Meeting the Challenges of Megacities in the Developing World

A Collection of Working Papers

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Maki Fife, Senior Program Assistant
Barbara Krause, Senior Program Assistant

PREFACE

In the next 30 years, the world's population is expected to increase by 2.5 billion persons. Most of this growth will occur in the cities of developing countries, which are adding about 55 million residents a year. These working papers are focused on the megacities--defined here as large, rapidly growing cities of 8 million or more residents. Megacities merit special attention because of the magnitude of their population increases and the enormity of the challenges involved in providing services to such rapidly growing populations. At the same time, many of the innovations and changes discussed in these papers are applicable to a broad range of cities. Early recognition of future growth can enable a city to address challenges before they become overly complex or expensive.

In the twenty-first century, the economic and social development of urban areas will be influenced by continued global economic integration and the need for a nation's commerce to be competitive in the global economy. City businesses will have to compete for investment and export markets in the global marketplace. A successful transition from industries relying on low-wage labor and cheap raw materials toward technology- and knowledge-based systems of production and services will require better-educated and more-skilled workers, effective infrastructure, and responsive public and private organizations.

In the two decades since the United Nations Conference on Human Settlements (Habitat) was held in Vancouver, there have been significant advances in both technologies and management strategies that can be applied to address megacity challenges. Nevertheless, rapid urbanization has outpaced the ability of governments to provide adequate shelter and basic services to the urban poor. Given the increasing importance of these challenges, the world's academies of science and engineering were asked by Dr. Wally N'Dow, Secretary General of the Second United Nations Conference on Human Settlements, to organize a scientific forum that would develop a joint statement for presentation to the United Nations delegates at the Conference on Human Settlements (Habitat II) in Istanbul in June 1996.

The U.S. National Academy of Sciences/National Research Council is also untaking a study of the many challenges faced by megacities in the developing world. Results of the full study are scheduled for publication later this year by the National Research Council. The working papers presented here--on labor markets, water ad sanitation services, and transportation--have bee prepared for that study by three panels of the National Research Council.

Transportation Options for Megacities in the Developing World

A Working Paper

Transportation Research Board

PANEL ON TRANSPORTATION OPTIONS

Members

Ralph Gakenheimer, Massachusetts Institute of Technology, *Chair*
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V. Setty Pendakur, University of British Columbia
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Consultant

Amrita Daniere, University of Toronto

National Research Council Staff

Stephen Godwin, Transportation Research Board
Valerie Gibson, (summer intern) University of California, Los Angeles

EXECUTIVE SUMMARY

With very few exceptions, rapid growth in demand for motorized transport has overwhelmed the transport capacity of cities in the developing world. Traffic congestion reduces the productivity of urban agglomerations everywhere, but the consequences in developing-country megacities are greater. Not only is the level of congestion higher in developing-country megacities, but many of these same megacities create a major part of their national gross domestic products. Therefore, reducing urban congestion is a central element of economic growth in these settings. Moreover, reducing congestion will also reduce automobile emissions and thus urban air pollution, which is currently a major health problem in most megacities. This paper examines a wide range of options for addressing the challenges of transportation in the developing world.

Traffic and Demand Management. Principal tools for confronting rapid motorization in developing-country cities are traffic and transport management. Nothing else can be implemented at a sufficiently high level or as rapidly. Relatively simple measures, such as the introduction of one-way systems and reversible-flow traffic lanes, improvements in street conditions, and improved training of engineers and traffic police, can do much to improve traffic flows quickly and inexpensively. Additionally, financial measures for demand management, which include increased fees for parking in congested areas, congestion pricing, and higher taxes on fuels, can greatly influence demand for private motorized transportation.

Environmental Measures. Air quality requires serious attention in all megacities. Eliminating leaded gasoline and requiring catalytic converters are the most cost-effective approaches to reducing automobile emissions. Additional controls on widely used two-stroke engines, such as timed fuel injection and catalytic exhaust aftertreatment, can significantly reduce emissions from these vehicles. Other measures discussed in the paper, such as land-use planning and encouragement of transit, can also help reduce emissions from transport.

Technology offers additional opportunities for reducing emissions. For instance, several cities in India are actively pursuing the conversion of rickshaws and other small vehicles to electric power. Since such vehicles can be recharged at night (when electricity is cheaper and reliable) and have low power needs (thereby requiring small batteries), they could be an attractive option for some cities and regions. Natural gas vehicles may also be attractive in some cities for economic, trade, and energy supply reasons. Developing nations should keep a close watch on opportunities for both telecommunications and technology breakthroughs in coming

years. Electric micro cars and, perhaps in the longer run, fuel cell vehicles powered by hydrogen could provide both mobility and air quality gains.

Private-Sector Participation. It will also be necessary to begin planning for new and upgraded transit facilities and for new high-capacity road facilities for cities built in the prehighway era. An important proactive and early step in this process is the preservation of government-owned or -controlled corridors and right-of-ways. These facilities should be commercialized to the maximum extent possible and with the participation of the private sector. Private financing and management can better ensure that services are priced at their full cost, thereby minimizing capital and operating costs and giving proper market signals for capacity expansion. International experience is quite well documented in the areas of private bus services, private toll roads, and development charges. In addition, there are a number of examples of successful transit privatization efforts in Chile, Sri Lanka, and across the globe. Key to the successful inclusion of the private sector have been public practices to ensure fair and adequate competition in bidding for new facilities and for the management or operation of existing facilities.

Linkage of Land-Use Planning and Transportation Investment. Land-use planning is an imperative in the face of rapid urban development (3 to 5 percent or more annually) accompanied by rapid motorization (over 10 percent annually). Motorization, particularly automotive transport, unleashes pressures for cities to decentralize; the sprawling, low-density development patterns characteristic of many western cities would not be possible without the automobile. Full-cost pricing of transportation can help constrain these pressures, as can public guidance of land development to ensure the transit serviceability of auto-generated suburbs. However in cities with high population densities and rising incomes, the pressures to decentralize will not be fully limited even by full-cost pricing. An example of guidance through land-use planning is provision for a regional polynucleated development pattern, with relatively high-density outlying nodes connected to the center by high-capacity road and bus service. Such a strategy can reduce land consumption while accommodating reduced population densities at levels high enough to support transit. Few cities are likely to be able to replicate the successes of Curitiba, Brazil, in this regard, but Curitiba does offer a model for future megacities. At a smaller scale, high-density development can be encouraged along transit stops and at major road intersections.

