# Chapter 3

# The Pattern of Automobile Dependence and Global Cities

## Introduction

Urban sustainability can be examined quantitatively using the indicators presented in Chapter 1. This chapter examines a number of these quantitative indicators associated with transportation energy, land, and air quality, as well as some key livability indicators relating to transportation and wealth in a city. The aim here is not merely to list these indicators, but to attempt to understand the forces shaping the structure of different cities as outlined in Chapter 2. The extensive data in this chapter will thus be analyzed to draw conclusions on how sustainability can be pursued through the planning and development priorities of a city.

The data for the analysis below comes from two separate though overlapping sources. The tables in the text are taken from our updated global cities study, *Cities and Automobile Dependence: An International Sourcebook* (Newman and Kenworthy, 1989a). That study covered thirty-two cities in North America, Australia, Europe, and Asia and had extensive land use, transportation, and energy data for 1960, 1970, and 1980. The 1980 data were principally used in the analysis in that original work.

In the update of this work to 1990, the cities of West Berlin and Moscow have been excluded. West Berlin is no longer a valid urban area to analyze and the complexity of revising the original data for 1960, 1970 and 1980 to cover the whole Berlin area was considered impractical (gathering data now on East Berlin would be very difficult). Moscow was excluded after it was found that data collection had become virtually impossible in the administrative and economic climate after the breakup of the Soviet Union.[1]

The new data set, however, has been expanded to include sixteen new cities (three in the United States, one in Australia, six in Canada, and six in the developing Asian region), giving a total of forty-six cities. The data in the text here are a selection from that study (Kenworthy et al., 1999). Table 3.1 lists the cities involved in the international comparisons in this chapter.

The other data used in the international comparisons in this chapter are from a study we conducted for the World Bank and are contained in Appendix 1 along with the methodology used in collecting and processing the data. They consist of

Table 3.1. Cities in the International Comparisons of Transport and Land Use

| *U.S. Cities* | *Australian Cities* | *Canadian Cities* | *European Cities* | *High-income Asian Cities* | *Lower-income Asian Cities* |
|---|---|---|---|---|---|
| Houston | Perth | Toronto | Hamburg | Tokyo | Seoul* |
| Phoenix | Brisbane | Vancouver* | Frankfurt | Hong Kong | Kuala Lumpur* |
| Detroit | Melbourne | Calgary* | Zurich | Singapore | Bangkok* |
| Denver | Adelaide | Edmonton* | Stockholm | | Jakarta* |
| Los Angeles | Sydney | Montreal* | Brussels | | Manila* |
| San Francisco | Canberra* | Winnipeg* | Paris | | Surabaya* |
| Boston | | Ottawa* | London | | |
| Washington | | | Munich | | |
| Chicago | | | Copenhagen | | |
| New York | | | Vienna | | |
| Portland* | | | Amsterdam | | |
| Sacramento* | | | | | |
| San Diego* | | | | | |

*Note:* The sixteen new cities in the sample are marked with an asterisk.

a subset of the above cities (thirty-seven cities in total, including Beijing, which is not part of broader international comparisons, but was required by the World Bank). The study for the World Bank has a range of different indicators of transportation efficiency in cities, particularly data related to the economics of urban transportation and environmental performance. These will be used in the discussion to expand on the analysis from the broader global cities study.

## Transportation Energy Patterns

We begin with an overview of the patterns of urban transportation energy use, since the level of energy use in the transportation sector in a city is quite an effective barometer of its degree of automobile dependence.[2]

As can be seen in Table 3.2, there is an enormous range in per capita transportation energy use across the global sample of cities. The data show that U.S. cities use, on average, 64.3 gigajoules (GJ) of fuel per capita for urban transportation compared to 39.5 GJ per capita in Australian cities, 39.2 GJ in Canadian cities, 25.7 GJ in European cities, and 12.9 GJ in Asian cities. These data include both gasoline and diesel fuel used in private urban passenger and nonpassenger transportation and public transportation. The pattern of gasoline use per capita follows a similar pattern (55.8 GJ, 33.6 GJ, 30.9 GJ, 17.2 GJ, and 6.3 GJ per capita, respectively, for the regional groupings above).

These figures reflect an enormous variation in the degree to which cities in different regions are dependent upon diminishing conventional liquid fossil fuel resources. U.S. cities, for example, are some 5 times higher in their total per capita use of transportation energy than the Asian cities. Even compared with cities of a similar nature in Australia and Canada, U.S. cities are 1.6 times higher in their use of transportation energy. Compared to even wealthier European

Table 3.2. Transportation Energy Use per Capita in Global Cities, 1990

| | *Private Transportation* | | | *Public Transportation* | | | | |
|---|---|---|---|---|---|---|---|---|
| City | *Gasoline (MJ)* | *Diesel (MJ)* | *% Private of total* | *Diesel (MJ)* | *Electricity (MJ)* | *% Public of total* | *Total Transportation Energy (MJ)* | *Total Transportation Energy/ $ of GRP (MJ/$)* |
| Sacramento | 65,351 | 10,998 | 100% | 305 | 19 | <1% | 76,673 | ? |
| Houston | 63,800 | 7,325 | 99% | 499 | 0 | 1% | 71,624 | 2.74 |
| San Diego | 61,004 | 5,689 | 99% | 527 | 28 | 1% | 67,248 | ? |
| Phoenix | 59,832 | 4,507 | 100% | 301 | 0 | <1% | 64,641 | 3.14 |
| San Francisco | 58,493 | 6,187 | 98% | 935 | 275 | 2% | 65,890 | 2.12 |
| Portland | 57,699 | 12,358 | 99% | 614 | 27 | 1% | 70,698 | ? |
| Denver | 56,132 | 11,560 | 99% | 594 | 0 | 1% | 68,286 | 2.78 |
| Los Angeles | 55,246 | 6,279 | 99% | 643 | 0 | 1% | 62,167 | 2.50 |
| Detroit | 54,817 | 7,522 | 99% | 405 | 0 | 1% | 62,744 | 2.78 |
| Boston | 50,617 | 6,676 | 98% | 845 | 252 | 2% | 58,391 | 2.10 |
| Washington | 49,593 | 9,732 | 98% | 753 | 376 | 2% | 60,454 | 1.68 |
| Chicago | 46,498 | 8,355 | 98% | 1,060 | 208 | 2% | 56,121 | 2.16 |
| New York | 46,409 | 3,747 | 97% | 975 | 494 | 3% | 51,626 | 1.80 |
| AMERICAN AVG. | 55,807 | 7,764 | 99% | 650 | 129 | 1% | 64,351 | 2.38 |
| Canberra | 40,699 | 3,333 | 98% | 962 | 0 | 2% | 44,995 | ? |
| Perth | 34,579 | 5,965 | 98% | 851 | 0 | 2% | 41,395 | 2.34 |
| Brisbane | 31,290 | 7,071 | 98% | 632 | 284 | 2% | 39,277 | 2.10 |
| Melbourne | 33,527 | 4,613 | 98% | 411 | 338 | 2% | 38,890 | 1.84 |
| Adelaide | 31,784 | 4,359 | 97% | 953 | 6 | 3% | 37,103 | 1.88 |
| Sydney | 29,491 | 4,481 | 97% | 776 | 326 | 3% | 35,074 | 1.63 |
| AUSTRALIAN AVG. | 33,562 | 4,970 | 98% | 764 | 159 | 2% | 39,456 | 1.96 |
| Calgary | 35,684 | 10,535 | 98% | 808 | 106 | 2% | 47,133 | ? |
| Winnipeg | 32,018 | 6,358 | 97% | 989 | 0 | 3% | 39,366 | ? |
| Edmonton | 31,848 | 11,116 | 98% | 1027 | 69 | 2% | 44,060 | ? |
| Vancouver | 31,544 | 4,740 | 98% | 743 | 184 | 2% | 37,211 | ? |
| Toronto | 30,746 | 1,058 | 95% | 1,286 | 523 | 5% | 33,613 | 1.49 |
| Montreal | 27,706 | ? | ? | 1,019 | 261 | ? | ? | ? |
| Ottawa | 26,705 | 5,421 | 95% | 1,526 | 0 | 5% | 33,562 | ? |
| CANADIAN AVG. | 30,893 | 6,538 | 97% | 1,057 | 163 | 3% | 39,173 | ? |
| Frankfurt | 24,779 | 12,771 | 98% | 243 | 499 | 2% | 38,293 | 1.09 |
| Brussels | 21,080 | 6,297 | 95% | 635 | 883 | 5% | 28,895 | 0.96 |
| Hamburg | 20,344 | 15,463 | 98% | 556 | 352 | 2% | 36,716 | 1.21 |
| Zurich | 19,947 | 3,875 | 94% | 609 | 813 | 6% | 25,244 | 0.56 |
| Stockholm | 18,362 | 6,636 | 93% | 1,06 | 751 | 7% | 26,817 | 0.81 |
| Vienna | 14,990 | 4,387 | 94% | 538 | 689 | 6% | 20,603 | 0.74 |
| Copenhagen | 14,609 | 4,091 | 92% | 1,313 | 372 | 8% | 20,385 | 0.68 |
| Paris | 14,269 | 9,026 | 96% | 323 | 946 | 4% | 24,241 | 0.72 |
| Munich | 14,224 | 2,598 | 92% | 210 | 1,166 | 8% | 18,197 | 0.50 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Amsterdam | 13,915 | 5,096 | 96% | 456 | 375 | 4% | 19,843 | 0.79 |
| London | 12,884 | 9,140 | 94% | 693 | 657 | 6% | 23,374 | 1.05 |
| EUROPEAN AVG. | 17,218 | 7,216 | 95% | 604 | 653 | 5% | 25,692 | 0.83 |
| Kuala Lumpur | 11,643 | 7,600 | 96% | 774 | 0 | 4% | 20,017 | 4.92 |
| Singapore | 11,383 | 4,957 | 90% | 1,608 | 131 | 10% | 18,079 | 1.40 |
| Tokyo | 8,015 | 9,305 | 95% | 212 | 711 | 5% | 18,243 | 0.49 |
| Bangkok | 7,742 | 7,409 | 83% | 3,026 | 0 | 17% | 18,176 | 4.75 |
| Seoul | 5,293 | 2,604 | 82% | 1,551 | 168 | 18% | 9,615 | 1.62 |
| Jakarta | 4,787 | 3,845 | 95% | 440 | 0 | 5% | 9,072 | 6.02 |
| Manila | 2,896 | 2,734 | 77% | 1,698 | 8 | 23% | 7,335 | 6.67 |
| Surabaya | 2,633 | 2,684 | 95% | 294 | 0 | 5% | 5,611 | 7.73 |
| Hong Kong | 2,406 | 5,679 | 84% | 1,217 | 310 | 16% | 9,612 | 0.68 |
| ASIAN AVG. | 6,311 | 5,202 | 89% | 1,202 | 148 | 11% | 12,862 | 3.81 |

