SUSTAINABLE MOBILITY IN THE CITY

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Summary

A salient feature of the 20th century has been the extraordinary growth in motorized transport, particularly in the world's rich countries and particularly by personal automobile. A disproportionate amount of car use occurs in and near cities, because people are richer there and because urban sprawl encourages car dependence. The principal causal relationships appear to be that affluence results in car ownership, which results in car use. Because car ownership impels car use, strategies for curbing car use that do not seek to limit ownership are likely to fail.

The 'high-technology' vision of World Commission URBAN 21 speaks to an increase in car ownership. It is an inappropriate vision because it would likely involve more urban sprawl, more use of land for transport, and more material consumption overall. Increases in car ownership in rich countries would stimulate even larger increases in presently poor countries. The Commission's high-technology vision—no matter how benign the proposed 'ecocar'—does not represent sustainable transport and is not consistent with progress towards sustainable transport. Moreover, the vision appears to rely on a technical feature, the fuel cell, that presents major and possibly insoluble problems in respect of its fuel supply and life-cycle energy intensity. The 'low-technology' vision presented to but rejected by the Commission offers more promise with respect to sustainable transport, chiefly because it speaks to a reduction in car ownership.

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1. Growth in transport activity

Several remarkable rates of growth set the 20th century apart in the course of human development. They include growth in population, in mobility, in degree of urbanization, and in information flow. The first two trends are unsustainable. Population growth shows signs of becoming sustainable; the growth in mobility does not.[1]

What was mostly new to the 20th century was not mobility or even mechanized mobility but *mechanized mobility by road and by air*. Travel has been a part of human experience since the migrations of our distant ancestors out of Africa, to Europe and Asia and to Australasia. The Americas have been the end points of some of the most astonishing movements of people: from Asia, across what is now the Bering Strait to as far south as Terra del Fuego, in the millennia before history, and more recently from Europe and Africa. Until the mid-1800s, travel everywhere was uncomfortable, dangerous, and enormously time-consuming.

Trains made the difference to the movement of both people and freight. The growth in their use in the late 19th century was extraordinary. But during the first few decades of the 20th century in North America—and some decades later elsewhere—even more powerful mobility phenomena took hold. They were the private automobile and its freight counterpart, the truck (lorry).*

During the 20th century, when the total human population increased fourfold, motorized movement of people and goods both increased more than one hundredfold, at higher rates in the second half of the century. Figure 1 shows the overall trends over the period 1850-1990. Figure 2 and Figure 3 show the trends by mode for respectively the movement of people and the movement of freight.[2]

The growth has not been evenly distributed. Each year, the average U.S. resident travels almost 30,000 kilometres, mostly by car. The average German resident travels about half that distance, also mostly by car. The average resident of the world's poorest countries travels less than 3,000 kilometres, mostly by foot or bicycle.[3] Freight—not the main subject of this presentation—is harder to allocate, but it is clear that large disparities also exist between the richest and the poorest countries.
The growth in motorized mobility has been mostly positive. It has facilitated and even stimulated just about everything regarded as progress. It has helped expand intellectual horizons and deter starvation. It has allowed efficient production and the ready distribution required for widespread consumption. Comfort in travel is now commonplace, as is access to the products of distant places.

But there have been costs—mostly environmental costs—that may now be exceeding the benefits. Motorized transport pollutes, as do many of the activities facilitated by transport. The tide of pollution from transport and from many other sources seems set to destroy the only niche in the universe that allows human existence. If transport's direct impact on the environment could be mitigated by the development of vehicles that emit no pollutants, we would still face the challenges of worldwide mass motorization. We would have the congestion of several billion vehicles—when all of humanity is motorized to the present level of the rich countries—rather than the present several hundred million. The several billion vehicles would embody and consume an unthinkable portion of the planet's limited resources.

And if, miraculously, we could have mass motorization without congestion and with little consumption, there could still be major problems in the form of the adverse social consequences of high levels of mobility**.** Geographer John Adams has argued that with increasing mobility societies become more polarized, more dispersed, more anonymous, less child-friendly, less culturally distinctive, less physically healthy, more crime-ridden, and less democratic. He provided evidence for these

* The words 'automobile' and 'car' are used interchangeably here to refer to personal motorized road vehicles including regular cars and also vans, light trucks, and sport utility vehicles used primarily for the movement of people. 'Truck' and 'lorry' are used to refer to motorized road vehicles used primarily for the movement of freight.

consequences from the U.K., which, he argued, is entering a condition of *hypermobility*.[4] North America, he would say, is well into hypermobility.

And if mass motorization could be environmentally and socially benign, there is still the vexing question of its economic costs. Motorization is usually considered to provide economic benefits, from the economic activity it represents, stimulates or facilitates. But motorization requires investment in what is mostly a means to an end rather than an end. Means are a cost, and economic efficiencies are achieved by reducing the need for them.

Figure 4 captures the idea of an initially positive benefit-cost balance followed by a negative balance as mobility grows. 'Hypermobility' could begin at points 'A' or 'B' in the figure.

2. Causes of automobile use

The surge in automobile use hardly needs explanation. It allows comfort, speed, privacy, and convenience in travel hardly dreamed of in former years, even by royalty. Households invest large portions of their disposable income to secure these features, as shown in Figure 5.[5] Alternatives for shorter journeys—walking, bicycling, and public transport—are usually less desirable in every respect. Alternatives for longer journeys—rail and air—compete more readily in terms of comfort and speed, although for travellers the marginal costs of these alternatives can be much higher than those for travel by car.

The essential causal relationship appears to be this: affluence results in car ownership, which results in car use. Other factors are certainly involved—purchase and operating costs, availability and utility of alternatives, etc.—but affluence and ownership seem to be the key factors.

The link between affluence and car ownership is portrayed for Canada over a 70-year period in Figure 6,[6] and for several countries over a shorter period in Figure 7.[7] This is part of the broader relationship between affluence and material consumption that underlies the growth in freight transport illustrated in Figure 1 and Figure 3.

The link between ownership and use is illustrated in Figure 8.[8] Over the 30 years represented in Figure 8, the number of cars in use and the distance travelled by car in the indicated countries both more than doubled. Figure 8 shows that the average number of kilometres driven by car remained mostly constant from year to year. This means that the growth in car *use* can be almost entirely attributed to the growth in car *ownership*.

The United States may now be the major exception to the apparent rule that the average amount driven per car remains mostly constant from year to year. Annual distances driven per car began to increase in the 1980s after being more or less constant at about 15,500 kilometres since the 1930s.[9] The increase can be seen in Figure 8, but it is more evident in Figure 9, which provides a more detailed account of the relationship between ownership and use for Canada and the U.S.[10] The only other country showing a comparable increase has been Denmark, where the cost of ownership has become relatively high and there is thus an incentive to wring more kilometres out of fewer cars.[11] In the United States—forever at the leading edge of personal motorized travel phenomena—the 'natural' constancy of annual distance driven per car may be being breached because of longer trip lengths necessitated by increasingly sprawling suburbs.

Also of note in Figure 9 is the flattening of growth in per-capita vehicle ownership in both Canada and the U.S. in the early 1990s, albeit at different levels. Continuing growth in the fleet of personal vehicles is now largely a matter of population growth in the two countries.

Data on car ownership and travel in urban regions are presented in Figure 10 and Figure 11.[12] Figure 10 shows that the number of motorized trips made by city residents is closely correlated with the level of car ownership. Figure 11 indicates, as might be expected, that the proportion of trips made by public transport declines sharply with car ownership.

A particular feature of the causation of automobile use is the existence of **several *positive* feedback loops** that reinforce ownership and use. High production volumes reduce costs thus increasing ownership and use. Widespread automobile use reduces public transport patronage and thus the viability of public transport. Large numbers of cars on the road require investment in road infrastructure, reducing the funds available for public transport and thus its attractiveness. **Above all, widespread automobilization changes settlement patterns in ways that favour automobile use and even make it essential.**

3. Car use in cities

Cities provide the opportunity to travel less—because people and what they want to visit can be closer together—and yet much of the world's growth in travel appears to be within cities. There are no worldwide data on what proportion of all travel occurs in cities or in the extensions of cities known as urban regions, but there are four reasons for supposing that most growth in travel is occurring there.

The first reason is that **people increasingly live in cities**. The left-hand panel of Figure 12 shows that the population living in urban circumstances is expected to increase in both rich and poor countries over the period 1990-2020, by about a third in presently rich countries and by more than threefold in poor countries. The rural population of poor countries will increase, but at a much lower rate than the urban population. The upper-right panel of Figure 12 shows the corresponding degrees of urbanization. The lower-right panel of Figure 12 shows that the proportions of the urban population in the largest cities are relatively constant, meaning that the trend is for greater growth in *all* cities rather than just the largest cities.[13] Figure 13 shows that urbanization rates vary widely among the different regions of the world,[14] suggesting that it is often inappropriate to treat 'poor' countries in a single category.

The second reason is that **people in cities are better off on average than people in rural areas** (which accounts for urbanization), and that amount travelled is correlated with income. Automobile ownership—to be discussed further below—is the main factor in this relationship. High incomes make inter-city and inter-continental travel more affordable, but on average most travel continues to be local travel, particularly by car.

The third reason is that **urban regions are expanding**, extending the average lengths of journeys made by their residents. In rich countries, particularly Australia, Canada, and the U.S., the size of urban regions increases at a much higher rate than their population, a phenomenon usually known as **urban sprawl**. In poor countries, the expansion of urban regions is more commensurate with population growth, but the growth is considerable, and the corresponding increases in journey length can be large.[15]

The fourth reason is the already noted **greater attractiveness of the car for travel with rather than between cities**, compared with the respective alternatives. A feature of travel within urban areas is that more of it is from suburb to suburb, rather than from suburb to core or vice versa, as illustrated for the Greater Toronto Area in Table 1 and in Table 2.[16] Jobs, shopping opportunities, and friends are found increasingly in suburbs, requiring journeys that are difficult to make by public transport. As well, leisure is replacing work as the main reason for travel (see Table 3), adding to the relative inconvenience of public transport, which often continues to focus on serving commuters.