Multimodal Transportation Systems. It is also extremely important to design traffic systems that can cope with the large variety of transport modes, all with different performance characteristics, negotiating the streets of most developing-country megacities. The range of transport modes in developing-country cities is far wider and richer than that of cities in the industrialized regions. The number and variety of transport modes observed in Jakarta or Shanghai, for example, present both different problems and opportunities than the cars, buses, and subways of New York or London. One cause of the extreme diversity in modal choice in developing countries is income; because much of the population of the developing world is unable to afford private or motorized transport, walking and other means of nonmotorized

transport need to be an integral part of transportation policies and investment strategies. Traffic systems also need to be accommodating of informal transit modes, such as jeepneys, becaks, and minibuses, because in many cities, the informal sector provides a significant share of the transportation services. Planning for efficient multimodal transport is difficult for both institutional and systemic reasons. However, some cities have made important contributions to their multimodal integration through single-fare arrangements and compatible scheduling between pairs of modes. In addition, the inhabitants of developing-country cities are generally more reliant on less-polluting modes, and building on this history represents a distinct advantage in terms of the environmental costs of future development.

The current trends of urbanization and motorization in developing countries are in many ways reproducing the patterns followed in developed countries. With the inevitable growth in population and the accessibility provided by motorized transport, residents are increasingly locating on cheaper land at the urban periphery. Changing residential patterns usually induce a substantial decentralization of employment, and in almost every case, these patterns are associated with an increase in the number and length of vehicular trips. The pattern followed in the industrialized cities has had environmental costs that can be avoided while the city still enjoys the substantial economic and mobility benefits provided by motorized transportation. Effective traffic management, full-cost pricing, environmental controls on fuels and vehicles, alternative technologies and fuels, privatization, land-use planning, and improved integration of multimodal transportation are all capable of ameliorating the grave mobility problems of megacities. Their effects are cumulative, and in important cases, they multiply each other's significance.

INTRODUCTION

The effective functioning of megacities depends in the most basic way on an efficient transportation system. In many parts of the developing world, however, urban transport is characterized by a rapid growth in demand that has overwhelmed transport capacity. The resulting high level of congestion in many large developing-country cities, particularly in Southeast Asia, China, India, and many parts of Latin America, has negative implications for the level of economic development that can be achieved. In Bangkok, Thailand, for example, where infrastructure improvements lag well behind the growth in travel demand, estimates suggest that 3 million person hours are lost daily in the metropolitan region as a result of average traffic delays of 2 hours per trip during much of the day (Sussman and Bonsignore, 1993). In addition, the strains placed on the road networks of many large cities have led to significant declines in safety, as well as poor-to-terrible air quality in many places. Perhaps the most compelling aspect of these problems is that the urban poor bear the brunt of both congestion and deteriorating environmental quality because they often face the longest commuting times and spend much of their lives out of doors on congested, noisy, and polluted streets.

Developing countries look to the industrialized nations to provide them with models, technologies, and strategies for dealing with growth in both urbanization and motorization. Certainly the experience of cities of the developed world with motorized transportation infrastructure planning and investment exhibits much that is attractive. Large cities in developed countries are productive urban agglomerations whose residents are frequently able to work in the dense center of the urban area while living in more spacious suburbs. Although many also rely on some form of rail-based mass transit, their life-style is, in most instances, based primarily on a high-quality road infrastructure.

Yet western models of urban transport are of limited value for meeting the transportation needs of developing-country megacities. For one thing, the benefits of a transportation system designed around the private automobile have come at significant cost in large cities of the developed world. Moreover, given the great differences among the world's megacities, it is important to recognize both the benefits and costs associated with various strategies for mobility and to choose the investments that hold the most promise for a specific urban setting.

This paper begins, then, by highlighting the distinguishing features of urban transport in megacities of the developing world. The sections that follow examine various transportation policies in some detail and emphasize strategies that can help developing-country megacities

improve mobility, reduce congestion, and avoid some of the more costly consequences associated with heavily auto-dependent societies. Some of the options available to developing-country megacities--such as using full-cost pricing to guide transportation use and investments--are less possible in many cities of the developed world, primarily because of existing infrastructure investments, established land-use patterns, and prevailing cultural norms. The options examined fall into seven areas:

- Improved traffic management
- Full-cost pricing
- Environmental measures
- Transport facility financing through private-sector participation
- Linkage of land-use planning and transportation investment
- Multimodal transportation systems
- Dissemination of knowledge and technology advances

We conclude with a brief summary and conclusions.

TRANSPORTATION PATTERNS IN DEVELOPING-COUNTRY MEGACITIES

There are a number of fundamental differences between the process of motorization taking place today in developing-country cities and that which took place in the cities of the developed world. Most important among these is the pace of motorization (Gakenheimer, 1994). In the developed countries, cities and their surrounding regions had several decades to respond to the challenges posed by the widespread use of private automobiles and increased reliance on trucking for transporting freight. In many cities in the developing world, an equivalent growth is occurring over only one or two decades. In Bangkok, for example, motor vehicle registrations have increased at the rate of 12 percent a year for the past 10 years, while even in China, one of the world's least motorized nations, the growth rate of motor vehicles has exceeded 18 percent per year since 1985.

Moreover, many large cities in the developing world have followed a dense pattern of development that complicates the process of providing roads and public transport services to urban residents. In Asian cities such as Shanghai and Calcutta, for example, the integration of work, residence, and commerce in the urban core is very high. Developing-country cities frequently have much less space allocated to roads than was true of western cities during their initial phase of motorization. In Chinese cities, for example, the amount of land devoted to road space is often less than 10 percent, while even in 1910, when New York City was at its most dense in terms of population per hectare, roads comprised fully 15 percent of the urban land area in Manhattan (Gakenheimer, 1995; Jackson, 1984).

The dense development and relative lack of land devoted to roads make it more difficult to build and operate efficient forms of transportation and increase the cost of acquiring land for

expanding the road network. At the same time, developing countries often have fewer resources to devote to the provision of urban transportation infrastructure than did large cities of the industrialized world at the turn of the century. Many industrialized cities had well-established sources of funding for public infrastructure that could be expended over a reasonable time horizon to modernize infrastructure. In contrast, megacities of the developing world must apply limited public revenues to a score of pressing public needs that include not only transportation, but also water and sanitation services, telecommunications, and power supply. In most developing-country cities, demand for public transportation (both motorized and nonmotorized) has also grown much more rapidly than the population and has far outstripped the growth in revenues available for transportation infrastructure (Armstrong-Wright, 1993).

Furthermore, most residents of developing-country megacities are not in a position to afford motorized public transport, let alone purchase a private vehicle. Any public investment that provides additional capacity for private vehicle use must often come at the expense of investment in public transport or nonmotorized modes that could potentially benefit a far greater number of people.

