2000.
38. For reports on the Centre's University Curriculum project, visit the Centre's Web site at www.cstctd.org.
39. For reports on the Centre's Sustainable Transportation Performance Indicators (STPI) project, visit the Centre's Web site at www.cstctd.org.