4. Curbing car use

The analysis so far suggests that if people have cars they will use them, increasingly within urban regions. The most effective and perhaps the *only* way to limit use may be to limit ownership.

David Banister, in his report prepared for the URBAN 21 project, noted that "demand management [i.e., limiting use of automobiles], combined with strong policies to promote public transport and the concentration of development, … is the key to sustainable development".[17] Seven basic objectives were proposed. Banister noted, "in practice the achievement of [these objectives] has been limited". The lack of success may have occurred because the objectives did not include reducing levels of car ownership.
Banister reviewed many measures for reducing car use and the effects of car use. Some of them could have the indirect effect of causing incidental reductions in ownership levels, but this was not an evident objective. As with many other discussions of curbing car use, his review sometimes seems infused with the implicit goal that every household or person should own a car but rarely use it. The logic is simple: cars in garages do not pollute; cars on roads do.[18] The data on distance travelled per car (Figure 8 and Figure 9) suggest that such restraint is unlikely to be achieved. Owning a car is the strongest imperative to use.

Indeed, there is a current disposition to reduce use while favouring ownership. Measures are proposed to reduce the fixed costs of operation of a car (e.g., sales taxes and annual licence fees) while increasing the variable costs (e.g., fuel taxes and tolls or other road charges). Some fixed costs could be "variabilized." Insurance, for example, could be paid through gasoline taxes, and therefore according to distance travelled, rather than as an annual lump sum independent of use.[19]

An additional point is that **measures for reducing the *effects* of car use—e.g., improving the energy efficiency of vehicles—can have perverse effects**. This is most evident in the case of improvements in energy efficiency, which may reduce the cost of operation of a vehicle and thus encourage its use.[20] Improvements in pollution control can have a more subtle effect. By making cars less harmful, such measures can improve or sustain the social acceptability of car use and thus encourage more travel by car. This is *not* to say that such measures are undesirable, only that they may have different from intended effects if action is not also taken to reduce car use, which may mean reducing car ownership.

5. Reasons given for discouraging use rather than ownership, presented with *countervailing points*[21]

The prevailing disposition is to discourage use rather than ownership. Some of the reasons for this are set out in this section *with some countervailing points in italics*:

- The present balance of high ownership costs and low use costs encourages use. Not only is the marginal cost of travelling each kilometre low—often lower than public transport—owners feel compelled to make the most of the investment in high fixed costs by spreading them out over as many kilometres as possible. *The data support this argument, up to a point. Cars are driven more where fixed costs are high and variable costs low, compared with countries where the opposite is true. However, there is less driving overall in the former kind of country*[22]*. The reductions in use resulting from variabilization of capital costs do not appear to be enough to offset the increases in use resulting from increased ownership.*

- There could be major economic consequences if restrictions on ownership were to reduce car purchases. *This may be true. However, it is difficult to imagine any transition to sustainable transport that would not involve economic dislocation of some kind. Constraints on use also have economic consequences. They reduce oil industry sales, the need for vehicle maintenance, and*

ultimately the need for vehicle replacement. Whatever is done must consider economic and other consequences and plan to minimize or counteract them.

- Restricting automobile ownership is undemocratic. It is associated with authoritarian regimes. Their demise is often marked by large increases in car ownership. Democrats argue that everyone should have freedom to be a member of the car-owning classes. Restrictions on use are not seen as so undemocratic because they are made in the name of safety or of the amenity of all car owners. *In the late 1980s, car ownership levels in East Germany and in the Warsaw area of Poland were similar to those in Japan.*[23] *However, in East Germany and Poland there were more restrictions on use than in Japan. Thus the reality may be that authoritarian regimes are actually concerned to restrict use more than ownership. A larger point is that widespread ownership may bring its own social costs. Where public transport services are displaced because of widespread ownership, the result may be severely restricted mobility, and thus restricted access to life's essentials, for quite large parts of the population. These parts include anyone who cannot drive or who does not have access to a car. An equally important point may be that automobile ownership creates a political constituency for automobile use that can worsen the plight of people without automobiles.*

- If ownership is discouraged, by high purchase costs, for example, early replacement of vehicles will be less likely, and so technological change will penetrate less easily. *This may be true, but a solution could emerge. Cars could be designed to accommodate technological improvements during their lifetimes, and incorporation of significant improvements could be mandatory. For example, the pollution control system for exhaust gases could be modular and designed to be replaced each year with an improved version.*

- Above all, the reason for discouraging use rather than ownership is the one given first: use pollutes, ownership does not. If use is the problem, curtail use. *The problem with this logic is evidence that it may be more effective to limit use through limits on ownership than to limit use directly. There is an addition problem: ownership pollutes as well as use. Production and disposal of automobiles consume resources and have environmental impacts, as does the storage of vehicles. In Europe, these impacts have been estimated to be about one third of the impacts of use over the lifetime of a typical vehicle;*[24] *it is perhaps a lesser proportion in North America on account of the greater amount of use per vehicle. If use is restrained, overall environmental effects decline, but the relative significance of the impacts of production, storage, and disposal increases.*

6. Strategies for reducing car use vs. strategies for reducing car ownership

Strategies for reducing automobile use directly can be quite different from strategies for reducing use through reducing ownership.

Strategies for reducing use usually focus on two things. One is raising the cost of automobile use. The other is providing alternatives to automobile use, particularly at peak use periods. Often only the second element is considered, chiefly in the form of provision of more public transport. Such provision, without complementary increases in the costs of automobile use, may result in underused public transport that uses as much energy use per passenger-kilometre as the automobiles it is designed to replace. This phenomenon is already evident in the United States, as suggested by Table 4.[25]

Strategies for reducing ownership are generally more holistic. They begin with an assessment of what would be required to prevent purchase of an additional automobile or to induce sale of one already owned. The necessary actions may include development of services that substitute not so much for regular uses of the automobile as for uncommon uses. These can include car rental, car sharing, demand-driven public transport, and delivery services.

The difference can be illustrated in part by this example. A woman purchased a car in order to visit the supermarket on Saturdays and her mother on Sundays but, because she has a car, uses it to travel to and from work each day even though public transport is available for this journey. The 'reducing use' strategy is likely to focus on the work-related trips, which are more readily replaceable by public transport. It seeks to discourage them and to make public transport more attractive. The 'reducing ownership' strategy addresses the shopping trips by ensuring availability of a delivery service (or a nearby store) and the Sunday visits by ensuring availability of a car sharing service.

The 'reducing use' strategy results in a car owner who leaves the car at home for work trips. Because the car is there, the owner is constantly tempted to use it. She may use it for work trips if public transport does not continue to be more attractive, and she readily uses it for other trips. The 'reducing ownership' strategy results in a person who does not own a car. Because, with this strategy, the barriers to ownership are high, he has a strong stake in ensuring that alternatives to the car are readily available, and he uses them.

7. The EANO principle for the design and organization of urban regions

The holistic nature of the 'reducing ownership' strategy can be captured in an overarching principle that can be applied to all aspects of the design and organization of an urban area: ***Every part of every urban region should be developed and organized so that the advantages of not owning a car are at least equal to the advantages of owning a car***. This principle can be known as the EANO principle (Equal Advantage for Non-Ownership).

Successful application of the EANO principle would result in people choosing to live without owning a car. Many do this already, including people who could readily afford to buy a car (see Figure 14).[26] Examination of the circumstances of their lives can provide clues as to how the whole urban region could be designed and organized to reduce automobile ownership and use.

People who now choose to live without cars tend to live in or near city centres, in places where public transport is good, shops are nearby, cultural and recreational opportunities are readily available, and work trips can be short. Paradoxically, the main problem with living in such areas is often the air pollution and noise from road traffic, mostly from the automobiles of people who live elsewhere but also from delivery vehicles. If these conditions applied throughout urban regions there would be less traffic, less pollution, and less noise in the central cities.

City centres are special places, and it may be difficult to provide all of the amenities that support living without a car in every part of a large urban region. Nor, with good public transport, might it be necessary. Could public transport be so good? The reasonable answer is "yes, if there were fewer cars."

The automobile is the natural enemy of public transport. It retards service with the congestion it causes. Above all, it competes for passengers and for the revenue they provide that makes good public transit possible.

Here, in summary, are some of the **amenities and services that support living without the car**:

- schools, stores, and recreational and cultural facilities within a walk, a bicycle ride or a short public transport journey.
- safe and enticing routes along which to walk or ride a bicycle.
- good public transport, which in lower-density areas will include demand-driven service to the door or to nearby pick-up and set-down points.
- ready access to places of employment and to the services that support home-based employment.

- car-sharing services for longer or special trips.
- delivery services for the carriage of purchased goods and for other purposes.
- excellent information about all of the above.

The EANO principle speaks to the evolution of a different kind of city, one where people rather than automobiles prevail. Such a city may be able to emerge only with much lower levels of automobile ownership than currently exist. A corresponding principle or set of principles is needed for the delivery of goods; its development is beyond the scope of this paper.

Application of the EANO principle would be largely at the initiative of local and regional authorities. They would act in two ways (always with appropriate consultation). First, they would attend to already developed parts of the region, taking steps to ensure that non-ownership is sufficiently advantaged in relation to ownership. Some interventions will be matters of urban design and infrastructure management, e.g., provision of adequate sidewalks and bicycle paths. Other interventions will require changes in land use, e.g., re-zoning to encourage the establishment of local stores and other commercial activities. These will take a relatively long time to achieve an effect. Yet other interventions will involve the facilitation and even the stimulation of new businesses, such as taxi-bus and car-sharing services, that are closely integrated with regular public transport, and goods delivery services.

Second, local and regional authorities would regulate redevelopment and new development according to the EANO principle, both within the urban envelope and at its edge. Developers would be required to ensure equal advantages for non-ownership throughout their proposed developments.

8. The low-technology strategy is better

In his report prepared for the URBAN 21 project, David Banister set out a 'business-as-usual' but "relatively cautious" reference case for the European Union in 2020 and **two visions of transportation in the sustainable city** in that year, a 'low-technology' vision and a 'high-technology' vision.[27] The reference case spoke to a 50-per-cent increase in passenger-kilometres travelled by automobile over the 1995 level; the two visions spoke respectively to a 24-per-cent reduction and a 30-per-cent increase.