Additionally, megacities in developing countries face more problematic obstacles to the implementation of transportation policies than is true of megacities in industrialized nations. In some cases, the obstacles are primarily institutional in nature and include overlapping and uncoordinated institutional structures, inadequate or poorly trained technical staff for planning and implementation functions, a lack of legal capacity to enforce regulations and laws, and limited institutional support for new, and often poorly understood, policies. In other instances, the major impediment to the implementation of transport strategies is the political framework in which decision making takes place (Daniere, 1995). These obstacles can be overcome only through a better understanding of the links between policy design and implementation in each particular city, as well as through changes in domestic legislation, the transfer of institutional skills, better training of personnel, and enhanced citizen participation. Although the majority of these strategies fall outside the rubric of traditional transportation policy and are not discussed here in any detail, it is important to recognize the effect of these obstacles on policy implementation. Transportation strategies that are transparent in nature, benefit the elite as well as the average citizen, and do not require large institutional changes are more likely to succeed in the developing-country context, and thus are emphasized in this paper.

In some cases, megacities in developing countries have important transportation advantages relative to cities of the developed world. Compared with their counterparts in industrialized nations, for example, developing-country urban residents are much less reliant on forms of transportation that pollute the environment and/or are heavily subsidized, and are more open to using different transportation modes. According to recent estimates, walking trips account for two-thirds of the total trips in large African cities such as Dar es Salaam. Walking and cycling trips account for between 40 and 60 percent of the total trips in large cities on the Indian subcontinent, while a 1990 study in Tianjin, China, found that 75 percent of all work trips are made by bicycle (Khisty, 1993; Ren and Koike, 1993). Bicycles, cycle rickshaws, pedal cars, and bullock carts are among the many forms of nonmotorized transport used by inhabitants of the developing world. Inevitably, as demand for urban transport and incomes have risen in

megacities, the dependence of urban residents on motorized modes of transport has increased as well. The growth in demand for motorized transportation is not limited to those able to purchase private automobiles (although these are certainly a main source of increased congestion), but also comprises the behavior of a far larger number of people who switch, for example, from bicycles to motorcycles or from walking to using buses or informal motorized transportation (e.g., jeepneys or converted trucks).

Even within the motorized transport sector, there is a far wider range of options available in developing-country cities than in the developed countries (Gwilliam, 1995). Urban areas in Africa and Asia are served by a multitude of two- and three-wheeled vehicles, such as auto rickshaws, six-seated passenger vehicles, two- and four-stroke motorcycles, and motor scooters. In these regions, and in Latin America as well, urban roads contain a rich assortment of four-wheeled motor vehicles that includes converted pickups in addition to regular taxis, minibuses, and private cars. The streets of the developing countries are also full of heavy motorized vehicles, including buses, trucks, and tractors. In Latin America, for example, public buses are the dominant transport mode in most large cities. Importantly, moreover, much of the transportation service in the developing world is provided by the private sector and receives no public subsidy.

At the same time, urbanization patterns in developing countries are in many ways following the model established by developed economies. With the inevitable growth in urban populations, residents are increasingly locating on cheaper land in the urban periphery. Frequently, moreover, changing residential and intercity transportation patterns also induce a substantial decentralization of employment. In general, suburbanization is associated with an increased reliance on motor vehicles and an increase in the number of cars per household, both of which raise the overall level of motorization further.

Finally, despite many similarities among developing-country megacities, it should be emphasized that their motorization levels and modal shares for different types of transport differ widely. In Latin American countries, for example, few people use bicycles, while in Mexico, Argentina, Uruguay, and Brazil, as many as a third of all urban residents own private automobiles. This situation is dramatically different from that of China or India, where bicycles are very prevalent, and a much smaller percentage of the population uses public transit or has access to private cars. Analysis of these patterns must be a basic component of any transportation plan or investment for a particular megacity. The options discussed in the sections that follow may or may not be appropriate for a specific urban setting.

The differences between developing- and developed-country cities elaborated above suggest that planning and investing in an automobile-dependent transportation system will be even more costly and difficult in the former than it has been in the latter. At the same time, greater reliance on nonpolluting modes of transportation in developing-country cities, coupled with strong integration of residential and economic activities, suggests those cities may be in a position to avoid some of the most costly mistakes of transportation investment in the industrialized countries. The thrust of this chapter is not to persuade developing countries to accept inferior transport to that of developed countries or to have any lower aspirations for

personal mobility. Rather, while we recognize that increased motorization is desirable, we emphasize that choosing transportation policies differently might well result in a more efficient urban form than many western cities have been able to achieve. It should also be emphasized that this paper is aimed primarily at megacity leaders and policymakers of the developing world. Thus while the discussion is firmly grounded in the literature, it is not focused at a technical level.

IMPROVED TRAFFIC AND DEMAND MANAGEMENT

Traffic and demand management measures attempt to increase vehicle speeds on existing transportation system infrastructure through technological improvements and traffic adjustments, financial restraint measures, and physical restraint measures.

Technological Improvements and Traffic Adjustments

A broad range of technological improvements and traffic adjustments can be implemented to improve the efficiency of vehicle flow in urban or congested areas. These measures include traffic signal synchronization, on-street parking bans, one-way systems and reversible-flow traffic lanes, time segregation of freight deliveries (providing incentives to businesses to schedule freight deliveries during less congested evening hours), high-occupancy vehicle lanes, work scheduling, incident response services, improvements in street conditions, and improved training of engineers and traffic police. Below we discuss a subset of these measures that seem to be particularly appropriate for developing-country megacities.

Traffic signal patterns can play a key role in improving traffic flow in city centers. In many urban areas, traffic signals are synchronized to produce a relatively smooth flow of traffic by minimizing the number of stops and delays and maximizing average speeds. Shorter traffic signal cycles can also improve traffic flow.

Unrestricted on-street parking (or on-street parking available because of unenforced restrictions) occupies road space and causes drivers to obstruct traffic flow while searching for parking. At the same time, large supplies of low-cost center city parking can encourage private vehicle travel and contribute to increases in traffic volume. Complete on-street parking bans in center cities, if enforced well, can improve traffic flow by offering more road space for moving vehicles (Pucher, 1988). For cities requiring a more intermediate solution, one method of restricting on-street parking is by providing metered space, which also raises revenue for the city. (See also the discussion of off-street paid-parking facilities in the subsection on financial restraints below.)

To satisfy growing demand within existing infrastructure, cities can opt to implement a system of one-way streets to manipulate demand during peak traffic periods. One-way systems

require fewer stops on heavily traveled routes and can use road space more efficiently, especially if they are implemented on major commuter routes during morning and evening hours. Another way to increase available road space is to create reversible-flow general traffic lanes that change direction according to peak-hour requirements. A number of cities have introduced with-flow or contra-flow bus-only lanes with good results. Other measures include regulations that provide for bus- and tram-only cross-traffic turns and give priority to buses and trams at traffic signals. Despite opposition from motorists, these schemes often provide benefits for all road users, including operators of private cars and commercial vehicles, as well as buses and trams. In some cases, with no reduction in general traffic speeds, reserved bus lanes have permitted bus journey speeds to increase to more than 20 kilometers per hour (Armstrong-Wright, 1993).

