Introduction

This chapter explores the link between greenhouse gas (GHG) emissions, transport mode, and city shape. Urban productivity is dependent on people’s mobility within a metropolitan area. GHG emissions, however, are only weakly linked to the number of kilometers traveled per person because of large variations between the emissions per passenger kilometer of different transport modes and differences in the carbon content of the various energy sources used for transport. Thus, to reduce urban GHG emissions due to transport, it is important to look at all the parameters that contribute to emissions. In this chapter, three concurrent strategies that could contribute to reducing GHG emissions due to urban transport are reviewed: technological improvements within mode, mode shift, and land-use strategy allowing spatial concentration of jobs. In particular, the chapter explores options for improving travel in urban areas by investigating the links between GHG emissions and transport modes, with consideration of associated travel costs and city shape. However, it is our contention that none of these strategies are likely to succeed if not supported by an energy pricing policy directly linking energy price to carbon content.

The central hypothesis is that carbon-based energy pricing could trigger a demand shift toward transit in dominantly monocentric cities, providing adequate zoning changes were made. More specifically, this chapter seeks to develop and determine the following:
Hypothesis 1: Price signals, including energy prices and carbon market-based incentives, road tolls, and transit fares, are the main drivers of technological change, transport modal shift, and land-use regulatory changes.

Hypothesis 2: Price signals could shift transport mode from individual cars to public transit for trips from the periphery to the central business district (CBD) only in cities that are densely populated (more than 50 people/hectare (ha) in built-up areas) and already dominantly monocentric.

GHG Emissions and Urban Transport

Urban GHG emissions per person in large cities are a fraction of the national average (figure 4.1). This difference appears as a paradox because cities have a higher gross domestic product (GDP) per person than the national average, and it is usually assumed that higher GDP means higher GHG emissions. In fact, modern cities with a large proportion of service jobs consume less energy per capita than smaller towns and rural areas. However, because GHGs are emitted in urban areas by a very large number of small sources—cars, appli-

Figure 4.1 CO₂ Emissions in Cities Compared with Countries

Source: EIU 2008; World Resources Institute 2009.

Note: CO₂e = carbon dioxide equivalent.
anes, individual buildings—as opposed to concentrated sources such as power plants or factories, it is difficult to develop an emission reduction strategy that would work for all emitters.

Reliable data on emissions in cities are difficult to collect because of ambiguity in determining which sources to include as urban. Should urban GHG emissions be limited to sources located within metropolitan boundaries? Or should emissions be counted on the basis of urban residents’ consumption in urban areas? The data for cities shown in figure 4.1 correspond to the first definition, although emissions from electricity are accounted for on the basis of consumption and not on emissions at the location of the power plant.

Some analyses solve the problem posed by emission location versus location of consumption by including life-cycle emissions (Button 1993; McKinsey and Co. 2007; Schipper, Unander, and Marie-Lilliu 1999). For instance, the emissions of a car are not limited to the fuel consumed but include also the energy used to manufacture it, to maintain it, and to scrap it after its useful life. Although this type of definition is reasonable, the resulting numbers are difficult to calculate, and the method implies a number of assumptions, in particular, concerning the number of years and the number of kilometers traveled during the useful life of a vehicle. It is important to be aware of the limitations of the data set available when comparing cities’ performance in GHG emissions. Some apparent inconsistencies in the data presented below can be attributed to slightly different assumptions in the data collected about emissions attributions.

The sample of five large cities in high-income countries shown in figure 4.1 gives a range of emissions from 4 to 7 tons per person per year in 2005 (EIU 2008). It is likely that GHG emissions in cities in low- and middle-income countries, for which no reliable data are available, are even higher than the Organisation for Economic Co-operation and Development (OECD) cities shown in figure 4.1. The use of older cars and buses, and the prevalence of two-stroke engines for motorcycles and three-wheelers, might contribute to higher GHG emissions per capita. The three main sources of GHG emissions in cities are buildings, transport, and industries. In the sample of five high-income cities included in figure 4.1, the proportion of GHG emissions due to transport varies from 25 percent of total emissions in New York City to 38 percent in Rome (figure 4.2).

This chapter will be limited to identifying the best strategies to reduce GHG emissions due to transport in a context of increasing urban productivity. The conclusions of this study would be particularly relevant to cities that have more than 1 million inhabitants. According to United Nations data and projections, cities with populations above 1 million accounted for about 1.2 billion, or 18 percent of the world population, in 2005. By 2025, it is expected that this will increase to 1.85 billion and will then represent 23 percent of the world population.
Transport is a key driver of the economy and is highly dependent (98 percent) on fossil oil. Although already a significant sector of GHG emissions, it is also the fastest growing sector globally. Between 1990 and 2003, emissions from the transport sector grew 1,412 million metric tons (31 percent) worldwide. The sector’s share of carbon dioxide (CO₂) emissions is also increasing. In 2005, the transport sector contributed 23 percent of CO₂ emissions from fossil fuel combustion. It is also the sector where the least progress has been made in addressing cost-effective GHG reductions (Sperling and Cannon 2006). As mentioned earlier, the fragmentation of emissions sources and the complexity of demand and supply issues in urban transport explain the lack of progress. Making transport activity more sustainable must be a top priority policy if climate change is to be addressed.

In most cities, numerous urban problems are transport related, such as congestion on urban roads, poor air quality, fragmented labor markets, and social fractioning due to poor access to economic and social activity and the like (Ng and Schipper 2005; World Bank 2009). Road transport accounts for, by far, the largest proportion of CO₂ emissions from the transport sector, principally from automobile transport. Against the projected increase in car ownership worldwide (expected to triple between 2000 and 2050), road transport will continue to account for a significant share of CO₂ emissions in the coming decades. Within cities, modal share and measures facilitating less GHG-intensive modes
such as public transport require closer examination. Modal shift policies are generally inadequately assessed in CO2 policy (OECD 2007). Because GHG emissions caused by urban transport have to be reduced while urban productivity has to increase, it is important to establish the links between urban transport, labor mobility, and city productivity.

**Mobility and Cities’ Economies**

Economic literature, both theoretical and empirical, linking the wealth of cities to spatial concentration is quite abundant and no longer controversial in academic circles (Annez and Buckley 2009; Brueckner 2001; Brueckner, Thisse, and Zenou 1999). The World Bank’s World Development Report (2009), “Reshaping Economic Geography,” and the Commission on Growth and Development report “Urbanization and Growth” (Annez and Buckley 2009) exhaustively summarize and document the theoretical and empirical arguments justifying the economic advantage provided by the spatial concentration of economic activities in large cities. The necessity to manage urban growth rather than to try to slow it down is eventually reaching mayors, city managers, and urban planners. The size of cities is not critical; what matters is the connectivity insured by urban transport networks between workers and firms and between providers of goods and services and consumers, whether these consumers are other firms or individuals. This connectivity is difficult to achieve in large cities. It requires coordination between land uses and investments in transport networks; difficult pricing decisions for road use, parking, and transit fares; and finally, local taxes and user fees that makes the maintenance and development of the transport network financially sustainable (Staley and Moore 2008).

Traffic congestion in slowing down mobility represents a management failure on the part of city managers. Congestion has a double negative effect: It acts as a tax on productivity by tying down people and goods, and it often increases GHG emissions even for vehicles that would otherwise be performing satisfactorily. It is conceivable that mismanaged large cities may reach a level of congestion that negatively offsets the economic advantage of spatial concentration. In this case, these cities would stop growing. However, the positive economic effect of agglomeration must be very powerful to offset the chronic congestion of cities such as Bangkok and Jakarta that are still the economic engine of their region in spite of their chronic congestion.