The low-technology vision would see a reduction in car ownership; the high-technology vision would see a moderate increase in ownership. Both visions would result in reductions in emissions from transport compared with 1995 levels, by 25 per cent in the case of carbon dioxide and by 80 per cent in the case of nitrogen oxides. In the low-technology vision, the reductions would be achieved mainly by reducing transport volume; in the high-technology vision, there would be a stronger emphasis on development of the "eco-car … primarily for use in urban areas … powered by hydrogen fuel cells".

First, it should be said that **neither vision can be regarded as sustainable**. According to the Intergovernmental Panel on Climate Change, reductions in greenhouse gases, mainly carbon dioxide, of 50 per cent or more worldwide from 1990 levels are required to prevent further climate change.[28] It seems reasonable that larger reductions should be implemented in richer countries to allow more room for development elsewhere.

Participants in the Environmentally Sustainable Transport (EST) project of the Organisation for Economic Cooperation and Development (OECD) have proposed that OECD Member countries reduce CO_2 emissions from transport by 80 per cent compared with 1990 levels.[29] In the same project, reductions in NO_x emissions from transport of 90 per cent are considered necessary for sustainability, al-

though such reductions are projected to be invariably achieved if CO_2 emissions are reduced by 80 per cent.

The two Banister visions can be regarded only as steps toward sustainability rather than sustainability itself, chiefly on account of the proposed modest reduction in CO_2 emissions from transport. The targetted 25-per-cent reduction from 1995 levels represents only a quarter of the absolute reduction proposed by the OECD's EST project's participants for sustainability.

The World Commission URBAN 21 compounded the insufficiency of the CO_2 target by opting for the high-technology scenario. This was a mistake, for several reasons. The most important reason is that **the low-technology scenario, because it speaks to reduced automobile ownership, would be more compatible with the more stringent targets required for sustainability**:

- Reduced automobile ownership, according to the analysis presented above, would mean that lower amounts of transport activity are more likely to occur.

- Increased automobile ownership, as featured in the high-technology scenario, would continue to **facilitate urban sprawl and associated high levels of energy use**, particularly within the larger buildings that are typically found at suburban fringes.

- **Automobiles require space for storage and movement**. Excessive land use for transport is itself environmentally unsound, because of drainage and barrier effects, and adds to the imperatives for sprawl.

- **Automobile ownership is associated with other kinds of material consumption**, because of the ease with which goods can be carried.

- **Emulation of high levels of automobile ownership in rich countries** is a major cause of automobilization in poor countries.

As well, there are risks in a commitment to personal vehicles powered by fuel cells. These lie in the viability and energy intensity of the fuel systems rather than in the basic feasibility of the fuel-cell technology. Mass production of hydrogen seems impracticable on account of the scarcity or unreliability of the sources and the difficulties of storage and distribution. On-board generation of hydrogen from fossil fuels—gasoline, natural gas or methanol—may be more energy intensive on a full-life-cycle basis than more direct use of the fuels in conventional or hybrid power systems.[30]

As difficult as it may seem, reducing automobile ownership may well involve less risk than reliance on unpromising technology. Of countries with market economies, Singapore has been the only one to address the issue of ownership successfully, through high taxes and a rationing scheme supported by stringent land-use controls and a rational approach to public transport. Singapore's example shows that ownership can be restrained, albeit by a democratically elected government that is unusually authoritarian. As well as the more benign measures associated with application of the EANO principle set out above, the more aggressive measures used in Singapore may well have to be applied throughout the world's rich countries to achieve reductions in ownership.

The first steps are to recognize the importance of the link between ownership and use of cars, and to include reduction in ownership as an explicit objective—perhaps the most important objective—towards attainment of sustainable transportation.

END NOTES

[1] The trend to urbanization—15 per cent of the world's population lived in cities at the beginning of the century, almost 50 per cent at the end—may be consistent with sustainability because urban living makes less resource use possible at a given level of material welfare. Information technology acts in contradictory ways largely because of its effect on transport, which it both facilitates and replaces.

[2] Figures 1, 2, and 3 are based on data compiled for Issue No. 3 of the *Sustainable Transportation Monitor* (Centre for Sustainable Transportation, Toronto, Canada, March 2000, available at www.web.net/~cstctd), and for Gilbert R, Sustainable Transportation, Volume 5 of *Encyclopedia of Global Environmental Change*, Wiley, London, UK, and New York (in press). Versions of Figures 2 and 3 appear in those two sources. The main source of the data in Figures 1-3 is Mitchell BR, *International Historical Statistics* (3 volumes). Macmillan, London, UK, 1992-5. Additional sources are: population, from United Nations Environment Program, *Global Environmental Outlook 2000*, Earthscan Publications, London, UK, 1999, p. 6; ocean freight, *European Transport in Figures*, European Commission, Brussels, Belgium, October 1999, Table 9.4; number of automobiles and trucks, from *World Motor Vehicle Data*, American Automobile Manufacturers Association, Detroit, Michigan, 1998, Page 8. Estimates of automobile passenger-kilometres (pkm) and truck tonne-kilometres (tkm) were made by multiplying numbers of vehicles by author's estimates of annual pkm and tkm. The estimates of walk/bicycle activity shown for comparison are also the author's, based in part on Ausubel JH et al, Toward green mobility: The evolution of transport, *European Review*, 6(2), 137-156 (1998). Figures 1-3 show relative trends rather than precise data; all estimates are approximate. Data for indicated years may be for a few years earlier. The relative positions of the lines concerning the motorized movement of freight and people in Figure 1 arise from the units used. If the unit of freight movement is 'three tonnes moved through one kilometre' rather than 'one tonne moved through one kilometre' the lines for freight and people follow almost identical trajectories. This suggests that movement of one person is in some way equivalent to movement of three tonnes of freight. It suggests too that movement of freight and people may be subject to the same underlying cause or causes.

[3] The estimate in this paragraph for the U.S. is for 1996 and is based on U.S. Department of Transportation, Bureau of Transportation Statistics, *North American Transportation Highlights*, December 1999, Table 5; to the given annual total of 27,000 kilometres, 2,000 kilometres has been added for international air travel and 500 kilometres for walking and bicycling. Data on international air travel per capita for the U.S. are represented in Box 4 of Issue No. 3 of the *Sustainable Transportation Monitor* (see www.web.net/~cstctd). The estimate for Germany is based on data provided to the OECD Environment Directorate by the Wuppertal Institute, also supplemented by 2,000 kilometres/person/year to allow for international air travel and walking/bicycling. Estimates of walk/bicycle activity and of transport activity in developing countries are the author's, based in part on the paper by Ausubel JH et al cited in Note 2.

[4] Adams JGU, *Social implications of hypermobility*, OECD, Paris, 1999.

[5] Data for Canada in Figure 4 are from Transport Canada's *Annual Report for 1998*, Tables 2-4 and Figure 2-3. (Figure 4 uses the overall percentages for various countries found in Figure 2-3 of the Transport Canada report.) The disaggregations set out for the other countries are based on the following sources. The data for European countries are from European Commission (Eurostat), *European Transport in Figures*, October 1999, Table 1.8. The data for the U.S. are from U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics*, 1997, Table 2-11. The data in Figure 4 suggest that in the indicated countries roughly one eighth of household disposable income is spent on the ownership and operation of private automobiles.

[6] Figure 5 is from a Transport Canada document entitled *The socio-economic context of the Canadian road and highway system*, available at www.tc.gc.ca/pol/en/report/Highway_Socio_Economic/Chapter4.htm.

[7] Figure 6 is from a presentation made by Lee Schipper of the International Energy Agency to a workshop on *Fuel Taxation* held by Transport Canada, Ottawa, March 4-5, 1999.

[8] Figure 7 is from the source detailed in Note 7.

[9] See Gilbert R, Reducing automobile use in urban areas by reducing automobile ownership: the EANO principle. In Proceedings of a workshop on "The future of urban travel", Centre Jacques Cartier, Lyon, France, December 1998.

[10] Data for Canada in Figure 8 come from Transport Canada's *Annual Report* for 1996 and from Statistics Canada's census data. Data for the U.S. come from Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics*, 1997, and from the U.S. Census Bureau.

[11] For a brief discussion of the factors in distance driven per car, see Johansson O, Schipper L, Measuring the long-run fuel demand of cars: Separate estimations of vehicle stock, mean fuel intensity, and mean annual driving distance, *Journal of Transport Economics and Policy*, pp. 277-292 (1997).

[12] Figures 9 and 10 are respectively Figures 2 and 1 in Knoflacher H, Does the development of mobility in traffic follow a pattern? In Hollister-Short G and James F, *History of Technology*, Vol. 15, Mansell (1993).

[13] Figure 11 is based on World Resources Institute et al, *1998-1999 World Resources: A Guide to the Global Environment*, Oxford University Press, London, 1999 (populations and degree of urbanization taken from Table 9.1), and *1999 World Development Indicators*, World Bank, Washington DC, 1999 (population in urban agglomerations larger than one million extrapolated—to allow for different dates—from Table 3.10).

[14] Figure 12 is based on Table 3.10 of *1999 World Development Indicators*, World Bank, Washington DC, 1999.

[15] See International Council for Local Environmental Initiatives (ICLEI), *Urban Land Use Management and Global Sustainability*, Background paper for the Eighth Session of UN Commission on Sustainable Development, April 2000.

[16] Tables 1, 2, and 3 are based on the author's analysis of the *Transportation Tomorrow Survey*, conducted every five years for various agencies by the Joint Program on Transportation at the University of Toronto (see www.jpint.utoronto.ca

[17] Banister D, *Sustainable Development and Transport*, Final Report for the URBAN 21 project, August 1998. The quotes in this paragraph are respectively from Pages 19 and 20.

[18] Schipper L, Determinants of automobile use and energy consumption in OECD countries. In *Annual Review of Energy and Environment*, pp. 325-386, 1995.