Roads with poor driving surfaces or illegible street signs are common in developing-country cities and greatly hamper transport system performance while leading to safety hazards, premature aging of vehicles, inefficient fuel use, and increased pollution. Improving street conditions by eliminating potholes, paving roads, and posting legible signs is a cost-effective way to enhance road travel. Bus lanes, pedestrian facilities, and nonmotorized transport lanes should be properly marked and, if appropriate, physically separated from facilities for private motorized modes. Separation not only improves safety for all modes, but also smoothes traffic flow, raises awareness of the rights of different vehicles, and may even encourage travelers to switch to public or nonmotorized transport modes.

What is heartening about the traffic management measures discussed here is that they represent relatively simple improvements and/or modifications to existing transport systems that can improve traffic flows relatively quickly and inexpensively. Often, however, these measures are not implemented because traffic engineers are not aware of some of the more recent and successful modifications that can be made at relatively low cost, or because there exist institutional problems, such as a lack of authority to enforce changes in the traffic system or a lack of priority given to basic maintenance activities such as signage and road repairs. Road maintenance, in particular, is traditionally underemphasized by the public works department in many countries because it is a much less visible and prestigious type of expenditure than new highway or road construction.

Traffic measures such as the above can be implemented more effectively if they are combined with the improved training of engineers and traffic police--the individuals with primary responsibility for designing and implementing the traffic flow patterns prevalent in all cities. New design techniques and lessons can be communicated through workshops and training sessions, perhaps relying on video techniques or using data available from the WorldWide Web, and held in the developing countries themselves. In congested situations, manual control of signals and traffic flow is often the rule, and it is crucial that personnel be trained to handle these situations as well as possible. Providing such training is one way developing countries can improve traffic patterns in large cities for a relatively low cost.

Financial Restraint Measures

Road pricing, a financial method for traffic management, employs a market mechanism to encourage the use of higher-occupancy vehicles and more efficient use of road space. The basic idea of pricing the use of roads for revenue purposes is an old one. In many countries, turnpikes of the late seventeenth and early eighteenth centuries were built as private toll roads. During the modern era, numerous toll roads have been built by public agencies, and tolls have long been used to finance unusually expensive bridges or tunnels. A newer variation on this idea is that of congestion pricing, i.e., charging each motorist a fee that is directly related to the amount of congestion he or she causes in using a road. In other words, roads are priced according to demand, making it more expensive to drive during peak periods than during low-travel periods (Gómez-Ibáñez and Small, 1994).

One advantage of congestion or peak road pricing is that it encourages motorists to find many ways of reducing congestion rather than promoting only a few, such as public transit and carpooling programs. For example, flexible motorists can change the time of day, route, location, or frequency of their travel, as well as switch to other modes. In addition, congestion pricing applies to all motorists who are causing congestion during peak hours and not just to captive groups such as commuters.[1]

Area pricing measures represent a form of road pricing within specific physical boundaries that does not necessarily require sophisticated technology. Area pricing schemes charge drivers if they enter a designated area; normally, the driver must buy a pass in advance or pay a fee at a toll booth located at the entrance to the area. Yet it should be noted that area pricing schemes can result in traffic jams at collection points and should be implemented with alternative forms of downtown transport to protect downtown business activity.

Several urban centers have experimented with area pricing schemes to earn revenues for road construction. Singapore, however, developed an area licensing scheme in 1975 to reduce central city car traffic (Gómez-Ibáñez and Small, 1994). The scheme was initially limited to cars entering the central business district in the morning rush hour. Carpools of four or more people were exempt; other car owners who wanted to enter the center city area during the restricted morning hours were required to purchase a sticker in advance and place it on the windshield of their automobile. The program immediately reduced the number of vehicles entering the central business district during the morning rush hour and shifted many people's morning commuting habits.

Singapore has updated its area licensing scheme over the years through the implementation of a number of measures, including extending morning restricted hours, raising

[1] The economic theory underlying the concept of congestion pricing is well developed and argued by numerous authors. Some particularly accessible discussions are provided by Hau (1992a, 1992b) and Transportation Research Board/Commission on Social and Behavioral Sciences and Education (1994).

fees progressively, expanding the area in which the scheme is applied, putting restrictions on evening hours, eliminating the carpool exemption, and including motorcycles and taxis in the restrictions. The scheme was supported by necessary improvements in public transport, such as the expansion of the bus system, the installation of a rapid mass transit line, and the provision of park-and-ride lots. Further deterrents to driving were also introduced, including a 100 percent increase in parking charges at public car lots within the restricted area and very large increases in car purchase fees. The combined impact of these measures has been dramatic. They caused a 25 percent drop in peak period traffic, which has been sustained despite rapid economic and population growth. In addition, private car traffic entering the zone during the restricted hours was reduced by 70 percent, the share of buses in the modal split increased by 8 percent, carpool levels doubled, and emission levels within the restricted area were reduced by 30 percent.

There are several examples of peak road pricing methods that rely on advanced electronic technologies, such as those in use in Bergen and Oslo, Norway, and, most recently, in Los Angeles, California (Gómez-Ibáñez and Small, 1994; Ayres, 1996). Hong Kong was the first city to pilot test the technological feasibility of large-scale electronic road pricing between 1983 and 1985. Although the system functioned properly, political and administrative problems prevented it from being implemented.[2]

Despite Singapore's success with congestion pricing, and although most transportation economists, planners, and engineers believe that it is a excellent idea, experience in other democratic countries suggests that congestion pricing is likely to be introduced on a piecemeal basis. Nonetheless, congestion pricing is being implemented even in countries where political resistance to charging for roads has always been high.

Another market mechanism, off-street paid-parking facilities in city centers, can complement congestion pricing schemes, provide an incentive to drivers to use their cars more wisely, and make public transport more competitive. In addition, off-street parking can help eliminate the problem of parked vehicles infringing on travel space. Research in the United States (Shoup, 1994) suggests that individuals respond rationally to price signals implied by parking fees, particularly if the fees cover most of the full costs associated with driving and parking in a congested urban area.