Note: The cities for which no energy per unit of GRP is available are those cities not included in the study for the World Bank and that therefore do not have the GRP data.

cities, U.S. cities use 2.5 times more transportation energy in keeping their urban passenger and goods movement systems operating.

The parameter of transportation energy per unit of wealth (i.e., MJ per dollar of GRP), also shown in Table 3.2, is an attempt to bring together both the environmental and economic aspects of energy use. Gross regional product (GRP) is the measure of all goods and services produced in the regional urban area of the particular city noted. The methodology for calculating this newly available parameter is set out in Appendix 1. Energy per unit of wealth thus brings together the two sides of the sustainability issue. Obviously on this very fundamental parameter there are some cities that are much more sustainable than others. For example, the U.S. cities consume an average of 2.4 MJ of transportation energy for every dollar of wealth they generate, ranging from a high of 3.1 MJ/$ in Phoenix to lows of 1.7 MJ/$ and 1.8 MJ/$ in Washington, D.C., and New York, respectively. Australian cities perform, on average, a little better than U.S. cities, with 2.0 MJ/$, while Toronto, the only Canadian region for which these data are available, uses only 1.5 MJ/$ in keeping its transportation system fueled. The European cities are even more fuel-efficient in relation to their urban economies, with just 0.8 MJ of energy expended per dollar of wealth produced.

The Asian cities present a mixed picture on this factor due to the huge disparities in wealth involved. While the wealthy Asian cities of Singapore, Tokyo, and Hong Kong expend a similar amount of energy per dollar as European cities (0.9 MJ/$) and are therefore low in an international context, the developing Asian cities with much lower incomes spend on average 5.3 MJ/$, or more than twice the level of transportation energy consumption relative to wealth as in U.S. cities. The demand for energy to run the transportation systems in these poorer cities appears to have a bigger impact on the local economy than in any of the other cities in the study.

The economic data on urban transportation are pursued in greater detail later in this chapter under "Car Use and Wealth." Before this we analyze the many fac-

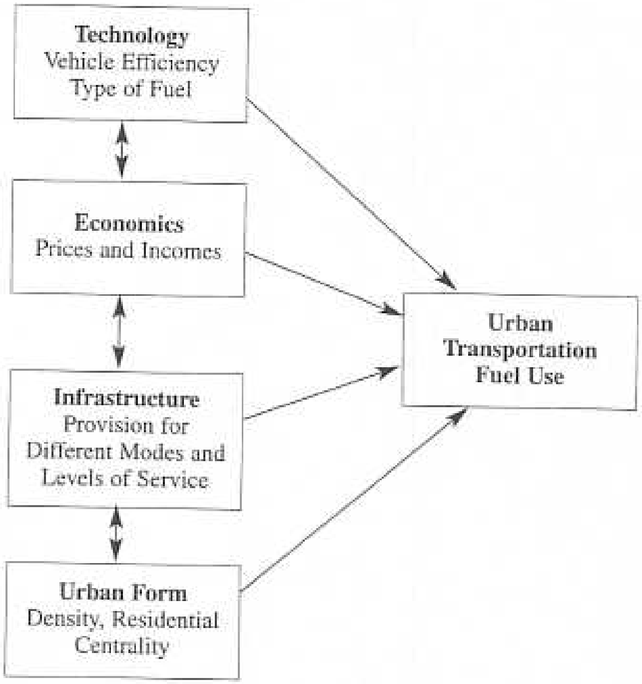

*Figure 3.1.* Interacting factors that explain differing levels of transportation fuel use in cities.

tors that can explain the variations in transportation energy use. As shown in Figure 3.1, the factors can be grouped into technology, economics, infrastructure, and urban form.

## Fuel Types

The breakdown by fuel in Table 3.2 shows that gasoline is by far the biggest contributor to transportation energy use, but this is most marked in U.S. and Australian cities, where the automobile is more dominant and gasoline use constitutes some 86 percent of total transportation energy use and electricity constitutes only about 0.3 percent. In contrast, where cities become more public transportation–oriented, diesel and electricity become much more significant. In European cities, for example, gasoline use decreases to 67 percent of energy used in transportation, and in Asian cities it is 49 percent. Tokyo has 44 percent gasoline, 52 percent diesel, and 4 percent electricity, whereas Phoenix has 93 percent gasoline, 7 percent diesel, and no electricity.

The breakdown between private and public transportation shows an overwhelming proportion of transportation energy is consumed by private transportation in every city. Transit uses an average of only 1 percent of transportation energy in U.S. cities, 2 percent in Australian cities, 3 percent in Canadian cities, 5 percent in European cities, and 11 percent in Asian cities.

Average diesel consumption has a remarkably uniform pattern across the cities, though there is some variation within the sample for each regional grouping of cities: U.S. cities consume 8 GJ per capita; Australian cities, 5 GJ; Canadian cities, 7 GJ; European cities, 7 GJ; and Asian cities, 5 GJ. In other words, unlike gasoline use and indeed overall transportation energy use, there is no systematic pattern of variation in this factor. This would appear to highlight the similar dependence that most cities now have on the light van and truck for urban freight movement.[3]

The major difference among the cities is in the comparative use of gasoline and electricity. Gasoline-oriented cities are heavy energy users while cities with any significant level of electricity use in their transportation system are low energy users overall.[4]

These fuel use patterns are important for discussions about greenhouse gases: transportation-based carbon dioxide is an important issue in the post-Kyoto world. One of the immediate responses for cities is to try to reduce their use of coal. Although this is a generally positive policy to pursue, there is a twist to the greenhouse issue when cities are the focus, rather than just nations, as shown in the data here. Despite coal-based electricity being less fuel-efficient than gasoline (and being four times worse than gasoline in terms of carbon dioxide produced per MJ of transportation energy), it does not mean that cities with electric transportation are worse in energy use or greenhouse gases; in fact, the reverse is the case. This is primarily because of the nature of the technology and the effect of either the car or the train/tram on the city. This difference is fundamental to the concepts being presented in this chapter and in the book overall.

The fact that cities that do use a lot of electricity (even from coal) have lower energy use and carbon dioxide production is an important factor in the energy and greenhouse debate, in which coal is considered to be so much more damaging. If coal is used to provide electricity for an electric train or tram system, then the city overall uses less fuel and will produce lower greenhouse gases from the transportation sector. The mechanism for this appears to be land use changes, greater walking and cycling in transit-oriented environments, and the linking of a number of trip purposes when using transit. (This is examined in more detail later under "Transit Leverage.")

In addition, the advantages of electric-based public transportation become far greater in terms of greenhouse and other factors, such as smog and acid rain, when the source of power is renewable fuel. For example, Zurich, which uses Swiss hydropower, usually produces only 6 grams of carbon dioxide per MJ of electricity, whereas Melbourne, which uses very poor quality coal, produces 414 grams of carbon dioxide per MJ. This will become a more significant factor in the decades ahead as the Climate Change Convention agreements have to be implemented. The renewable-energy future will be one based on electricity, linking together the many dispersed ways of producing power from wind, the sun, biomass, garbage, and waves. A future based upon electric power will favor electric transit, perhaps supplemented by electric automobiles; but this must not be a one-for-one substitution of electric cars for gasoline cars because the need for energy conservation will require a substantial move toward electric transit–based cities. Further details on carbon dioxide are also provided under "Transportation Emissions" later in this chapter.

## Technology-Vehicle Efficiency

Vehicle efficiency technology is often the first factor considered in discussions on fuel use. Obviously, the efficiency of vehicles must impact on fuel use, but how important is it in explaining the variations in urban fuel use? The data presented below show it is only a small factor in explaining the variation, if motor vehicles are the focus. But if we also consider public transit systems and their associated ridership, then we can begin to see some major variations.

For the 1980 data on cities we made a simple calculation to throw light on this issue. Table 3.3 adjusts the 1980 per capita gasoline use in the global cities for vehicle efficiency—that is, the table shows what the per capita gasoline use would be in other cities if all those cities had vehicles like those in the U.S. cities. Overall, the variation from U.S. cities to Asian cities in their gasoline use is reduced from a factor of ten to a factor of seven, and the variation from U.S. to European cities reduces from four times to three times. Thus this technological factor is a relevant parameter, but clearly it is not the dominant factor often described in energy conservation literature (LaBelle and Moses, 1982; Chandler, 1985; Wachs and Crawford, 1991). Other economic factors as well as planning factors need to be considered.

