UMTRI-2010-2 FEBRUARY 2010

THE FUTURE OF PERSONAL TRANSPORTATION IN MEGACITIES OF THE WORLD

JUHA LUOMA
MICHAEL SIVAK
SUSAN ZIELINSKI

UMTRI
UNIVERSITY OF MICHIGAN
TRANSPORTATION RESEARCH INSTITUTE

THE FUTURE OF PERSONAL TRANSPORTATION IN MEGACITIES OF THE WORLD

Juha Luoma
Michael Sivak
Susan Zielinski

The University of Michigan
Transportation Research Institute
Ann Arbor, Michigan 48109-2150
U.S.A.

Report No. UMTRI-2010-2
February 2010

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
UMTRI-2010-2		

4. Title and Subtitle The Future of Personal Transportation in Megacities of the World	5. Report Date February 2010
	6. Performing Organization Code 383818
7. Author(s) Juha Luoma, Michael Sivak, and Susan Zielinski	8. Performing Organization Report No. UMTRI-2010-2
9. Performing Organization Name and Address The University of Michigan Transportation Research Institute 2901 Baxter Road Ann Arbor, Michigan 48109-2150 U.S.A.	10. Work Unit no. (TRAIS)
	11. Contract or Grant No.
12. Sponsoring Agency Name and Address The University of Michigan Sustainable Worldwide Transportation	13. Type of Report and Period Covered
	14. Sponsoring Agency Code

15. Supplementary Notes

The current members of Sustainable Worldwide Transportation include Bendix, Bosch, Continental Automotive Systems, FIA Foundation for the Automobile and Society, Ford Motor Company, General Motors, Nissan Technical Center North America, and Toyota Motor Engineering and Manufacturing North America. Information about Sustainable Worldwide Transportation is available at: http://www.umich.edu/~umtriswt

16. Abstract

This study examined the future of personal transportation in megacities of the world. Of particular interest was the future role of personal vehicles. To span ranges of geographical, political, and economic factors, the following 15 megacities were included in the analysis: Chicago, New York, London, Moscow, Paris, Buenos Aires, Mexico City, Rio de Janeiro, São Paulo, Bangalore, Calcutta, Delhi, Mumbai, Hong Kong, and Shanghai. The current and future values of the following factors were considered: population, wealth, level of motorization, public transportation, and modal split. Also discussed were selected urban transportation plans and strategies.

Based on the analysis, projections through 2025 were made for each megacity for changes in ownership of personal vehicles; distance traveled by personal vehicle within inner core, for commuting, and for leisure; and for number of road fatalities.

The projections were based on treating the different transportation modes as independent and exclusive options. However, there is growing implementation and use of new mobility networks—integrated networks that provide a variety of connected and IT-enhanced transportation options door-to-door. Although such networks are expected to reduce reliance on personal vehicles, the magnitude and nature of this effect remain to be ascertained.

17. Key Words	18. Distribution Statement
megacities, personal transportation, automobiles, projections, future	Unlimited

19. Security Classification (of this report)	20. Security Classification (of this page)	21. No. of Pages	22. Price
None	None	31	

Acknowledgments

This research was supported by Sustainable Worldwide Transportation (http://www.umich.edu/~umtriswt). The current members of this research consortium are Bendix, Bosch, Continental Automotive Systems, FIA Foundation for the Automobile and Society, Ford Motor Company, General Motors, Nissan Technical Center North America, and Toyota Motor Engineering and Manufacturing North America.

Juha Luoma's contribution was prepared while he was a visiting research scientist at UMTRI from the VTT Technical Research Centre of Finland (http://www.vtt.fi).

Contents

Introduction

On average, a person spends about 70 minutes per day traveling (Schäfer, Jacoby, Heywood, and Waitz, 2009). This time budget is relatively constant over time and across countries. Consequently, wealthy people tend to travel faster and over longer distances.

In the future there will be an overall increase in mobility throughout the world. For example, Schäfer and Victor (2000) projected that by 2050 the average citizen of the world will travel (by all modes) as much overall distance as the average Western European did in 1990. From 2000 to 2050, the mobility of the average American will increase by a factor of 2.6, to 58,000 km/year. Schäfer and Victor (2000) forecast that the average Indian will increase his/her travel to 6,000 km/year by 2050, comparable to the level of West Europeans in the early 1970s. In total, in 2000, people traveled 23 billion km, and by 2050 that figure is expected to grow to 105 billion km (Schäfer and Victor, 2000).

At the same time, urban population continues to expand, and the number of megacities—cities with over 10 million inhabitants—is expected to double within a generation (World Bank, 2002). As cities grow and become richer, vehicle ownership and use tend to increase rapidly. This, in turn, has an influence on travel speed, congestion, and air pollution.

The above trends have resulted in wide discussion about sustainable transportation in metropolitan areas. In broad terms, movement to sustainable urban transportation involves accessibility and the generation of wealth by cost-effective and equitable means, while safeguarding health and minimizing the consumption of natural resources and the emission of pollutants (Kennedy, Miller, Shalaby, Maclean, and Coleman, 2005). Frequently, this has been feasible with wide use of public transportation in general, and rapid rail transportation in particular. For example, there are cities such as Tokyo and Hong Kong that invested in public transport to provide extensive, high-quality, public transport systems before private vehicle ownership was high (Barter, Kenworthy, and Laube, 2003). In these cities, bus travel was at a high level until rapid mass transit was built and became affordable.

However, personal vehicles are an integral part of modern city life, providing a number of benefits to individuals and society no matter how they are used—as single occupancy vehicles or as shared or shuttle vehicles. Consequently, as pointed out by Kennedy et al. (2005), planning for a new generation of sustainable personal vehicles is critical for the sustainable development of cities. Through technical innovation and the application of concepts of industrial ecology, there are several possible candidates for the sustainable personal vehicles of the future (Kennedy et al., 2005).

In addition, it is likely that many applications of intelligent transportation systems will substantially affect future urban transportation. These applications include, for example, demand management (demand-responsive public transportation, car pooling and sharing, access control, road-use charging), trip planning systems/real-time traveler information, and signal priorities for public transport.

This study was designed to examine the future role of personal vehicles in megacities of the world. Of particular interest was whether there would likely be a change by 2025 from the current level of usage, and the variability of future usage across megacities and types of trips.

Approach

To study current and future personal transportation in megacities, 15 metropolitan areas worldwide were selected. The selected metropolitan areas were classified by region as follows:

North America:	Chicago, New York
Europe:	London, Moscow, Paris
Central and South America:	Buenos Aires, Mexico City, Rio de Janeiro, São Paulo
India:	Bangalore, Calcutta, Delhi, Mumbai
China:	Hong Kong, Shanghai

For each metropolitan area, a set of key indicators affecting future transportation was examined. Two databases were used as the main sources for worldwide transportation data: *Mobility in Cities Database* published by the International Association of Public Transport (UITP, 2006), and *City Profiles* published by the Urban Age Project (Urban Age, 2009). The information for Chicago, Hong Kong, London, Moscow, Paris, and São Paolo was obtained from *Mobility in Cities Database*, while information for Bangalore, Buenos Aires, Calcutta, Delhi, Mexico City, Mumbai, New York, Rio de Janeiro, and Shanghai came from *City Profiles*. (Potential inconsistencies between the methodologies of these two studies were not ascertained.)

In addition, population information was retrieved from the database of the United Nations (Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, 2009), and income information from the database of International Monetary Fund (IMF, 2009).

