The Centre for
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In this issue:

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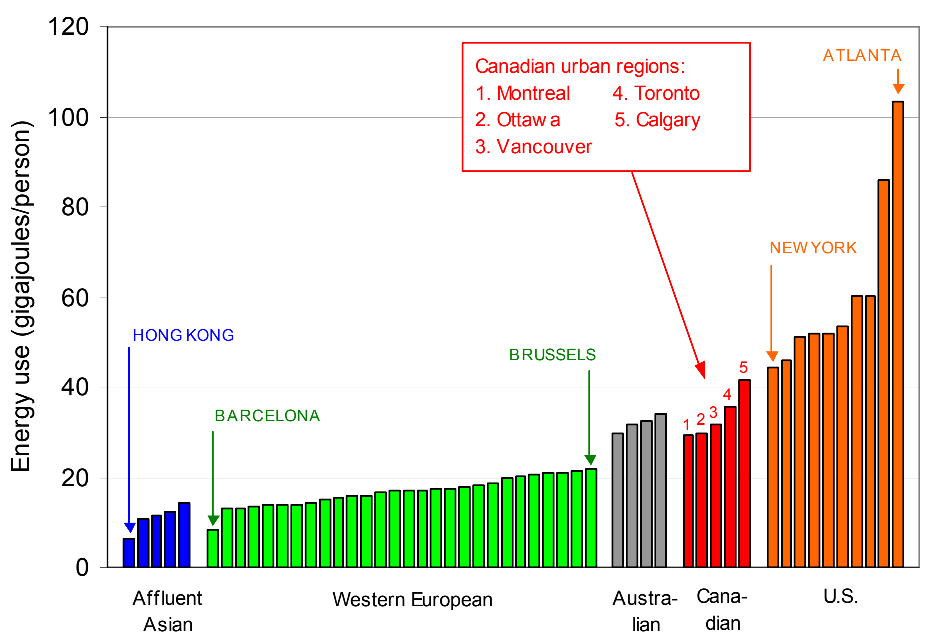
CANADA'S MAJOR URBAN REGIONS: HOW THEY COMPARE

Most of this issue of the *Monitor* is devoted to providing transport-related data on Canada's five largest urban regions, usually in relation to affluent urban regions in other countries. The source of the data is the *Millennial Cities Database*[1†] produced by the International Association of Public Transport, an organization of public transit[2] associations often known by the acronym UITP, derived from its French name (Union Internationale des transport publics). The *Database* contains up to 230 indicators for each of 100 urban regions, all for the year 1995. Of the 100 urban regions, 60 were *affluent* urban regions in that each had per-capita regional GDP of more than US$10,000 in 1995.

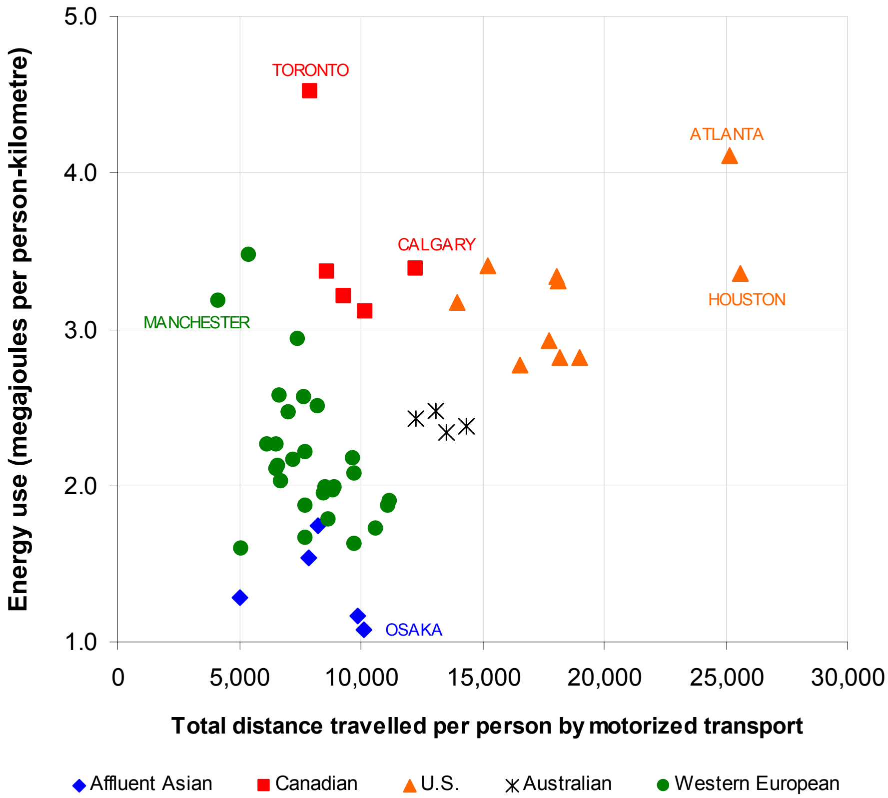
The five Canadian urban regions represented in the *Database* are Toronto, Montreal, Vancouver, Ottawa, and Calgary.[3] In what follows they are often compared with 47 other affluent regions in the database.[4]

As may be expected in such a massive exercise in data compilation, the *Database* has errors, both errors of detail[5] and a few errors of a more fundamental nature.[6] It is also far from being 'user-friendly'.[7] Nevertheless, it is reasonable to agree with UITP that con-

Box 1. Energy use for passenger transport in 52 affluent urban regions, 1995



Box 2. Distance travelled and energy used per kilometre, 52 urban regions, 1995



cerning the world's urban regions it is "the most comprehensive and reliable mobility data compilation produced to date".[8] **A major problem with the *Database* is that the data are for 1995 only, and are thus no longer current**. Repeat of the massive exercise of data compilation would not only provide more current data, it would also provide indications of trends.