Poor migrants moving to large cities often have difficulties in participating in the urban economy, either because their housing is located too far from the urban transport networks or because they cannot afford the cost of transit or motorized transport. It has been observed that some slums appear to be self-
sufficient and that many slum dwellers are able just to walk to work. Some have argued that slum dwellers’ lack of motorized mobility and inclination toward walking would constitute an advantage in terms of GHG emissions and should be emulated by higher-income groups. This argument is a cruel joke on the poor because their lack of mobility condemns them to live in large cities with all its costs but none of its benefits. The lack of mobility in many slums and in some badly located government housing projects constitutes a poverty trap rather than an advantage to be emulated in the future (Gauteng in South Africa being a case in point).

Although walking and cycling do constitute an indispensable transport mode in large cities, people using these modes should do it by choice, not because they are forced to do so by lack of access or affordability of other means of transport. Because mobility is a necessity for economic survival in large cities, a reduction of GHGs should not be made by reducing mobility and certainly not by preventing an increase in mobility for the poor. The reduction of the number of passenger kilometers traveled (PKmT) should not be targeted for reduction to reduce GHG emissions. To the contrary, because of the lack of mobility of a large number of poor people living in large cities, PKmT should increase in the future. Various alternative solutions to decrease GHG emissions while increasing PKmT are discussed.

**Identifying Key Parameters in Urban Transport GHG Emission Sources**

GHG emissions from transport are produced by trips that can be divided into three broad categories:

1. Commuting trips
2. Noncommuting trips
3. Freight

Commuting trips are the trips taken to go from residence to work and back. In most low-income cities, commuting trips constitute the majority of trips using a motorized vehicle (with exceptions in some East Asian cities where nonmotorized trips still constitute a large number of commuting trips). Noncommuting trips are trips whose purpose is other than going to work, for instance, trips to schools, to shops, or to visit family or other personal reasons.

In high-income countries, commuting trips constitute only a fraction of total trips. For instance, in the United States, commuting trips represented 40 percent of all motorized trips in 1956; in 2005, they represented only slightly less than 20 percent of all motorized trips (Pisarski 2006). In low-income cities, most of
these trips involve short distances and are using nonmotorized transport. When noncommuting trips become more numerous and longer they tend to be made via individual cars or motorcycles because destinations are not spatially concentrated and transit networks cannot easily accommodate them. For instance, in New York City in 2005, transit was used for 30.8 percent of all commuting trips but only for 9.6 percent of all commuting and noncommuting trips (O’Toole 2008).

Freight trips, including public vehicle travel and urban goods and services travel, constitute a sizable portion of all trips but vary significantly between cities. Because freight trips within urban areas are always done by individual vehicle and cannot use transit, these trips are adversely affected by road congestion, which results in significant costs to the economy of cities.

Will the trends observed in the United States anticipate what will happen in other parts of the world when these cities reach a level of income comparable to that of the United States today? This appears unlikely because of differences in city density between the United States and other parts of the world. Most cities outside the United States have a density far higher than U.S. cities, often by two orders of magnitude. Although densities of large cities tend to decrease over time, the decrease is slow and is unlikely to ever reach the low density of U.S. cities. It is probable that in high-density cities noncommuting trips will largely use nonmotorized transportation, taxis, or transit, as is the case in high-density Manhattan today.

Analysis in this research will therefore concentrate on emissions from commuting trips because these trips are the most common type in low- and middle-income cities. In addition, commuting trips require the most capital investment because of the transport capacity required during peak hours. Commuting trips often define a transport network whereas the other types of trips, including freight, piggy-back onto the transport investments made initially for commuting trips.

In East Asia, commuting trips, using walking or bicycles, constituted the majority of commuting trips in the 1980s and 1990s. During the past 20 years, because of the physical expansion of cities and increase in floor space consumption due to rising incomes, the share of nonmotorized transport has unfortunately been shrinking. In 2006, for instance, the share of nonmotorized commuting trips has been reduced to about 20 percent in Shanghai from about 75 percent in the early 1980s.

**Disaggregating Commuting Trips by Mode**

Commuting trips can be disaggregated into three modes: nonmotorized mode (walking and cycling, and increasingly included in this category, people working at home and telecommuting); motorized self-operated vehicles (SOVs),
including motorcycles and private cars (car pools included); and transit mode (minibuses, buses, bus rapid transit [BRT], light rail, subways, and suburban rail). The types of vehicles used in the last two modes vary enormously in emission performance. In addition, within each mode—SOV and transit—each city has a fleet of vehicles, which have a wide range of GHG emissions performance. Comparisons between vehicles often differ by orders of magnitude depending on technology, maintenance, age of vehicle, energy source, and load (the average number of passengers per vehicle). To see more clearly the impact of different transport strategies on the reduction of GHG emissions, we have built a simple model linking the various vehicle fleet parameters to GHG emissions per commuter. The model is limited to analyzing CO$_2$ emissions from commuting trips, which are still the most common motorized trips in low- and middle-income cities. For each mode, the inputs of the model are the following:

1. The percentage of commuters using the mode
2. The average commuting distance (in kilometers)
3. The CO$_2$ equivalent (CO$_2$e) emission per vehicle kilometer traveled (VKmT), calculated for full life cycle when data available
4. The load factor per type of vehicle

Numerous publications provide GHG emissions expressed in grams of CO$_2$ per PKmT (table 4.1). However, the data assume a passenger load to calculate the CO$_2$ per PKmT. Because the load is a crucial parameter in the model, it has been necessary to calculate the CO$_2$ emissions per VKmT. However, fuel consumption may vary for the same vehicle, depending on the load; therefore, load and fuel consumption are not completely independent variables. We have therefore slightly adjusted the energy consumption values by VKmT to reflect this. A more sophisticated model would establish more accurately the relationship between load and fuel consumption for each type of vehicle. For demonstration purposes of the proposed methodology, results were found to be robust enough to allow this simplification. The equation used in the model showing the daily GHG emissions as a function of the number of passengers using different modes, with different average commuting distances, load factor, and engine fuel performance, is presented in the annex.

Based on the equation given in the annex, it can be shown that trying to reduce the average commuting distance per day (variable $D$)—de facto reducing labor mobility—would not provide much effect on $Q$ (GHG emissions per day) compared with a change in vehicle fleet performance (variable $E$), a mode shift (variable $P$), or an increase in the load factor (variable $L$). As seen in table 4.1, the possible values taken by $E$ vary by a factor of four between a hybrid diesel
and an SUV, and by a factor of two between the New York City subway and a Toyota Prius! By contrast, land-use changes might, at best, reduce average commuting distance $D$ by 5 to 10 percent within a minimum period of 20 years. This model, which could be used as a rough policy tool, was tested for parameters for New York City and Mexico City. The inputs and outputs of the model using New York City parameters in 2000 are shown in table 4.2.

The model shows the difference of performance in terms of GHG emissions between transit and cars in New York City: Emissions per car passenger per year are nearly six times more than the emissions per transit passengers. The model allows testing of the impact of alternative strategies; for instance, what would be the impact of an increase of hybrid cars over the total number of cars, everything else staying constant? Or what would be the impact of an increase in transit passengers, or in the load factor of buses, and so on? Table 4.3 shows the impact of two alternatives in reducing GHG emissions.

Table 4.3 demonstrates the potential impact in New York City of a change in the composition of the car fleet and, alternatively, a mode shift from cars to transit. The changes concern only the value of variable $P$ in the model’s equation. The current situation in 2005 is shown in column A. In column B, an increase from 0.5 to 19 percent in the number of commuters using hybrid cars, representing about one out of five cars used by commuters, bring a 28 percent reduction in GHG emissions. In column C, a mode shift from car to transit, raising the share of transit from 36 percent of commuters to 46 percent, decreases GHG emissions.