Key indicators by metropolitan area

Population and wealth

Demand for personal transportation is influenced by a variety of factors. Size of the population (for absolute demand) and wealth of the population (for both absolute demand and per population demand) play vital roles (Sivak and Tsimhoni, 2008). Consequently, Figure 1 and Table 1 present the expected growth in population of the examined megacities, and Table 2 presents the expected growth in wealth per capita for the countries in which the megacities are located.

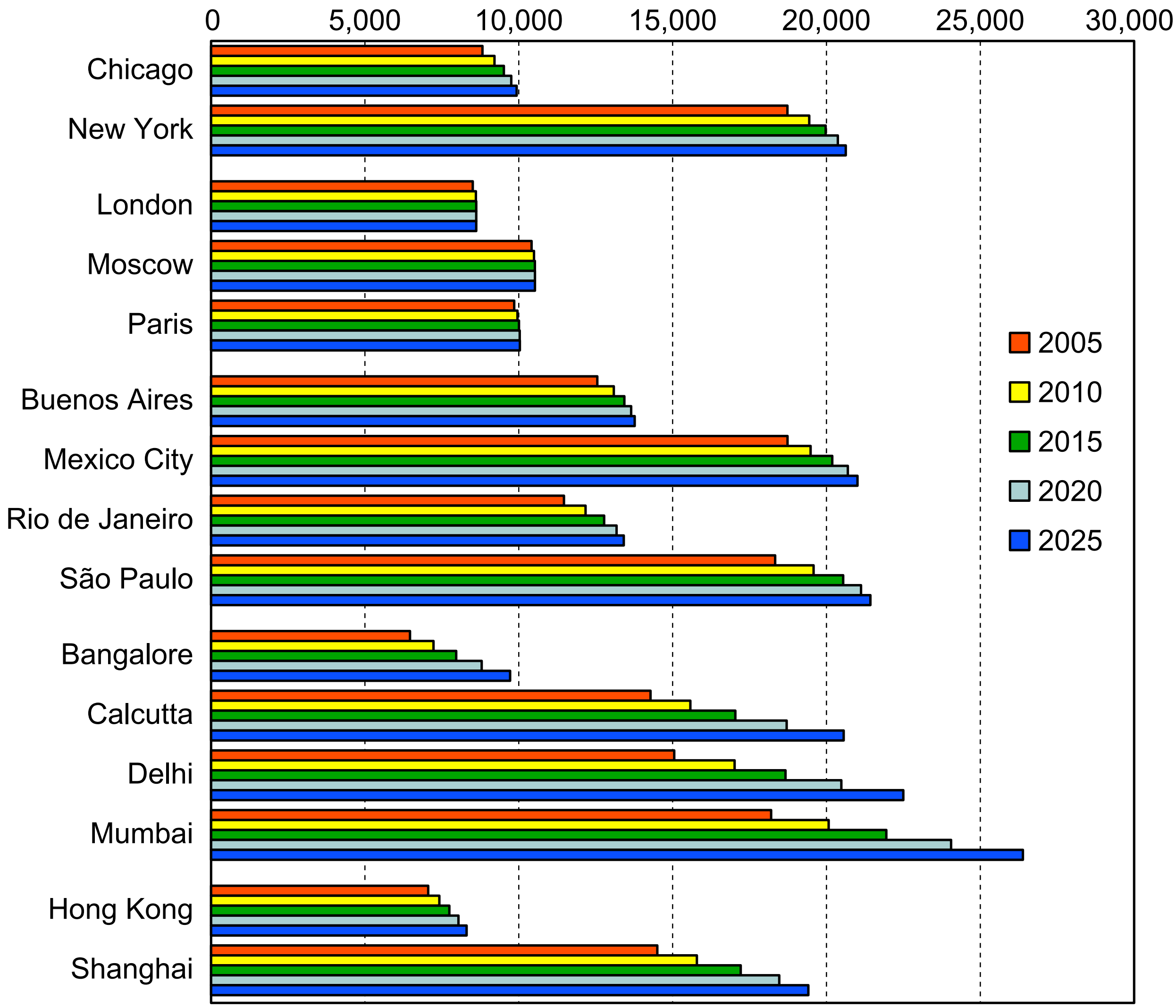


Figure 1. Population (in thousands) for examined metropolitan areas (Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, 2009).

Table 1
Expected growth in population of megacities in four, five-year periods (Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, 2009).

Metropolitan area	2005-2010 (%)	2010-2015 (%)	2015-2020 (%)	2020-2025 (%)
Chicago	4.4	3.3	2.5	1.8
New York	3.8	2.7	2.0	1.3
London	1.2	0.1	0.0	0.0
Moscow	0.8	0.3	0.0	0.0
Paris	1.1	0.5	0.2	0.0
Buenos Aires	4.3	2.6	1.6	0.8
Mexico City	4.0	3.6	2.5	1.5
Rio de Janeiro	6.1	5.0	3.2	1.8
São Paulo	6.8	4.9	2.8	1.4
Bangalore	11.8	10.2	10.4	10.5
Calcutta	9.1	9.4	9.8	9.9
Delhi	13.0	9.7	9.7	9.8
Mumbai	10.3	9.3	9.6	9.7
Hong Kong	5.1	4.4	3.8	3.3
Shanghai	8.9	9.0	7.3	5.1

The results indicate that the highest proportional increases from 2005 to 2025 (more than 30%) is predicted for Bangalore, Calcutta, Delhi, Mumbai, and Shanghai, followed by modest increases (12-18%) for Chicago, Hong Kong, Mexico City, Rio de Janeiro, and São Paulo. The lowest increases (less than 12%) are predicted for Buenos Aires, London, Moscow, New York, and Paris. Overall, the highest increase of population will take place in the examined Indian and Chinese metropolitan areas.

Table 2
Expected growth in gross domestic product per capita based on purchasing-power-parity from 2005 to 2010 and from 2010-2014 (IMF, 2009). (Hong Kong is presented separately from the rest of China because of the greatly different projected growth.)