It should also be pointed out that the variation between U.S. cities and other cities in terms of fuel efficiency of vehicles has generally diminished between 1980 and 1990, as U.S. vehicle fleets have been downsizing. The 1990 average car fuel efficiencies based on actual 1990 fuel use are provided in Table 3.4 below. What appears to be clear by comparing Tables 3.3 and 3.4 is that all cities have improved their urban car fuel efficiencies. Whereas in 1980 the U.S. cities had cars that operated in city conditions with 1.28 times higher fuel use than the cars in the wealthy Asian cities (Singapore, Tokyo, and Hong

Table 3.3. Average 1980 Gasoline Use per Capita in Cities by Region to Account for Vehicle Efficiency (Relative to U.S. Vehicle Efficiencies, Using National Values and Adjusted for Average Speed in Cities)

| | *Unadjusted Gasoline Use per Capita (MJ)* | *Average Vehicle Efficiency (National Values)* *(liters per 100 km)* | *Adjusted for Average Speed in Cities* *(liters per 100 km)* | *Gasoline Use Per Capita U.S. Vehicle Efficiency (MJ)* | |
|---|---|---|---|---|---|
| | | | | *National Values* | *Adjusted for Average Speed* |
| American | 58,541 | 15.35 | 19.33 | 58,541 | 58,541 |
| Australian | 29,829 | 12.50 | 15.33 | 33,446 | 37,612 |
| Toronto | 25,962 | 16.30 | 21.72 | 24,449 | 23,105 |
| European | 13,280 | 10.66 | 16.38 | 19,123 | 15,727 |
| Asian | 5,493 | 7.63 | 15.05 | 11,051 | 7,248 |

*Notes:*

1. Detailed data on vehicle efficiencies are contained in Newman and Kenworthy (1989a).
2. Adjustments for average speed are made by using $y = 1.0174x + 37.4291$, where $y$ = fuel consumption in ml/km and $x$ is the inverse of average speed in s/km and national fuel efficiencies are assumed to be at an average speed of 60 km/h.

Table 3.4. Fuel Efficiencies of Urban Cars in Global Cities, 1990

| *Cities* | *Fuel Efficiency (MJ/km)* | *Fuel Efficiency (liters per 100 km)* |
|---|---|---|
| American | 5.03 | 14.50 |
| Australian | 5.11 | 14.73 |
| Canadian | 4.85 | 13.98 |
| European | 3.79 | 10.93 |
| Wealthy Asian | 4.93 | 14.21 |
| Developing Asian | 3.53 | 10.18 |

Kong), in 1990 the cars in U.S. cities operated at only 1.02 times higher fuel use than cars in those same cities.

Despite this flattening out in fuel efficiencies of the urban car fleets between U.S. and wealthy Asian cities, there still remains a very considerable difference in gasoline use per capita (U.S. cities are still 8 times higher than their wealthy Asian counterparts). Obviously, automobile technology cannot be the main factor in this considerable variation.

Likewise, in 1980, U.S. cities had 1.26 times higher fuel consumption in urban cars than Australian cities, but in 1990 the situation had changed so that U.S. cities are actually marginally more fuel-efficient in their urban cars than are Australian cities (1.02 times better, primarily due to Australia having one of the world's highest average ages for their car fleet and therefore lower penetration rates for new, more fuel-efficient cars; see note 9 in Chapter 4, which shows that the Australian car fleet has not improved its fuel efficiency for thirty-five years). Per capita gasoline use in U.S. cities, however, is still 1.7 times higher than in Australian cities.

Through the data that are available on all forty-six cities in this study, it is possible to develop an even more detailed picture of actual energy efficiencies by mode of urban transportation. These data measure energy efficiency in terms of MJ per passenger kilometer (i.e., including vehicle occupancy), as opposed to the technological efficiency of the mode as expressed in Tables 3.3 and 3.4. These data are summarized here in Table 3.5.

The data show that energy efficiency by car travel is at least less than half the efficiency of transit travel, or even worse when compared to urban rail systems (the only exception is U.S. city buses, which are comparatively inefficient compared to buses in other cities[7]—see below). Urban car travel in North America (i.e., U.S. and Canadian cities) is 13 to 16 percent less fuel-efficient than car travel in Australian and wealthy Asian cities, 34 percent less efficient than car travel in European cities, and 66 percent less efficient than in newly developing Asian cities.

Table 3.5 shows that fuel efficiency of bus travel varies considerably by region and in comparison with other modes within that region. U.S. bus systems are similar in fuel efficiency to European urban car travel and are 19 percent *less* efficient than car travel in newly developing Asian cities. This is primarily because

Table 3.5. Modal Energy Efficiencies for Regional Groupings of Cities, 1990

| | (MJ per passenger km) | | |
|---|---|---|---|
| *Cities* | *Car* | *Bus* | *All Rail* |
| American | 3.52 | 2.52 | 0.74 |
| Australian | 3.12 | 1.64 | 1.12 |
| Canadian | 3.45 | 1.61 | 0.51 |
| European | 2.62 | 1.32 | 0.49 |
| Wealthy Asian | 3.03 | 0.84 | 0.16 |
| Developing Asian | 2.12 | 0.74 | 0.24 |

*Notes:*

1. Rail energy efficiency includes heavy rail, light rail, and trams where relevant.

2. The data in Table 3.5 vary little from the data shown in Appendix 1 because they cover all forty-six cities in the study, whereas the data in Appendix 1 from the study for the World Bank cover only thirty-seven cities. Note also that Beijing is included in Appendix 1 data but is excluded from the above table to be consistent with averages for other parameters on the developing Asian cities used throughout the book (i.e., Beijing was included only in the study for the World Bank and is not one of the forty-six cities).

of their low patronage levels, since buses throughout the world are not very different in technology. Bus systems in European cities and in places such as Sydney and Toronto are about two to three times as efficient as in the U.S. cities. In Asian cities bus travel is about three to four times as efficient as in U.S. cities, with Beijing having an efficiency of 0.15 MJ per passenger kilometer, which is seventeen times more efficient; bus loadings in peak hours in Chinese cities reach twelve persons per square meter (Hu and Kenworthy, 1996). Such data show that the gains in energy to be made from bus transport technology are dwarfed by the possibilities offered through ridership improvements.

Rail modes (trains and trams) are by far the most energy-efficient motorized transport technology in each regional grouping of cities. The only cities that are exceptions to this are Perth and Adelaide, which in 1990 still had old diesel train systems with low ridership (see Appendix 1). Perth has since electrified its rail system and is now much more efficient (see Chapter 4 case study on Perth and Newman, 1992). Apart from these two cities, the others show that rail travel is between 2.5 and 5 times more energy-efficient than bus travel. Rail energy use reaches a low of 0.06 MJ per passenger kilometer in Manila (0.07 in Beijing), which is some 59 times more energy-efficient than car travel in the United States. More typically, rail systems in European cities are 7 times more energy-efficient than car travel in U.S. cities.

Electric rail technology tends to be more energy-efficient because of its speed and capacity, which lead to higher ridership. Electric rail also has a demonstrated capacity to induce higher-density development around stations due to its ability to take large numbers of people to and from concentrated nodes of development without harming the pedestrian qualities of an area. Furthermore, electric rail can also be linked to renewable energy, which is a significant advantage as we enter the next century with its reduced oil production.

Not shown in Table 3.5 are the ferry systems that exist in a few of the cities (the averages are somewhat irrelevant because of the paucity of systems in each region). As shown in Appendix 1, however, ferries are remarkably inefficient in their use of fuel. The only possible exceptions are in Sydney, New York, and Bangkok, where small ferries and reasonable patronage seem to ensure a system roughly equivalent to the energy efficiency of buses. The efficiency of all other ferry systems is very poor, however. Hamburg has the least energy-efficient ferry system (9 times less efficient than their car system). Boston's ferries are 5 times less efficient than their cars, and even Hong Kong's ferries are 26 percent less efficient than their car system. Ferries in Hamburg have suffered from declining tourist patronage, which helps to explain their poorer energy efficiency.

Ferries, overall, are the least well exploited of urban public transport modes, and it might be expected that these figures could be significantly improved upon with research and wider planning commitment to better integrated urban ferry systems.

Table 3.6 summarizes modal energy efficiencies in the global sample of cities even further by showing the overall modal averages from all the global cities combined, but separating the rail modes into heavy and light rail, and dividing heavy rail into electric and diesel systems. It also shows the comparative loadings, or vehicle occupancies, which contribute significantly to the energy efficiency differences among the various modes.

**Photo 3.1.** Electric rail is the most energy-efficient motorized mode. European cities with good rail systems, such as the light rail systems in Bremen (*top*) and Hanover (*bottom*), have distinctly less automobile-dependent transportation patterns.

Table 3.6. Overall Modal Energy Efficiencies in the Global Sample of Cities, 1990

| Mode | *MJ per Passenger Kilometer (average all cities)* | *Measured Average Vehicle Occupancy (average all cities)* |
|---|---|---|
| Car | 2.91 | 1.52 |
| Bus | 1.56 | 13.83 |
| Heavy Rail (electric) | 0.44 | 30.96 |
| Heavy Rail (diesel) | 1.44 | 27.97 |
| Light Rail/Tram | 0.79 | 29.73 |

*Note:* Rail mode occupancies are given on the basis of the average loading per rail car, not per train. The average occupancy of cars is a twenty-four-hour figure.