[19] See, for example, Litman T, *Distance-based vehicle insurance*. Victoria Transport Policy Institute (available at www.vtpi.org).

[20] See, for example, Greene DL, Vehicle use and fuel economy: how big is the 'rebound' effect? *The Energy Journal*, 13, pp. 117-143, 1993.

[21] This section and the next two have been adapted from the source detailed in Note 9.

[22] See the source detailed in Note 18.

[23] Wolf W, *Car Mania: A Critical History of Transport*, Pluto Press, 1996.

[24] See, for example, Martin D, Michaelis L, *Research and technology strategy to help overcome environmental problems in relation to transport*, United Kingdom Atomic Energy Authority, 1992.

[25] Table 4 is abstracted from US Dept. of Transport, Bureau of Transportation Statistics, *National Transportation Statistics*, 1999, at www.bts.gov/ntda/nts.

[26] Car ownership data in Figure 13 come from the 1991 TTS survey (see Note 16). Individual and household income are from the *Census of Canada*, 1991.

[27] See the source detailed in Note 17.

[28] The report of the Intergovernmental Panel on Climate Change is Houghton JD, et al. eds., *Climate Change 1995: The Science of Climate Change*. Cambridge University Press, Cambridge UK, 1996

[29] The reports on the OECD's EST project are available at www.oecd.org/env/trans/.

[30] See, for example, Kolke R (German Environmental Protection Agency, UBA), Alternative and advanced propulsion systems from the environmental point of view. Presentation at the Global Powertrain Congress, Detroit, U.S.A., 1998; and Keller M, Zbinden R, EST-Alpine: Feasibility of the technological changes, INFRAS, Berne, Switzerland, April 2000.