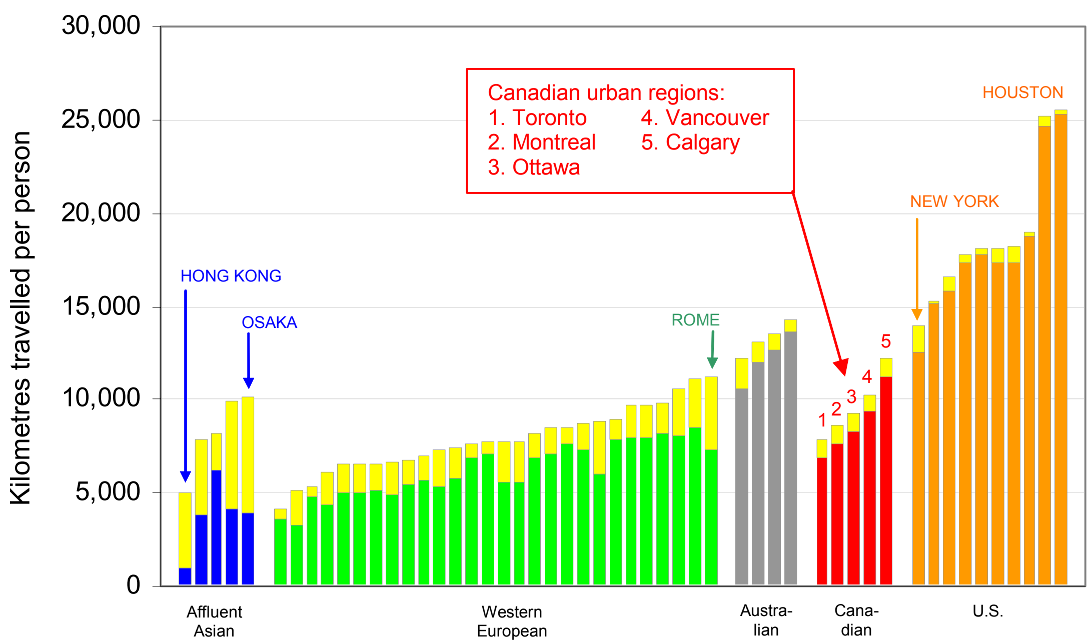
One of the aims of this issue of the *Monitor* is to illustrate the value of the *Database* and to encourage interest in updating it soon. **The more immediate aim is to provide a snapshot of transport activity and its impacts in Canada's five largest urban regions in relation to comparable urban regions in other countries.**

The *Database* concerns the movement of people only. This is likely to be the larger part of transport activity in all 52 urban regions represented here. However, it should not be forgotten that a full description of transport activity in these urban regions should also include the movement of freight. Moreover, when *economic* as opposed to *environmental* and *social* sustainability is being considered, freight transport is especially important.

ENERGY USE

From the perspective of transport sustainability, perhaps the most important indicator is energy use for transport.[9] Just about all energy used for transport comes from the combustion of one form or another of non-renewable fossil fuel, use of which is environmentally and economically unsustainable.[10]

Box 3. Distance travelled per person in 1995 by public transit and taxicab (upper parts of bars, yellow shading) and by private vehicles (lower parts of bars, other colours)



Energy use is closely correlated with several adverse impacts of transport, notably emissions of greenhouse gases and of locally acting pollutants such as nitrogen oxides and particulates. Energy use can also be an indicator of transport activity, and thus dependence on transport. Of importance too is the ease with which energy use can be readily compared across transport modes and across types of energy.[11]

Energy use is a key indicator of sustainability, higher levels of consumption being less sustainable than lower levels.

Box 1 shows energy used per capita in 1995 for the movement of people *within* each of the 52 urban regions.[12] The average for the five Canadian urban regions[13] was 33.1 gigajoules.[14] This was more than five times greater than the lowest use (Hong Kong, 6.5 gigajoules), but less than a third of the highest use (Atlanta, 103.3 gigajoules).

High levels of energy use for transport occur for one or both of two reasons: long distances are travelled and travel is energy intensive (meaning that more energy is used per kilometre). Box 2 shows how the 52 urban regions differed on these variables. There was a more than fivefold difference in distance travelled (Manchester, Houston) and a more than fourfold difference in energy use per person-kilometre (Osaka, Toronto).[15]

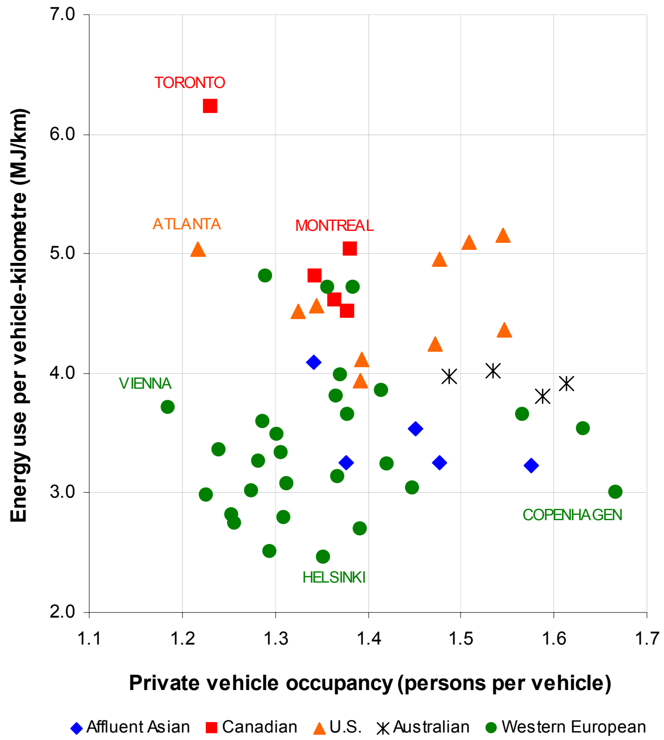
Movement in Canadian urban regions required more energy use per motorized person-kilometre than movement in other urban regions, as shown in Box 2.[16] This matter is discussed further below.

An interesting feature of Box 2 is the indication that residents of Asian, Canadian, and European cities travelled similar distances[17] but used very different amounts of energy to travel those distances. Residents of Australian and, particularly, U.S. urban regions travelled much farther.[18]

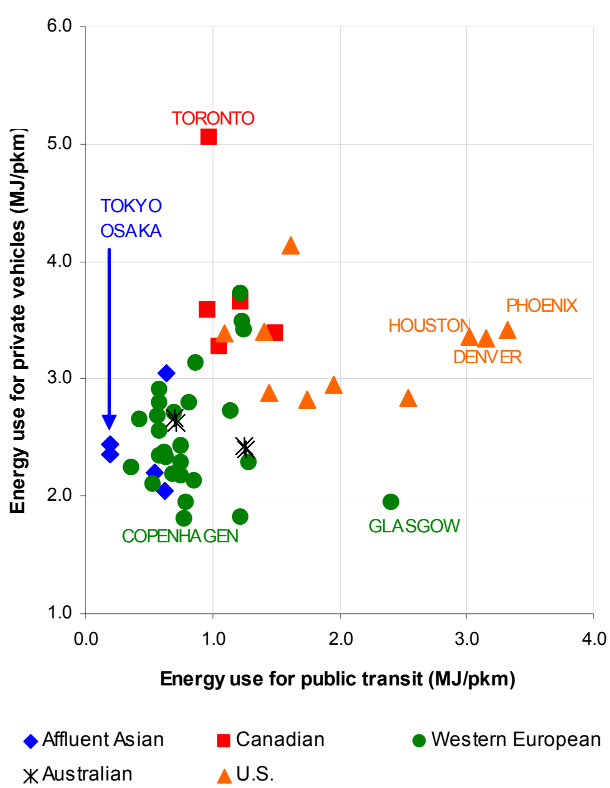
Distance travelled by motorized vehicles is shown again in Box 3, this time according to **how the travel was made**, whether by public transit (including taxicabs) or by private vehicles (cars, SUVs, motorcycles etc.). Box 3 shows that in the Asian cities other than Sapporo, most of the distance travelled was by public transit. In Sapporo and all the represented European, Australian, Canadian, and U.S. cities, most travel was by private vehicle. Indeed, in six of the European regions, and in all of the Australian, Canadian, and U.S. regions, over 85 per cent of distance travelled was by private vehicles. In Perth (Australia) and in all the U.S. regions except New York, more than 95 per cent of the distance travelled was by cars and other private vehicles.