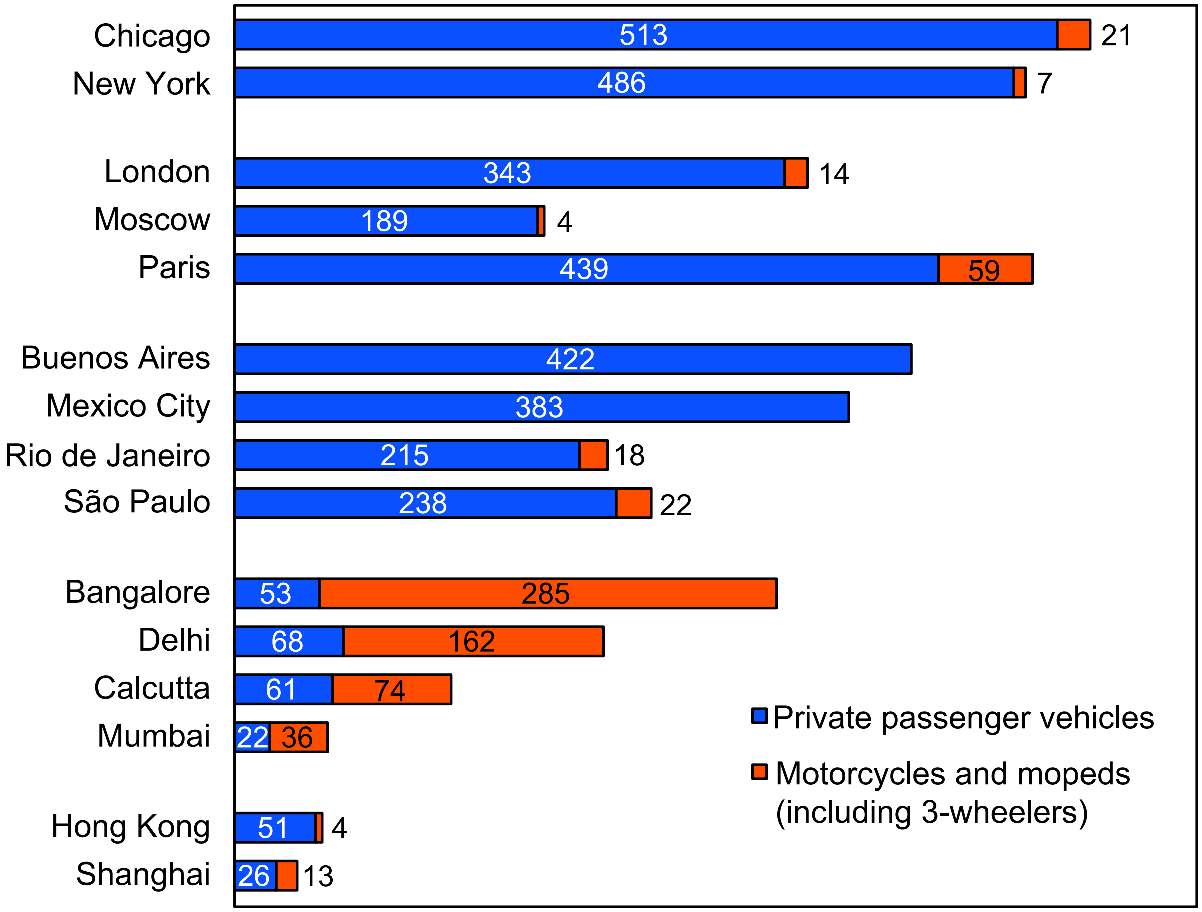
Country	2005-2010 (%)	2010-2014 (%)
United States	11.0	13.8
United Kingdom	11.9	18.1
Russia	32.0	27.1
France	12.6	14.3
Argentina	32.6	15.9
Mexico	12.5	26.1
Brazil	26.5	19.8
India	50.4	37.1
Hong Kong	24.8	22.6
China	77.4	52.4

Table 2 indicates that the highest increase of incomes from 2010 to 2014 is expected for China, followed by India, Russia, Mexico, Hong Kong, Brazil, United Kingdom, Argentina, France, and the United States.

Private motorized passenger vehicles

The number of private vehicles and motorcycles per thousand inhabitants by metropolitan area are shown in Figure 2.

The highest ownership of private vehicles is in the North American metropolitan areas, followed by the European and Central/South American metropolitan areas, while it is substantially lower in the Indian and Chinese metropolitan areas. However, motorcycle ownership in the Indian metropolitan areas is high.



New York: NYMTC (2003)
Buenos Aires: 2005; city of Buenos Aires only; no motorcycle data
Mexico City: city of Mexico City only; no motorcycle data
Rio de Janeiro: 2005; city of Rio de Janeiro only; motorcycles and mopeds from DENATRAN (2005)
Calcutta: 2005; city of Calcutta only
Mumbai: 2005
Shanghai: 2003

Figure 2. Private passenger vehicles (4-wheelers) and motorcycles (2- and 3-wheelers) per thousand inhabitants. The data are for 2001, except as noted.

Public transportation modes operated

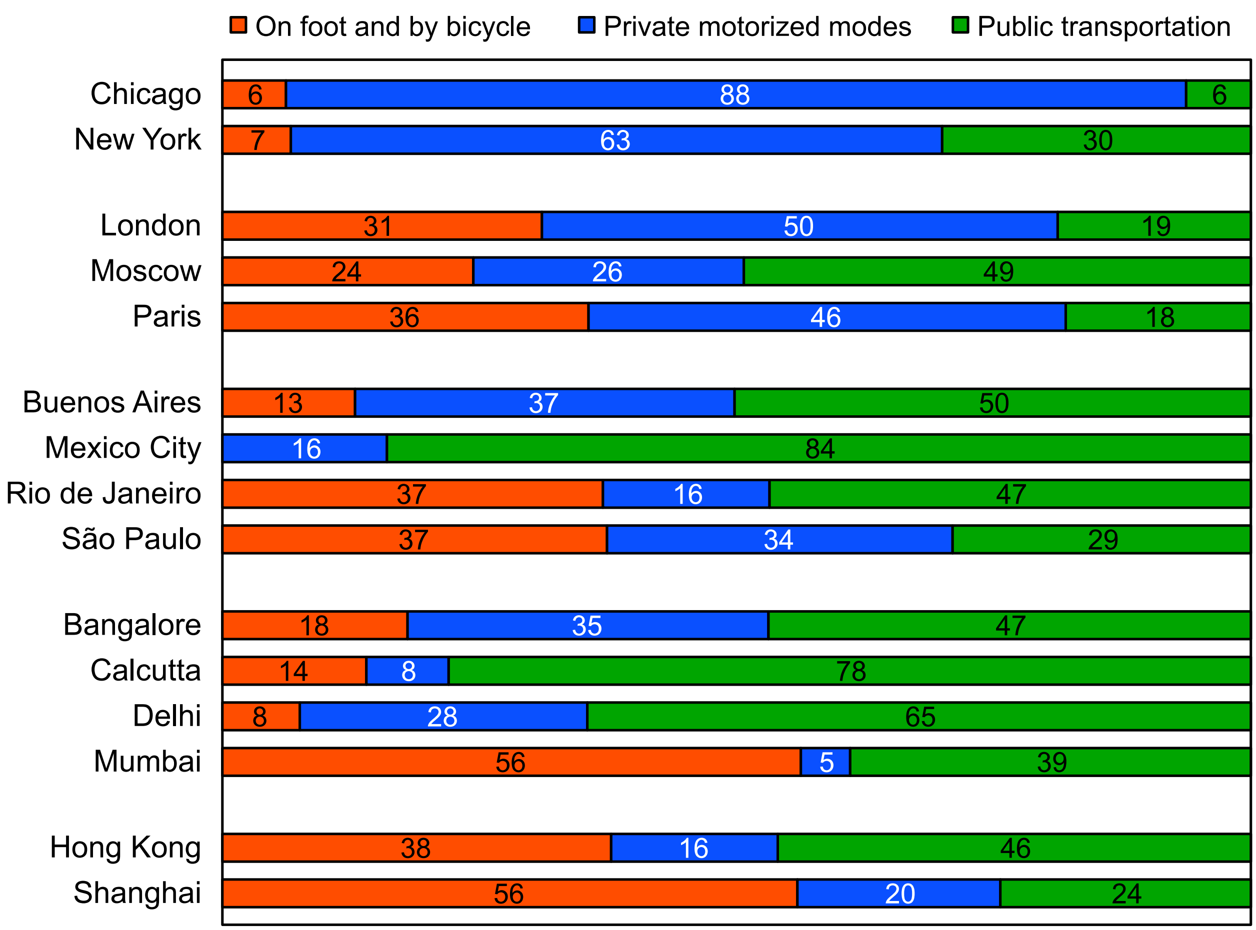
Table 3 presents public transportation modes operated by the examined metropolitan areas. The results indicate that buses are available in each metropolitan area, as is a version of a rail system. (Taxicabs are presumably available in each metropolitan area too.)