**TABLE 4.1**

<table>
<thead>
<tr>
<th>Vehicle type</th>
<th>Grams of CO$_2$ per passenger mile</th>
<th>Grams of CO$_2$ per passenger kilometer</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUV</td>
<td>416</td>
<td>258</td>
</tr>
<tr>
<td>Average U.S. car</td>
<td>366</td>
<td>227</td>
</tr>
<tr>
<td>Motor buses</td>
<td>221</td>
<td>137</td>
</tr>
<tr>
<td>Light rail</td>
<td>179</td>
<td>111</td>
</tr>
<tr>
<td>Commuter rail</td>
<td>149</td>
<td>93</td>
</tr>
<tr>
<td>Hybrid gas</td>
<td>147</td>
<td>91</td>
</tr>
<tr>
<td>Toyota Prius</td>
<td>118</td>
<td>73</td>
</tr>
<tr>
<td>Hybrid diesel</td>
<td>101</td>
<td>63</td>
</tr>
<tr>
<td>Metro</td>
<td>94</td>
<td>58</td>
</tr>
<tr>
<td>New York MTA</td>
<td>73</td>
<td>45</td>
</tr>
<tr>
<td>New York subway</td>
<td>58</td>
<td>36</td>
</tr>
</tbody>
</table>


Note: MTA = Metropolitan Transportation Authority.
### TABLE 4.2
Input and Output of GHG Emissions for New York City

<table>
<thead>
<tr>
<th>Mode / Symbol</th>
<th>Average distance per passenger per commuting trip</th>
<th>Number of commuters per mode</th>
<th>Percent of commuters per mode</th>
<th>Grams of CO$_2$e per VKmT</th>
<th>Load factor as % of total vehicle capacity</th>
<th>Grams of CO$_2$e per PKmT</th>
<th>Total tons of CO$_2$ emitted by commuters per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walk</td>
<td>2.5</td>
<td>470,000</td>
<td>5</td>
<td>—</td>
<td>100</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Cycle</td>
<td>5.0</td>
<td>94,000</td>
<td>1</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Car (gasoline)</td>
<td>19.0</td>
<td>4,324,000</td>
<td>46.0</td>
<td>375</td>
<td>1.63</td>
<td>33</td>
<td>230</td>
</tr>
<tr>
<td>Car (diesel)</td>
<td>19.0</td>
<td>47,000</td>
<td>0.5</td>
<td>256</td>
<td>1.63</td>
<td>33</td>
<td>157</td>
</tr>
<tr>
<td>Car (hybrid)</td>
<td>19.0</td>
<td>47,000</td>
<td>0.5</td>
<td>105</td>
<td>1.63</td>
<td>33</td>
<td>64</td>
</tr>
<tr>
<td>Car (electric)</td>
<td>19.0</td>
<td>—</td>
<td>0</td>
<td>163</td>
<td>1.63</td>
<td>33</td>
<td>100</td>
</tr>
<tr>
<td>Motorcycle 2-stroke</td>
<td>8.0</td>
<td>94,000</td>
<td>1</td>
<td>119</td>
<td>1.1</td>
<td>55</td>
<td>108</td>
</tr>
<tr>
<td>Minibus gasoline</td>
<td>20.0</td>
<td>—</td>
<td>0</td>
<td>720</td>
<td>7</td>
<td>58</td>
<td>103</td>
</tr>
<tr>
<td>Minibus diesel</td>
<td>20.0</td>
<td>—</td>
<td>0</td>
<td>600</td>
<td>7</td>
<td>58</td>
<td>86</td>
</tr>
<tr>
<td>Bus diesel</td>
<td>20.0</td>
<td>564,000</td>
<td>6</td>
<td>1,000</td>
<td>30</td>
<td>50</td>
<td>33</td>
</tr>
<tr>
<td>Bus natural gas</td>
<td>20.0</td>
<td>1,128,000</td>
<td>12</td>
<td>1,200</td>
<td>30</td>
<td>50</td>
<td>40</td>
</tr>
<tr>
<td>Rail transit</td>
<td>20.0</td>
<td>2,632,000</td>
<td>28</td>
<td>3,950</td>
<td>110</td>
<td>73</td>
<td>36</td>
</tr>
</tbody>
</table>

Total transit = 9,400,000 100 Tons per day  

$Q = 44,698$
<table>
<thead>
<tr>
<th>Number of people in New York City MSA</th>
<th>14,687,500</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kg/per year per commuter</td>
<td>1,240</td>
</tr>
<tr>
<td>E/P ratio (%)</td>
<td>64</td>
</tr>
<tr>
<td>Kg/year by transit passenger</td>
<td>38</td>
</tr>
<tr>
<td>Number of commuting days per year</td>
<td>261</td>
</tr>
<tr>
<td>Kg/year by Car passenger</td>
<td>2,217</td>
</tr>
</tbody>
</table>

Source: Authors’ analysis.

Note: Total number of commuters \((T) = 9,400,000\). Figures in italics are input of the model, other figures are output. MSA = metropolitan statistical area; PKmT = passenger kilometer traveled; VKmT = vehicle kilometer traveled.
emissions by 13 percent. Further reductions could be achieved by introducing hybrid buses or increasing loads of both cars and transit.

The use of the model allows a back-of-the-envelope calculation of the impact of potential changes in technology and transport mode on GHG emissions. The model does not have anything to say about the feasibility or the probability of such a change to occur. Although the rough calculations shown imply that the combined impacts of technology change and mode shift could be large, how to achieve these changes remains the main problem to be solved. Most of the vehicle technology, such as hybrid engines, that reduces fuel consumption has been around for at least 10 years. Rail transit using electricity has been common in large cities for more than 100 years. The fact that in many cities the use of transit represents a minority mode raises important questions about

<table>
<thead>
<tr>
<th>Mode / Symbol</th>
<th>Change in CO₂e emissions</th>
<th>Change in CO₂e emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Walk</td>
<td>5%</td>
<td>5%</td>
</tr>
<tr>
<td>2 Cycle</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>3 Car (gasoline)</td>
<td>56%</td>
<td>37.5%</td>
</tr>
<tr>
<td>4 Car (diesel)</td>
<td>0.5%</td>
<td>0.5%</td>
</tr>
<tr>
<td>5 Car (hybrid)</td>
<td>0.5%</td>
<td>19.0%</td>
</tr>
<tr>
<td>6 Car (electric)</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>7 Motorcycle 2-stroke</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>8 Minibus gasoline</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>9 Minibus diesel</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>10 Bus diesel</td>
<td>5%</td>
<td>5%</td>
</tr>
<tr>
<td>11 Bus natural gas</td>
<td>10%</td>
<td>10%</td>
</tr>
<tr>
<td>12 Rail transit</td>
<td>21%</td>
<td>21%</td>
</tr>
</tbody>
</table>

**Source:** Authors’ analysis.

**Note:** n.a. = not available.
consumer preferences for urban transport. The transport mode split for New York City in 2005 shown in table 4.2 represents a state of equilibrium. It is important to know what factors could change this equilibrium to a new state that would be more favorable for GHG reductions.

**Consumers’ Demand for Transport**

The loss of transit share over the past few decades in most of the world’s major cities has to be acknowledged. Even in Singapore transit mode share declined from 55 percent of commuters in 1990 to 52.4 percent in 2000 (Singapore Department of Statistics 2000). This decrease is striking because Singapore has had the most consistent transport policy over two decades favoring transit, including strict limits on car ownership, and has been a world pioneer for congestion pricing using advanced technology. In addition, Singapore has always had excellent coordination between land use and transport investments. Although the preceding section has shown that there is an overwhelming case for increasing transit mode to reduce GHG emissions, consumer choice seems to follow the opposite trends. It is therefore important to understand why transit is losing ground in so many cities and what alternative strategies exist and in which type of cities the trend could possibly be reversed.