As well as being strongly correlated with the proportion of travel by private vehicles, distance travelled per capita was also strongly correlated with the

Box 5. Private vehicle occupancy and energy use



Box 4. Energy use in megajoules per person-kilometre for public transit and private vehicles



Box 6. Private vehicle energy use and occupancy

	Energy use (MJ/vkm)	Occupancy (pers./veh.)
Canadian	**5.33**	**1.32**
U.S.	4.64	1.44
Australian	3.95	1.54
Asian	3.44	1.44
European	3.29	1.34

urban region's length of road per capita, and with the residential density of its developed area (negative correlation).[19]

The strong correlation between distance travelled and road length could mean that long distances are travelled in some regions because there is much road to travel on. Equally, it could mean that there is much road to travel on because long distances are travelled, i.e., governments build roads where there is a lot of traffic. However, a strong correlation means only that two variables go together, without either necessarily causing the other. In this case, it seems likely that each causes the other; roads are built because there is much travelling to be done, and the building of them encourages more travelling.[20]

Travel by car is more energy intensive than travel by public transit. This is shown in Box 4, where it can be seen that energy use for private vehicles, chiefly cars, ranged by a factor of almost three, from 1.8 to 5.1 megajoules per person-kilometre travelled (Copenhagen, Toronto), with a median value of 2.7 MJ/pkm, and energy use for public transit ranged by a factor of more than 17 from 0.2 to 3.3 MJ/pkm (Tokyo, Phoenix), with a median value of 0.8 MJ/pkm. In one city only, Glasgow, energy use by public transit was reported as higher per person-kilometre than energy use by private vehicles.

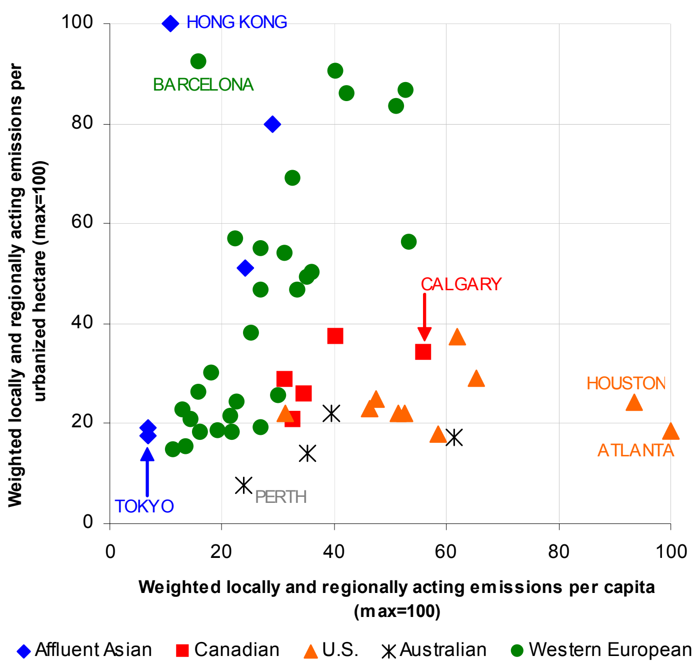
High energy use per person-kilometre occurs when vehicles use a lot of energy or when they are not well occupied, or both. These two variables are shown for private vehicles in Box 5 and Box 6. **Private vehicles in Canadian urban regions were reported to have had on average both the highest energy use and the lowest occupancies**. Toronto's private vehicles appear to use exceptionally large amounts of energy and have among the lowest occupancies. Buses in the five Canadian urban regions also perform relatively poorly in terms of energy use, although better than average in terms of occupancy (Box 7).

Box 7. Bus energy use and occupancy

	Energy use (MJ/vkm)	Occupancy*		
		A	B	C
Canadian	23.7	15.9	43.1	37%
U.S.	**29.3**	**11.9**	38.2	31%
Australian	17.5	12.2	45.3	**27%**
Asian	16.2	19.6	50.1	39%
European	16.3	15.2	45.4	33%

* A = occupied seats per vehicle B = seats per vehicle C = per cent occupancy

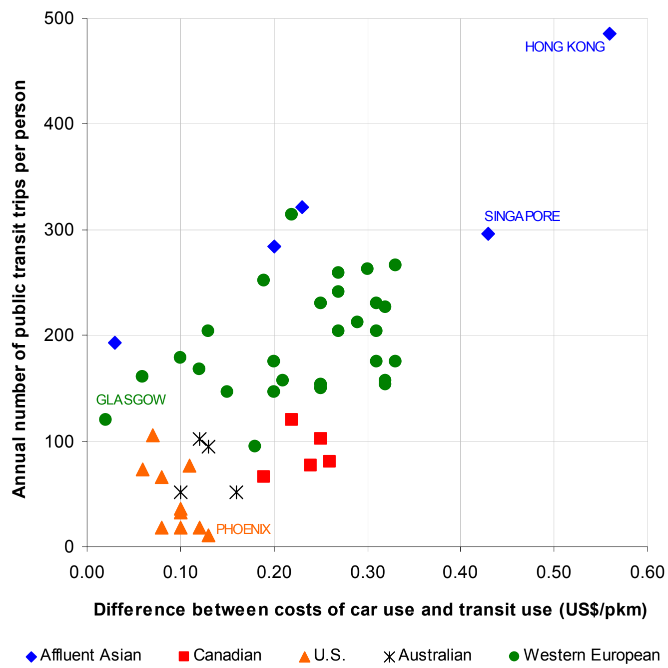
Box 8. Weighted emissions from transport of four locally or regionally acting pollutants per capita (horizontal scale) and per urbanized hectare (vertical scale)



Travel by private vehicle in large Canadian urban regions seems particularly energy intensive more because cars use larger amounts of energy than because they carry fewer people.[21] Why does so much energy appear to be used per vehicle-kilometre in Canadian cities? It could be a matter of extreme climate, but that would not explain why Toronto—after Vancouver the most moderate of the represented Canadian cities—appears to have the most poorly performing vehicles. The low occupancy rates are also of interest. Are Canadians in large urban centres less sociable than other urbanites?

As for all of the effects noted here, explanations also include possible misreporting of data by cities and misrepresentation by the compilers of the *Database*.[22] These too would deserve investigation, to ensure future improvements. If the apparent differences among regions are confirmed, they deserve remedy. If, for example, Canadian vehicle efficiency and occupancy were raised to what seem to be Australian levels, fuel use and thus greenhouse gas emissions would be reduced by well over 30 per cent.