In some developing-country megacities, there is currently a shortage of urban parking. In China, for example, there are few parking facilities available for private vehicles in most of the major cities. Given burgeoning demand for private cars, new auto owners are beginning to engage in searches for parking. The need for parking may will spark the redevelopment of urban parcels into parking structures as the prices bid for parking spaces rise. Redevelopment may, in

[2] Of particular concern to Hong Kong motorists were the high fees they would be expected to pay for using the roads, as well as the potential loss of privacy that might result from the capability of the government theoretically to monitor drivers' movements at all times. The policy change in Hong Kong may also have been the result of a new administration in the midst of reorganizing its whole fiscal program ahead of the anticipated events in 1997 (Gómez-Ibáñez and Small, 1994).

turn, exacerbate traffic congestion in Chinese cities as it has in other motorizing countries. When this process begins, it is very important to charge users for the full costs of both parking and congestion. Despite the apparent benefit of providing parking, an ample supply of free off-street parking can hurt urban transport by promoting private vehicle travel. Studies show that parking policy in the United States, for example, where 75 percent of commuters park in free off-street parking provided by employers, strongly favors automobile use.

Another complement to or possible surrogate for congestion pricing is gasoline taxation, particularly if the funds are spent to finance transportation improvements. Taxing of fuel is relatively transparent to implement, administer, and enforce. Taxation at the pump generally induces all drivers to consume less fuel and to use their vehicles more prudently than they would otherwise. Although taxing of fuel is a very imperfect proxy for congestion pricing, in many cases it may be the only practical measure in terms of enforcement and collection, particularly in the context of developing countries. In addition, if the revenues are dedicated to transportation investment and improvements, taxpayers are generally willing to accept the extra cost.

Physical Restraint Measures

In general, measures based on physical restraint of vehicle movement are more problematic and ambiguous in their outcome than the financial restraint measures discussed above. One of the most common physical restraint measures is heavy-vehicle restrictions, which attempt to minimize the congestion, noise and air pollution, and premature road deterioration these vehicles can cause. While such bans can be effective, they can also adversely affect urban business and commerce, and need to be coordinated with other shipping policies, such as limitations in delivery hours or transfers to more environmentally acceptable vehicles for local delivery.

Traffic flow has been reduced in some cities by dividing the central business district into cells. Cars can travel freely within one cell or zone, but must travel by an outer-ring road to enter the next zone. These zoning systems are designed to limit through-traffic on dense center city streets, increase city street safety, and reduce transport-related air and noise pollution in the center city. Public transport, pedestrian, and nonmotorized transport facilities can be developed to allow for travel between zones. The city of Gothenburg, Sweden, for example, developed such a cell system, which successfully decreased traffic accidents by 56 percent and lowered center city traffic volume by 45 percent between 1970 and 1982 (Organization for Economic Co-operation and Development, 1988). The completed first phase of a similar scheme in Tunis has produced promising results that may be replicable in other cities where spare capacity is available on routes bypassing the city centers. In other cities, the cost of providing additional capacity for intracity travel, together with the cost of additional fuel consumed in more circuitous journeys, needs to be carefully weighed against the benefits of reduced congestion and traffic accidents in the city center.

Several cities, such as Mexico City, Santiago, Chile, and Athens, Greece, have implemented day-long vehicle travel bans according to license plate numbers. Although somewhat successful in encouraging people to carpool or ride public transport, these schemes have faced many problems, including extreme public backlash. They also create a market for cheap, second-hand vehicles that are generally more polluting and less efficient than newer models and subvert the intent and the impact of the ban. Moreover, while vehicle bans may be effective short-term rationing measures to alleviate crisis situations, they also curtail demand indiscriminately without regard to the transport need to be met.

Overall, sophisticated measures of traffic and demand management, such as congestion pricing or zoning systems, are likely to be difficult to administer, while simple ones, such as vehicle bans, may have perverse side effects. Given these drawbacks, it is clear that successful traffic and demand management initiatives in developing-country megacities will depend on the development of better enforcement and regulatory capabilities. Developed nations may well be in a position to help with the development of these capabilities through assistance programs targeted specifically at improving the enforcement and regulatory departments of transportation ministries.

FULL-COST PRICING

Motorists impose different costs on one another and society. At a minimum, "full" costs would include charges sufficient to cover the cost of building, maintaining, and operating transportation facilities and the delay costs that users impose on one another in congested conditions (Transportation Research Board/Commission on Behavioral and Social Sciences and Education, 1994).[3] Full-cost pricing is often defined to include environmental, safety, and other costs that users impose upon others, but although a good deal of research is under way to develop estimates of the economic costs of environmental damage, there is not consensus on the appropriate economic value to assign to these kinds of costs.

Most countries underprice the use of roads in highly congested urban areas, giving individuals an incentive to rely on motorized transport, particularly private motorized transport, for getting to and from high-density central business districts. These subsidies have contributed to sprawling urban form, increased congestion, and environmental degradation. In addition to the financial measures discussed in the previous section, full-cost pricing can provide consumers with market-based signals regarding the use of motorized transport and, consequently, dampen demand for private automobiles.

Developing-country cities still in the midst of building their road infrastructure have the opportunity to set the price of various transport services equal to the actual cost of those services.

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[3] As indicated in Appendix B of Transportation Research Board/Commission on Behavioral and Social Sciences and Education (1994), economists distinguish between short-run marginal costs, such as delay and operating costs, and long-run capital costs of providing facilities; under a plausible set of assumptions, it can be shown that pricing highway investment needs according to short-run marginal costs will generate sufficient revenues to just cover the cost of providing new facilities.

Such full-cost pricing--charging users the full cost of transportation activities, including congestion costs--can influence the relationship between city form and urban infrastructure investment. Private automobile users in the developing world have relatively high incomes and can help pay the costs of the infrastructure they require for their vehicles. Moreover, fuel taxes that exceed the costs of road construction and operation--as are applied in European nations--can be justified based on the economic costs of air pollution (Small and Kazimi, 1995). Relying on such pricing measures to provide optimal incentives to individual households can help developing-country cities achieve better urban economies.

ENVIRONMENTAL MEASURES

One of the primary motivations for all of the transportation options discussed in this chapter is the contribution of motorized transport to environmental degradation, particularly with respect to air quality. Transport vehicles burning fossil fuels emit pollutants such as hydrocarbons (HC), nitrogen oxides (NO_x), carbon monoxide (CO), sulfur oxides (SO_x), suspended particulate matter, and lead. Moreover, when these pollutants combine, they are potentially more damaging than in their separate forms, and the adverse effects of all pollutants are intensified by the high concentration of motor vehicles and congested driving conditions in most urban areas. Many pollutants can damage human health as well as the environment, but the two most harmful types of pollutants are probably particulates and lead.