Figure 1. Motorized movement of freight and people, 1850-1990

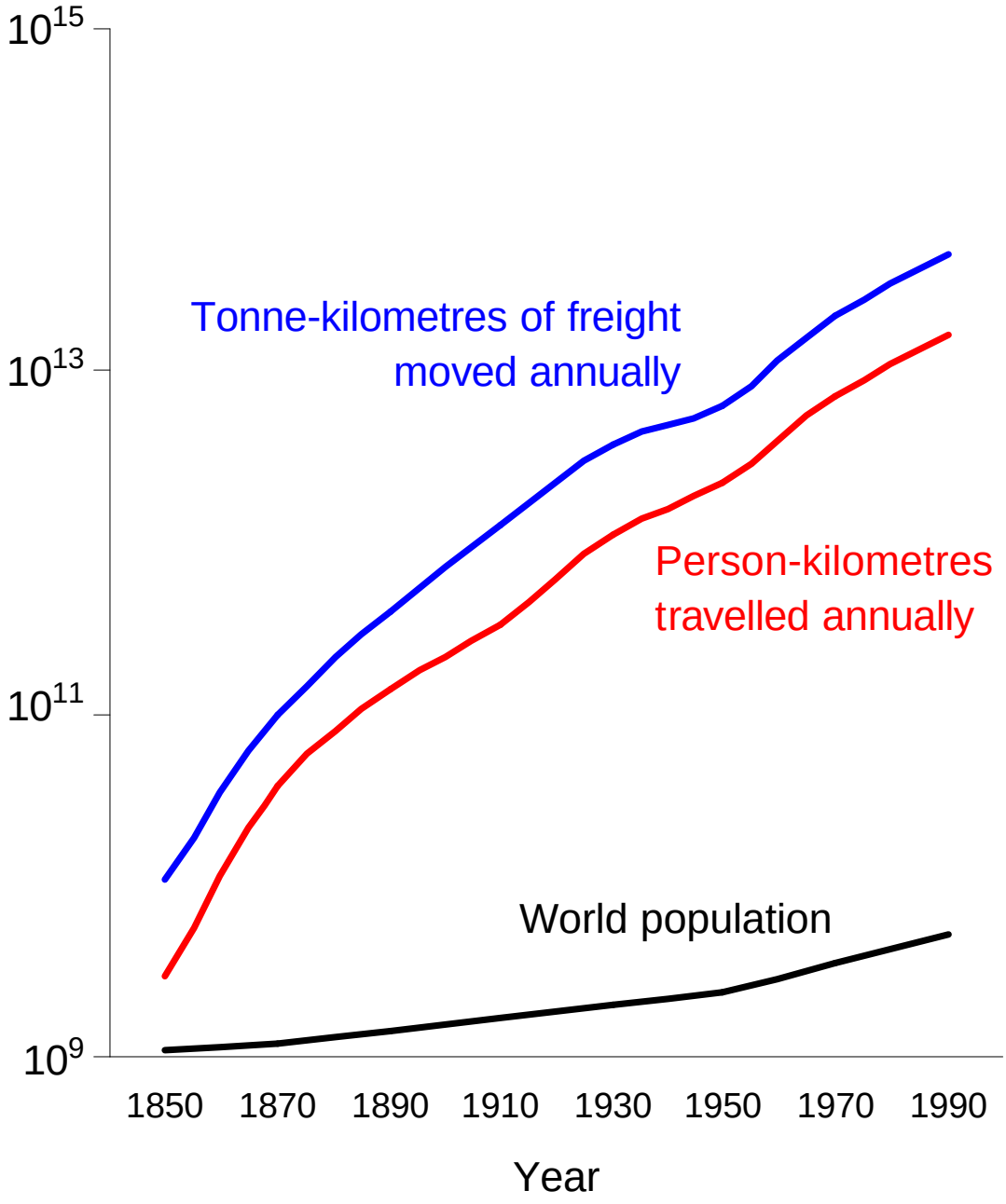


Figure 2. Movement of people by mode, 1850-1990

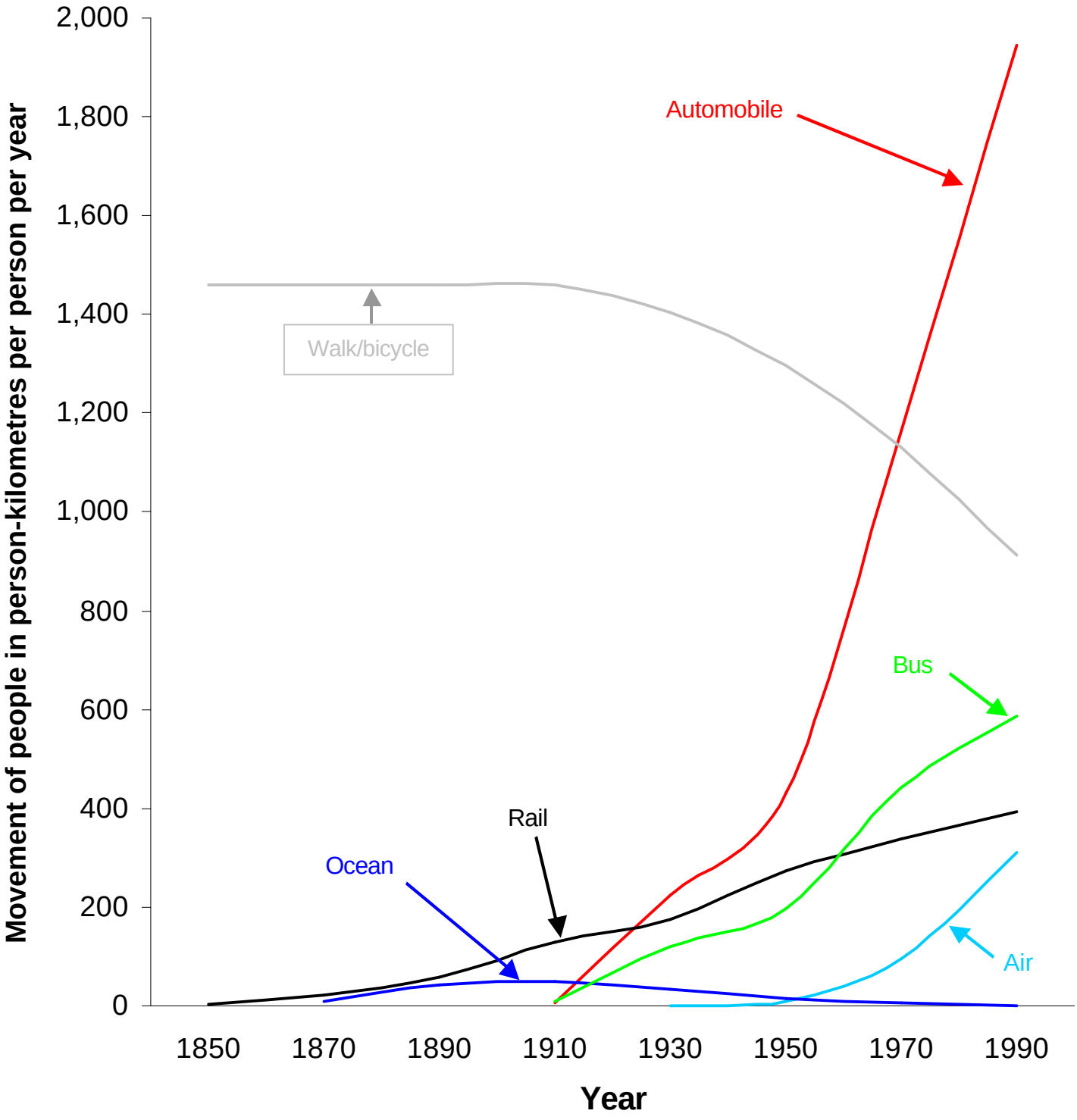


Figure 3. Motorized movement of freight by mode, 1850-1990

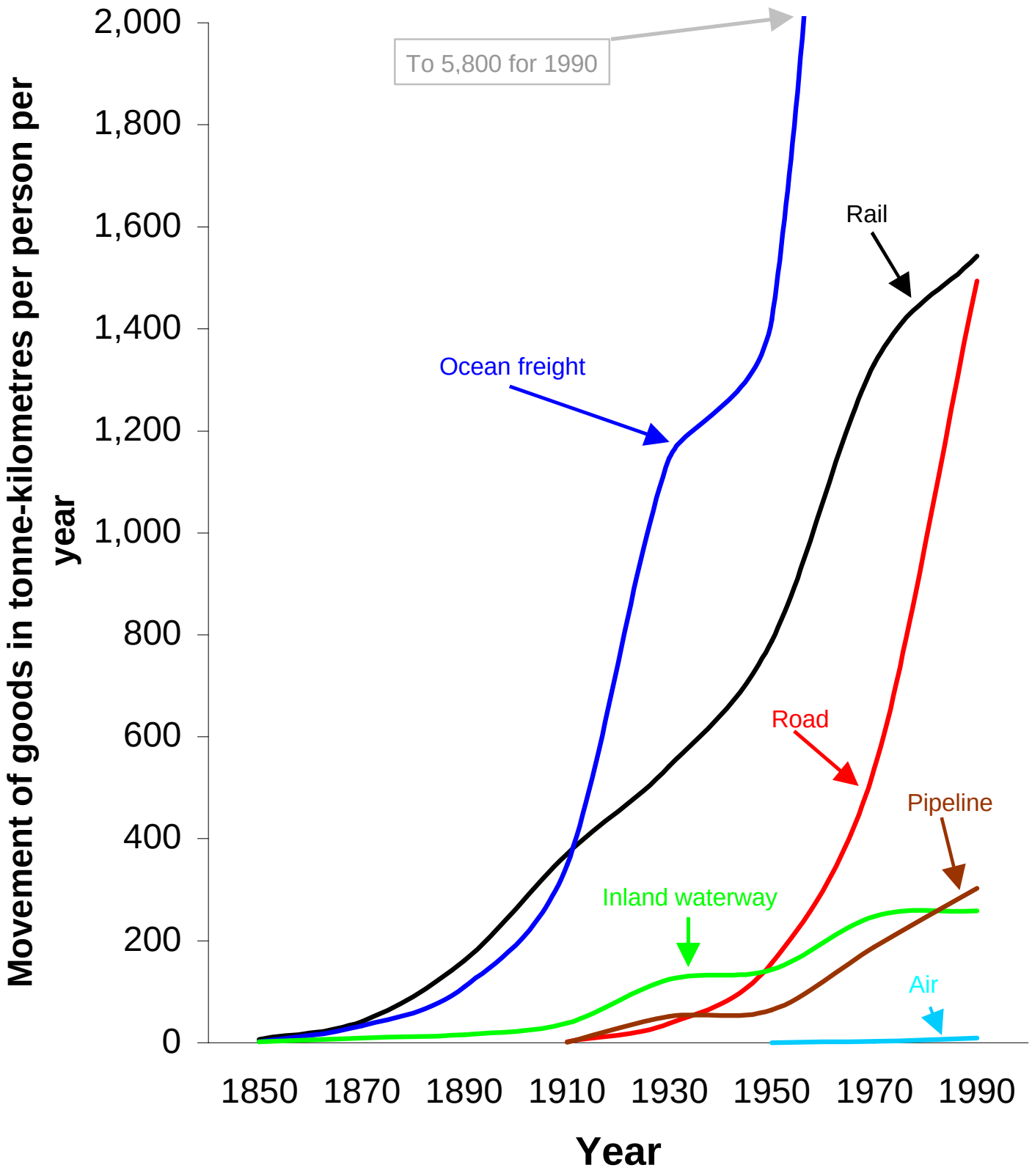


Figure 4. Schematic of the balance of the benefits and costs of transport with increasing motorization. ('A' or 'B' represents the beginning of 'hypermobility'.)

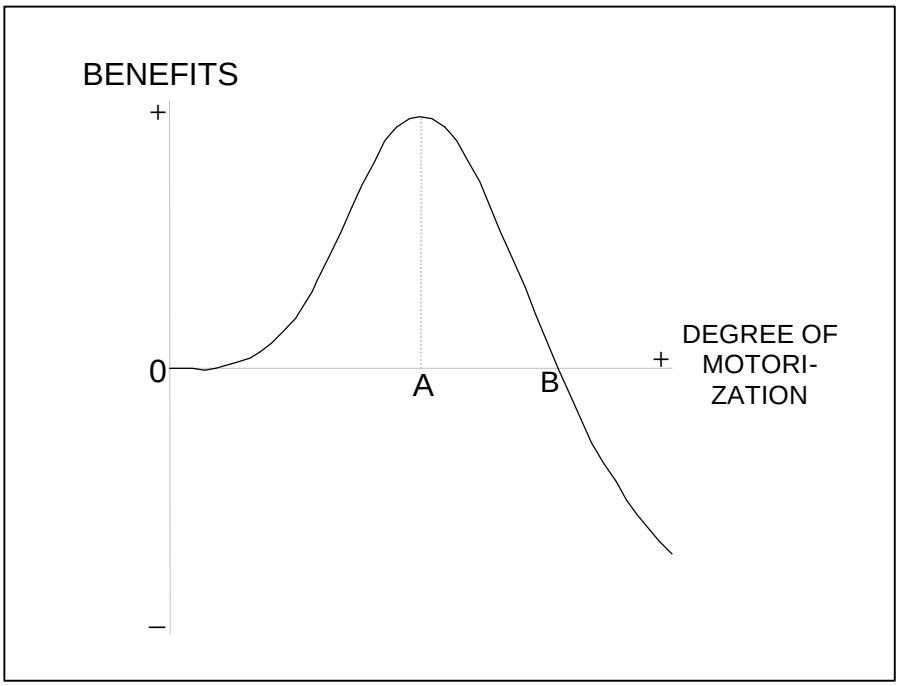


Figure 5. Household expenditures on transport as a percentage of all after-tax expenditures for selected countries, showing—except for Japan and Australia—proportions spent on ownership and operation of personal vehicles and on local and other purchased transport