Box 9. Transit ridership and the relative cost of car ownership per person-kilometre



Box 10. Average cost in US$ of one person-kilometre when travelling by car and by public transit, by region

	Car	Transit	Difference
Asia	0.42	0.13	0.29
W. Europe	0.36	0.13	0.23
Canada	0.31	0.08	0.23
Australia	0.21	0.08	0.13
U.S.	0.18	0.09	0.10

EMISSIONS OF GREENHOUSE GASES FROM TRANSPORT

Emissions of greenhouse gases are not directly addressed in the *Database*. However, because the fuel used by nearly all transport is derived from crude oil, energy use usually provides a good indication of greenhouse gas emissions.[23] Thus, almost all of the comparisons of energy use discussed above also apply to greenhouse gas emissions.

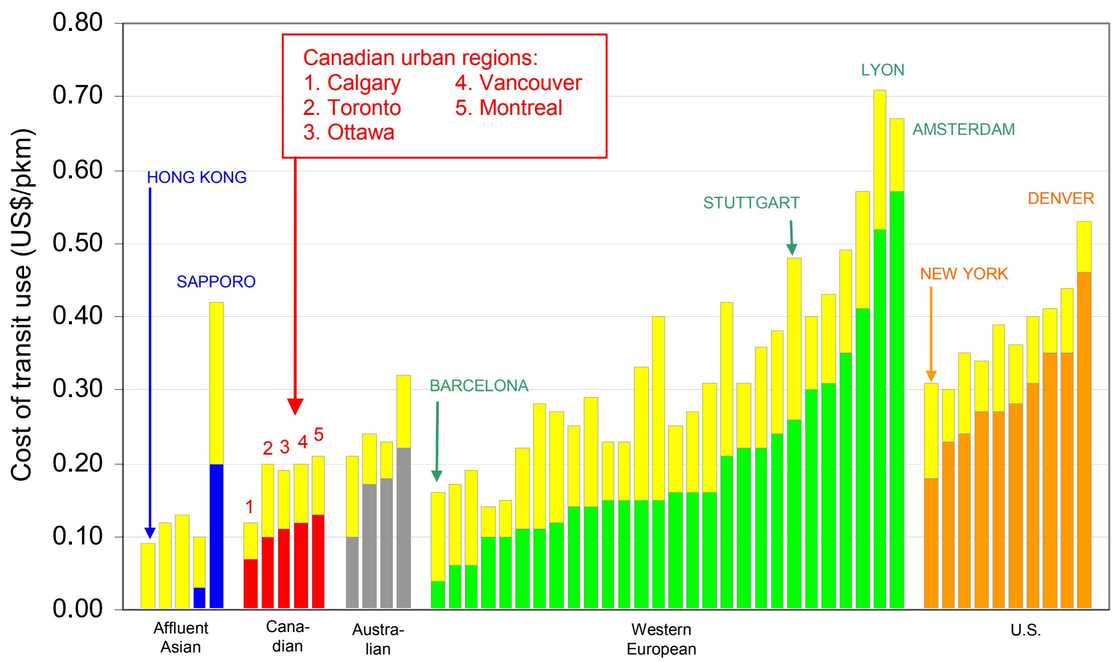
For example, it seems that—in accordance with the energy use data in Box 5 and Box 6—**travel in Canada's large urban regions, particularly Toronto, resulted in emission of more greenhouse gases per person-kilometre than travel in other affluent urban regions**. This was mostly because private vehicles in Canadian urban regions produce more greenhouse gases per kilometre, but also because vehicle occupancy in Canadian urban regions is relatively low.

POLLUTION FROM TRANSPORT

In cooperation with provincial governments, Environment Canada regularly monitors five common air pollutants, sulphur dioxide (SO_2), carbon monoxide (CO), nitrogen dioxide (NO_2), ground-level ozone (O_3), and suspended particulate matter (PM). All of these are in vehicle exhausts, or are the result of chemical reactions involving vehicle emissions. O_3 is formed by the action of sunlight on nitrogen oxides (NO_x, which include NO_2) and volatile organic compounds (VOCs).

The *Database* provides information on emissions from transport of four of the above pollutants: CO, SO_2, NO_x, and VOCs. For the present report, data for the four pollutants have been aggregated for each urban region to provide two indices; one is of total emissions per person; the other is of total emissions per hectare of urbanized area.[24] Each index was normalized so that the

Box 11. Cost of transit use per person-kilometre showing the parts covered by fares (upper parts of bars, yellow shading) and by other income, mainly subsidies (lower parts of bars, darker colours)



Box 12. Average revenues, in US$ per person-kilometre, from fares and other sources (mostly subsidies)

	Fares	Other	Total
U.S.A.	0.09	0.29	0.38
W Europe	0.13	0.20	0.33
Australia	0.08	0.17	0.25
Canada	0.08	0.11	0.18
Asia	0.13	0.05	0.17

value of the highest ranking city is 100 and the others are proportionately lower. Box 8 shows the values of the two indices for each urban region.

The per-capita emissions index (the horizontal scale in Box 8) shows the extent to which transport activity is causing atmospheric pollution. The per-hectare emissions index (the vertical scale in Box 8) shows how spatially concentrated the emissions are. This index may thus be more strongly associated with air quality, which is not directly represented in the *Database*.

Box 8 shows that the urban regions where the highest amounts of pollution are produced from transport are mostly in the U.S., whereas the urban regions where pollution is produced with the highest spatial intensity are mostly in Europe. This means that urban regions where large amounts of pollution are emitted, for example Houston and Atlanta, are so spread out there could be effective dilution of the pollution. On the other hand, urban regions where little pollution is produced, e.g., Hong Kong and Barcelona, are so compact there could still be high local concentrations of pollution.

It's difficult to compare air quality data from urban regions on different continents because of the limited availability of data and because of differences in how data are reported and presented. Moreover, transportation is only one of several factors that can contribute to poor air quality, although it is usually a major factor. One comparison involving the four urban regions mentioned in the previous paragraph concerned *background* ground-level ozone levels, perhaps the pollutant of greatest concern. Continuous readings were taken for about a month each in March and August 1999. Average ozone levels across the two periods were higher in Houston and Atlanta (61 and 65 micrograms per cubic metre) than in Hong Kong and Barcelona (35 and 38 mg/m^3).[25]