These data reveal that urban car travel is, on average, nearly 2 times as energy-consumptive as average urban bus travel, 6.6 times more energy-intensive than average urban electric train travel, and 3.7 times more than typical light rail or tram system travel. Light rail and tram systems typically operate in environments requiring a lot more stopping and starting than heavy rail, with much closer station spacings than heavy rail. So although their average loading is similar to heavy rail, their energy efficiency is a little poorer than electric heavy rail but better than diesel heavy rail.

The data in Table 3.6 also show that diesel rail is only a little more fuel-efficient on average than an urban bus and that average train carriage occupancies are roughly equal across the three rail types. Rail occupancies are on average more than twice those of buses and about twenty times higher than cars. Overall, these data reemphasize the importance of developing a good backbone of electric rail in cities if energy conservation is to be enhanced. Those cities without such systems are the ones with very high gasoline use.

## Price and Income

The economics of transportation is dominated by considerations of price (especially gasoline prices) and income; these are considered to be among the major determinants of travel demand and, in particular, significant determinants of the level of car ownership and, through this, the level of car use.

Obviously the price of gasoline and how much disposable income people have will be big factors in determining how residents of cities travel. When we examined the 1980 data on per capita transportation fuel patterns (Newman and Kenworthy, 1989a), we made an analysis to adjust for price and income (as well as fuel efficiency, as discussed above). The results showed that the extent of the economic factors can be questioned. The data provided in Table 3.7, which makes adjustments for price and income, indicate that these economic factors are not able to explain the major variations in per capita gasoline use between the cities. The effect of the economic adjustments in Table 3.7 is to give all cities high U.S. incomes and low U.S. gasoline prices.

the global city, and they again show that sustainability is not necessarily made more difficult by the emerging global information-oriented city. Indeed, it could signify the end of the automobile as the primary influence on urban form and the beginning of an era in which information technology is more dominant. Since these trends in urban form are only in their early phase, it is hard to distinguish on such a large scale; so more detailed internal studies would help to confirm that the process of concentrating, particularly around quality urban environments, is under way and that this is related to information processing.

For example, Cervero (1995) has shown how Stockholm has made its transition to an information-oriented city by stressing its transit corridors and subcenters. Gehl and Gemzøe (1996) have shown that Copenhagen has had a deliberate strategy for thirty years to build a competitive global city by continuously reducing car parking and creating more attractive public spaces in its central area. Monheim (1988) has shown that global businesses are attracted to pedestrian-oriented European urban environments that are very intensely active but are largely car-free. Roberts (1989b) found similar results for traffic-calmed areas in a study of six European cities. Linneman and Gyourko (1997) showed that in U.S. global cities big corporation headquarters are attracted to large central open space parks.

The processes of urban change that may be halting the apparently unstoppable sprawl of cities all appear to be related to the need for more face-to-face contact in quality urban environments. This need will be explored in subsequent chapters.

The next section brings together some data on the economic and environmental costs of automobile dependence in the thirty-seven global cities surveyed for the World Bank (data from Appendix 1). It aims to gain perspective on the commonly held belief that wealth is the primary determinant of automobile dependence and, in this sense, the automobile is seen as an "irresistible force" as wealth rises. The following data appear to debunk this position.

## Car Use and Wealth

For many years there has been an implicit assumption among transportation planners, engineers, and economists that there is a close link between mobility and wealth (see Rainbow and Tan, 1993, and the "Price and Income" section above). This leaves very few policy options open to cities for managing growth in car use. However, as with Lave's negative assessment of transit, the data for such assertions tend to be national data and are rather selective.

Below we examine the link between mobility and wealth by comparing the per capita use of cars in thirty-seven global cities and seeing how this compares with their per capita city wealth (called gross regional product, or GRP). This is part of a study that we did for the World Bank and includes a number of other indicators of transportation economic performance with considerable significance for sustainability. These are therefore also examined to fill out the picture that is now developing—that mobility is not necessarily related to wealth.

The data on car use and wealth (in 1990 U.S. dollars) are given in Table 3.15 and also in Figure 3.9.

There is no obvious pattern to the data. Statistical analysis shows that only

Table 3.15. Car Use and Gross Regional Product per Capita for Thirty-seven Global Cities, 1990

| *Cities* | *Car Use per Capita (km)* | *GRP per Capita ($US, 1990)* |
|---|---|---|
| *Australian* | | |
| Perth | 7,203 | 17,697 |
| Adelaide | 6,690 | 19,761 |
| Brisbane | 6,467 | 18,737 |
| Melbourne | 6,436 | 21,088 |
| Sydney | 5,885 | 21,520 |
| AVERAGE | 6,536 | 19,761 |
| *American* | | |
| Phoenix | 11,608 | 20,555 |
| Denver | 10,011 | 24,533 |
| Boston | 10,280 | 27,783 |
| Houston | 13,016 | 26,155 |
| Washington | 11,182 | 35,882 |
| San Francisco | 11,933 | 31,143 |
| Detroit | 11,239 | 22,538 |
| Chicago | 9,525 | 26,038 |
| Los Angeles | 11,587 | 24,894 |
| New York | 8,317 | 28,703 |
| AVERAGE | 10,870 | 26,822 |
| *Canadian* | | |
| Toronto (Metro) | 5,019 | 22,572 |
| *European* | | |
| Frankfurt | 5,893 | 35,126 |
| Amsterdam | 3,977 | 25,211 |
| Zurich | 5,197 | 44,845 |
| Brussels | 4,864 | 30,087 |
| Munich | 4,202 | 36,255 |
| Stockholm | 4,638 | 33,235 |
| Vienna | 3,964 | 28,021 |
| Hamburg | 5,061 | 30,421 |
| Copenhagen | 4,558 | 29,900 |
| London | 3,892 | 22,215 |
| Paris | 3,459 | 33,609 |
| AVERAGE | 4,519 | 31,721 |
| *Wealthy Asian* | | |
| Singapore | 1,864 | 12,939 |
| Tokyo | 2,103 | 36,953 |
| Hong Kong | 493 | 14,101 |
| AVERAGE | 1,487 | 21,331 |
| *Developing Asian* | | |
| Kuala Lumpur | 4,032 | 4,066 |
| Surabaya | 1,064 | 726 |
| Jakarta | 1,112 | 1,508 |
| Bangkok | 2,664 | 3,826 |
| Seoul | 1,483 | 5,942 |
| Beijing | 351 | 1,323 |
| Manila | 573 | 1,099 |
| AVERAGE | 1,611 | 2,642 |

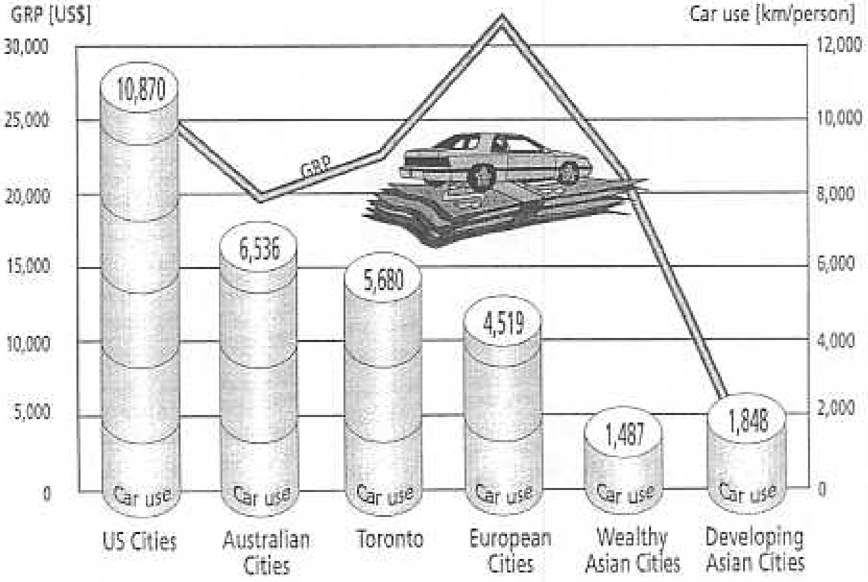

*Figure 3.9.* Car use per capita (VKT) in 1990 and wealth (GRP per capita in 1990 U.S. dollars).

18 percent of the variance can be explained by a linear correlation. If a bell-shaped curve were fitted to the data, then 36 percent of the variance could be explained. This suggests that cities with high wealth (mostly European and wealthy Asian) are associated with lower mobility than those in the mid-wealth range (U.S. and Australian).

Some of the possible explanations for this can be pursued by examining the other indicators of transportation efficiency.

As already noted, North American and Australian cities have considerably higher car use per capita than would be expected just considering the level of economic activity or wealth, especially in comparison to the European and developed Asian cities.

The large U.S. cities in this sample have:

- 1.66 times higher car use than the major Australian cities but are only 1.36 times higher in GRP;
- 2.17 times higher car use than Metropolitan Toronto but are only 1.19 times higher in GRP;
- 2.41 times higher car use than the average European city but actually have only 0.85 the level of GRP per capita;
- 7.3 times higher car use than the wealthy Asian cities but have only 1.26 times the level of GRP.

Perhaps even more significant is the comparison between the developing Asian cities of Kuala Lumpur, Surabaya, Jakarta, Bangkok, Seoul, Beijing, and Manila and the three wealthy Asian cities of Tokyo, Singapore, and Hong Kong: the poorer cities have 108 percent as much car use but have an average GRP that is only 12 percent of that in the developed Asian cities. This is even more accentuated in the case of Kuala Lumpur, the most motorized developing Asian city. Kuala Lumpur has 2.7 times the average car use per capita of the wealthy Asian cities, yet only 19 percent of the per capita GRP.