Studies released in the last few years indicate that particulates may be the most serious urban air pollution problem. By correlating daily weather, air pollutants, and mortality in six U.S. cities, scientists discovered that nonaccidental death rates are strongly correlated with daily levels of particulates, but not with other pollutants (Dockery et al., 1993). Other research in 15 U.S. cities indicates that sulfates and fine particulate air pol-lution are associated with a difference of 16 percent in mortality risks between the most and least polluted cities (Walsh, 1996). Certain particulates, including diesel particles, appear to be especially hazardous because of their chemical composition and extremely small size.

A growing body of data on the adverse health effects of lead, especially in young children, indicates there may be no Asafe@ level, and that lead in gasoline contributes to behavioral problems, lowered IQs, and decreased ability to concentrate in exposed children. The U.S. Environmental Protection Agency has also uncovered evidence linking lead in the blood and high blood pressure (Schwartz et al., 1985). In addition, the lead scavengers that accompany leaded gasoline have been identified as human carcinogens.

Inhabitants of cities in developing countries face greater risks from particulates and lead than many developed-country residents because the lead content of gasoline is usually considerably higher in the former countries (e.g., Thailand, Indonesia, Pakistan, and India) than in the latter (e.g., the United States or Italy) (Birk and Zegras, 1993). In general, the levels of local automotive pollution in many large developing-country cities are the source of considerable concern. They result from many of the same factors apparent in industrialized countries, including the content of the fuel, the level of vehicle technology, the level of maintenance and age of a vehicle, driving conditions within the metropolitan area, and the number of vehicles.

Unfortunately, in many megacities of the developing world, these variable factors are particularly conducive to high levels of pollutants.

Individual vehicle efficiency and emissions can be improved through improvements in fuel quality, advances in vehicle technology, and the adoption and enforcement of national standards. The actions that should receive the highest priority involve improved fuel quality, particularly the removal of leaded gasoline from urban roads, but the best and most successful strategies rely on a comprehensive approach, such as that adopted in Mexico City in 1990 (Walsh, 1996).

Integrated Program Against Air Pollution in the Mexico City Metropolitan Area

This program comprises 42 specific measures that include changes in fuel composition to reduce pollutant emissions from mobile sources, changes in the refining and distribution infrastructure for automotive fuels, new catalyst-forcing emissions standards for gasoline vehicles, replacement of existing taxis and minibuses with vehicles meeting emission standards, implementation of a vehicle inspection and maintenance program, improvements in parking and traffic management systems, and the authorization of new private bus routes. The program also encompasses a number of measures intended to develop data and analytical techniques that can support more effective air quality management, as well as measures to increase the supply of trained personnel to plan and execute air quality programs. Examples of the latter are a global air quality study being conducted in cooperation with the U.S. Department of Energy's Los Alamos National Laboratory and an epidemiological study intended to evaluate the health impacts of air pollution in the Mexico City metropolitan area.

Mexico's Integrated Program constitutes a major step forward in air pollution control in the Mexico City metropolitan area and appears to have been responsible for an approximately 50 percent improvement in CO levels over the last 5 years. Fuel improvements have led to the most significant progress to date, although important contributions have also been made by the adoption of stringent standards for new vehicles, especially passenger cars; the replacement of older taxis and microbuses with new catalyst-equipped ones; and the conversion of large numbers of cargo trucks to liquefied petroleum gas fuel using certified, closed-loop, three-way catalysts. Although severe air pollution problems remain, in the last 6 years Mexican officials have moved forward more comprehensively, quickly, and aggressively than has been observed in virtually any other city in the world.

Improved Fuel Quality

Fuels used in many developing countries are of a poor environmental quality and often contain excessive lead, in the case of gasoline, and excessive sulfur, in the case of diesel fuel. Besides being a direct health hazard itself, lead in gasoline eliminates the possibility of incorporating catalysts as a vehicle exhaust treatment technology because lead renders catalysts ineffective. Switching to low-lead or unleaded fuels is a very important and relatively easy way to reduce harmful emissions.

Governments are gradually requiring that gasoline sold in their countries contain less lead, as well as making greater use of unleaded fuels. In 1992, the Taiwanese government introduced unleaded gasoline and reduced the lead content of regular gasoline to below 0.12 gm/liter. In India, the lead content of gasoline will be reduced to 0.15 gm/liter by 1998, and lead content is scheduled to be progressively reduced to ensure lead-free gasoline by the turn of the century. With a few exceptions, such as Mexico and Thailand, progress in this area is quite slow, primarily because the costs of modifying refineries to produce unleaded fuel are high and immediate, while the long-term health consequences of continuing to burn leaded gasoline are not widely appreciated by consumers.

Reducing the Lead Content of Gasoline

In Thailand, largely as a result of the deteriorating air quality in Bangkok, the national government supported the introduction of reduced-lead and unleaded gasoline in 1991. As of January 1996, the use of unleaded gasoline has been mandatory. The government has encouraged demand for unleaded fuel by using a tax subsidy to make it cost-effective for local refiners to produce unleaded gasoline. Reduced-lead gasoline is taxed 10 percent less and unleaded fuel 25 percent less than leaded fuel. In addition, the government recently decided to reduce the sulfur level in diesel fuel from the current 0.5 standard to 0.05 by the year 2000.

Indonesia, with abundant oil reserves and a well-developed refining industry, is also in a good position to reduce the lead content of its gasoline. The country's government introduced gasolines with reduced lead content in 1989 and unleaded gasoline in 1994. A recent study in Indonesia indicates that unleaded fuel and the substitution of natural gas for gasoline are economical for that nation because of their effects on health-related costs (World Bank, 1993). Compressed natural gas, in particular, is an attractive alternative for countries like Indonesia that have natural gas supplies, since it can be burned in gasoline-powered engines with only minimal adaptation. About a half-million vehicles worldwide, about half of these in Italy, currently operate on compressed natural gas. Vehicles optimized for natural gas would generally have about 10 percent greater efficiency than gasoline vehicles, create less pollution, and have lower fuel costs, but would cost about $700 to $1000 more up front because of the need to install high-pressure fuel tanks (Sperling, 1995). Conventional vehicles powered by natural gas or alternative fuels are, at best, an incomplete answer to the problems of vehicular air pollution, but can represent an improvement in terms of the levels of greenhouse gases and critical pollutants emitted relative to gasoline-powered transport.

Without lead, refiners must raise the octane levels in gasoline through more costly measures, such as improved refining techniques and the addition of other high-octane blending components. This increases the cost of fuel at the pump, which represents a problem for car owners in most developing countries. However, despite the barriers involved, unleaded gasoline is available in most industrialized countries. Many other nations, such as Brazil, Chile, Korea, and a number of Eastern European countries, are expanding the availability of unleaded fuel, with plans to mandate its use in the future.