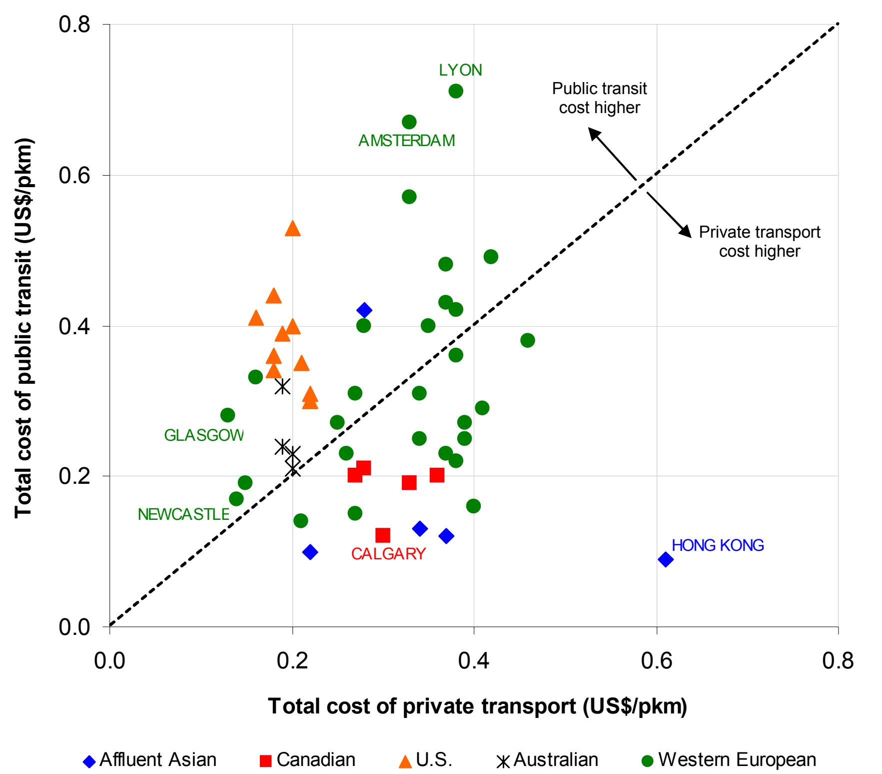
From these limited data, overall emissions from transport would appear to be a more important factor in background levels of pollution than the spatial concentration of emissions. However, spatial concentration, at least in the vicinity of monitoring stations, would necessarily make a stronger contribution to peak pollution levels. Which of the two—high background levels or high peak levels—makes a stronger contribution to human and ecosystem disease needs further investigation. The result could well depend on which pollutant is being considered and on the specifics of the two kinds of exposure.

FINANCIAL COSTS OF TRANSPORT

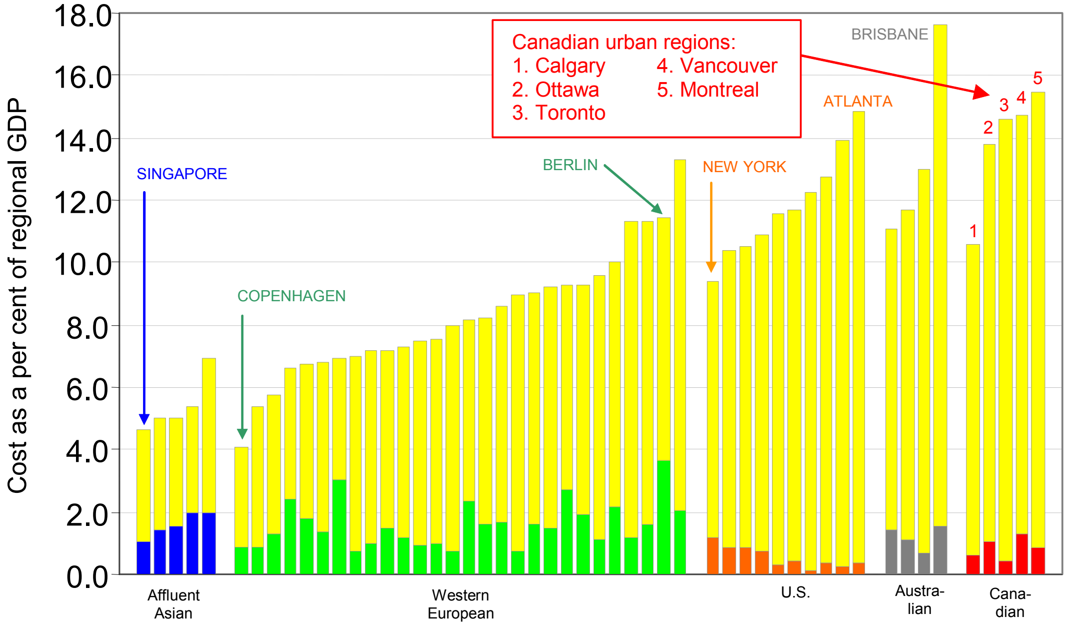
The relationship between transport's financial costs and sustainability is complex. The Centre's definition requires a sustainable transportation system to be "affordable",[26] and yet if transport is cheap it can be used unduly and thus unsustainably. The ideal arrangement could be to price transport according to its degree of sustainability, perhaps according to energy use per person-kilometre.

As indicated above, energy use for journeys by transit was lower than energy use for automobile travel in 51 of the 52 urban regions. It could thus make sense to ensure that the user cost of transit is lower than the cost of travelling by car. This was true of all 52 urban regions when the *overall* costs of private transport are considered. However, it was not necessarily true of the variable costs, i.e., costs such as for

Box 13. Total costs of public transit and private transport use per person-km



Box 14. Overall spending on private transport (yellow portions of bars) and public transport (darker-coloured portions) as a per cent of regional GDP



fuel and parking, which vary with use. The *Database* does not clearly show variable costs.[27]

Box 9 shows the difference between car and transit user costs per person-kilometre for the 52 urban regions, and also the annual number of trips made by transit per person. These two variables are strongly correlated, even when the extreme points of Hong Kong and Singapore are omitted.[28] Although Box 9 shows there was considerable variation within the geographic groupings, it is useful to examine the averages for each of the five areas. These are shown in Box 10, where it can be seen that Canadian urban regions have relatively high car costs for users, but relatively low transit costs.

User costs are only a part of the financial picture. The total costs include subsidies and also unpaid costs such as the health costs of air pollution. The *Database* gives indications of transit subsidies, but not of unpaid costs (which may be mostly associated with automobile use). Total costs of transit are shown in Box 11, organized by geographic area and by the extent of non-farebox revenue (by far the largest part of which is usually subsidy, capital or operating, or both).

In three urban regions there were no evident subsidies for transit (Hong Kong, Tokyo, and Osaka). These also had the lowest costs, achieved in part through very high ridership levels (see Box 9). Transit in the U.S. had consistently the highest subsidies, but Europe had the regions with the highest subsidy rate (Amsterdam) and the highest overall cost of transit (Lyon). The highest transit fares were found in Sapporo and Stuttgart; the lowest in Hong Kong.

The position of Canadian transit systems in Box 12 is remarkable. Their average overall cost of providing a passenger-kilometre of service—shown in the right-hand column of Box 12—was almost as low as the Asian systems, which had very much higher ridership (see Box 9) and could thus achieve much greater economies of scale. This represents extraordinary financial efficiency in Canadian transit operations that could result from good management, high productivity, selective service provision or a combination of some or all of these factors.

Box 13 provides another perspective on public and private transport costs. The 22 urban regions where the total cost of transit use per person-kilometre was *lower* than that of car use are below and to the right of the diagonal dashed line. All five Canadian urban regions are in this category, as well as the five affluent Asian regions. In the other 30 urban regions, the total cost of transit use per person-kilometre was *higher* than that of car use. This category includes all U.S. and Australian regions.[29]

Transit that costs more overall than automobile use may be less sustainable than transit that costs less than automobile use. Such transit is certainly less affordable, perhaps not so much for the users as for the communities that support it.