The car use per capita figures in developing Asian cities in some cases include a reasonable amount of motorcycle use (motorcycle use is also included in other cities but is not as significant). However, this does not fundamentally affect the point being made here, which is that developing Asian cities, despite low levels of wealth compared to their more developed neighbors, are experiencing very much higher levels of private mobility. Within the United States, there is also a significant difference between cities that cannot be explained by simple economic factors alone. For example, New York (the lowest car-using U.S. city) has 36 percent less car use per capita than Houston (the highest car-using U.S. city) but is 10 percent higher in GRP.

The economic parameters discussed below provide some detail as to why there may be a negative link between economic performance in a city and high levels of mobility through automobiles. They confirm the picture presented in Chapter 2. The discussion covers direct economic costs, such as road expenditure, percentage of GRP spent on the journey-to-work, and transit cost recovery, as well as the indirect costs due to transport deaths and transportation emissions. Detailed data on these items can be found in Appendix 1.

## *Road Expenditure*

Road expenditure per capita (Figure 3.10) follows the pattern of car use and car dependence in the sample of cities, though it does not display such extreme differences (U.S. cities spend $264 per capita each year, Australian cities, $142; Toronto, $150; European cities, $135; wealthy Asian cities, $88; and developing Asian cities, $39). There is a higher level of road maintenance in North American and Australian cities due to their greater length of roads per capita, but it is obvious that considerable road building is still occurring in these car-based cities. The sustainability agenda will require a change in these priorities in the future if car dependence is to be eased. It is apparent from the above data and the economic parameters below that such a change can also constitute a move toward lower transportation costs.

Road expenditure in European cities is relatively high since they also have many new areas on their peripheries where a more car-dependent urban form has been created. For example, Copenhagen suburbs and surrounding villages that have been developed into suburbs since the 1940s have densities of 25 and 21 persons per ha and have much greater car use than the old city, which has a density of 63 persons per ha. Such areas will also require reassessment in light of the sustainability agenda with a view to redirecting road funds to other modes as part of a strategic plan to reduce car dependence (see Newman et al., 1997).

In wealthy Asian cities, road expenditure per capita is one-third what it is in U.S. cities and 50 percent to 60 percent of what it is in Australian cities and Toronto. As shown below, it is also the lowest in relation to city wealth.

Road expenditure per capita in newly developing Asian cities appears to be comparatively small in absolute terms, though in Bangkok, Seoul, and Beijing, there is evidence of relatively heavy spending on roads compared to other cities

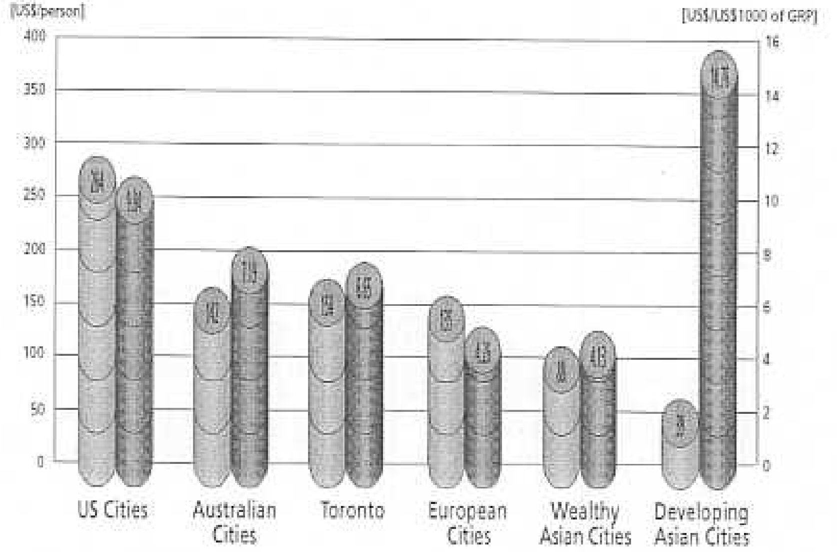

*Figure 3.10.* Road expenditure in global cities, 1990.

in this group ($61 to $72 compared with the average of $39). However, in terms of road expenditure per $1,000 dollars of GRP, or in other words, in relation to a city's capacity to pay, money spent on roads in these developing cities is high. The figures for all the cities are: $9.84 for the U.S. cities, $7.19 for Australian cities, $6.65 for Toronto, $4.26 for European cities, $4.13 for wealthy Asian cities, and $14.76 for developing Asian cities. This latter figure is 1.5 times higher than in U.S. cities, the next highest relative spender on roads. Bangkok is spending $18.56 per $1,000 of GRP or 1.9 times U.S. levels and Beijing is spending $46.11 or 4.7 times that in the U.S. cities.

## *Percentage of GRP Spent on the Journey-to-work*

The percentage of GRP spent on commuting is very similar across all the global cities at about 6 percent (Figure 3.11). It is slightly higher in the United States at 6.9 percent and slightly lower in Europe at 5.4 percent. The developing Asian cities are higher with 7.4 percent of GRP spent on commuting due to their considerably lower GRPs and rapidly growing use of cars. Based on the data here, Manila and Surabaya seem to spend the most on getting to work (8.5 percent and 10 percent of GRP respectively).

It is not unexpected that most cities end up with about the same commitment of their resources to commuting. It appears to be related to the way commuting times adjust to about thirty minutes on average in all cities, independently of how they are provided with transportation infrastructure. Despite all the massive differences in transportation investment priorities and the large differences in transportation patterns in different types of cities, urban people everywhere put a very similar amount of their wealth into commuting. This at least suggests that cities have an opportunity to be strategic in how they invest in transportation.

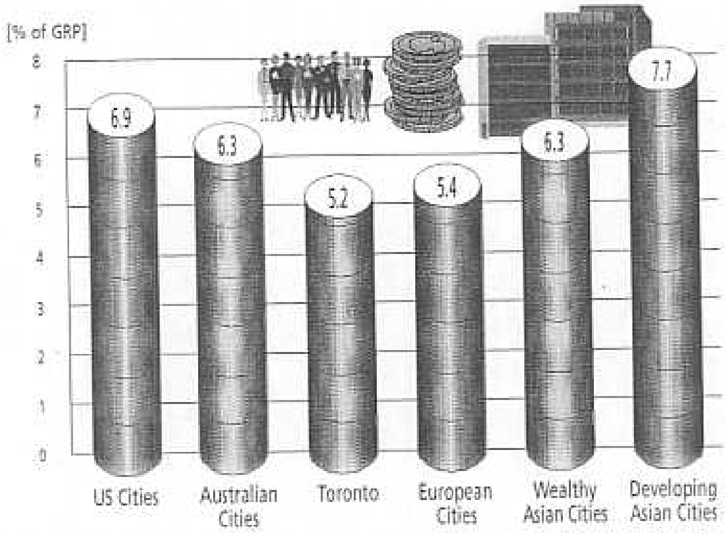

***Figure 3.11.*** The proportion of city wealth spent on the journey-to-work in global cities, 1990.

In terms of sustainability this is a very hopeful sign. The sample of global cities shows that there are very similar levels of economic efficiency despite huge differences in car use. Thus transforming the transportation pattern of a city into one that is sustainable can be achieved without damaging overall economic performance (Serageldin and Barrett, 1993; World Bank, 1996).

## *Transit Cost Recovery*

The indicator of transit cost recovery is one of the most emotionally debated issues of any area of public policy. This survey, which measures operating cost recovery, is one of the first to show a comparative set of data from the major cities of the world that has been compiled on as consistent a basis as possible. It shows that the percentage transit cost recovery follows very precisely the level of car dependence in the city (see Figure 3.12).

U.S. and Australian cities average a low 35 percent and 40 percent. Toronto stands out at 61 percent. The most bus-based, low-density, car-dependent cities of Perth, Phoenix, and Houston have a mere 28 percent and Denver only 19 percent cost recovery. In such cities, even if fares are set reasonably high, it is difficult to have a high cost recovery because of the inherently higher cost structures of such systems (e.g., high labor input per passenger kilometer, low occupancy per service unit, etc.).

European cities average 54 percent cost recovery, with a variation from 93 percent in London to 27 percent in Brussels. Such variations are not just reflections of inherent economic differences among systems, but are also the result of conscious political choices made by each city as to how much of their public transportation expenses they want to recover. London chooses to set high fares and recover almost all their costs (since the Thatcher years), while other cities, such as those in Germany and Belgium, choose to recover a lesser proportion in

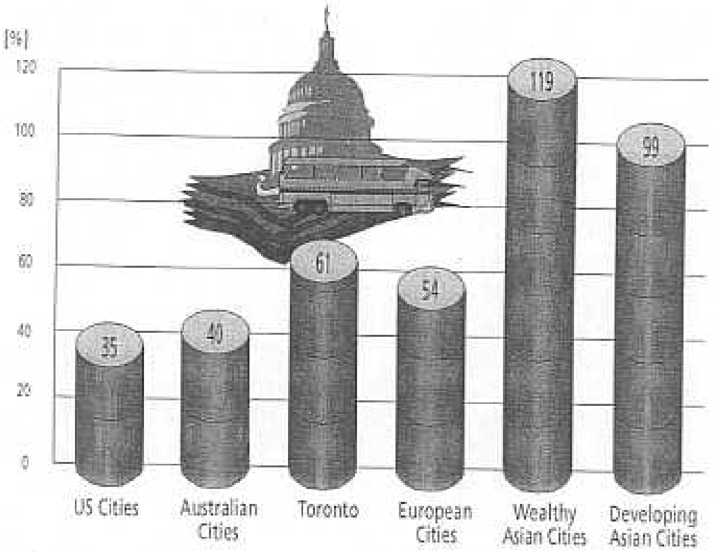

***Figure 3.12.*** Transit operating cost recovery in global cities, 1990.

recognition of the fact that roads are also being subsidized. The case of Stockholm, with only 33 percent recovery, also reflects a social/political position on the role of transit in the community. Of course, having made a decision to recover a relatively high proportion of transit expenses, it is certainly easier to do so in a city environment that is physically supportive of high transit use and where the quality of transit services enables transit to compete with the car. Thus in London it is extremely expensive to use the underground, but it is still the best way to get around for many trips.