Table 3
Public transportation modes operated by metropolitan area.

Metropolitan area	Bus/ minibus/ trolley-bus	Tramway/ streetcar	Subway/ metro	Suburban/ regional/ light railway	Ferry/ boat	Rickshaw
Chicago	✓			✓		
New York	✓	✓	✓	✓	✓	
London	✓	✓	✓	✓		
Moscow	✓		✓	✓		
Paris	✓		✓	✓		
Buenos Aires	✓		✓	✓		
Mexico City	✓		✓			
Rio de Janeiro	✓	✓	✓	✓	✓	
São Paulo	✓		✓	✓		
Bangalore	✓					✓
Calcutta	✓	✓	✓	✓	✓	✓
Delhi	✓		✓	✓		✓
Mumbai	✓			✓	✓	✓
Hong Kong	✓	✓	✓	✓	✓	
Shanghai	✓		✓			

Modal split

Figure 3 shows the modal split for all trips by metropolitan area. However, for some of the metropolitan areas, the information was available only for work trips.



New York: 2000; work trips only
Buenos Aires: 2004; work trips only
Mexico City: 2000; "On foot and by bicycle" excluded. (However, the data for 1994 show only 1% for bicycle.)
Rio de Janeiro: 2003
Delhi: no year given
Mumbai: 2005
Shanghai: 2004; work trips only

Figure 3. Percentage of daily trips (a) on foot and by bicycle, (b) by private motorized modes, and (c) by public transportation. The data are for 2001, except as noted.

For work trips, the percentages for public transportation are likely to be higher than for all trips, and vice versa for other modes of transportation. This assumption is supported by the data for London that were available for all trips (UITP, 2006) and for work trips (Urban Age, 2009). The percentages for work trips (vs. all trips) were as follows: on foot and by bicycle 22% (vs. 31%), by private motorized modes 37% (vs. 50%), and by public transportation 41% (vs. 19%).

With the above proviso in mind, the results indicate that the role of private motorized modes is highest in North American metropolitan areas, followed by Western European metropolitan areas. Public transportation dominates in Mexico City, Calcutta, Delhi, Buenos Aires, Moscow, Rio de Janeiro, Bangalore, and Hong Kong. In São Paulo, Mumbai and Shanghai, most trips are currently made on foot or by bicycle.

In addition to the differences among metropolitan areas, the modal split tends to vary by city area. For example, the modal split in the city center is different from that in the overall metropolitan area. This is evidenced by comparing the data from the New York metropolitan area and New York City. Figure 3 shows that in the New York metropolitan area, 7% of all work trips were made on foot or by bicycle, 63% by private motorized modes, and 30% by public transportation. In comparison, the corresponding percentages in New York City were 10%, 38%, and 52%, respectively (Urban Age, 2009).

Furthermore, the detailed information on the number of trips and modal split between and within central, inner, and outer London provides a useful insight into the structure of transportation in a metropolitan area (Transport for London, 2009). (Inner London is the group of London boroughs that surround central London and form the interior part of greater London. In turn, inner London is surrounded by outer London.) First, walking and cycling dominate for the trips made within central London (approximately 75%) and for the trips made within inner London (approximately 50%), but not between these areas. Second, most trips between the central area and other areas of London are made by public transportation. Third, private motorized transportation dominates in other trips. (Trips in central and inner London account for 26% of all trips, compared with 12% for trips between the central area and other areas of London, and 61% for all other trips.)

Urban Age (2009) presents the following general assessment of travel patterns in several megacities:

> The relatively compact Indian cities reveal that very high numbers of people take public transport or walk to work—a direct consequence of the proximity of residential buildings and offices in these high-density, mixed-use urban environments where distances to work average less than 2 km. Approximately 40% of midtown residents in New York's Manhattan walk to work and more than 90% of business workers use public transport to go to London's financial hub. Travel patterns are more complex in Shanghai and Mexico City. Although Mexico City counts on a reliable metro system, only 14% of the city's population use it, while minibus services account for more than half of all trips. The share of public transportation in Shanghai is rapidly growing, with 24% of daily journeys to work using some form of public transportation–rail, metro, or bus.

Travel speed by mode

Travel speed is one of the key efficiency indicators of travel modes. Figure 4 compares mean travel speed by size of metropolitan area and mode of transportation. The first group of cities includes 33 metropolitan areas in the *Mobility in Cities Database* with a mean population of 1.9 million inhabitants. The data for this group show that the mean speed for the road network (mostly by private vehicles) is much faster than the speed for public road modes only (typically bus). However, the public rail mode provides approximately the same speed as that of the road network.

The second set of data provides the same type of information for six large metropolitan areas averaging 10.5 million inhabitants. In large metropolitan areas, the travel speed for the road modes is lower than in smaller metropolitan areas. Furthermore, the average speed for rail transportation is substantially higher than the speed for road transportation in general or public road transportation in particular. Also, the average speed for rail transportation in large metropolitan areas is somewhat higher than in smaller metropolitan areas.