Consumers’ decisions to use one mode of transport over others depend on three main factors:

1. Cost
2. Speed
3. Convenience, as determined by frequency and reliability of service and comfort

For low-income commuters, the cost of transport is the major consideration. For very low-income commuters, walking is often the only affordable option, which significantly lowers their ability to take advantage of the large labor market offered by large cities. In Mumbai, for instance, about 4 million people walk to work every day (about 45 percent of the active population). Middle- and low-income users above extreme poverty are the prime customers for transit, as buying and maintaining a car is beyond the means of most of these, although subsidized fares frequently exist to make transit more affordable. However, in numerous middle- and high-income countries, some cities retain a significant number of transit users who are middle or high income—for instance, Hong Kong, London, New York City, Paris, and Singapore, among others. How these cities have managed to maintain a high use of transit among affluent households will be described in the next section.
In an increasing number of cities in low- or middle-income countries, the dispersion of employment makes it inconvenient to use transit, because no transit route goes directly to their location of employment. For those commuters who cannot afford to use individual cars or motorcycles, the most convenient options are collective taxis or minibuses. Commuting by microbuses at the expense of transit has become the dominant transport mode in Gauteng, Mexico City, and Tehran, for instance. As households’ income increases, the speed of transport and convenience become more important factors than cost, or rather, higher-income commuters give a higher value to the time spent commuting than do lower-income ones. Speed of transport is limited in most transit system by frequent stops and the time required for transfers. In city structures where a car is a feasible alternative mode of transport, commuters who can afford the cost would normally switch to individual cars.

The exhaustive study conducted by Pisarski (2006) on commuting characteristics in U.S. cities gives an order of magnitude of the speed difference between transit and individual cars in those cities (figure 4.3). The average commuting distance is about the same between the different modes except for walking, cycling, and rail transport. One can see that in spite of the congestion prevalent in most U.S. cities, commuting time by transit requires about double the time required by individual cars. Travel time for car pooling when involving

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**Figure 4.3 Average Travel Time in U.S. Cities by Transport Mode**

Source: Pisarski 2006.
more than four people becomes similar to transit. This explains in great part the loss of transit share in U.S. cities in the past two decades.

In Singapore, with one of the most efficient transit systems in the world, the ratio of transit travel time to car driving time is lower than in U.S. cities. However, the difference in travel time is significant enough (see table 4.4) to indicate that transit would not be a first-choice transport mode for people who can afford an alternative. The high speed of car commuting is, of course, part of the success of Singapore’s transport strategy. Congestion pricing, constantly adjusted to facilitate fluid traffic, ensures high speed for all car commuters who can afford the high premium paid for car ownership and for congestion tolls.

The challenge is to propose urban transport strategies that would result in reducing GHG emissions while maintaining mobility as reflected by commuters’ mode preference. These different strategies would have to be adapted to different spatial forms of urban growth—monocentric, polycentric, high and low densities—and to a context of increasing urban income and a decreasing cost of car acquisition. These strategies will have to rely on the three tools available to urban managers: pricing, regulations, and land-use policy.

**Energy Pricing, GHG Emissions, and Market-Based Incentives**

As discussed earlier, a significant reduction in GHG in urban transport could be achieved in two ways: technological change to reduce carbon content per VKmT and transport-mode shift from private car to transit. As alluded to earlier, the pricing of energy based on its carbon content is an indispensable policy instrument to trigger these changes to reduce GHGs in the long run. The pricing of energy based on carbon content could be achieved through a carbon tax or through “cap and trade.” The merit of each approach is discussed next.

**TABLE 4.4**

**Singapore: Travel Time by Transport Mode**

<table>
<thead>
<tr>
<th>Mode</th>
<th>Median travel time (minutes)</th>
<th>Distance (kilometers)</th>
<th>Speed (kilometers/hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car</td>
<td>27</td>
<td>29.2</td>
<td>65</td>
</tr>
<tr>
<td>Metro</td>
<td>41</td>
<td>11.5</td>
<td>17</td>
</tr>
<tr>
<td>Metro + bus</td>
<td>51</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bus alone</td>
<td>38</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Source: Singapore Department of Statistics 2000.*
In each city the current use of low-carbon technology and the ratio between transit and car commuting is reflecting an equilibrium state between supply and demand. Any change in technology or transport-mode share will require a move to a new state of equilibrium in the economy of transport. Significantly higher gasoline prices, as experienced in 2008, temporarily modified this state of equilibrium. Demand for transit increased and VKmT decreased. However, as long as renewable energy sources were not available at a competitive price, the high price of oil made it cheaper to generate electricity from coal or shale oil. Electricity is used mostly as a source of energy for rail transit, but electrical cars that would recharge their batteries from the electricity grid will use it increasingly. Electricity produced by coal-burning power plants generates twice as much GHG per kilojoule than power plants using natural gas. Without a system of pricing energy based on its carbon content, higher oil and natural gas prices could increase GHG emissions rather than reducing them by shifting electricity generation to coal-fueled power plants.

However, carbon pricing cannot be decided at the local level and is dependent on national policy and increasingly on international agreements. It must be acknowledged that these policy instruments will have a limited impact in the absence of carbon pricing.

Various policy instruments are currently available to reduce GHG emissions due to urban transport. Their effectiveness is often limited by the quality of national and local governance, as well as a city’s income distribution and spatial structure. Policy instruments can be divided among three principal categories:

1. Regulatory instruments, such as limitations on the number of vehicles on the road on a given day (for example, Beijing, Bogota, and Mexico City *pico y placa* (peak and [license] plate) and limitation on the number of cars registered in the city (for example, Singapore car quota system)

2. Pricing instruments modifying relative prices between private car and transit modes, such as road pricing: fixed tolls and congestion pricing (for example, London, Singapore, and Stockholm); a fuel tax, which needs to be compared with an increase in the price of a barrel of oil due to oil market evolution (for example, Bogota, Singapore, Chicago, and most other U.S. cities); transit fare subsidies (for example, Los Angeles and San Francisco); and pricing and taxing of parking (for example, Edinburgh, New York City, Peterborough, and Sheffield)

3. Investment in transport infrastructure in order to increase and improve the supply of transit modes (for example, Bogota, Jakarta, and Singapore)
Regulatory Instruments

Regulatory instruments aiming at mode shift from car to transit are generally not effective because the choice of a transport mode must be demand driven. Regulatory instruments aiming to limit or reduce car ownership and car usage could seriously limit mobility in the absence of adequate investments in transit to replace the decrease in car trips. The example of Singapore in fixing a quota for car growth is rather unique. It could have been very disruptive to the economy if the government had not simultaneously been able to finance and develop a very effective transit system consistent with its land-use policy. This important aspect will be developed later.

In countries with high economic inequality (such as Colombia or Mexico), policies such as pico y placa create an incentive for higher-income households to buy a second car. This second car is often a secondhand car with worse engine performance than most recent models. As a result, the pico y placa policy has often resulted in worse pollution and higher GHG emissions than the status quo ante. The availability of a new type of low-cost car—the Tata Nano, for example—could make this policy even more ineffective.

Pricing Instruments

Pricing instruments are normally aimed at pricing transport at its real economic price (Button 1993; Goodwin, Dargay, and Hanly 2004). When this can be achieved, it removes the distortions that hidden subsidies introduce in resource allocation. Congestion pricing and parking pricing, for instance, aim at adjusting the price of using a highway or of a parking space to reflect its real economic value, including externalities due to congestion (Luk 1999). The aim of economic pricing is not to be punitive but to seek a more efficient allocation of resources. Pricing instruments also include subsidies, which have a different aim than economic pricing. Subsidies aim at being redistributive. For instance, most transit fares are heavily subsidized. Transit-fare subsidies are aiming at increasing the mobility of low-income households, allowing them to fully participate in a unified metropolitan labor market.

It is tempting also to use transit-fare subsidies as a financial incentive to convince car commuters to switch to transit. This is not a very effective way to increase transit-mode share in the long run. The subvention for transit operation and maintenance often comes from local government budget allocation. The larger the number of users, the larger the subsidies required. This works as a reverse incentive for the transit operator to improve services. In the long run, the subsidies paid by the government to the transit authority usually fall short of the real cost of operation and maintenance, resulting in a deterioration
of service. An example of this problem came to light during the latest financial crisis in the United States. Local governments, because of increasing deficits, were obliged to scale down transit services, including frequency, right at the moment when the high price of fuel and declining households' income were forcing some commuters to switch from car to transit commuting.