Asian cities have, on average, very high transit cost recovery at 105 percent, with the highest in Hong Kong (136 percent) and Kuala Lumpur (135 percent), and the lowest in Beijing, at 20 percent, due to its very low fares and high staffing levels. Chinese bus and trolley bus tickets are perhaps the cheapest in the world, the average rate in the early 1990s being less than U.S. 0.5 cent per passenger kilometer. This compares with public transportation prices (all modes) in other cities that range from a low of about U.S. 1.7 cents per passenger kilometer in Manila, through averages of about U.S. 6 to 9 cents per passenger kilometer in Australian, U.S., and European cities (Hu and Kenworthy, 1996).

The transit cost recovery debate tends to focus on how to reduce government costs. It often concludes that it would be much cheaper to provide only buses since these have lower capital and sometimes lower maintenance requirements. These data suggest that buses are effective in transit cost recovery only in situations where there are large numbers of captive users, as in newly developing Asian cities such as Manila. The more fundamental way to recover transit costs in developed cities is to influence the form of the city toward a more transit-oriented structure. The role of rail systems in influencing and facilitating this cannot be underestimated.

## Traffic Deaths

In this section we examine the very real but nevertheless external costs of transportation due to traffic accidents. Many others have estimated what these costs actually represent—for example, in the United States, the cost of road accidents was estimated as US$150 billion in 1996 (*USA Today*, January 3–5, 1997). Here we simply present the various patterns of traffic deaths in the different cities. Deaths are gathered from all modes for 1990 but are negligible for rail systems and thus are called traffic deaths rather than transportation deaths.

The data show that traffic deaths tend to follow both the degree of automobile dependence and the level of development of the traffic regulatory system (Figure 3.13). In U.S. cities, despite their highly developed road systems, strictly regulated traffic, and a population generally well educated in traffic safety issues, traffic deaths are highest of all the regional groupings of cities (14.6 per 100,000 people). This seems to be due to the world's highest level of exposure of the population to auto traffic.

Traffic deaths then decline with decreasing car use, though not in a parallel way, due presumably to the level of traffic regulation: Australian cities have 12.0 deaths per 100,000 people; Toronto, 6.5; European cities, 8.8; wealthy Asian cities, 6.6; and developing Asian cities, 13.7 deaths per 100,000 people.

Thus, in developing cities such as Kuala Lumpur, which are motorizing at a very rapid rate, with high levels of motorcycle ownership and use and a relatively poorly developed traffic regulatory environment, traffic deaths are also very high at 22.7 per 100,000 people. This is despite the fact that the absolute level of automobile dependence is still very low compared to U.S. and other developed cities. Overall, the newly developing Asian cities have an average traffic death rate of 13.7 per 100,000 which is a far worse record than their level of car use would predict.[11]

Beijing, with 71 percent of total daily trips made by walking and cycling, also has a comparatively low rate of traffic deaths compared to other cities, as do most

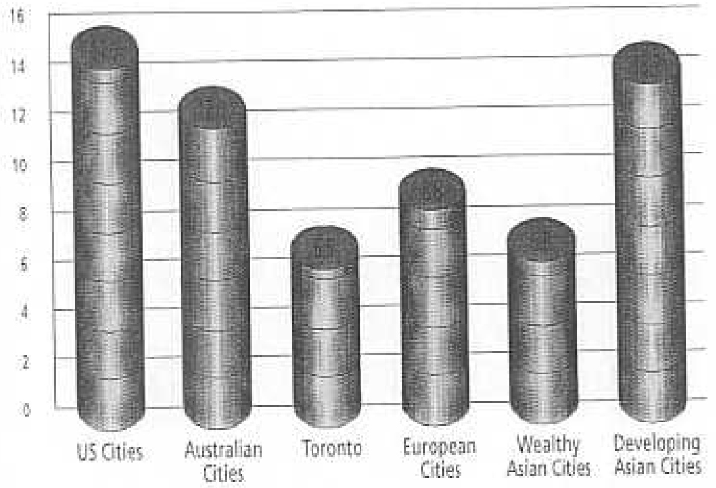

*Figure 3.13.* Traffic deaths in global cities per 100,000 people, 1990.

Chinese cities (6.1 deaths per 100,000). A study of seven large Chinese cities suggests a traffic death rate of 4.8 per 100,000 (Hu and Kenworthy, 1996). The situation in Chinese cities can, however, be expected to worsen, and perhaps begin to mirror the picture in the other rapidly motorizing Asian cities in this sample, as more and more traffic begins to mix with the high numbers of pedestrians and cyclists. This is especially true if little or nothing is done to slow down this rate of motorization or to plan for effective harmonization of motorized and nonmotorized transportation.

Overall, the data show how traffic deaths decline with car use though not to the same magnitude as the differences in car use; Australian cities have 18 percent fewer traffic deaths per 100,000 people but 40 percent less car use per capita than U.S. cities; European cities have 40 percent fewer deaths than U.S. cities but 59 percent less car use; and wealthy Asian cities have 55 percent fewer deaths but 86 percent less car use. As suggested above, there are therefore other factors at work that lend themselves to reducing traffic deaths; these include traffic engineering, management, and education. However, there are enormous resources and human energy poured into road safety when by far the biggest gains would be made by shifting to other modes and reducing the overall level of car use. This approach is rarely mentioned in road safety discussions.

There are some exceptional cities in terms of the patterns of traffic-related deaths:

- Metro Toronto, at 6.5 deaths per 100,000, has fewer than half the traffic fatalities found in U.S. cities, which suggests that a good transit system can have other flow-ons in terms of traffic safety (e.g., fewer teenagers need to drive). Metro Toronto's traffic death rate seems to be reasonably consistent with its other features (e.g., 24 percent of total travel is on transit, compared to only 3 percent in U.S. cities).
- Amsterdam, at 5.7, and Copenhagen, at 7.5 deaths per 100,000, have among the lowest rates in Europe and have among the highest rates of bicycle usage. This puts into perspective the perception that cycling is dangerous, perhaps indicating that the social patterns developed in a city to accommodate cyclists (such as giving priority to them at all intersections) can flow on to a generally safer road system. The case study on Copenhagen in Chapter 4 gives more detail on why that city has managed to reduce its traffic accident rates through an emphasis on bicycling and a "culture of respect" for all nonmotorized travelers.
- Tokyo and Hong Kong have among the best traffic safety records at 5.3 and 5.7 deaths per 100,000 due to their exceptional transit systems, which appear to be far more important in determining overall traffic safety levels than their congested major road systems.[12]

## *Transportation Emissions*

This section examines the main greenhouse gas emissions (i.e., CO$_2$) and the main smog emissions (i.e., NO$_x$, SO$_2$, CO, VHC, and VP) that come from transportation in the different cities. These are a major external cost for urban economies.

## Carbon Dioxide

Carbon dioxide is now a focus of international agreement on greenhouse gas reduction strategies, with all developed cities having to show how they are reducing $CO_2$. As discussed in Chapter 2, many documents have been presented on the issue at international forums, but invariably the area that is seen to be the least amenable to reduction is transportation $CO_2$ (OECD/ECMT, 1995; McKenzie and Walsh, 1990). The data here give some idea as to how progress can be made.

First, it is not just a matter of making technological improvements, as has already been shown. More fuel-efficient vehicles can just be used more, particularly if road conditions are improved to create freer-flowing traffic. An integrated transportation strategy is required that simultaneously improves technology, facilitates modal shifts, and reduces the need for travel. That this is possible without harming city economies is clear. The large variation in U.S. cities with respect to $CO_2$ generation rates shows some indication of this (total transportation $CO_2$ per capita varies from 3,778 kilograms per capita in the New York region up to 5,193 kilograms in Houston), but the fact that Toronto has 46 percent less $CO_2$ per capita than the average U.S. city suggests that its $CO_2$ generation rate in transportation can serve as a best-practice indicator in North American cities.

Toronto is providing transportation at a rate of 0.108 kilograms of $CO_2$ per dollar of GRP compared to 0.160 kilograms per dollar for U.S. cities (48 percent higher than in Toronto). Australian cities can do much better as well, with 0.141 kilograms of $CO_2$ per dollar of GRP. European and wealthy Asian cities may be approaching world best practice at 0.059 kilograms and 0.054 kilograms of $CO_2$ per dollar of GRP. The newly developing Asian cities at 0.317 kilograms of $CO_2$ per dollar of GRP need to do better, though their apparently high rate of $CO_2$ emissions per dollar of GRP is probably mostly due to their much lower wealth.

Figure 3.14 summarizes $CO_2$ emissions per capita for the global cities in 1990, showing the contribution from private and public passenger transportation. In all cases, $CO_2$ from transit is very small relative to that from automobiles.