Perhaps more important for an urban region than the *unit* costs of transport (e.g., cost per person-kilometre) are the **overall costs of transport as a share of the region's economy**. An overly large share dedicated to the movement of people could mean that other parts of the economy are disadvantaged. People spend money on transport that could be spent, for example, on education. Alternatively, residents' quality of life could

Box 15. Cost of private and public transport as a per cent of regional GDP

	Private	Public	Total
Canada	12.97	0.86	13.83
Australia	12.16	1.18	13.34
U.S.	11.27	0.55	11.82
W. Europe	6.69	1.59	8.28
Asia	3.81	1.60	5.41

Box 16. Average automobile journey time and speed, and road usage

	Average journey time by car (minutes)	Average automobile speed (km/h)	Average daily vkm per km of road
Canadian	15	45	3,551
Australian	16	44	2,532
U.S.	18	49	5,866
Asian	21	31	5,197
European	23	33	5,078

be being diminished by the excessive labour required to support the high transport costs. On the other hand, an overly small share of the economy could indicate that transport is not being used to an optimum extent in support of economic and social activity.

Box 14 shows all spending on the movement of people within each region as a percentage of its Gross Domestic Product. The range is large, from 4.1 to 17.1 per cent of GDP (Copenhagen, Brisbane). In every urban region, private transport contributed the larger share, ranging from 3.2 to 16.1 per cent of GDP (Copenhagen, Brisbane). Public transport's share ranged from 0.1 to 3.6 per cent of GDP (Phoenix, Berlin).

As a group, Canadian urban regions had the highest overall cost of private transport as a per cent of GDP, and of all transport; however, overall cost of public transport was the second lowest. These differences are illustrated in Box 15.

CONGESTION

The relationship of congestion to sustainability is uncertain, perhaps even more uncertain than that of the financial costs of transport. As a consequence, there is no reference to congestion in the Centre's definition of a sustainable transport system.

Delays in travel caused by streets clogged with traffic are a major cause of frustration among road users. Much transport policy seems directed towards relieving congestion.[30] On the face of it, relieving congestion could be consistent with progress towards sustainability, in that freely flowing traffic uses less energy than stop-and-start traffic.[31] However, congestion is more often than not relieved by increasing road capacity, which induces further traffic, and eventually more congestion. **The result is a vicious cycle of growth in road capacity and growth in traffic that is quite inconsistent with sustainability.**[32] Moreover, there is evidence that congestion deters traffic,[33] and that *removal* of road capacity reduces traffic overall.[34]

Adding public transit capacity and giving it more priority on the road are often seen as the main alternative strategies to combat congestion. They usually have little success. If public transit is improved *and* road capacity is increased, drivers often continue in their preference for driving. If adding public transit is effective in reducing traffic, the effect is often temporary. New traffic fills the roads, as surely as adding roads increases traffic overall. Congestion can be reduced when transit capacity is increased *and* the automobile is restrained, for example by additional taxes, by rules about occupancy, or by straightforward limitations on car use (as in car-free city centres).

An often-used indicator of congestion is the extent to which the rated capacity of a road is approached or even exceeded. Information of this kind is not available in the UITP *Database*. However, the *Database* contains three indicators relevant to congestion: average journey time by car, average car speed, and vehicle-kilometres per kilometre of road. Congestion is worse to the extent the first and third are high and the second is low.

Commuters and traffic engineers in Canada's major cities may be surprised to find that in the *Database* Canadian urban regions rank lowest in one of these indicators (journey time), second lowest in another (total vehicle-kilometres per kilometre of road), and second highest in yet another (traffic speed). This is illustrated in Box 16. In these terms, Ottawa's roads were particularly uncongested; Ottawa had the shorted travel time per car trip and the fifth highest road network speed. Calgary and Toronto had the fourth shortest average travel times by car.

CANADIAN EXTREMES

As a group, and in some cases as individual regions, Canadian cities were extreme among the affluent urban regions represented in the UITP *Database*. Usually, the extremes were at the end of a continuum associated with *unsustainable* rather than sustainable transportation. Again, it should be cautioned that the comparisons may be flawed, either because of the way the data were reported by Canadian contacts or because of the way the reports were used by the compilers of the *Database*, or both.[35]

In brief, the analysis so far has concluded that the Canadian group of urban regions in the UITP *Database* had:

- the **highest energy use** per person-kilometre for car travel and for all travel, with Toronto recording the highest energy use among urban regions, and also the highest energy use per vehicle kilometre for car travel;
- the **lowest automobile occupancy**;
- the **lowest user costs of transit** (with Australian urban regions), and almost the lowest in overall costs of transit;
- the **highest overall costs of private transport** and of all transport as a percentage of regional GDP;

- the **least congested roads**, in terms of journey time by car, with Ottawa overall having the shorted average journey time.

As well, there are instances in the *Database* where individual Canadian urban regions stand out, as follows:

Calgary was reported to have had the second highest level of car ownership per capita among the cities in the *Database* (703 per 1000 residents). First is Atlanta (746), with Houston third (693), Perth fourth (658), and Rome fifth (655). Montreal (429) had fewer cars per 1000 residents than all the other Canadian, U.S., and Australian regions, and eleven of the European regions. Calgary was also third lowest in the proportion of trips by non-motorized modes. These two extremes are perhaps in the direction away from sustainability.

In the direction towards sustainability, **Calgary** had the fewest transport-related deaths per vehicle- and person-kilometre, and the fourth-fewest transport-related deaths per capita.

Montreal had few extremes. Its central area parking charges were the fourth highest, its revenue per transit trip was the fourth lowest, and its car energy use was the fourth highest. The first two of these could be considered positive in relation to sustainability, but not the third.

Ottawa had several distinguishing features. It had the smallest urbanized area as a proportion of the total region, the fourth highest length of road in the urbanized area, and the fifth highest proportion of regional GDP spent on roads. It spent the second highest proportion of regional GDP on car operating costs and—after Brisbane—on the motorized movement of people generally. Montreal was third in this respect. Ottawa also had a relatively low amount of segregated transit routing in relation to the length of expressways.

Toronto's forte, as noted, was to be the biggest private-vehicle energy hog in the *Database*. Toronto also had the lowest length of reserved bus lanes per hectare, the second lowest number of daily walking trips, the fourth lowest transit speeds relative to automobile traffic, and the fifth lowest number of trips per person per day, by any mode. (This stay-at-home feature of Torontonians may be related to the unusually low car occupancy rates noted above.)

Vancouver's only extreme was in its low penalty for obstructing public transit, the third lowest among the 52 urban regions.

CONCLUDING REMARKS

Again with every possible qualification as to data quality, it does seem that Canadian urban regions ranked relatively poorly in terms of their potential for progress towards sustainable transportation. Several questions have been raised that deserve further investigation, whether to refute the points made above, or to remedy them. Addressing these questions in one way or the other should be a key feature of securing progress towards sustainable transportation in Canada's major urban regions.