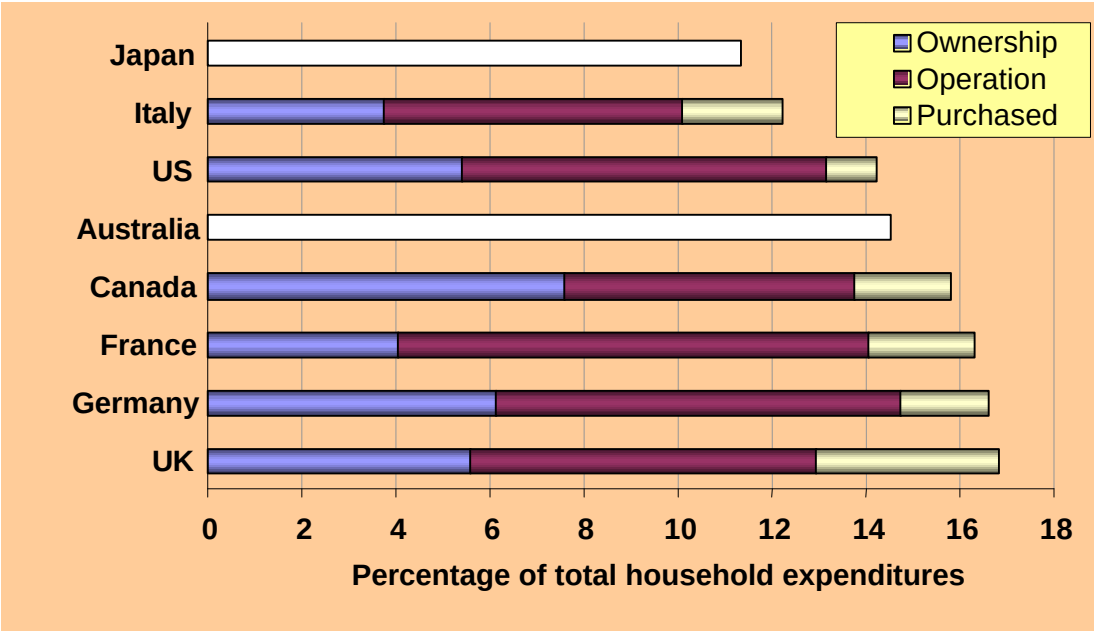


Figure 6. Affluence and ownership of personal vehicles, Canada, 1920-1990

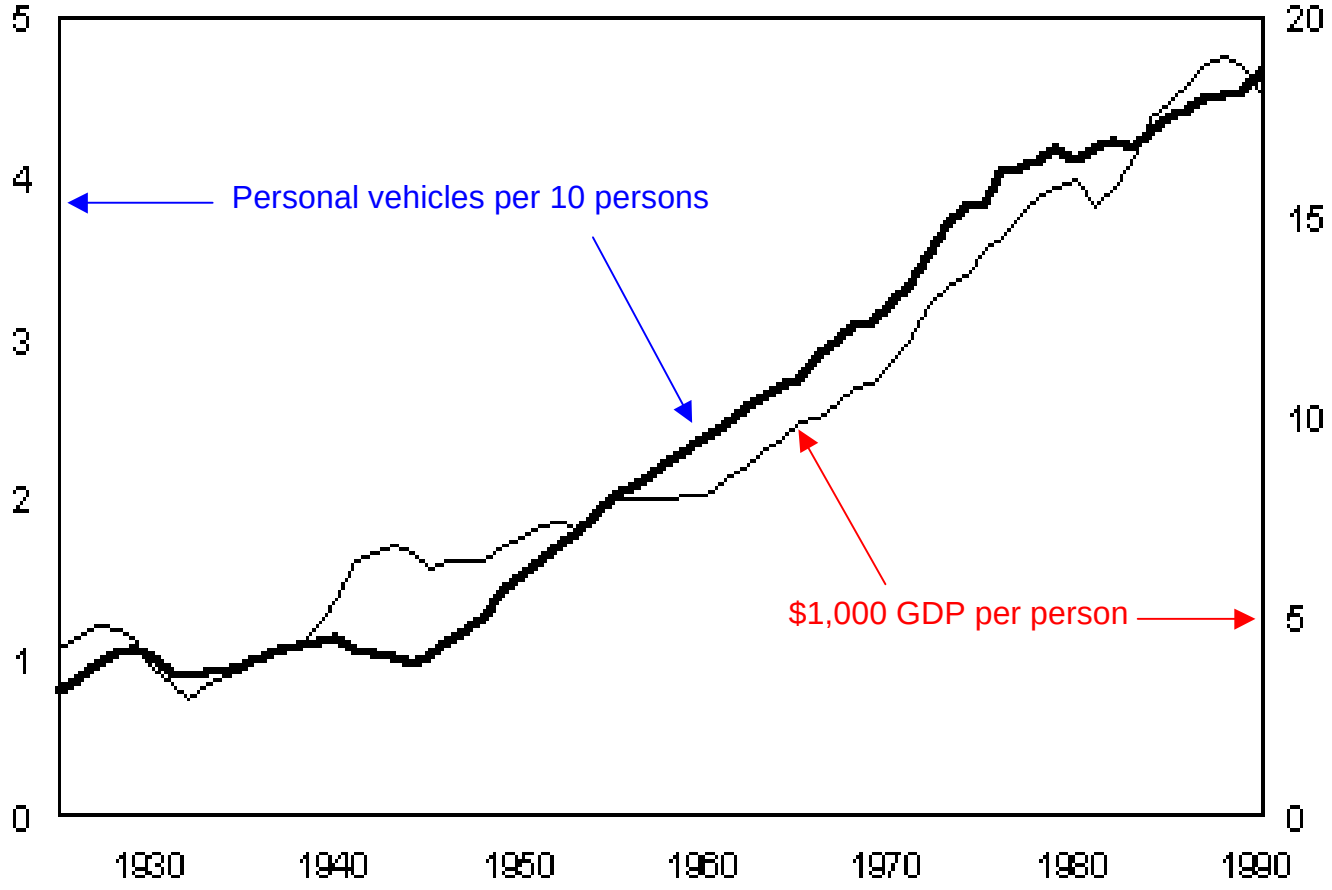


Figure 7. Rates of ownership of personal automobiles and per capita GDP, various countries

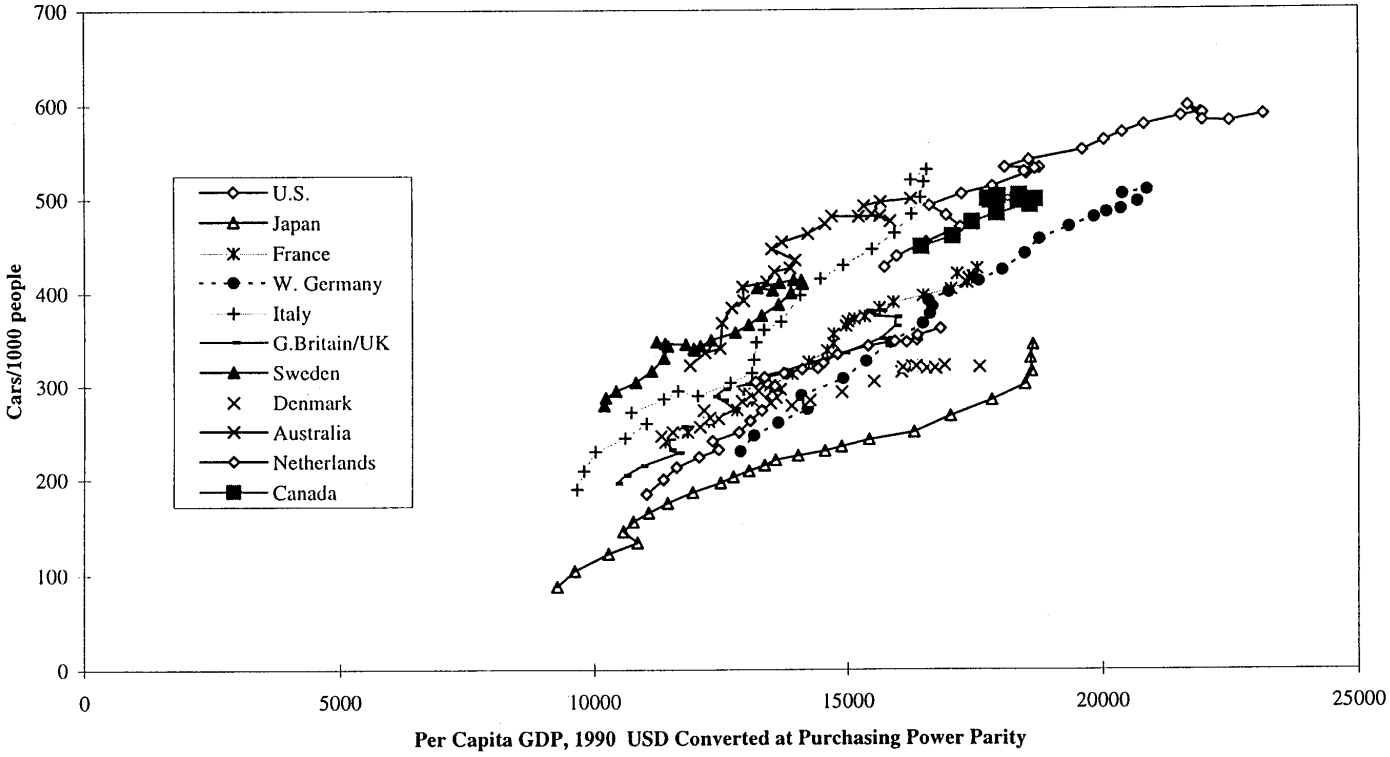


Figure 8. Distance driver per vehicle, several countries, 1970-1995.

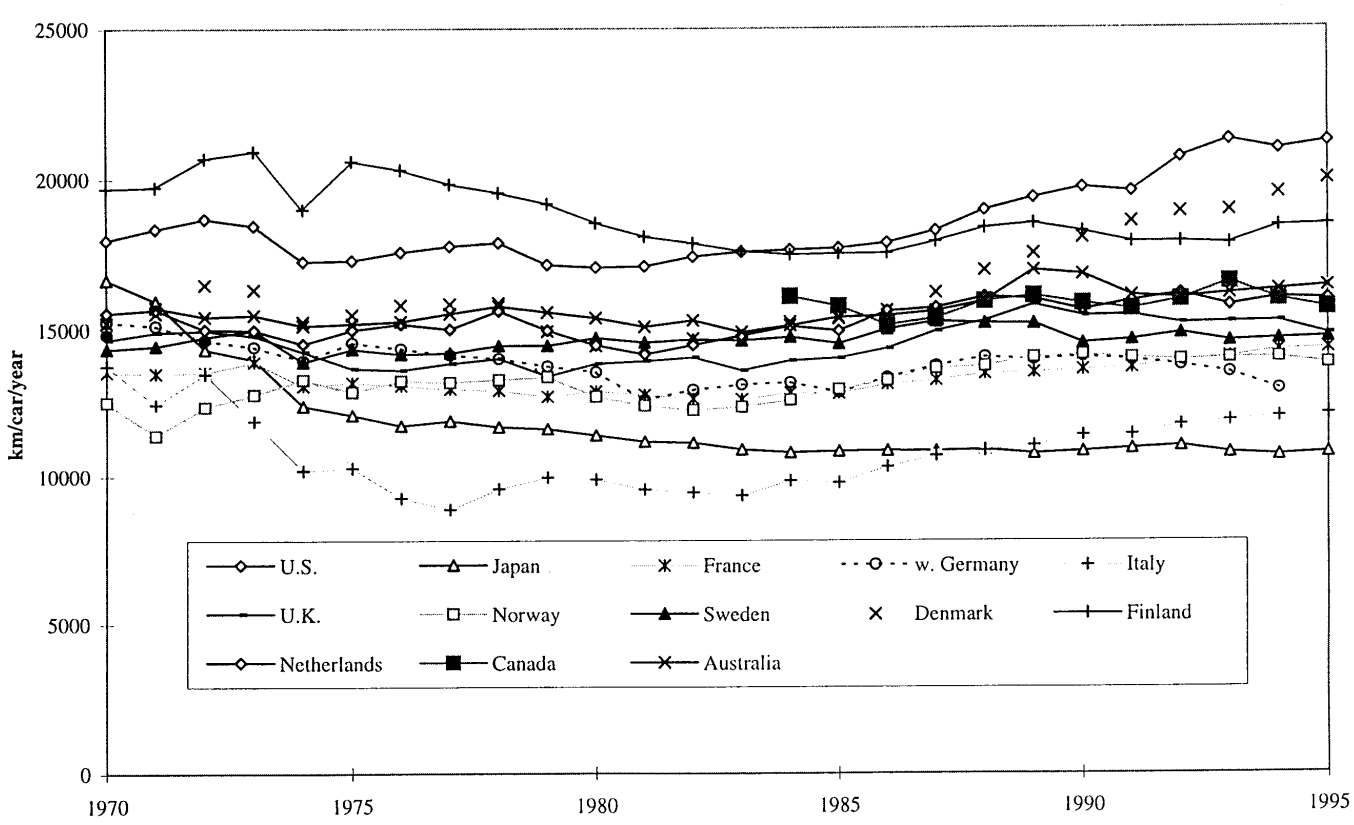


Figure 9. Personal vehicles in use and distances travelled, Canada and the U.S., 1965-1995