## Smog Emissions

The major automotive emissions of concern to health and regional air pollution, including photochemical smog precursors, presented in terms of $NO_x$, $SO_2$, CO, volatile hydrocarbons (VHC), and volatile particulates (VP), follow the same patterns as car use, with a few interesting exceptions (see Figure 3.15).

Australian cities are almost identical in per capita air pollutant emissions to U.S. cities, despite having 40 percent less car use per capita. This is presumably because the vehicle fleet is very old due to lower wealth, there are lax systems of vehicle inspections, and there are lower emissions standards on new vehicles than in the United States (see Newman et al., 1996).

Policy debates continue to emphasize traffic management as a solution to air pollutant emissions. Australian urban traffic congestion is probably among the lowest in the world, as suggested by the data in Table 3.9 on average speeds; this shows how minimal is the factor of smooth traffic flow in reducing emissions, compared to the sheer amount of vehicle use and the state of the vehicles them-

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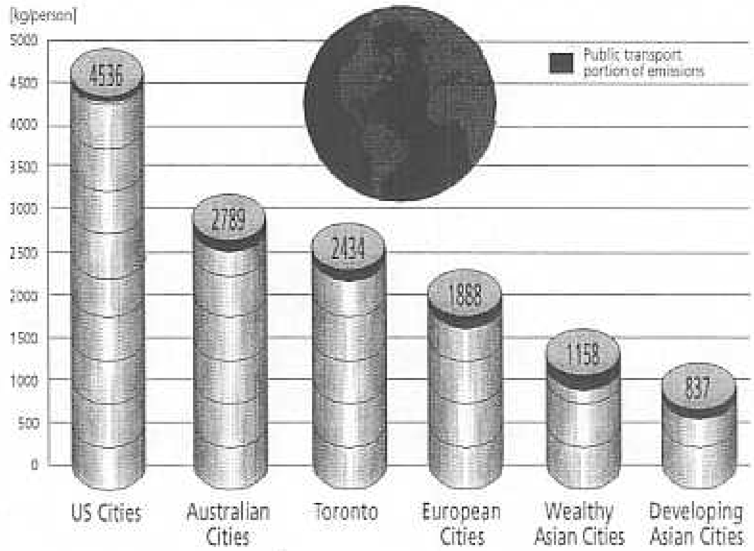

*Figure 3.14.* Per capita carbon dioxide emissions from private and public transportation in global cities, 1990.

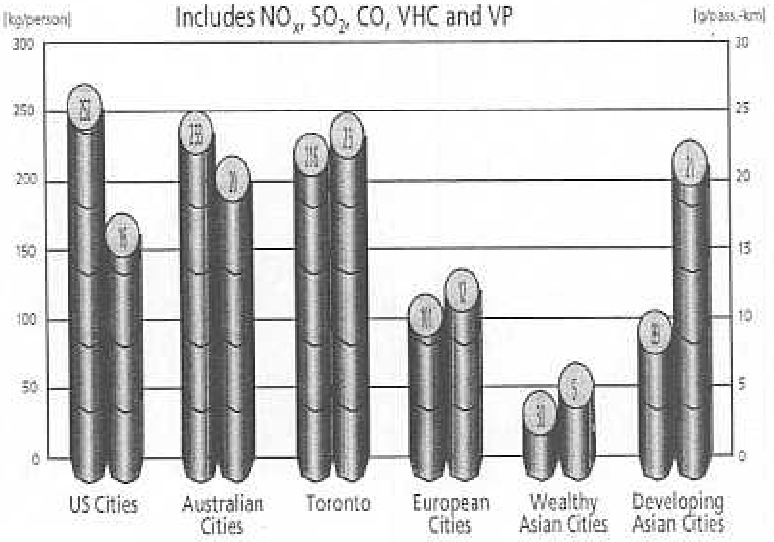

*Figure 3.15.* Per capita emissions of smog-related air pollutants in global cities, 1990.

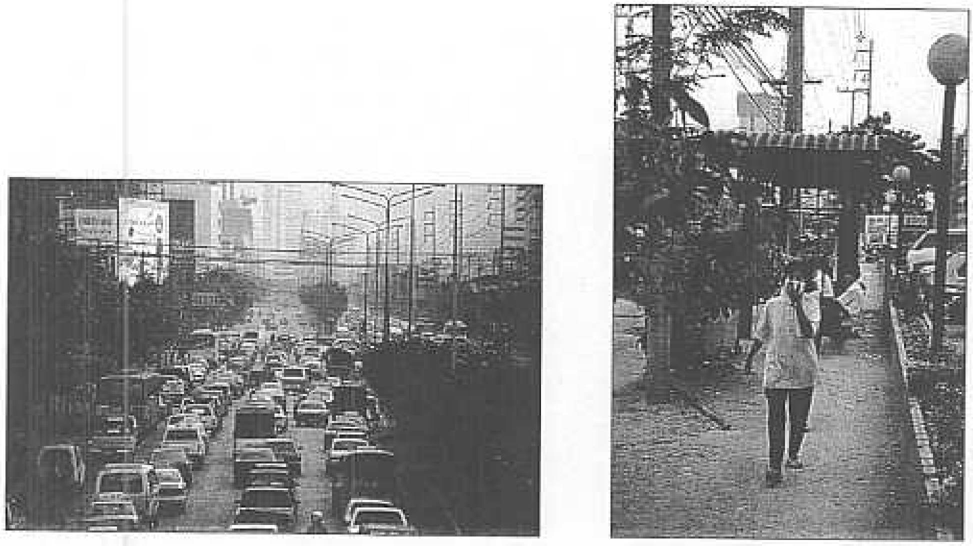

*Photo 3.5.* Automobile domination in dense Asian cities such as Bangkok has created traffic and air quality problems second to none.

selves. U.S. cities have even higher average traffic speeds than do Australian cities, but with very high per capita transportation emissions, again emphasizing the futility of trying to tackle automotive air pollution through improvements in traffic flow.

Toronto is low in $CO_2$ due to its transit system and integrated land use (see Kenworthy and Newman, 1994), but it is only an average North American city in other emissions. This is probably again due to a vehicle factor, as its fleet is older and it has the least fuel-efficient cars in North America at 4.38 MJ/passenger kilometer, compared to an average of 3.51 MJ/passenger kilometer for the U.S. cities.

European city air pollutant emissions are, as expected, much lower in general than those in cities in North America and Australia, with 57% of the level of $NO_x$ per capita in North American cities, 36 percent of the CO, 52 percent of the VHC, and 63 percent of the particulates.[13] $SO_2$ is 20 percent higher, however, due presumably to the higher amount of electricity (and hence coal) used in powering transit and the higher share of diesel fuel in the transportation system.

Asian cities for the most part have the lowest per capita air pollutant emissions. The exception is Bangkok, which, for its relatively low level of motor vehicle use, has very high volatile hydrocarbons: 23.2 kilograms per capita, similar to levels in U.S. and Australian cities with much higher vehicle use, and much higher than the European cities which produce 11.6 kilograms per capita. In addition, Bangkok has by far the highest level of particulates in the world: 9.1 kilograms per capita compared to a little over 1 kilogram per capita in most other cities.

Both these pollutants are linked to health problems. Volatile hydrocarbons are primarily from very inefficient, poorly maintained vehicles that are often

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idling for hours in traffic jams, with Bangkok being a global extreme in these problems. Particulates mainly come from poorly tuned diesel buses and trucks, as well as two-stroke motorcycles, and such vehicles are very common in Bangkok (they are also common in Jakarta and Surabaya, where particulate emissions are also comparatively high). It is not surprising that Bangkok traffic police wear gas masks and that there are increasing air pollution–related health problems in this city (see Kenworthy, 1995).

## *Proportion of City Wealth Spent on Transportation*

A final parameter that in many ways brings together this perspective on automobile dependence is the percentage of GRP spent on transportation. This is the sum of all the direct costs attributable to private and public passenger transportation that is then expressed as a proportion of the city's wealth. It shows "how much" transportation-related goods and services are as a proportion of total goods and services in the city.

Figure 3.16 shows that those cities with the highest automobile dependence (Australian and U.S. cities) have the highest overall proportion of transportation costs. These proportions would rise even further if they incorporated external costs such as traffic deaths and smog, which are also higher in these car-dependent cities.

The cities (in the developed world) with the highest proportion of their wealth going into passenger transportation are Perth at 17 percent, Phoenix at 16 percent, and Adelaide, Detroit, and Denver at 15 percent.

The cities (in the developed world) with the least wealth going into transportation are the European and wealthy Asian cities (at 8 percent and 5 percent, respectively), with their stronger commitment to transit systems. The best North American and Australian cities—Toronto at 7 percent, New York at 10 percent,

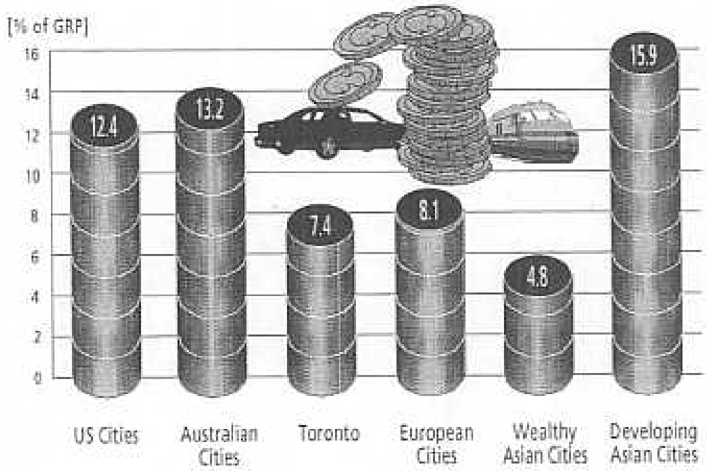

Figure 3.16. The proportion of city wealth spent on passenger transportation in global cities, 1990.