The most serious matter is that of energy use and, by extension, greenhouse gas emissions. If Toronto in particular and Canada's five largest urban regions as a group do indeed use the most energy per unit of transport activity among the world's affluent urban regions, this would certainly require investigation and remedy. Is it a matter of which vehicles are used, how they are used, climate, road conditions, any combination of these factors, or perhaps other factors? Does transportation in other Canadian urban regions also use larger-than-usual amounts of energy? Given good answers to these questions, what would be the best way to bring Canadian consumption down to or even below the world average?

More questions have been raised here than have been answered. An important step towards answering some of them would be to update the *Database*, perhaps for the year 2005. This is sufficiently far ahead that adequate preparation can be done to ensure the best possible data collection during that year (with precautions to ensure that a focus on 2005 does not distort data). UITP should be encouraged to conduct an update, or work with another organization in doing so. Indications of cooperation of Canada, and perhaps even financial support, would serve as strong and necessary encouragement.

Canada's contribution could be part of a much-needed program to enhance the scale and scope of collection and analysis of transport data in Canada. Earlier issues of the *Monitor* have noted the paradox that Canada may be more transport-dependent, economical and socially, than any other industrialized country, and yet may have the poorest data on transport of all these countries.

With the support of four departments of the federal government, the Centre is making a small contribution towards achieving better transport data through its *Sustainable Transportation Performance Indicators* project. The final report on the current phase of work on this project—which sets out an initial set of indicators—should be available at the Centre's Web site late in October 2002. Much more needs to be done, involving much cooperation among all governments and agencies in Canada responsible for transportation.

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 seventh issue of the *Sustainable Transportation Monitor*, published annually from 1998 to 2000 and now twice or more times a year. 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.

This issue has been written by Richard Gilbert, the Centre's research director. The content has been endorsed by the Board of Directors acting as individuals rather than as representatives of the organizations with which they are affiliated (and not unanimously in every instance).

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 to become a corporate or individual member of the Centre.

REFERENCE NOTES

1. The full citation of the UITP database is Kenworthy J, Laube F, *The Millennium Cities Database for Sustainable Transport*, Union Internationale des transports publics (UITP), Brussels, Belgium, 2001 (CD-ROM). This resource is available for a fee from UITP at the URL below. The *Database* was compiled mostly from responses to detailed questionnaires sent to local government officials, supported by several other methods. A challenging aspect of the creation of the *Database* involved setting the boundaries of the urban regions. A document accompanying the *Database* (Vivier J, *Millennium Cities Database for Sustainable Mobility: Analyses and Recommendations*, May 2001) says the following about the boundary setting: "In some cases, the available data are compiled by administrative bodies whose confines do correspond to the most relevant metropolitan area for the mobility study. Adjustments had to be made where the study's optimal geographical area did not coincide with the area for which most of the data researched were available. The metropolitan areas selected were defined with the utmost care and the list of districts or groups of districts included in the metropolitan areas is specified." Notwithstanding the final sentence, specifications of each urban area are not evidently available.
   http://www.uitp.com. Accessed September 27, 2002.
2. What is know as transit, urban transit, and—usually for heavy rail services—mass transit in North America is known as public transport elsewhere.
3. The *Database* is concerned with *urban regions* rather than Central cities. Thus, the listed 1995 populations of the five Canadian urban regions in the *Database* were Toronto, 4,628,883; Montreal, 3,224,130; Vancouver, 1,898,687; Ottawa (actually Ottawa-Hull), 972,456; and Calgary, 767,059. These in order of population size are presently the five largest urban regions in Canada. However, in 1995, The Edmonton Census Metropolitan Area had a higher population than that of Calgary (862,597 vs. 821,628, according to the 1996 Census of Canada). By 2001, Calgary's CMA population had become larger (951,395 vs. 937,845). In the *Database*, the Calgary region's 1995 population is given as 767,059, which happens to be exactly that of the City of Calgary in 1996, as indicated by that year's Census.
4. The 47 other urban regions are: **Affluent Asian cities:** Hong Kong, Osaka, Sapporo, Singapore, and Tokyo. **Australian cities:** Brisbane, Melbourne, Perth, and Sydney. **North American cities**: Atlanta, Chicago, Denver, Houston, Los Angeles, New York, Phoenix, San Diego, San Francisco, and Washington. **Western European cities:** Amsterdam, Athens, Barcelona, Berlin, Brussels, Copenhagen, Dusseldorf, Frankfurt, Glasgow, Hamburg, Helsinki, London, Lyon, Madrid, Manchester, Marseille, Milan, Munich, Nantes, Newcastle, Oslo, Paris, Rome, Ruhr, Stockholm, Stuttgart, Vienna, and Zurich. Of the 55 non-Canada urban regions in the *Database*, data from five were not used because their populations were below 500,000. they were: Graz, Berne, Wellington, Geneva, and Bologna. Data from three urban regions were not used because they had an unusually large number of missing data points: Lisbon, Turin, and Lille.
5. One error of detail is elaborated in Note 3.
6. A more fundamental error in the *Database* is the summing of atmospheric concentrations of four common, transport-related air pollutants to provide an aggregate indicator of air pollution. Because the concentration of carbon monoxide is invariably much higher than the concentration of the other three pollutants combined (nitrogen oxides, sulphur dioxide, and volatile organic compounds), the aggregate indicator mostly reflects carbon monoxide levels only. Better representation can be achieved by appropriate weighting of the concentrations of each pollutant, as is done later in this issue of the *Monitor* (see Note 24).
7. The provided format for accessing the *Database* is rigid and not conducive to the kind of analyses provided here. For these analyses, the whole *Database* was laboriously transformed into the much more flexible Microsoft Excel format. Documentation for the *Database* is weak and often inconsistent. The specification of variables involving financial costs is especially confusing.
8. The quote about the *Database* is from Vivier (2001), detailed in Note 1.
9. For the Centre's (and the European Union's) definition of sustainable transportation see Issue No. 6 of the *Sustainable Transportation Monitor* (May 2002).
10. For an indication of the unsustainability of fossil fuel use, see Issue No. 2 of the *Sustainable Transportation Monitor* (February 1999). For fuller, more recent account of depletion of oil and natural gas see Bentley RW, Global oil and gas depletion: an overview. *Energy Policy*, 30, 189-205, 2002. Also see the papers presented at the International Workshop on Oil Depletion, Uppsala, Sweden, May 23-25, 2002, available at http://www.isv.uu.se/iwood2002. Accessed September 27, 2002.
11. Some energy use—e.g., use of electricity generated from wind turbines—is much more sustainable than other energy use, notably use of the oil products that fuel almost all transport. Almost none of the more sustainable forms of energy are used for transportation. A significant example of the use of wind energy for transport purposes is Calgary's 'Ride the Wind' program, which involves use of wind-generated electricity by light-rail trains. See http://www.calgarytransit.com/environment/ride_d_wind.html. Accessed September 27, 2002.
12. Unless otherwise indicated, the data source for the boxes in this *Monitor* issue is the *Database* detailed in Note 1. The boxes have all been created for this issue except Box 1, which also appeared in Issue No. 6 of the *Monitor*.
13. Where the average of a value for a group of urban regions is given here, the actual average is shown, not the average of the averages for the individual urban regions. Thus, in the present case, the average energy use per capita for the five Canadian urban regions is the average use per person by all the residents of the five regions.
14. A gigajoule is a billion joules. It is roughly the amount of energy in 29 litres of gasoline, or in 26 litres of diesel fuel or in 278 kilowatt-hours of electricity.
15. A person-kilometre is the amount of travel that occurs when one person moves through one kilometre. Thus ten people travelling one kilometre in a bus and one person travelling 10 kilometres in a car both amount to 10 person-kilometres (also expressed as 10 pkm).
16. Residents of Canadian cities used 3.72 megajoules/person-kilometre, compared with 3.15, 2.42, 2.09, and 1.18 megajoules for the U.S., Australian, European, and Asian regions, respectively.