The most direct strategy for eliminating lead in gasoline is to ban its use; several countries have adopted this approach. Failing a ban, the production of unleaded fuel and alternative fuels, such as compressed natural gas, can be actively encouraged by governments motivated to improve air quality. The promotion of unleaded gasoline, for example, is relatively straightforward, and a number of countries have devised ways of encouraging existing refineries to modify their systems sufficiently to produce unleaded fuel. Thus, passing laws that require all new motor vehicles to use unleaded fuel while at the same time increasing the price of leaded gas relative to unleaded gas or alternative fuels can make a major improvement in urban air quality for a relatively small cost.

It is desirable for the introduction of cleaner fuels to be accompanied by appropriate pricing strategies that acknowledge the costs of environmental damage caused by motor vehicle emissions. Taxing fuel, particularly leaded fuel, at a high rate also has the effect of lowering emissions simply because of its effect on consumption of gasoline. Recent research by Eskeland (1993) in Mexico City, for example, finds that a gasoline tax can reduce the cost of emission reductions by as much as 24 percent if the gas tax rate is set appropriately. Eskeland argues that the use of both technical controls, such as catalytic converters and the use of cleaner fuels to make cars cleaner, and a gasoline tax, to give users an incentive to economize on the use of cars, mimics the incentives that would be provided by an emissions fee--the most efficient albeit currently impractical way to reduce the level of emissions from motorized vehicles.

Finally, taxing fuel and requiring all new vehicles to use unleaded fuels require relatively less reliance on enforcement mechanisms than do other types of strategies. These measures are straightforward, can be implemented easily and uniformly across a wide geographic area, and do not need to rely on trained staff or sophisticated equipment to achieve their ends.

Vehicle Technologies

In addition to improved fuel quality, new emission and propulsion technologies can play a large role in improving urban air quality. In North America, Europe, and Japan, catalytic converters are, of course, widely used as the technology to limit HC, CO, and NO_x emissions from gasoline-powered engines. In addition, the combination of lead-free gasoline and catalysts can facilitate very substantial reductions in other harmful pollutants, such as aldehydes and polynuclear aromatic hydrocarbons. These emission reductions can occur simultaneously with equally significant improvements in fuel economy and reductions in vehicle maintenance. Based

on studies in Canada, reduced maintenance with the use of unleaded as compared with leaded gasoline can save about 2.4 cents per liter (Walsh, 1996).

Other available technologies for reducing emissions in gasoline-powered cars include the recirculation of exhaust gases, ventilation canisters for capturing evaporative emissions, electronic control of engine performance, and advanced combustion techniques. In two-stroke motorcycles, which comprise a large portion of Asian vehicle fleets, timed fuel injection and catalytic exhaust aftertreatment can significantly reduce emissions. In the case of vehicles that run on diesel fuel, emissions can be controlled by changes in engine design and combustion characteristics and the use of catalytic converters (Faiz et al., 1990). Many emission-control technologies, such as better fuel injection, can improve fuel efficiency by decreasing the amount of fuel consumed. In the long run, we can look forward to technologies, such as electric and fuel cell vehicles, that create no emissions on city streets.

In some regions, particularly in countries with substantial supplies of hydro or nuclear power, the use of battery-powered electric vehicles may be highly attractive since electric vehicles will generally be recharged in the evening, when electric power plants are otherwise underused and the cost of supplying electricity is lower. Electricity supply at night tends to be more reliable in developing countries than that during the day because of lower demand. In Sao Paulo, electric buses, an essentially pollution-free alternative, have been in use for years, although they have not gained in importance mainly because of political and economic problems. Increased reliance on electric buses would result in substantial improvements in air and noise pollution (Walsh, 1996). Small electric vehicles, such as rickshaws and microcars, also hold promise for developing-country megacities because they use far less energy than cars, and thus do not pose the battery limitations that currently represent a major barrier to widespread production and use of electric cars in industrialized nations.

Taiwan's Environmental Protection Agency recently mandated a 5 percent market share for electric motorcycles by 1998 in an effort to limit air pollution caused by the high number of motorcycles, many of them with two-stroke engines, in that country. The mandate accompanies strict emissions standards applied to all new motorcycles sold in Taiwan (as of 1993) and a motorcycle inspection and maintenance system. Zero-emission (electric) motorcycles are already available in Taiwan, but although they are priced similarly to gasoline-fueled bikes, sales are very low. Public resistance is related to poor performance and difficulties in recharging; many Taiwanese live in apartments and are unable to leave their motorcycles on the street at night and still recharge them. To encourage consumers to buy electric motorcycles, the government grants a tax rebate equal to approximately a sixth of the purchase price of the electric motorcycles and is developing infrastructure that will allow consumers to replace run-down batteries with fully-charged batteries in a matter of minutes (Walsh, 1996).

Given California's well-publicized 10 percent zero-emission vehicle mandate in 2005, electric vehicle technology is advancing rapidly. All major car manufacturing companies have begun to develop prototype vehicles, and the expectation is that small, affordable electric

vehicles will become a reality soon. Electric vehicles emit much less pollution while greatly reducing the use of petroleum in almost all areas, except those that rely on coal-fired power plants at night (Wang et al., 1990). Electric vehicles would also tend to more reliable, last longer, and require less maintenance than conventional gasoline-powered automobiles, although this might not be true of the first generation of vehicles. In addition, electric vehicles could offer the opportunity for the creation of a new industry and new jobs.

Fuel cell vehicles also hold promise for improving the air quality of megacities within the next two decades (Sperling, 1995). A fuel cell is a device that transforms hydrogen and oxygen into electricity; unlike a battery, which stores energy, the cell produces electricity through a continuously supplied source of fuel. Fuel cell vehicles would consume about half the energy of conventional gasoline-powered vehicles, emit no pollution or greenhouse gases, and run more quietly. Early models may run on petroleum fuels, methanol, or hydrogen made from natural gas, but scientists hope that eventually, these fuel cell vehicles will run on hydrogen made from water using solar energy.

Development of Fuel Cell Vehicles

Fuel cell demonstration projects are under way in the United States and Europe. General Motors and Daimler Benz both have major fuel cell vehicle projects. Perhaps the most advanced research is a bus project developed by Ballard Power Systems of Canada in collaboration with several other Canadian and U.S. companies. The first bus, completed in June 1993, is a 32-foot transit vehicle powered by compressed hydrogen and a Ballard proton-exchange membrane (PEM) fuel cell. A second-generation bus using more advanced PEM fuel cells and compressed hydrogen, possibly to be supplemented with a battery for peak power, is scheduled for completion in 1996. In addition, several fuel cell buses and smaller vehicles are under construction in various industrialized countries. While these technologies will not be widely available or affordable for some time to come, a great deal of progress is being made, and the governments of developing countries should consider policies that encourage the development and use of alternative technologies as they modernize their vehicular fleets.