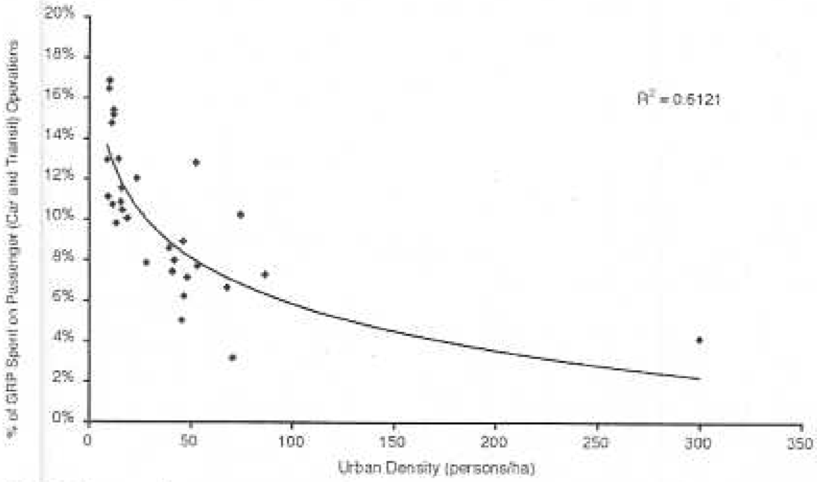

*Figure 3.17.* The total operating costs of passenger transportation versus urban density in developed cities, 1990.

and Sydney at 10 percent—also suggest that transit orientation is good for a city's economy.

The possible mechanism for this has been discussed in Chapter 2, where it is suggested that car dependence creates inefficiencies due to the extra land it consumes, the extra costs of infrastructure, and the direct and indirect costs of the automobile. Perhaps there is also a loss of investment associated with traffic-dominated urban environments (compared to quality pedestrian-friendly urban environments) and some opportunity costs due to loss of investment in productive industries instead of investment in unproductive suburb building.

Figure 3.17 demonstrates the significance of density in this relationship to city wealth. Dense cities have the lowest proportion of transportation costs and the sprawling car-dependent cities have the highest costs.

The cities that don't follow this trend are the developing Asian cities, which are not car-dependent but are car-dominated. These cities are pouring their productive financial and human capital into auto-related activity but are not showing much benefit from it. The transit-oriented model of the wealthy Asian cities, on the other hand, appears to represent world best practice on how to create wealth and not have car-dependence problems.

## Conclusions

The patterns of transportation infrastructure and land use in cities around the world reveal automobile dependence to be a combination of high car use, high provision for automobiles, and scattered low-density land use.

It is now possible to conclude that these patterns of automobile dependence are not sustainable (as defined here) based on economic and environmental indicators.

1. There appears to be no obvious gain in economic efficiency from developing automobile dependence in cities, particularly as it is shown in U.S. and Australian cities. There is no relative gain in GRP per capita or in the percentage of GRP spent on commuting: trip times to work are roughly the same everywhere, transit cost recovery is much worse, and road expenditure is higher.
2. There are, on the other hand, significant external and environmental costs due to automobile dependence that have clear implications for sustainability. There are much higher levels of per capita transportation energy use and emissions generated, more urban land per capita, and more traffic deaths. As the global agenda is focussing increasingly on sustainability, there is an obvious need to address these differences by overcoming automobile dependence.
3. Trends in car use suggest that U.S. cities have continued to grow in automobile dependence up to 1990, but some reductions are appearing in Australian cities. The latter is an important trend that is consistent with the pattern of increasing density and focused land use. It suggests that the new information economy and reurbanization of cities may assist in the sustainability agenda. More recently, in the second half of the 1990s, U.S. cities have also begun to show some positive trends in the comeback of central- and inner-city areas both residentially and economically. This appears to have been due to a combination of factors, such as successful programs against crime resulting in major reductions in homicides and robbery in some cities, including Boston, New York, and Chicago, and a renewed appeal of central and inner areas for retired people tired of suburban inconveniences and professional people weary of long commutes on congested roads. It remains to be seen whether this can have any significant effect on auto dependence, which appears to have a long-term exponential trend upward in U.S. cities.
4. European and wealthy Asian cities appear to have transportation systems that are both the least costly and the least environmentally damaging. However, these cities will still need to do better in terms of car use, which is growing in all but a few cases.
5. Rapidly developing Asian cities have considerably less efficient and sustainable transportation systems than would be expected from their levels of wealth. The positive side, however, is that they still have strongly transit-oriented urban forms, which means that good electric rail systems and more provision for nonmotorized transportation have the potential to rapidly transform their transportation patterns into more sustainable ones.
6. Rail transit systems, compared to all other motorized transportation, appear to have the best energy efficiency and greatest ability to attract people out of cars. They are the most important factor in the recovery of transit operating costs; they seem to be the catalyst for compact subcenter development; and they make a major contribution to sustainability on all indicators. Moving cities toward sustainability in both economic and environmental terms would appear to involve good rail systems.

7. Nonmotorized transportation is highly significant in both economic and environmental indicators. Cities that implement plans for improving the contribution of nonmotorized transportation are likely to see immediate and long-term benefits.

From a global perspective on automobile dependence, this chapter has shown a mixture of hope and continuing concern when reviewing the comparative performance of cities. The hope reveals that the process of developing policies to overcome automobile dependence is worth pursuing.

## Notes

1. We did have an experienced student located in the city, but even this on-site effort yielded very little useful information.
2. Transportation energy consumption not only gives an indication of the extent to which a city is using fossil fuels, especially oil, but is also an indicator of the quantity of air pollutants the city is producing (including smog and greenhouse gases). Other factors, such as the dominance of cars and the lack of transit, are also reflected in per capita transportation energy use. All of these other parameters can be measured, and in many cases we discuss them in this chapter; but the idea of highlighting transportation energy is to present first one of the most strategically important parameters for city sustainability.
3. This suggestion is somewhat confounded in the developing Asian cities, where there is a higher proportion of diesel fuel for passenger transportation.
4. Of course, the case of developing Asian cities again needs to be qualified. Even though they have not yet developed electric rapid transit systems, and therefore consume no electricity in transportation, they are also low energy users overall because their motorization and gasoline use are still very low in international terms.
5. Having asserted the importance of physical planning in this process of explaining urban patterns, we should also state that the economic parameters are significant. Kirwan (1992) has analyzed our data in terms of multivariate regressions and concluded that the price of fuel is the most significant variable in influencing travel patterns. He does admit, however, that there are strong factors influencing travel patterns that are part of the structure or physical form of the city. Obviously, pricing does influence travel and must be considered in any policy package designed to save transportation energy. We have begun a multivariate analysis on our new data using GRP as the wealth parameter, length of road as the infrastructure parameter, and density as the urban form parameter. It shows that density and road length are far more important in explaining vehicle kilometers traveled (VKT) than wealth; car ownership also follows the same pattern. This is discussed further, especially in Chapter 4.
6. Canberra is the only exception, at 34 km/h, due to its very low traffic density and high-speed services along bus lanes between subcenters.
7. The second graph is weaker because probably (1) there are some medium-density European cities that have done a lot to facilitate walking and cycling and have very high levels of use for these modes to work (Copenhagen and Amsterdam), and (2) there are some high-density Asian cities, such as Bangkok, that have atypically low walking and cycling to work for their density because of peculiar local conditions,

such as very hostile urban environmental conditions in Bangkok and difficult topography in Hong Kong.

8. It is also necessary to include nonwork journeys in this argument because they constitute about 70 percent of all travel, and they are far more local and thus shorter in denser, mixed-use cities than in dispersed, low-density cities. For example, in the Kanton (State) of Zurich, which is heavily urbanized, the percentage of work trips on foot and bicycle in 1989 was 26 percent, whereas shopping trips were 35 percent by foot and bicycle, and recreation trips were 33 percent (Statistische Berichte des Kantons Zürich, 1991).
9. The capital and variable cost of cars per kilometer in Australian cities is considerably higher than in U.S. cities (US$0.37 per kilometer compared to US$0.29, or 28 percent higher in Australia), which when combined with lower wealth (US$19,761 in Australia compared to US$26,822 in the United States) may also be contributing to lower increases in car use. However, these economic differences are less pronounced now than they were, so the other reasons above may be more fundamental.
10. Lave's analysis suffers from being based mainly on national data that are strongly influenced by factors such as air travel growth.
11. The apparent exceptions are Surabaya and Jakarta (7.8 and 4.5 deaths per 100,000, respectively). We are, however, suspicious of these low figures and suspect they are from police records (which always understate traffic deaths), whereas the other data are from health departments that use a standard WHO method for reporting causes of death (International Classification of Diseases, or ICD; see Appendix 1).
12. The parameter found in Appendix 1, "percentage traffic deaths of total deaths," follows the same pattern as discussed above except that the Asian cities are relatively higher. This may be due to their younger age structure and much lower homicide rate than in Western cities.
13. Two outliers that are hard to explain are Stockholm, which is much higher than average, and Vienna, which is much lower than average, but this is probably due to variability in the quality of data, as explained in the methodology (Appendix 1).