17. Residents of Asian, Canadian, and European cities travelled 9281, 8896, and 7635 kilometres respectively.

18. Residents of Australian and U.S. cities travelled 12,980 and 17,241 kilometres, respectively.

19. The stronger correlation of distance travelled was with length of road per person (+0.71) rather than with settlement density (-0.51). 'Strongly correlated' here refers to a correlation coefficient whose absolute value (i.e., without its sign) is greater than 0.36; 'correlated' refers to such a coefficient being greater than 0.27. (According to Table 5 of Quenouille MH, *Rapid Statistical Calculations*, London (UK): Griffin, 1959, these are respectively the 1% and 5% significance levels for 52 pairs of data points.)

20. For how adding road capacity induces traffic, see Noland RB, Cowart WA, Analysis of Metropolitan highway capacity and the growth in vehicle miles of travel. *Transportation Research A*, 27, pp. 363-390 (2000). For evidence that *reducing* highway capacity reduces traffic, see Cairns S, Hass-Klau C, Goodwin PB, *Traffic Impact of Highway Capacity Reductions: Assessment of the Evidence*, London (UK), Landor Publishing (1998).

21. This statement is based on the observation that the divergence of Canada from the overall mean is greater in the case of vehicle energy use that in the case of vehicle occupancy.

22. See Note 35 for more discussion about the quality of the data in the UITP *Database*.

23. Diesel fuel and gasoline produce almost identical amounts of carbon dioxide per unit of energy released (respectively 67.8 and 67.2 grams per megajoule). Diesel vehicles tend to use less fuel per kilometre than gasoline vehicles, other things being equal, partly because a litre of diesel fuel contains 11% more energy (38.7 vs. 34.8 megajoules per litre, see also Note 14), and partly because diesel vehicles usually use fuel more efficiently. In Europe, where fuel prices are high, there are many diesel automobiles on the road. They are reported to have an average fuel use of 6.5 litres/100 kilometres compared with gasoline cars, which use an average of 8.0 L/100 km. Thus, about half of the diesel vehicles' lower fuel use results from the higher energy content of the fuel and half from the lower energy intensity of the vehicle. (Data in this note are from Page 202 of *CO_2 Emissions from Transport*, European Conference of Ministers of Transport, 1997, and from Page 282 of *National Transportation Statistics*, U.S. Bureau of Transportation Statistics, 1997.)

24. In order to avoid distortion by the relatively high weights of CO (see Note 6), the amount of each pollutant was weighted by its total amount across all 52 cities. This result was divided by population to give one index and by urbanized area to give the other index. Each index was adjusted so that the highest value was 100.

25. Ozone data are from the Global Ozone Passive Monitoring Project, at http://www.thesalmons.org/ozone. Accessed September 27, 2002.

26. The Centre's definition is on Page 1 of Issue No. 6 of the *Sustainable Transportation Monitor*, available at http://www.cstctd.org. Accessed September 27, 2002.

27. The parts of the *Database* dealing with financial costs are the most frustrating to use. 'Operating'and 'overall' costs are not defined well. Variables are missing in the actual database that are noted in the documentation (e.g., Raw Indicators 56a-56h, "elements of the cost of a car trip". It could be that better definitions are available on the purchased CD-ROMs, and the missing data are also available, but navigation among the contents of the CD-ROMs was a further challenge.

28. For all 52 urban regions, r = 0.67. For all regions less Hong Kong and Singapore, r = 0.54. See Note 19 for the significance of these correlations.

29. The unpaid costs of transport are not included here; if they were, there could have been more urban regions with lower transit cost.

30. An example of the policy focus on relieving congestion is the name of one of the two "priority issues" of the Ontario Government's Central Zone Smart Growth Panel. It is "unlocking gridlock and promoting livable communities" (press release, February 11, 2002).

31. For a chart of how fuel use increase dramatically with decline in vehicle speed below about 40 km/h, see Box 7 of Issue No. 5 of the *Sustainable Transportation Monitor* at the source detailed in Note 26.

32. See Note 20.

33. Newman PWG, Kenworthy JR, and Lyons TJ, Does Free-Flowing Traffic Save Energy and Lower Emissions in Cities? *Search*, 19, (1988).

34. See the second source cited in Note 20.

35. The data in the UITP *Database* can be compared with other sources. The most readily available, single alternative source for data on Canadian urban regions is a survey conducted in 1999 for the Transportation Association of Canada concerning 1996 data. Some of the data points in the two surveys (UITP and TAC) are amenable to comparison. They are set out in the table below. In the cases of population, employment, and energy use, the correspondence is acceptably close. For the other data points, there are considerable differences between the two sets, notably in the indications of the sizes of the urban areas—perhaps different definitions were used—and in reported car vehicle-kilometres/capita. The reports on the two surveys, particularly the UITP survey, are not such as to allow detailed examination of the bases for the discrepancies.

	Calgary		Montreal		Ottawa		Toronto		Vancouver	
	UITP	TAC	UITP	TAC	UITP	TAC	UITP	TAC	UITP	TAC
Population (millions)	0.77	0.82	3.22	3.33	0.97	1.01	4.63	4.27	1.90	1.83
Employment (millions)	0.41	0.44	1.35	1.50	0.49	0.50	2.32	2.06	0.92	0.91
Urbanized area (km^2)	368	720	1,017	2,026	311	1,027	1813	2,300	879	1,300
Transit trips/capita/year	80	91	120	125	77	102	102	119	66	73
Car vkm/capita	11,712	10,293	12,648	7,519	11,340	8,140	11,828	9,782	12,981	8,103
Transit costs (C$/capita)	190.4	145.8	307.5	281.6	234.3	234.7	281.2	354.7	303.2	202.3
Energy use (GJ/capita)	41.4	40.3	29.1	29.5	29.8	31.9	35.7	38.3	31.8	31.7