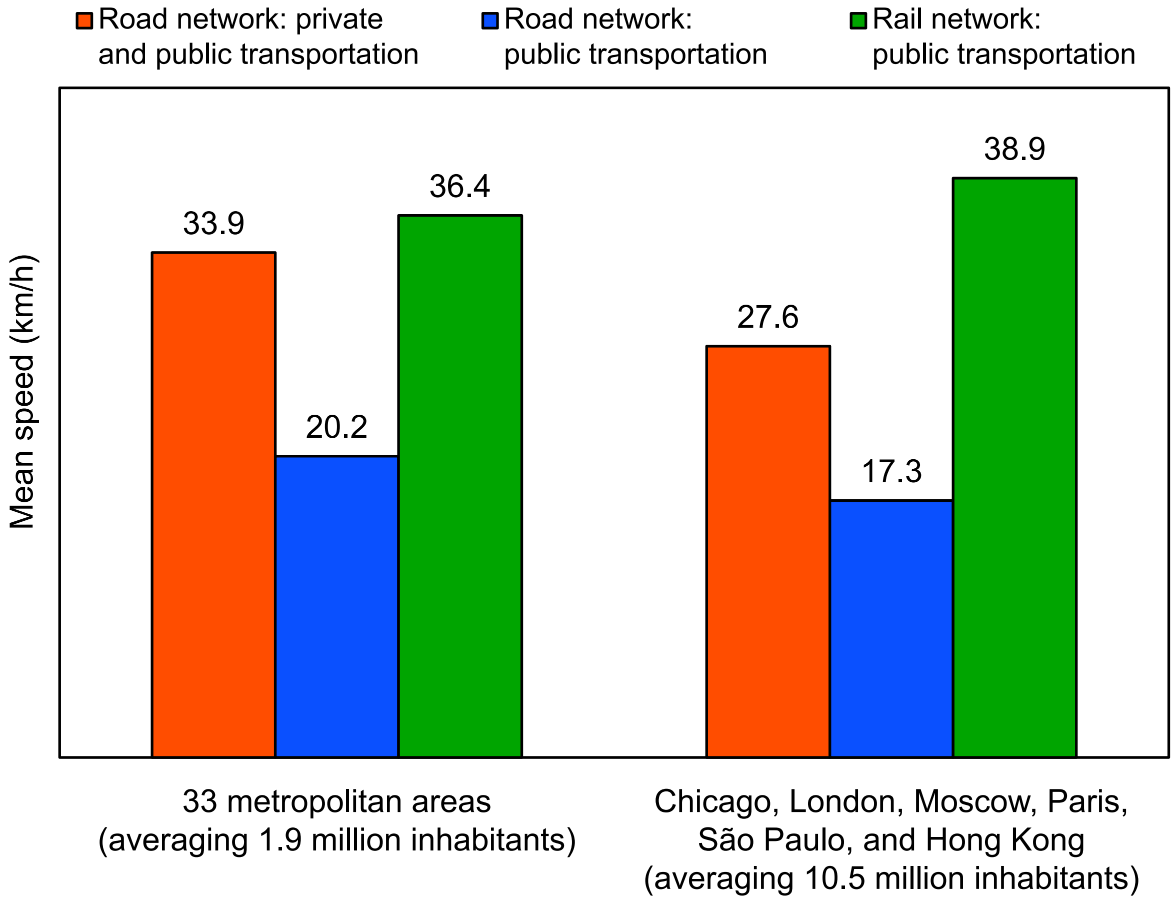
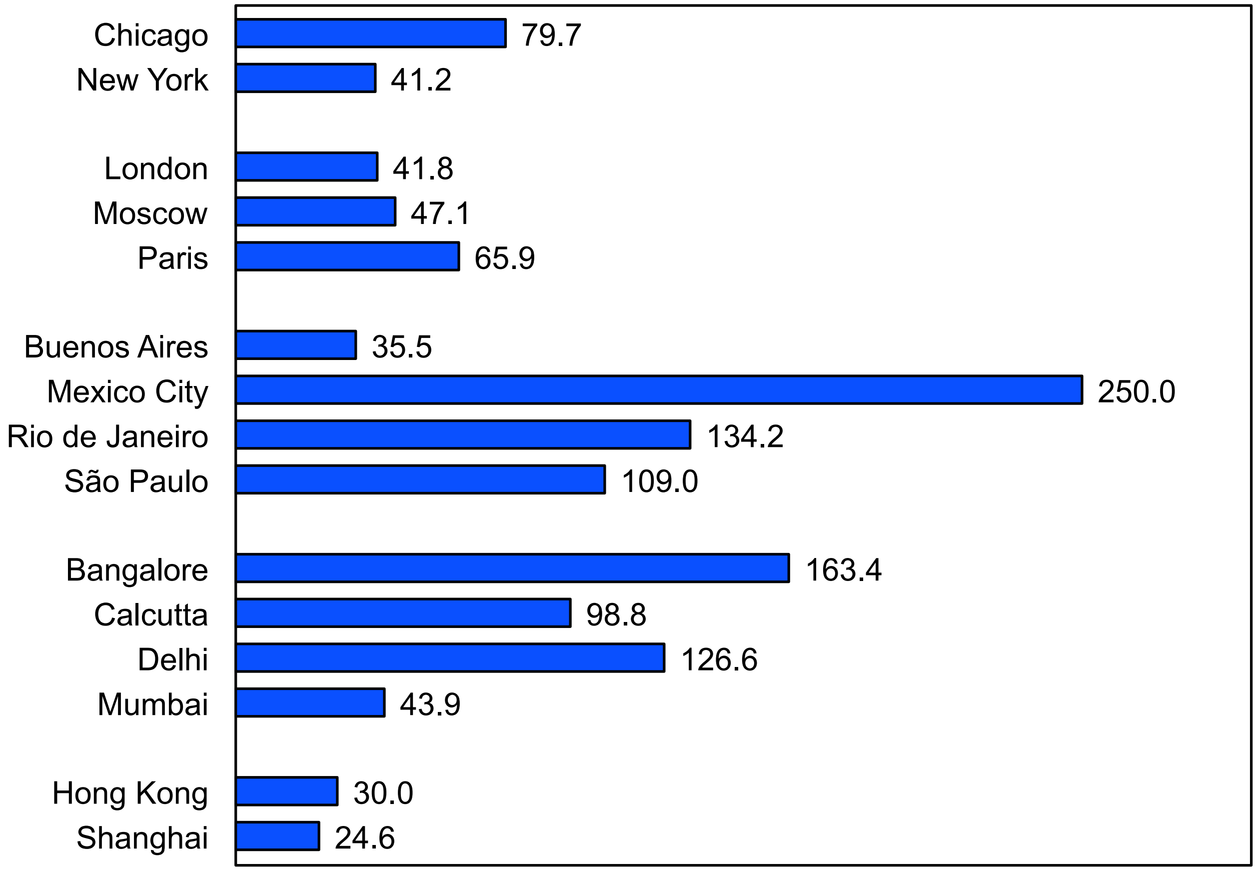


Figure 4. Travel speed by size of metropolitan area and mode of transportation. The data are for 2001.

Road fatalities

Traffic safety is an important factor in assessing the sustainability of a transportation system. Consequently, the number of road fatalities per million inhabitants by metropolitan area was examined (see Figure 5). The highest fatality rate is in Mexico City, followed by several Indian and South American metropolitan areas. However, the rates vary substantially within the regions.



New York: 2005; New York City only
Buenos Aires: 2005; city of Buenos Aires only
Mexico City: city of Mexico City only
Rio de Janeiro: 2005; city of Rio de Janeiro only
Delhi: 2002 (for the number of fatalities)
Mumbai: only Greater Mumbai included
Shanghai: 2005

Figure 5. Number of road fatalities per million inhabitants. The data are for 2001, except as noted.

Selected urban transportation plans and strategies

Many metropolitan areas have developed transportation plans and strategies to outline their vision for the future. Based on key challenges, the objectives and policy measures are given. The measures usually include the following: (1) land use measures (instruments to influence where homes, workplaces, shops, and other facilities are located), (2) attitudinal and behavioral measures (instruments to encourage people to think more about how, when, where, and whether they travel), (3) infrastructure measures (instruments that add new infrastructure to the transportation system), (4) management of the infrastructure (instruments that make more effective use of the existing infrastructure or the services on that infrastructure), (5) information provision (instruments to enable travelers to make more informed decisions about how, when, where, and whether to travel), and (6) pricing (instruments that influence the price that users pay for using elements of the transportation system) (Konsult, 2009).

The following section summarizes the main aspects of transportation strategies in one metropolitan area per region. The metropolitan areas included are New York City, London, São Paulo, Mumbai, and Shanghai. (For links to 39 urban transportation plans worldwide, see GTZ, 2009.) The presented summaries do not necessarily convey a complete description of the strategies. For example, the urban transportation plans of large metropolitan areas typically involve many government structures at national, regional, and local levels (see e.g., Urban Age, 2009), and each level can have its own strategy. Consequently, the presented summaries are designed to highlight the main objectives, focuses, and measures planned by the selected metropolitan areas for the next 10 to 20 years. The emphasis is on the planned modal split (i.e., how the strategies envision the future role of private vehicles, public transportation, and nonmotorized transportation.

New York City

The goal of the regional transportation plan (PLANYC, 2007) is to meet the city's and region's transportation needs through 2030 and beyond, and to improve travel speed. The plan includes strategies to improve the transit network and reduce growing gridlock on the roads through better road management and congestion pricing. The specific initiatives include the following: (1) to increase the capacity on key congested routes, (2) to provide new commuter rail access to Manhattan, (3) to expand transit access to underserved areas, (4) to improve and expand bus service, and (5) to improve local commuter rail service.