Transit-fare subsidies, when they exist, should be targeted to low-income households or to the unemployed. Transit-fare subsidies directed to the affluent are in fact a transfer payment made by government to commuters for not polluting instead of charging car commuters for the externalities they cause.

Pricing instruments reflecting real economic costs have a value in themselves because they contribute to better allocation of resources. However, they do not necessarily change consumer behavior. For instance, a toll charge on a highway may not reduce congestion if it is set too low. Congestion pricing, as practiced in Singapore, involves increasing tolls until the desired decrease in congestion is achieved. Congestion pricing consists of increasing or decreasing prices until equilibrium between supply and demand is reached. Congestion pricing does not aim at recovering the cost of a highway, but at limiting traffic volume to obtain a desired speed.

Pricing parking at the market price is equivalent to congestion pricing: The operator will increase the price of parking until all the parking spaces are filled. In New York City, the municipality taxes a private parking space at 18 percent of the daily rate paid (in addition to the property tax and business tax). In this way, the municipality recovers a share of the private market rate without having to set a municipal parking rate. The transaction cost of recovering the rate from consumers and adjusting it to the market price is paid by the private operator. Taxing privately operated parking garages might be a more effective way of recovering an area-wide congestion fee than the way it is currently recovered in London.

Congestion pricing is not always possible. It requires technology investment that may be expensive to install and operate, and the high transaction cost may greatly reduce the income of the operator. In some cases, congestion pricing is not politically acceptable. For instance, it would be difficult to increase or decrease the transit fare every hour depending on the number of commuters boarding at any given time.

In the case in which congestion pricing is not feasible, the effectiveness of increasing or decreasing prices (that is, changing prices to increase or decrease demand) depends on the price elasticity of demand. The price elasticity of demand depends on numerous factors and can be measured from empirical experience, but it cannot be calculated in advance without empirical data. Various factors affect how much a change in prices impacts travel demand for a given travel mode: type of price change, type of trip, type of traveler, quantity
and price of alternative options, and time period (short term [one year] and long term [5–10 years]).

Nearly all studies assume that the effects of a reduction are equal and opposite to the effects of an increase or, in other words, that elasticity is “symmetrical” (Goodwin, Dargay, and Hanly 2004). Empirical evidence suggests that this assumption might not be true. However, because of the number of factors affecting elasticity, it is often difficult to extrapolate with certainty results from one city to another in the absence of an empirical local database. With this caveat, available data from the literature on the price elasticity of demand in urban transport are reviewed. The current literature on price elasticity in transports could be summarized as follows:

- Long-run elasticities are greater than short run ones, mostly by factors of 2 to 3 (Goodwin, Dargay, and Hanly 2004).
- Fuel consumption elasticities to fuel price are greater than traffic elasticities, mostly by factors of 1.5 to 2.0 (Goodwin, Dargay, and Hanly 2004).
- Motorists appear to be particularly sensitive to parking prices. Compared with other out-of-pocket expenses, parking fees are found to have a greater effect on vehicle trips, typically by a factor of 1.5 to 2.0 (Gordon, Lee, and Richardson 2004): A $1 per trip parking charge is likely to cause the same reduction in vehicle travel as a fuel price increase that averages $1.50 to $2.00 per trip.
- Shopping and leisure trips elasticities are greater than commuting trip elasticities. Although we can reduce or avoid travel or the need to travel for shopping, we are more likely to continue traveling to commute.
- Road pricing and tolls effects depend on the pricing mechanism design. Luk (1999) estimates that toll elasticities in Singapore are −0.19 to −0.58, with an average of −0.34. Singapore may be unique; the high cost of car ownership constitutes a very high sunk cost, which may tend to make travel less sensitive to price.
- Transit price effects are significant: Balcombe and others (2004) calculate that bus fare elasticities average around −0.4 in the short run, −0.56 in the medium run, and 1.0 over the long run, whereas metro rail fare elasticities are −0.3 in the short run and −0.6 in the long run. Bus fare elasticities are lower during peak (−0.24) than off-peak (−0.51).

**Carbon-Based Investment in Transport Infrastructure**

Carbon-based investments in transport infrastructure face three main barriers: financial, institutional, and political. Carbon markets have been positioned as an economically efficient market-based incentive for answering these three barriers.
Today, however, their usage for cities, and even more for urban transportation, is limited for several reasons:

- Cities’ participation in carbon markets is limited to flexibility mechanisms such as offset, voluntary, or Clean Development Mechanism (CDM)/Joint Implementation projects.
- These markets have been rarely used for promoting a more energy- and carbon-efficient urban transportation pattern: To date, 1,224 CDM projects have been registered by the UN Framework Convention on Climate Change Executive Board, and only two have been transportation projects, representing less than 0.13 percent of total CDM projects (the Bogota BRT TransMilenio and the Delhi subway regenerative breaking system).
- Carbon markets favor low-hanging fruit projects, which do not have the greatest potential to reduce GHG emissions: The majority of the CDM transportation projects accepted or proposed claim their emission reductions through switching fuels used. Some entail improvements of vehicle efficiency through a different kind of motor or better vehicle utilization. Few projects deal with modal shift, and none involves a reduction of the total transportation activities.

Given these barriers, two questions must be addressed. The first is, How and why are carbon markets biased against projects targeting urban transportation? Several explanations can be explored:

1. CDM and transport projects differ widely in terms of challenges and opportunities. There is a scale gap between the two realities in which the main leaders of each project evolve:
   a. (Local) transport projects aim to change the city and make it economically attractive. Challenges include involving all stakeholders in the decision-making process.
   b. (International) challenges for CDM projects are technical (convincing CDM executive boards and international experts) and financial.

2. Diffuse emissions, such as in the transportation sector, are costly to aggregate, thus the CDM “act and gain money” incentive has rather limited effects.

3. Classic CDM challenges are particularly vexing for the transport sector:
   a. Defining project boundaries, because of complex up- and downstream leakages.
   b. Establishing a reliable baseline, when behavioral parameters are key.
   c. Implementing a reliable monitoring methodology, because data generation is costly.
The consequences of this bias are that transport and CDM projects are conducted in parallel; without interaction, cities outsource CDM projects to international experts and organizations without much involvement; and CDM project-based design is missing the main GHG reduction opportunities. Thus, within their existing framework, carbon markets can be used as a source of funding significant only at the local level to do the following:

- Subsidize (and reduce) transit fares.
- Finance intermodality infrastructures and thus facilitate modal shift.
- Finance well-bounded technology-oriented CDM projects, such as changes in fuels and technology, optimization of the balance between bus supply and demand, traffic-light systems, and more generally, new information technologies for vehicle or system operations. These well-bounded, technology-oriented CDM projects could be levered by bundling them through the newly existing programmatic CDM.

The second question asks: How could the design of carbon markets evolve to be more “urban transportation friendly”? In the perspective of the post-2012 transportation sector, a unanimous call is heard for changes in the carbon markets’ design. Many important opportunities for transportation emission reductions would not easily fit into an individual CDM project. Various propositions are under discussion:

1. A sectoral policy-based approach crediting new green policy or enforcement of standards. A sectoral approach would not reduce methodological difficulties. Its advantages would rather be to scale activities up to a level that is equal to the scale of the challenges faced in redirecting transport into a more sustainable direction.

2. Cities’ commitment to reduce GHG emissions and a “No Loose Target” approach.

3. Registries including National Appropriate Mitigation Actions for cities and the urban transportation sector.

4. Integrate Global Environment Fund and Official Development Assistance in CDM funding, notably to finance transaction costs, to fund capacity-building activities, and to generate data.