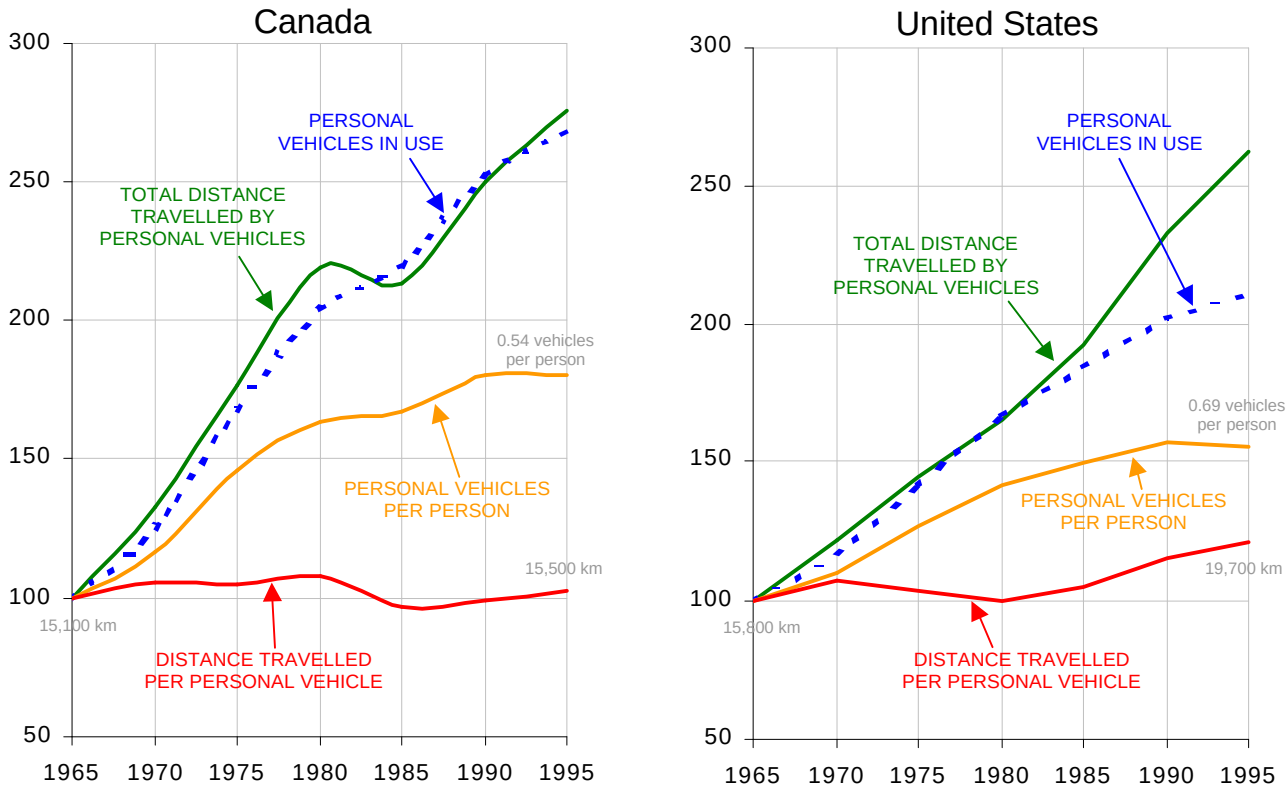
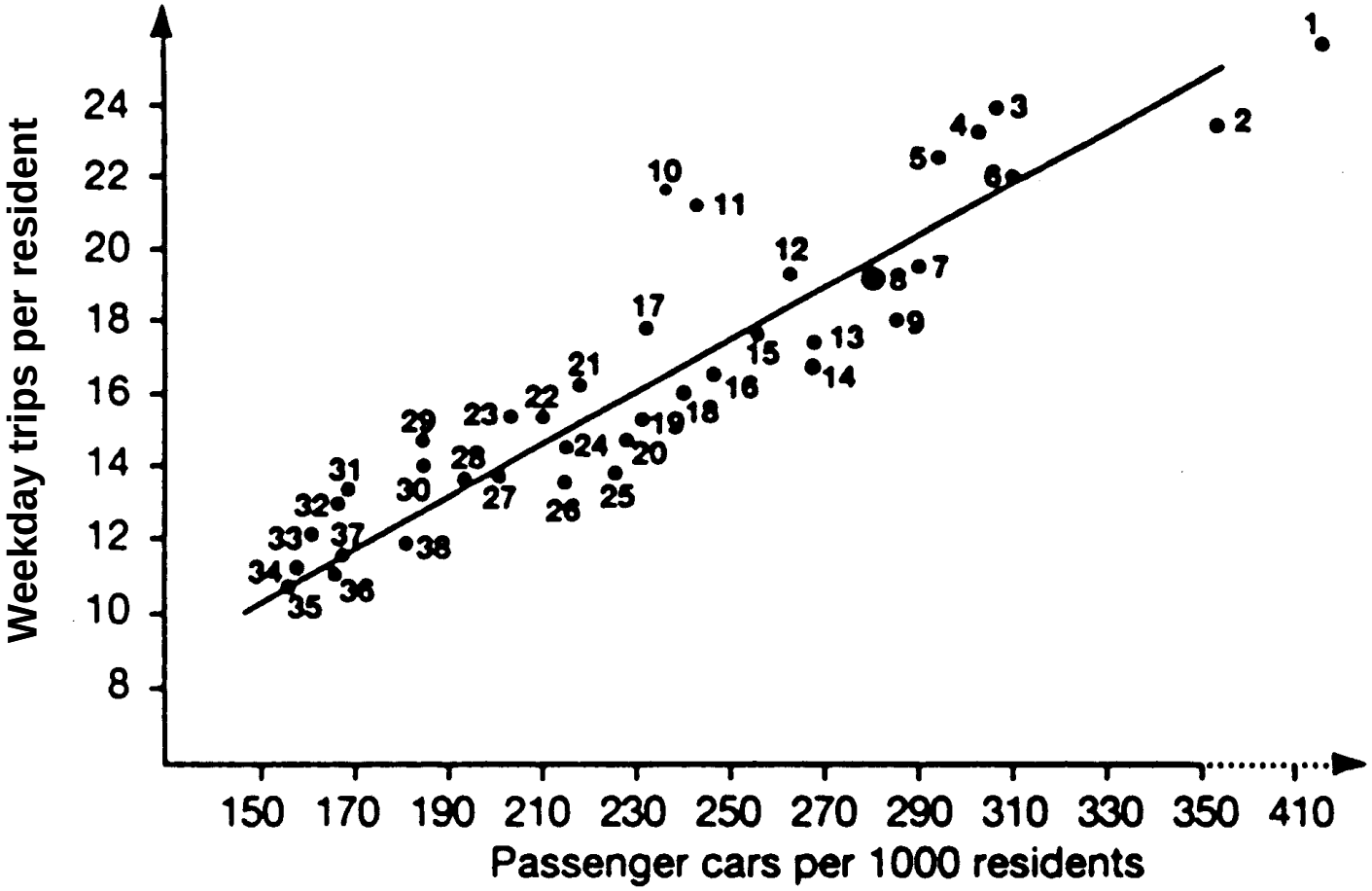


Figure 10. Weekday trips per resident according to car ownership; 38 cities in Europe and the United States.



1 Reno 1955
2 Phoenix 1957
3 Charlotte 1958
4 Nashville 1959
5 Houston 1953
6 Kansas City 1957
7 St Louis 1957
8 KONTIV 1975
9 Detroit 1953
10 Ingolstadt 1969
11 Salzburg 1969
12 Chicago 1956
13 Washington 1955
14 Pittsburgh 1958
15 Aachen 1972
16 Munich 1970
17 Bonn 1970
18 Heidelberg 1969
19 Mannheim 1969
20 Nettetal 1970
21 Hamburg Region 1971
22 Erlangen 1967
23 Munich 1965
24 Grevenbroich 1970
25 Ludwigshafen 1969
26 Nuremberg 1967
27 Krefeld 1968
28 Fürth 1967
29 Gütersloh 1964
30 Ham 1965
31 Wuppertal 1964
32 Brühl 1964
33 Hanover 1962
34 Kreis Krempen-Krefeld 1964
35 Lünen 1966
36 Opladen 1966
37 Untere Werre 1967
38 Kreis Minden 1967