In addition, New York City has recently introduced its own strategic plan (NYCDOT, 2008). Its major goals include, for example cutting city traffic fatalities by 50% from the 2007 levels, implementing bus rapid transit lines and measures to increase bus speeds city-wide, doubling bicycle commuting by 2015, initiating city-wide parking policies to manage curb space to reduce cruising and congestion, adopting complete-street design templates for reconstruction projects, launching a Main Street Initiative to develop people-friendly boulevards in key corridors across the city, and delivering better street surfaces.

London

Mayor's Transport Strategy (2009) identifies the following key challenges:

- supporting economic development and population growth
- providing a better quality of life for all inhabitants
- ensuring the safety and security of all inhabitants
- improving transport opportunities for all inhabitants
- tackling climate change, e.g., reducing greenhouse gas emissions by 60% (from their 1990 levels) by 2025

Guiding principles of the strategy emphasize factors such as respecting choice, keeping people informed, protecting the environment, developing outer London, connecting transport and planning, working with the boroughs, providing transport for all, and delivering value for money.

The major components of the Transport for London (TfL) Business Plan include:

- building Crossrail (e.g., to connect outer suburbs to the city)
- improving the Tube (subway), improving TfL Rail and National Rail, enhancing bus travel which will remain the dominant form of public transport, and making more use of the river Thames
- smoothing traffic flows (e.g., by upgrading equipment at signalized intersections)
- delivering a "cycling revolution" and making "walking count"
- catalyzing the shift to electric road vehicles (e.g., a total of 25,000 charging spaces across London by 2015, a continuation of the 100% Congestion Charge discount for electric vehicles)

São Paulo

The Integrated Urban Transportation Plan—PITU 2020 (Governo do Estado de São Paulo, 2009)—includes five broad transportation policy objectives:

- *Competitive*: increase accessibility in general and to neighboring regions specifically, and reduce traffic congestion
- *Healthy*: increase access to public transportation for low income people, and reduce the number of crashes, air pollution, and noise
- *Harmonious*: increase access to commercial sub regions and job opportunity hubs and increase access to the metropolitan downtown area
- *Responsible*: integrate the operation of the transportation network and thereby efficiently utilize the available resources
- *Concerned with citizenship*: reduction in the use of private means of transportation, improvement in the quality of transportation services, preservation and promotion of urban spaces

The improvements in the rail system are designed to (1) reach the major metropolitan subcenters and connect them to the city, (2) implement faster subway lines, (3) coordinate the operation of long-distance regional trains on the current railroad tracks, (4) improve the CPTM (São Paulo Metropolitan Train Company) train system to reach peripheral areas within the metropolitan region, and (5) develop special trains for connecting the three local airports.

Road system goals include (1) emphasis on bus systems, (2) implementation of light vehicle on-tire (LVT) system and corridors linked to the rail systems, complemented by microbuses in the expanded downtown area, and (3) development of intermodal terminals.

The program foresees an expansion of the existing metropolitan road system through the increase of road capacity, elimination of road discontinuities, and elimination of many road crossings. It also seeks to promote the internal and external integration of the metropolitan region facilitating passing-through displacement and providing the integration of public transport systems.

The program also proposes the completion of the Rodoanel road and implementation of fast priority traffic rings seeking to promote the use of orbital routes, thus decreasing the radial nature of the metropolitan road network within the municipality of São Paulo.

Furthermore, the program proposes the integration of private and public transport by the establishment of park-and-ride facilities. In addition, the program advocates upgrading traffic control systems, new parking policies to regulate private vehicle usage, and stimulating public transportation.

Mumbai

The objectives of the transport strategy between 1996 and 2011 include (1) ensuring adequate levels of accessibility in the expanding urban areas, (2) assisting the economic development of the region, and (3) improving the safety record of the transport system (MMRDA, 1999).

Upgrading road networks has been the dominant strategy so far. However, public transport is envisioned as the only solution to providing adequate access for a region where a large number of households will not own a private vehicle in the foreseeable future. It was proposed that the suburban rail network could provide the core of the transportation system because of the relatively linear distribution of the population. The economic analysis shows that the aggregate economic return is the highest for a strategy with substantial investment in the metropolitan railway system and a modest investment in the road system. This strategy is also beneficial from an environmental standpoint. The strategy for rail system development must address the present acute overcrowding with a substantial increase in capacity (e.g., full integration of the two existing suburban railway systems and optimization of services including an introduction of new rolling stock of a radically improved design, and longer trains running at three-minute intervals).

The bus strategy focuses on the demands of a growing number of middle-class households. Consequently, high-standard bus services are planned. These include features such as improved vehicle design and comfort level, faster travel with limited stops, and perhaps air conditioning. The objective is to deter these individuals from using their private vehicles.

The strategy for development of highway networks is focused on the suburbs and the outer region where the majority of the population will be located during the next two decades.

The demand management aims to restrain inefficient use of private vehicles. In addition, it will mitigate the adverse effects of road congestion on delays and the unreliability in bus service, in turn causing an increase in costs and loss of passengers. Demand management also includes collecting fees for parking on roadways and the development of commercial, off-street parking facilities. These measures are planned to be complemented with new bus service between the peripheral parking areas and the central business district.

Shanghai

The Shanghai Metropolitan Transport White Paper (EMBARQ and Shell Foundation, 2002) predicts that population will increase to over 16 million people by 2020. The number of private vehicles will increase to 2.5 million, while the number of motor trips per day will more than double to 7 million. The overall goal of the plan is to "provide accessible, safe, comfortable and clean transport services." The plan calls for the number of trips in the city attributable to public transit to increase from 21% in 2000 to 35% in 2020. Other major goals for 2020 include the following:

- increasing the arterial road capacity from 2.7 million to 6.5 million vehicle km/h, and increasing off-street parking capacity from 8,000 to 300,000 spaces
- completing rail transit network of 540 km of track, and increasing the number of rail system rider trips per day from 1.5 million to 12 million
- increasing daily bus ridership so that buses will serve most short- and medium-distance travel in the city

Future transportation in the examined metropolitan areas

Based on the reviewed information, Table 4 provides projections that we developed for likely changes in the future use of personal vehicles in the examined metropolitan areas. *Personal vehicles* here include light-duty vehicles (e.g., cars, minivans, pickup trucks, and SUVs) as well as potential novel variants of them. Motorcycles, mopeds, and bicycles are not included.

The projections include personal vehicle ownership, distance traveled by personal transportation for different trip types (within cities' inner core, commuting, and leisure trips), and the number of road fatalities. The time span of the projection is 15 years (2025).

Caution is advised in considering these projections, due to the limited availability of relevant information for these metropolitan areas. Furthermore, the projections are dependent on no catastrophic increases in the price of fuel and no new major city-based developments (such as a substantial restriction on the use of personal vehicles).

Table 4
Likely changes in personal transportation in metropolitan areas by 2025.
+++ = substantial increase, ++ = moderate increase, + = minor increase,
± = no change, - = decrease. (Projections by the authors.)