In brief, a broader and flexible approach, based on a bottom-up mechanism, would do the following:

- Foster cities to take the lead on GHG emissions reduction strategies (financial and electoral motivations)
- Give cities incentives to act for the short term (low-hanging fruits) as well as for the long term and, thus, change the urban development trajectory
• Leave intact their ability to create and implement solutions that are relevant and palatable with local specificities—for example, to implement land-use policies that increase the floor area ratio (FAR) in CBDs or transport policies that modify the relative prices of different transport modes

**Urban Spatial Structures and Transport Mode**

Price and speed are not the only determinant of consumers’ choice for transport mode; urban spatial structures play a major role in determining the type of transport that is likely to be the most convenient. Urban structures are defined by the spatial distribution of population densities within a metropolitan area and by the pattern of daily trips. Depending on a city’s spatial structure, commuters may be able to switch from car to transit, or their choices may be limited between individual cars, minibuses, and collective taxis. In high-density cities, sidewalks and cycle lanes could be designed in such a way as not to discourage walking and cycling. Although urban structures do evolve with time, their evolution is slow and can seldom be shaped by design. The larger the city, the less it is amenable to change its structure. However, it is important for urban managers to identify the opportunities present in their city and to take full advantage of them to reduce GHG emissions with transport strategies consistent with their spatial structures. Identified next are the most common types of spatial structures and the transport strategies that would have the most chances of success for each type of spatial structure.

**Type of Urban Spatial Structures and Choice of Transport Modes**

Urban economists have studied the spatial distribution of population densities intensively since the pioneering work of Alonso (1964), Mills (1970), and Muth (1969, 1985), which developed the classical monocentric urban density model. Empirical evidence shows that in most cities, whether they are polycentric or monocentric, the spatial distribution of densities follows the classical model predicted by Alonso, Muth, and Mills (Bertaud and Malpezzi 2003).

The density profile of most large cities shows that the traditional monocentric city model is still a good predictor of density patterns. It also demonstrates that markets remain the most important force in allocating land, in spite of many distortions to prices due to direct and indirect subsidies and ill-conceived land-use regulations. The profile of the population densities of 12 cities on four continents (figure 4.4) shows that in spite of their economic and cultural differences, markets play an important role in shaping the distribution of population around their centers. All the cities shown in figure 4.4 follow closely the
Figure 4.4 Distribution of Population Densities in 12 Cities

Source: Bertaud 2006.
negative sloped gradient predicted by the classical monocentric urban model, although several cities in the samples are definitely polycentric (Atlanta, Mexico City, Portland, and Rio de Janeiro). The density profile indicates that some parts of metropolitan areas are incompatible with transit. In areas where residential densities fall below 50 people per hectare, the operation of transit is ineffective.

Land use and the transport network determine the pattern of daily trips taken by workers to commute to work. As income increases, noncommuting trips—trips to shopping centers, to take children to school, to visit relatives, or to take leisure trips—become more important. The proportion of commuting trips in relation to other types of trips is constantly decreasing.

Figure 4.5 illustrates in a schematic manner the most usual trip patterns in metropolitan areas. In monocentric cities (figure 4.5A) where most jobs and amenities are concentrated in the CBD, transit is the most convenient transport mode because most commuters travel from the suburbs to the CBD. The origin of trips might be dispersed, but the CBD is the most common trip destination. Small collector buses can bring commuters to the radials, where BRT or an underground metro can bring them at high speed to the CBD. Monocentric cities are usually dense (density more than 100 people per hectare).

In polycentric cities (figure 4.5B), few jobs and amenities are located in the center, and most trips are from suburbs to suburbs. Although a very large
number of travel routes are possible, most will have few passengers per route. The trips have dispersed origins and dispersed destinations. In this type of city structure, individual means of transportation or collective taxis are more convenient for users. Mass transit is difficult and expensive to operate because of the multiplicity of destinations and the few passengers per route. Polycentric cities usually have low densities because the use of individual cars does not allow or require much concentration in any specific location.

Figure 4.5C shows the so-called urban village model that is often shown in urban master plans but does not exist in the real world. In this model, there are many centers, but commuters travel only to the center that is the closest to their residence. This is a very attractive model for urban planners because it does not require much transportation or roads and it dramatically reduces VKmT and PKmT and, as a consequence, GHG emissions. According to this model, everybody could walk or bicycle to work even in a very large metropolis. The hypothesis behind this model is that urban planners are able to perfectly match work places and residences! This model does not exist in reality because it contradicts the economic justification of large cities. Employers do not select their employees on the basis of their place of residence, and specialized workers in large cities do not select jobs on the basis of their proximity from their residence (with the exception of the very poor who walk to work and are limited to work within a radius of about 5 kilometers from their home). The “urban village model” implies a systematic fragmentation of labor markets, which would be economically unsustainable in the real world.

The five satellite towns built around Seoul are an example of the urban village conceit. When the towns were built, the number of jobs in each town was carefully balanced with the number of inhabitants, with the assumptions that these satellite towns would be self-contained in terms of housing and employment. Subsequent surveys are showing that most people living in the new satellite towns commute to work to the main city, and most jobs in the satellite towns are taken by people living in the main city.

The “composite model” shown in figure 4.5D is the most common type of urban spatial structure. It contains a dominant center, but a large number of jobs are also located in the suburbs. In this type of city most trips from the suburbs to the CBD will be made by mass transit, whereas trips from suburb to suburb will use individual cars, motorcycles, collective taxis, or minibuses. The composite model is, in fact, an intermediary stage in the progressive transformation of a monocentric city into a polycentric one. As the city population grows and the built-up area expands, the city center becomes more congested and progressively loses its main attraction. The original raison d’être of the CBD was its easy accessibility by all the workers and easy communication within the center itself because of spatial concentration.
As a city grows, the progressive decay of the center because of congestion is not unavoidable. Good traffic management, timely transit investment, strict parking regulations and market price of off-street parking, investments in urban environment (pedestrian streets), and changes in land-use regulations allowing vertical expansion would contribute to reinforce the center, to make it attractive to new business, and to keep it as a major trip destination. These measures have been taken with success in New York City, Shanghai, and Singapore, for instance. However, the policy coordination between investments and regulations is often difficult to implement. This coordination has to be carried out consistently for a long period to have an impact on the viability of urban centers. Failure to expand the role of traditional city centers through infrastructure and amenities investments weakens transit systems in the long run because the number of jobs in the center becomes stagnant or even decreases while all additional jobs are created in suburban areas.

The comparison between the distributions of population in Jakarta (Jabotabek) and Gauteng (figure 4.6) explains why Jakarta is able to successfully

Figure 4.6 Spatial Distribution of Population in Jakarta and Gauteng Represented at the Same Scale

Source: 2001 census.
implement a BRT network in addition to the existing suburban rail network, whereas in Gauteng suburban rail is carrying barely 8 percent of commuters, and the great majority of low-income commuters rely on microbuses. The dispersion of population in Gauteng is due in part to its history of apartheid. In the past 10 years, a very successful subsidized housing program has contributed to further disperse low-income people in distant suburbs while significantly attenuating the extreme poverty created by apartheid. The comparison as seen on the three-dimensional representation of population densities between the resulting city structure of Gauteng and that of Jakarta is striking. A BRT is being planned for the municipality of Johannesburg (one of the municipalities in the Gauteng metropolitan region), but the current urban structure will make it difficult to operate for a long time. In addition, the violent opposition of microbus operators is making the project politically difficult. A change in transit mode involves a new equilibrium of transit types, which creates losers as well as winners. This is not an easy process, even when the final long-range outcome seems desirable for all.

The structure of cities is path dependent. Once a city is dominantly polycentric, it is nearly impossible to return to a monocentric structure. Monocentric cities, by contrast, can become polycentric through the decay of their traditional center. The inability to adapt land-use regulations, to manage traffic, and to operate an efficient transit system are the three main factors that explain the decay of traditional CBDs.

**Transport Strategies Need to Be Consistent with Cities’ Spatial Structures**

Findings concerning the relationship between urban spatial structures and transit can be summarized as follows:

- Transit is efficient when trips’ origins are dispersed but destinations are concentrated.
- Individual transport and microbuses are more efficient when origin and destinations of trips are both dispersed and for linked trips if amenities are dispersed.
- Mode shift toward transit will happen only if price and speed are competitive with other modes.
- Trips toward dense downtown areas (more than 150 people/ha) should be prevalently made by transit. Failure to provide efficient transit service to the CBD and to regulate traffic and parking would result in a dispersion of jobs in suburban areas, making transit inefficient as a primary means of transport in the long term.
The question to be answered is then: Is it possible to have a land-use and traffic policy to reinforce commuting destination concentration and enabling transit to be competitive with car trips?