Figure 11. Relative use of public transport in relation to car ownership level

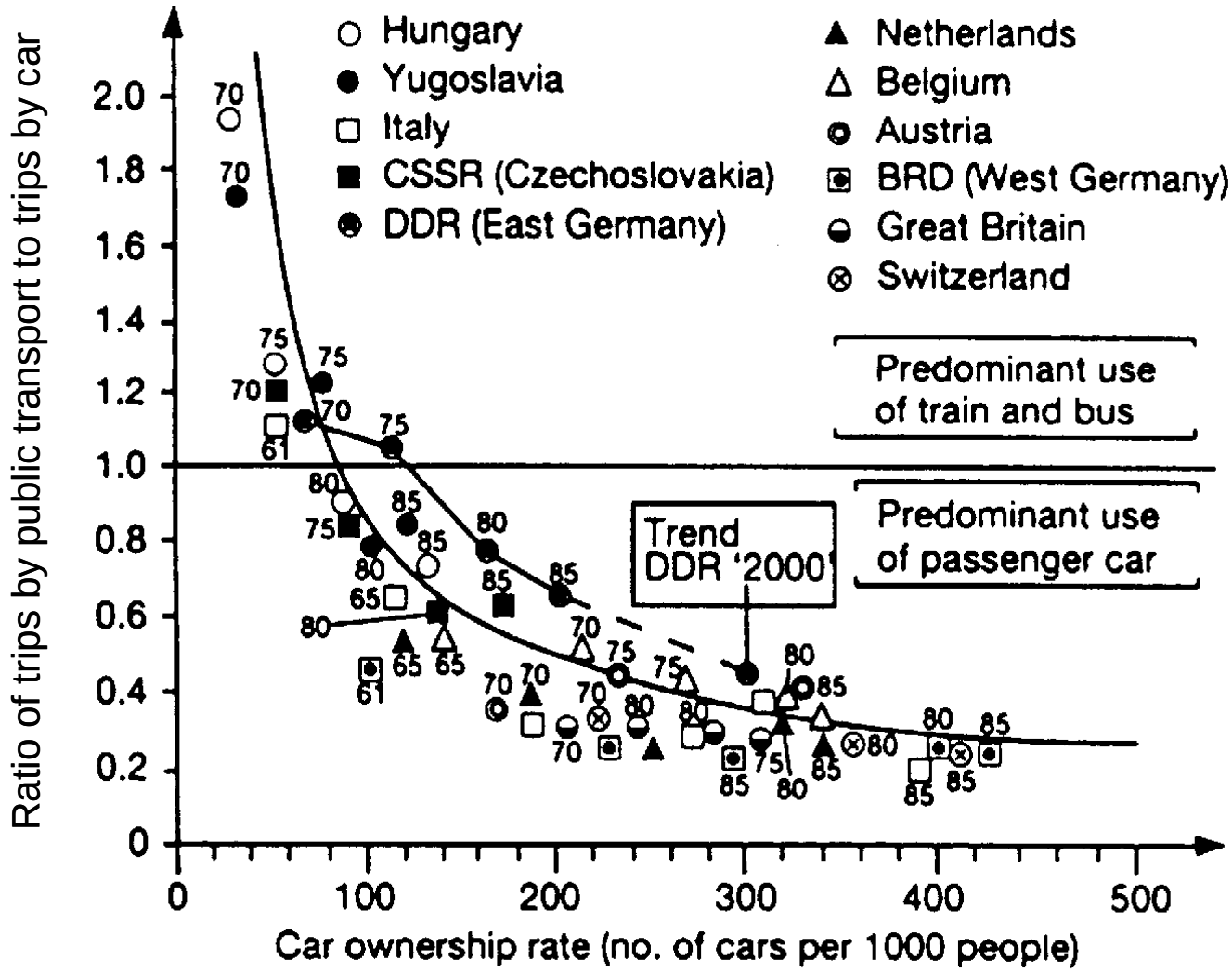


Figure 12. Main population trends in developing and developed countries

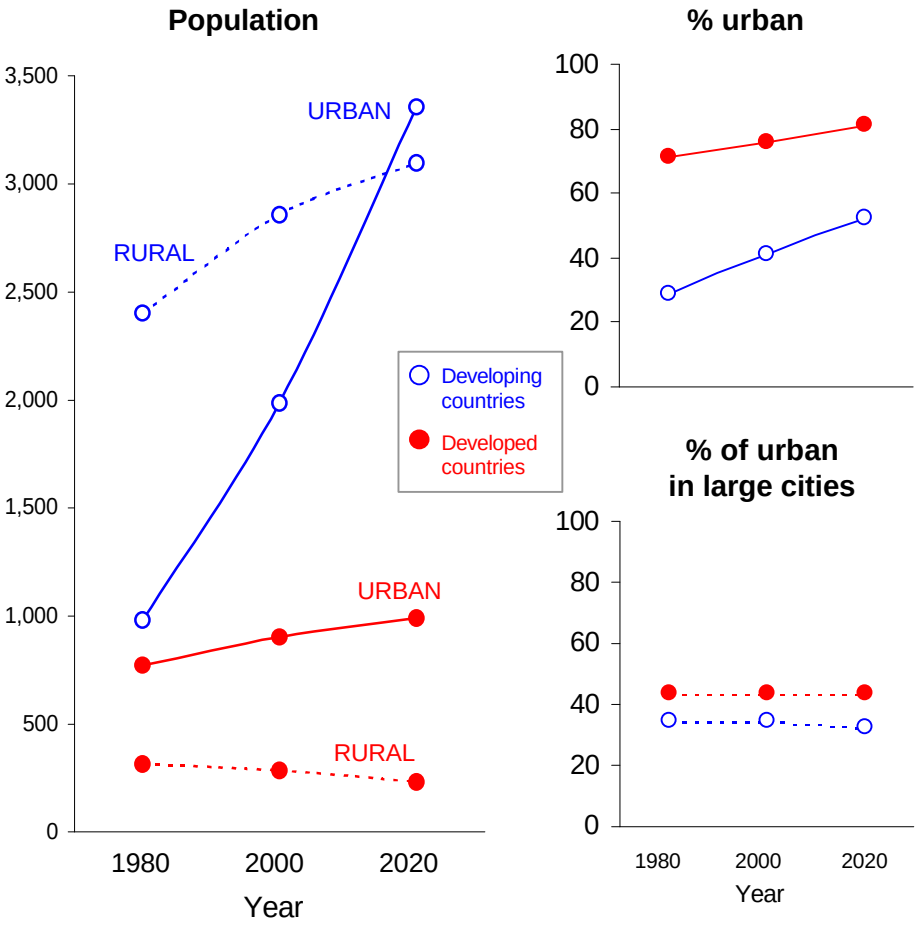


Figure 13. Urban growth and urbanization

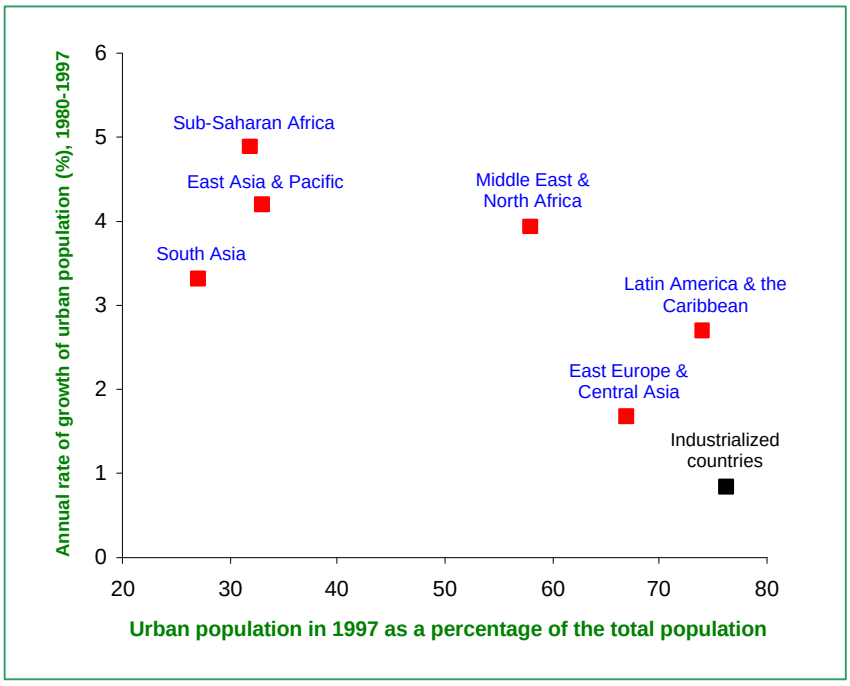


Figure 14. Car ownership, individual and household income, and place of residence, Greater Toronto Area, 1991

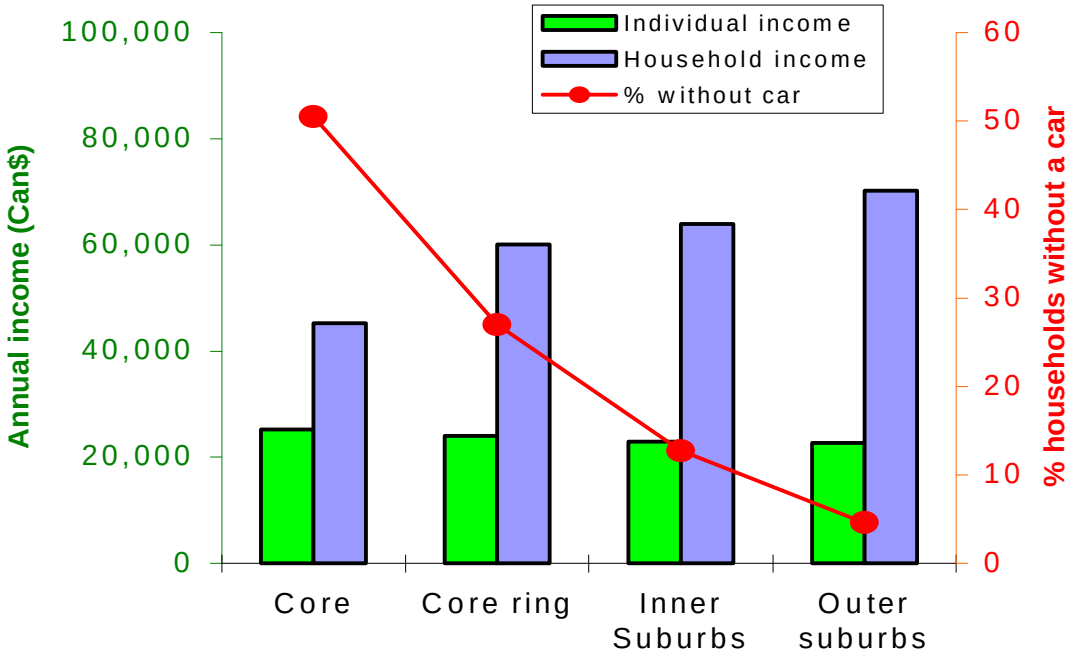


Table 1. Distributions of population and trips in the Greater Toronto Area (GTA), 1986-1996

	City	Suburbs
GTA's population, 1996 (total = 4.5 million)	52%	48%
Population added between 1986 and 1996 (0.83 million)	21%	79%
Origins of all trips, 1996 (9.0 million)	53%	47%
Origins of new trips, 1986-1996 (1.9 million)	25%	75%
Destinations of all trips, 1996 (9.0 million)	53%	47%
Destinations of new trips, 1986-1996 (1.9 million)	15%	85%
Average lengths of 1996 motorized trips by residents of: (i.e., not including 8% and 5% walk/bicycle trips by City and Suburban residents)	7.6 km	11.6 km

Table 2. Origins and destinations of trips in the Greater Toronto Area, 1986-1996

	All trips 1996	New trips 1986-1996
Percentage of trips that are:		
Suburb to Suburb	39	65
City to Suburb, or vice versa	16	20
City to City	45	15

Table 3. Purposes of trips in the Greater Toronto Area, 1986-1996

	All trips 1996	New trips 1986-1996
Percentage of trips that are:		
Home to work, or vice versa	35	19
Home to education, or v.v.	13	14
Home to other, or v.v.	38	50
Not home-based	15	17

Table 4. Actual and comparative energy intensities by mode, U.S., 1997

Mode	Actual Energy intensity (1000 joules/pkm)	Actual billions of passenger-kilometres (pkm)	Actual average occupancy (%)	Energy intensity at 50% occupancy
Domestic aviation	2683	747	69	3703
International aviation	2594	277	74	3839
Regular automobile	2398	3843	32	1535
Other automobile	2902	2243	27	1567
Intercity bus	643	233	53	682
Intracity bus	2514	33	22	1106
Intercity rail	1442	8	18	519