Metropolitan area	Personal vehicle ownership per capita	Distance traveled per capita by personal vehicles			Number of road fatalities per capita
		Inner core	Commuting	Leisure	
Chicago	±	±	± or -	± or -	-
New York	±	±	± or -	± or -	-
London	±	±	± or -	± or -	-
Moscow	++	+	±	++	++
Paris	±	±	± or -	± or -	-
Buenos Aires	± or +	±	±	+	+
Mexico City	± or +	±	±	+	+
Rio de Janeiro	++	±	±	++	++
São Paulo	++	±	±	++	++
Bangalore	+++	±	±	++	++
Calcutta	+++	±	±	++	++
Delhi	+++	±	±	++	++
Mumbai	+++	±	±	++	++
Hong Kong	+	±	±	+	+
Shanghai	+++	±	±	+++	+++

Personal vehicle ownership per capita

First, the projections assume that personal-vehicle ownership will not increase in the U.S. and Western European metropolitan areas, based on the current high level of ownership in both regions and the extensive public transportation in Western European metropolitan areas.

Second, no or only minor increases are projected for Buenos Aires and Mexico City. There are two competing trends of relevance in these two megacities. On the one hand, the incomes are projected to increase. On the other hand, the current ownership per capita is at a high level (similar to that in London and Paris). Consequently, the future level of ownership will depend on other factors (e.g., the availability of attractive public transportation, degree of traffic congestion, etc.).

Third, the projections call for a minor increase in ownership in Hong Kong and moderate increases in Moscow, Rio de Janeiro, and São Paulo. These projections are based on much lower current ownership than in the earlier-mentioned metropolitan areas and on the predicted moderate increases in income. In Hong Kong, the public transportation is efficient which might contribute to a somewhat lower increase in comparison with Moscow, Rio de Janeiro, and São Paulo.

Fourth, substantial increases are projected for the four Indian metropolitan areas and Shanghai—the metropolitan areas with currently very low levels of ownership, but with likely substantial increases in future income.

Distance driven by personal vehicles per capita within cities' inner core

Because of limited space and congested traffic (at least during commuting times), trips made by personal transportation within the inner core of large metropolitan areas will confront substantial problems everywhere. None of the examined strategic plans aims to increase the use of personal transportation for trips of this type, although many of them emphasize freedom of choice. Given that the population of many metropolitan areas is projected to increase, distance traveled by personal transportation within the inner core per capita might even decrease. However, if personal-vehicle ownership increases and population does not increase, as has been projected for Moscow, there is space for an increase in trips of this type.

Distance driven by personal vehicles per capita for commuting

Commuting by personal vehicle is projected not to increase anywhere because the roads are already congested at the commuting times. There might be some local road improvements (as indicated in some of the strategic plans), but they are not likely to change the overall picture. Thus, it is projected that commuting by personal vehicle will remain at about the same level, or will even decrease in the U.S. and Western European metropolitan areas. There might be some decrease in other metropolitan areas as well if new, efficient, and attractive public transportation is introduced. However, no specific information about such measures is available.

Recently, there has been considerable discussion about congestion pricing in many large metropolitan areas (Bhat, Higgins, and Berg, 2009). Because such policy has been successfully implemented in some metropolitan areas (e.g., Singapore and London), several other metropolitan areas have explored whether congestion pricing could solve some of their congestion problems as well (e.g., New York, São Paulo, Mumbai, Hong Kong). However, based on the available information, no additional implementations of congestion pricing in the examined metropolitan areas have been put forth. In addition, if a metropolitan area includes several discrete geographical areas (as is the case in Delhi), congestion pricing might be challenging to introduce (Mohan, 2008). Nevertheless, it is likely that some of these metropolitan areas will introduce congestion pricing that would focus on commuting by personal transportation.

Distance driven by personal vehicles per capita for leisure trips

Overall, it is assumed that the real price of fuel will increase during the time period considered. In the absence of substantial increases in income and ownership of personal vehicles, this will most likely limit particularly the number and length of leisure trips made by personal vehicle. Because of these considerations, no increases were projected for the U.S. and Western European metropolitan areas.

In other metropolitan areas, the leisure trips are projected to increase because of relatively more substantial increases in income and ownership of personal vehicles: minor increases in Buenos Aires, Mexico City, and Hong Kong; moderate increases in Moscow, Rio de Janeiro, São Paulo, and the four Indian metropolitan areas; and a substantial increase in Shanghai.

Number of road fatalities per capita

Distance driven is a critical factor affecting the number of road fatalities. Consequently, the projections for road fatalities are based mainly on the projected increases in distance traveled for different type of trips. At the same time, however, most metropolitan areas have plans to reduce the number of road fatalities, but it is difficult to predict to what degree they will be able to implement effective safety countermeasures.

The megacities with projected decreases in fatalities per capita include those in the U.S. and Western Europe. Minor increases in fatalities are projected for Buenos Aires, Mexico City, and Hong Kong. Fatalities are projected to increase substantially in Shanghai and moderately in the remaining metropolitan areas because of the expected increase in distance traveled.

New mobility networks

Thus far, this report has considered the different transportation modes mainly as independent and exclusive options. However, there is growing interest in more integrated networks that provide a variety of connected and IT-enhanced transportation options.

There are many reasons why approaches that combine and seamlessly connect various transportation modes and services are both in greater demand, and important to the future of transportation. Most importantly, as the population continues to move to urban centers, approaches that focus predominantly on personal vehicle use face increasing challenges related to road space and land use, congestion, flagging or insufficient infrastructure, a rapidly growing aging population, safety, equity and affordability, quality of life, and harmful emissions.

However, simply implementing one alternative solution to personal vehicles will seldom fully address these issues either. For example, alternative fuels for personal vehicles may improve air quality and mitigate climate change to some extent, but they do not solve land use, safety, or equity differentials in urban regions. Bus rapid transit or commuter trains may address congestion, pollution, and equity to an extent but they cannot get users the "last kilometer" (or few kilometers) home. There is also frequently a lack of spatial, technological, informational, or institutional connectivity to link the bus rapid transit to other modes seamlessly and to inform the user where mode and service proximity exist. Lack of connected door-to-door service (and related information about it) can affect mode shift, and therefore sustainability and equity.

In response, emerging approaches are more frequently focusing on providing last segment and door-to-door transportation within city regions, combining a range of modes, services, and design, and applying information technology to offer seamless connectivity and integrated journey planning, wayfinding, and fare payment for the user, as well as enhanced and integrated traffic information and management and revenue collection for the operator. While connecting modes is not new per se, systematically mapping and optimizing to create region-wide multimode (including single-occupancy vehicle), multiservice networks is just beginning to take hold, mostly because of increasing demand and partly because vastly improved telecommunication technology tools have made it more possible and affordable for both users and operators.

One example of systems-based integrated mobility and accessibility is referred to as *new mobility networks*. The concept originated in Bremen, Germany (e.g., Glotz-Richter, 2003), and it is now being customized and developed in city regions in India, South Africa, and North America in partnership with SMART at the University of Michigan (Zielinski and Berdish, 2008). The process starts by bringing together transportation leaders and professionals, related corporate players and entrepreneurs, relevant nongovernmental organizations and associations, and researchers to map already existing physical connection points, then to enhance, pilot, and promote the connected door-to-door network.

Beyond providing more connected options, pilot cities are beginning to experience added benefits of this approach, including scalability—optimizing what's there (in some cities, phase one simply involves mapping and communicating existing connections using maps and signage and basic IT enhancements); cost effectiveness based on scalability; a positive mix of immediate-term and long-term benefits; increased personal safety and equity; increased attractiveness of the system for new users (moving beyond sustainable transportation as the second, lower-status choice and towards a feasible and attractive option); and a wide array of innovation, business, and new employment opportunities.