Two cities are maintaining a high ratio of transit trips: Singapore with 52.4 percent of total commuting trips (Singapore Department of Statistics 2000) and New York City with 36 percent. Their performance is particularly intriguing because these two cities have a high-income population, and higher-income households are less likely to use transit than lower-income ones. By contrast, Mexico City, with a density more than twice that of New York City, has only 24 percent of commuters using transit. It implies that both New York City and Singapore have long had successful policies to keep such a large number of commuters using transit. Are these examples replicable in lower-income cities with less performing governance?

**New York City, Singapore, and the Counterexample of Mumbai**

This section reviews the policies of New York City and Singapore, comparing these with the counterexample of Mumbai, where transit is the dominant commuting mode but where city managers try to disperse jobs and housing.

**New York City**

The high ratio of transit trips in New York City is the result of a deliberate policy of spatial concentration and diversification of land use. The extremely high concentration of jobs is the most striking feature of the spatial structure of the New York City metropolitan area: 35 percent of the total number of jobs are concentrated in Manhattan, which represents only 0.9 percent of the total metropolitan area (53 square kilometers). Within Manhattan, four districts (19 square kilometers) have 27 percent of the jobs in the entire metropolitan area (population 15 million). This concentration did not happen by chance; it was the result of a deliberate regulatory policy, which was responding to the high market demand for floor space in Manhattan. The Midtown district reaches the astonishing density of 2,160 jobs per hectare! This extreme spatial concentration of people and jobs is extremely intellectually fertile, innovative, and productive, in spite of the management problems it poses for providing services in such a dense area.

The zoning regulations controlling FARs is one of the main factors contributing to this concentration. The map of Manhattan regulatory FARs shows high FARs in the Midtown and Wall Street areas (FAR values ranging from 11 to...
15). The pattern of high FARs shows that the regulations have been adjusted to demand as the two main business centers in Manhattan expanded over time. The zoning of Manhattan also allows a mix of zoning for office space, commerce, theaters, and housing. The mixed land use favors transit because it generates trips outside the traditional rush hours. Because of the theater districts, the subway and buses run late at night, making transit more convenient for workers who work different shifts. In a different setting of homogenous land use, those workers with schedules outside normal hours would have to commute with individual cars. The land use in Manhattan makes it possible for New York City transit to have a high passenger load, significantly reducing GHG emissions, as discussed earlier. The urban management initiatives taken in New York City that contribute to a high share of transit use and, as a consequence, to a lower GHG emission per capita include the following:

- High FAR responding to market demand
- Mixed land use in the CBD
- Encouraging amenities in or close to the CBD (museums, theaters, and universities)
- Providing the majority of parking off the street in privately operated parking areas charging market price, but also specially taxed by the municipality; a complementary strategy is progressive removal of most on-street parking except for loading and unloading
- Improving the transit system continually with a radial-concentric pattern of routes

**Singapore**

In Singapore, the transport sector was the second-largest contributor to CO\textsubscript{2} emissions in 2005. Efforts to mitigate GHG emissions have mainly concentrated on buildings, and the transport sector has received less attention. Unlike the United States and other OECD countries, where transport data are readily available, statistics on Singapore’s transport sector and CO\textsubscript{2} emissions by mode are extremely difficult to locate.

Like New York City, Singapore is a highly dense, compact city. It has a land area of 700 square kilometers, accommodating a population of 5 million. The average density in the built-up area was about 110 people per hectare in 2000. Through comprehensive planning, Singapore has expanded its downtown and redistributed population throughout the city-state. Transport infrastructure is closely integrated with land use. Key infrastructure such as the airport, port, and network of expressways and mass rapid transit is planned and safeguarded in the city’s long-term development plan to support a good living environment. The long-term planning frame gives the assurance that projected needs
can be met within the city’s limited land area. To keep Singapore economically vibrant, its transport planning is focused on access and mobility with emphasis on a transit-oriented and compact urban structure, vigorous restraint of private car ownership and usage, and strong commitment to public transport. Urban development has been increasingly planned in such a way as to reduce the need to travel and dependence on motorized vehicles.

At the neighborhood level, neighborhoods and their new towns are structured with a host of amenities and services that could be readily reached within a five-minute walk. Smart infrastructure design reduces the need for transportation. Public housing towns where 80 percent of the population lives are connected to one another and to the city by public transport, principally the mass rapid transit. At the city level, with the redistribution and growth of population in new towns in the suburbs, new growth centers have been planned in these regions in immediate proximity of the transit network to provide employment to the local population in concentrated areas, which are easily accessible by transit.

Decentralizing some economic activities to the dense regional centers helps bring numerous jobs closer to homes and facilitates linked trips using public transport. It also reduces the usual peak hour traffic congestion to and from the CBD. At the same time, these centers provide lower costs for businesses that do not require a central area address, supporting a competitive economy. Over the next 10 to 15 years, more regional centers will be developed.

To manage the usage of private cars, much focus is given to travel demand management, including a choice of transport mode and making public motorized transport more efficient. Singapore is one city that has actively promoted the use of public transport as a more sustainable way to travel. Strong policy measures have been implemented to discourage private car usage, including high vehicle and fuel taxation measures and parking management, vehicle quota systems, and congestion pricing. These deterrents are complemented by mode-shift strategies aimed at improving the public transport system and new solutions such as car sharing. Improvements to public transport involve the following:

- Expanding the system or service, such as extending the geographical coverage of the bus and rail networks, including an extensive rail network that has been planned to serve high-population areas
- Improving the operation of the system, such as mode transfer improvements, better coordination of schedules, through ticketing, and increased frequency
- Improving the service with increased vehicle comfort and bus shelter/rail station enhancements
The government continues to invest in the mass rapid transit network to improve its accessibility to the population as the city grows. It has announced an additional $14 billion investment to double the rail network from the present 138 to 278 kilometers by 2020, thus achieving a transit density of 51 kilometers per million people, comparable to that of New York City. To allow more rail usage, land use is intensified around the mass rapid transit stations, and mixed-use developments are encouraged.

One of the most crucial land-use decisions has been to develop a new downtown area adjacent to the existing CBD. To increase the accessibility of the new and current downtown, floor area ratios have been kept high (some lots have a FAR of 25, but the majority of FAR values are about 12). Once completed, this new downtown will reinforce the effectiveness of the radial-concentric metro system.

**Mumbai**

Mumbai, with a metropolitan population of 18 million people in 2001 and a density of about 390 people per hectare in the municipal built-up area, is both much denser and larger than Singapore or New York City. The transit mode share is evaluated at 71 percent of commuters using motorized travel (the number of people walking to work is estimated to be around 4 million). The main modes of transit are buses and two main lines of suburban train. Private cars, taxis, and rickshaws account for about 12 percent of commuting trips, and motorcycles 17 percent (Baker and others 2004).

Since 1964, Mumbai urban managers have tried to reduce congestion by reducing the number of people living in the city and by trying to disperse jobs and people in far-away suburbs or satellite towns such as Navi Mumbai. Strict control of the FAR, which was progressively reduced from an initial 4.5 in the CBD (Nariman Point) to the current 1.33, has been the main tool used to reach their dispersion objective. The objective was to promote a density reduction in the central areas of the city and a dispersion of jobs. In a certain way, Mumbai urban managers were trying to transform a dense monocentric Asian city into a “Los Angeles” model where jobs and population are dispersed randomly within the metropolitan area.