Overall, integrated, multimodal, IT-enhanced mobility—in particular through new mobility networks—is expected to reduce reliance on personal vehicles. However, the speed and extent of this shift is not yet clear, because the reductions are likely to vary with the specifics of each megacity and the details of the approach employed. Furthermore, the feasibility of implementing certain aspects of such approaches throughout most of the areas of each megacity has yet to be determined. These and related issues promise fertile ground for future research.

Summary

This study examined the future personal transportation in megacities of the world. Of particular interest was the future role of personal vehicles. To span ranges of geographical, political, and economic factors, the following 15 megacities were included in the analysis: Chicago, New York, London, Moscow, Paris, Buenos Aires, Mexico City, Rio de Janeiro, São Paulo, Bangalore, Calcutta, Delphi, Mumbai, Hong Kong, and Shanghai. The current and future values of the following factors were considered: population, wealth, level of motorization, public transportation, and modal split. Also discussed were selected urban transportation plans and strategies.

Based on the analysis, projections through 2025 were made for each megacity for changes in ownership of personal vehicles; distance traveled per capita by personal vehicle within inner core, for commuting, and for leisure; and for number of road fatalities per capita. The forecasts include the following:

- The largest increases in personal vehicle ownership will occur in the four Indian megacities and Shanghai.
- There will be no increase in the use of personal vehicles for inner-core transportation in any of the megacities.
- No increases are expected in the use of personal vehicles for commuting.
- The largest increases in the use of personal vehicles for leisure traveling (and the largest increases in road fatalities) will take place in Shanghai, followed by the four megacities in India, Rio de Janeiro, and São Paulo.

Overall, no substantial decrease in the reliance on personal vehicles is foreseen in the next 15 years anywhere in the examined megacities. To the contrary, an increased role of personal vehicles is forecasted for the megacities in India, China, and Brazil.

The above trends are based on treating the different transportation modes as independent and exclusive options. However, there is growing implementation and use of new mobility networks—integrated networks that provide a variety of connected and IT-enhanced transportation options door-to-door. Although such networks are expected to reduce the reliance on personal vehicles, the magnitude and nature of this effect remain to be ascertained.

References

Barter, P., Kenworthy, J., and Laube, F. (2003). Lessons from Asia on sustainable urban transport. In, Low, N.P. and Gleeson, B.J. (eds.), *Making Urban Transport Sustainable.* Basingstoke, UK: Palgrave- Macmillan.

Bhat, K., Higgins, T., and Berg. J.T. (2009). U.S. and worldwide experience with congestion pricing. An overview. *TR News*, 263, 8-15.

DENATRAN [Departamento Nacional de Trânsito]. (2005*). Estatísticas da frota Brasileira de Veículos* (Retrieved December 30, 2009 from http://www.denatran.gov.br/frota.htm.)

EMBARQ and Shell Foundation. (2002). *Background paper: Shanghai metropolitan transport white paper.* (Retrieved December 2, 2009 from http://www.unep.org/pcfv/PDF/ EMBARQ-WhitePaper.pdf.)

Glotz-Richter, M. (2003). *About the "egg-laying wool-milk sow" of car sharing—new concept of integration, partnership and awareness raising*. (Retrieved January 27, 2010 from http://www.epomm.org/ecomm2003.ecomm/papers/MichaelGlotz-Richter.pdf.)

Governo do Estado de São Paulo. (2009). *The integrated urban transportation plan — PITU 2020*. (Retrieved December 4, 2009 from http://www.stm.sp.gov.br/index.php? option=com_content&view=article&id=2221&Itemid=231.)

GTZ (Deutsche Gesellschaft für Technische Zusammenarbeit. (2009). *Urban Transport Policy and Planning Documents. An overview on urban transport plans and strategies from all continents***.** **(**Retrieved December 3, 2009 from http://www.gtz.de/de/dokumente/en-urban-transport-policy-documents-0202-2009.pdf.)

IMF (International Monetary Fund). (2009). *World economic outlook database, October 2009*. (Retrieved December 14, 2009 from http://www.imf.org/external/pubs/ft/weo/2009/02/ weodata/weoselgr.aspx.)

Kennedy, C., Miller, E., Shalaby, A., Maclean, H. and Coleman, J. (2005). The four pillars of sustainable urban transportation. *Transport Reviews, 25,* 393–414.

Konsult. (2009). *Knowledgebase on sustainable urban land use and transport.* (Retrieved November 16, 2009 from http://www.konsult.leeds.ac.uk/.)

Mayor of London. (2009). *Mayor's transport strategy.* London: Greater London Authority. (Retrieved November 20, 2009 from http://www.london.gov.uk/mayor/publications/2009/docs/transport-strategy.pdf.)

Mohan, D. (2008). *Personal interview*. Outlookindia.com, March 1, 2008. (Retrieved December 10, 2009 from http://www.outlookindia.com/article.aspx?236827.)

NYCDOT (New York City Department of Transportation). (2008). *Sustainable streets 2008 and beyond. Strategic plan for the New York City.* (Retrieved December 3, 2009 from http://www.nyc.gov/html/dot/html/about/stratplan.shtml.)

MMRDA (Mumbai Metropolitan Region Development Authority). (1999). *Transportation: A strategic perspective*. (Retrieved December 2, 2009 from http://www.regionalplan-mmrda.org/N-11.pdf.)

NYMTC (New York Metropolitan Transportation Council). (2003). *Regional transportation statistical report 2000-2001*. (Retrieved December 3, 2009 from http://www.nymtc.org/files/rtsr_2000-2001.pdf.)

PLANYC. (2007). *A greener, greater New York*. (Retrieved December 2, 2009 from http://www.nyc.gov/html/planyc2030/html/home/home.shtml.)

Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat. (2009). *World population prospects: The 2006 revision* and *World urbanization prospects: The 2007 revision*. (Retrieved November 30, 2009 from http://esa.un.org/unup.)

Schäfer, A., Jacoby, H.D., Heywood, J.B., and Waitz, I.A. (2009). The other climate threat: Transportation. *American Scientist, 97*, 476-483.

Schäfer, A. and Victor, D.G. (2000). The future mobility of the world population. *Transportation Research Part A, 34*, 171-205.

Sivak, M. and Tsimhoni, O. (2008). *Future demand for cars in developing countries: Going beyond GDP and population* (Technical Report UMTRI-2008-47). Ann Arbor: The University of Michigan Transportation Research Institute.

Transport for London. (2009). *London transport report 2007*. London: Author. (Retrieved November 30, 2009 from http://www.tfl.gov.uk/londontravelreport.)

UITP. (2006). *Mobility in cities database*. Brussels: International Association of Public Transport.

Urban Age. (2009). *A worldwide investigation into the future of cities*. (Retrieved November 30, 2009 from http://www.urban-age.net/publications/cityProfiles/.)

World Bank (2002). *Cities on the move – A World Band urban transport strategy review*. Washington, D.C.: The World Bank. (Retrieved December 2, 2009 from http://siteresources.worldbank.org/INTURBANTRANSPORT/Resources/cities_on_the_move.pdf.)

Zielinski, S. and Berdish, D. (2008). New mobility solutions to urban transportation. *The Journal of the International Institute*, *16* (1), 7 and 16. (Retrieved January 30, 2010 from http://www.ii.umich.edu/UMICH/ii/Home/PUBLICATIONS/II%20Publications/4-Zielinski-Berdish-web.pdf.)