However, the suburban railway lines carrying 6.4 million commuters a day converge on the traditional CBD. The policy of reducing the FAR to promote dispersion did not succeed because it contradicted the pattern of accessibility established by the transit network. The highest demand for office space is still in Nariman Point, the traditional CBD. The price of office space in Nariman Point is about the same as the average in Manhattan. The number of passengers boarding and exiting at various suburban train stations shows that the two
stations closest to Nariman Point handle most commuters. The map of maximum regulatory FARs completely contradicts demand as expressed by floor space price and the pattern of boarding and exiting railway stations. A FAR value of 1.33 imposed on the CBD of a dense city of 18 million people is completely unrealistic (as compared with 15, the value in New York City, and 25, the highest value in Singapore). The highest FAR values are 4 in the slum of Dharavi and in the new business center of Bandra-Kurla, which is not currently connected to the railway network, thus requiring a bus transfer to access it from the railway network. The railways are operating at full capacity with the existing tracks, and although new metro lines are being planned, it is without a clear spatial strategy for changing the current land-use regulations to adapt them to the new transport system and consumers’ demand.

The very low FAR values in Mumbai have succeeded only in making land and floor space more expensive. Density has increased because location is everything in a large metropolis, but floor space consumption has decreased to one of the lowest in India (and probably in Asia).

The absence of a clear spatial strategy linking land use regulations, consumer demand, and the transport network has been the major failure of the urban management of Mumbai. The major lesson to be drawn from the Mumbai example is that designing cities through regulations without taking into account consumer demand does not achieve the desired results. If the strict low limit put on the FAR regulations had succeeded and jobs and population had dispersed, the impact on GHG emissions would have been disastrous. The current transit system, for all its flaws, would have been made less efficient because it would have not have been able to connect commuters to dispersed businesses. Motorcycles and minibuses would have become the most practical and efficient modes of transportation.

**Summary of Measures in New York City and Singapore That Maintain a High Level of Transit Share**

Singapore and New York City are succeeding in maintaining a high rate of transit use even among high-income populations. This strategy will contribute in the future in significantly lowering GHG emissions due to transport. It is useful to summarize the measures that have been taken by New York City and Singapore to maintain a high density of jobs and activities in their downtown areas:

- High FARs in the CBD (up to 15 in midtown Manhattan, up to 25 in Singapore)
- Physical expansion of the downtown area through land reclamation in both Singapore and New York City
- Prioritizing and improving connections to public transport, including a high level of transit services by buses and metro (in other cities, BRT might
prove more cost effective than underground metro for conveying commuters toward areas with high job concentrations)

- Charging relatively high prices for the use of cars in downtown areas, implemented through congestion pricing in Singapore, tolls to enter Manhattan from bridges and tunnels, and allowing parking prices to be set by the market in New York City and Singapore

- Ensuring a high level of amenities that make the downtown area attractive outside office hours, such as theater districts, museums, and the new Chelsea art gallery district in New York City, and cultural centers, auditoriums, rehabilitation of ethnic districts and waterfront with restaurants, leisure and entertainment, commerce, seaside promenade, pedestrian streets, and so on in Singapore

- As in Singapore, promoting large-scale but compact mixed-use development located at integrated bus-transit transport hubs such as Ang Mo Kio and Woodlands, new towns where shopping centers, amenities, offices, and civic functions in the bus/metro hub allow linked trips while using transit

**Conclusions**

Differential pricing of energy sources based on carbon content is often posited as the only way to promote better urban transport efficiency and to reduce GHG emissions due to urban transport in the long run for most cities. As demonstrated in this chapter, integrating transport and land-use planning, investing in public transport, improving pedestrian environment and links, and dynamically managing parking provision and traffic management are equally important for improving the effectiveness of the transport network serving the city. GHG emissions arising from suburb-to-suburb trips will be reduced not only through energy carbon pricing but also from better traffic management to reduce congestion and improvements in car technology.

GHG emissions in many dense and still monocentric cities could be reduced if the demand for suburbs to CBD trips increased. This would require coordinating carefully land use and transit networks. Large increases in the FAR in CBDs could trigger a transport mode shift toward transit if coordinated with new BRT networks and parking pricing policy.

An increase in the job concentration in CBDs could also increase urban productivity by increasing mobility without increasing VKmT or trip time. However, this does not mean that all economic activities should be concentrated in the CBD. To the contrary, flexibility in zoning should allow commerce and small enterprise to grow in the best location to operate their business, as has been the case in Singapore. Too often, zoning laws overestimate the negative
externalities created by mixed use—preventing, for instance, small retail shops from locating in residential areas—while underestimating the positive externality of reducing trip length for shopping or even entertainment. Most current zoning laws should be carefully audited to remove the bias against mixed land use and against large concentrations of businesses in a few areas.

The coordination needed between transport investment and management, pricing of roads and parking, and land use to manage existing and future transport infrastructure and capacity is difficult to achieve in the real world. Urban problems cannot be solved sector by sector but spatially. This is why the autonomy of municipal authorities is so important. In some cities, urban transport is managed by national line agencies (this is the case in Mumbai). However, in very large cities the urban area covers several autonomous local governments, making it difficult to coordinate land use, transport networks, and pricing across the many boundaries of a typical metropolitan area.

The population of New York City includes less than half of the metropolitan area population, making coordination and policy consistency difficult. Most of Mumbai’s regulatory decisions and infrastructure investment budget are decided by the legislature of the state of Maharashtra, not by the municipal corporation, which may explain the lack of spatial development concepts being applied to zoning regulations. Singapore, being a city-state, has the advantage of avoiding the contradictions and cross-purpose policies of a metropolitan area divided into many local authorities with diverging interests. This may explain in part the extraordinary consistency and continuity in urban development policies over a long period that has contributed to create such a successful city. The same could be said of Hong Kong, continuing the tradition of Italian renaissance city-states such as Venice and Florence.

Although good governance and policy consistency are important in reducing GHG emissions, in the long run only the pricing of energy based on carbon content will be able to make a difference in urban transport GHG emissions. Pricing transport as close as possible to the real economic cost of operation and maintenance is the only way to obtain a balance between transport modes that reflects consumer convenience and maintains mobility.

Annex

For each motorized transport mode:

\[ Q = VKmT \times E, \]
\[ VKmT = PKmT/L, \]
\[ PKmT = 2D \times P. \]
where

\[ Q = T \times \sum_{i=1}^{N} \frac{2 \times D_i \times P_i \times P_i}{L_i \times 10^6} \]

where

- \( Q \) is the total carbon equivalent emitted per day by passengers while commuting to work (does not include noncommuting trips) in metric tons per day
- \( T \) is the total number of commuters per day
- \( N \) is the number of commuting transport modes types numbered from 1 to \( N \)
- \( D_i \) is the average commuting distance one way per passenger in kilometers per type \( i \) of commuting mode
- \( P_i \) is the percentage of commuters using transport mode type \( i \)
- \( E_i \) is the carbon emissions of vehicle used for mode \( i \) in grams of carbon equivalent (full life cycle) per VKmT
- \( L_i \) is the load factor expressed in average number of passengers per vehicle of type \( i \).

**Notes**

2. We define urban transport network as including all public or private spaces and systems devoted to circulation of good and people, from sidewalks, elevators, and cycle tracks to bus rapid transit networks and underground rail.
3. This figure from the 2000 census reflects resident working persons aged 15 years and above by mode of transport to work, which includes public bus, mass rapid transit, or taxi.
4. *Pico y placa* consists of limiting the number of vehicles on the road on a given day by allowing on alternative days only vehicles with a license plate ending with an odd or even number.
5. The Hong Kong metro is an exception: Neither capital cost nor operation and maintenance are subsidized.
6. The limits imposed on FAR is a common regulation linked with zoning. A FAR of 2, for instance, allows building an area of floor space equal to twice the area of the plot on which it is built. A FAR of 2, therefore, would allow 2,000 square meters of floor space to be built on a 1,000 square meters plot. If half of the land is built on, the building would have four floors to fully use the allowed FAR. A regulatory limit put on FAR is therefore not the equivalent of a limit on height or number of floors because most buildings have to leave some of their lot open for light ventilation or circulation or often to follow regulations on setbacks.

References