National Standards

National standards can be an important complement to fuel quality and vehicle technology measures. Vehicle emission standards are almost always implemented at a national, rather than provincial or regional, level, usually because automobile markets in most countries are relatively small and because it is more difficult to administer and enforce regional than national standards. Many industrialized countries have regulations and incentives to promote reductions in individual vehicle fuel consumption. In Australia, an agreement between the

government and the automotive industry to increase the fuel efficiency of domestic vehicles decreased the average fuel consumption of new passenger cars by over 20 percent between 1979 and 1988. A number of governments have successfully implemented policies for reducing vehicle emissions. The United States, for example, passed the Clean Air Act in 1970, which forced automobile manufactures to reduce vehicle emissions substantially.[4] Some governments in developing countries, including Mexico, Korea, Thailand, India, and Brazil, have in place standards requiring that new vehicles not exceed certain emission levels.

In China, the National Environmental Protection Agency has already issued 11 motor vehicle emission control standards and formulated a Management Procedure and Technical Policy for vehicle emission control.[5] The implementation system in China, however, is quite different from that in other countries, which may explain why a complete set of standards for new and existing motorized vehicles has yet to be formed. In spite of efforts to date, the air quality in most major Chinese cities has not improved and may well be declining. In some cases, for example, national standards do not account for the more stringent needs of extremely polluted urban areas.

In many other developing countries, as noted earlier, enforcement of legal requirements is much more problematic than is the case in industrialized countries. While vehicle technology advances hold great promise for improving vehicle emissions and efficiency, urban areas in developing countries usually have little control over the average vehicle technologies that actually operate on their streets. The technology level that prevails in an urban area results from the individual consumption and maintenance decisions of the motor vehicle operators and depends critically on the incomes and choices available through the marketplace. An urban area generally lacks the political or economic clout to force automobile manufacturers to change the technological composition of the vehicle fleets they offer for sale. However, since most developing nations still import the majority of their motor vehicles, many may soon have a large enough vehicle population to demand that manufacturers meet certain standards. It is very important that these nations develop the enforcement capability required to ensure compliance.

A key complementary element of effective national standards is the implementation of improved vehicle maintenance. It is widely acknowledged that strategies to improve the maintenance of older vehicles can be a very effective tool for reducing emissions and improving fuel economy. Many countries in the developed world have yet to implement effective vehicle

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[4] The act's maximum automobile emission standards have been progressively tightened over the past 30 years, and manufacturers have successfully reduced automobile exhausts of the most toxic emissions by 70 to 90 percent (Birk and Zegras, 1993).

[5] The National Environmental Protection Agency of China is in charge of formulating and revising the standards for controlling major vehicle emission pollutants, while local Environmental Protection Bureaus are responsible for supervising and putting emission standards into effect. A number of standards, including emission standards for smoke and pollutants at idle speed from vehicles with either gasoline or diesel fuel, were implemented as early as 1983. Most of these standards were revised in 1994, including standards regarding the exhaust and evaporative emissions of both light and heavy gasoline-fueled vehicles. Motorcycle emissions came under control as of January 1996. To reduce CO and HC by 30 percent on medium- and heavy-duty gasoline-fueled vehicles, exhaust emission standards for these engines were put into effect at the beginning of 1995 (Walsh, 1996).

maintenance programs, while several developing countries, such as China, Thailand, and Mexico, have implemented maintenance programs with varying degrees of success. The impact of maintenance strategies seems to differ according to the institutional structure and political desire to implement strong testing programs, along with enforcement mechanisms. While vehicle maintenance programs hold promise, therefore, they may not make a great deal of difference to air quality and fuel economy in the short run without substantial institutional reform.

Although fuel efficiency and emission standards can promote significant reductions in energy use and emissions, it should be noted that with rising incomes, people tend to drive more and to purchase larger vehicles, thus offsetting the benefits achieved by such standards. Thus standards must be part of a mix of solutions that includes taxes and other measures to restrain traffic growth.

PRIVATE-SECTOR PARTICIPATION

As discussed earlier, in most large cities within both industrialized and developing countries, transportation services are underpriced. Transit, i.e., buses, metros, and light rail, is often heavily subsidized because of political concerns that higher transit prices might cause widespread dissatisfaction, as well as a genuine belief that commuters cannot afford higher fares. Roads and highways are often provided for free to both motorized and nonmotorized vehicles. At the same time, cities in the developing world tend to be dramatically underserved in terms of the capacity of their transportation systems. Funds for the construction and maintenance of urban and rural roads are not available, and the resources devoted to public transportation rarely keep pace with inflation.

To help address these financial problems, many countries have recently turned to private suppliers to provide services formerly offered by public agencies. Interest in shifting to the private sector is based on the understanding that doing so would increase efficiency and/or tap new sources of funds to supplement the constrained resources of the public sector. The private sector is thought to be inherently more efficient than the public sector, and many argue that a private contractor, motivated by profit, is more cost-conscious and customer-oriented than a public enterprise. In addition, privatization offers the potential for financing infrastructure without overt increases in taxes since infrastructure can be supported by user charges. In fact, it has become a tenet of current development literature that provision of infrastructure services can be left increasingly in the hands of the private sector.

On the other hand, the efficiency and financing arguments in favor of privatization may not always reflect reality. A newly privatized state enterprise, for example, will not be more efficient if it operates in a monopoly or noncompetitive situation. Similarly, subcontracting the provision of services to a private firm may not reduce costs if the bidding process is biased or uncompetitive. Furthermore, private service provision may not increase the level of investment

that is possible. A public agency can frequently issue bonds secured by revenues from infrastructure facilities, much in the same way that a private firm will raise capital. The process of privatization can create winners and losers, and the underlying complexities posed by any privatization efforts must be carefully and thoughtfully analyzed.[6]

Nonetheless, the positive cumulative experience in the field of transportation supports further reliance on privatization, particularly in instances where it is possible to introduce important elements of competition, such as bus or bus-like services or toll highways. In addition, there is room in most developing countries for levying charges on developers for the provision of urban infrastructure, including a much-expanded application of beneficiary principles.[7]

Opportunities Within Bus Transport

Buses are the primary form of motorized public transportation in most cities of the world; frequently, buses have higher ridership than all other public modes combined.[8] Urban bus services are particularly important in cities of developing countries, where buses typically represent 50 to 80 percent of all motorized trips. Good bus transportation can help meet the aspirations for a motorized mode in many developing-country cities. It is very important in emerging megacities, not only because so many people are dependent on buses to get to work, but also because good bus service has the potential to help forestall unnecessary growth in automobile traffic.

Almost all developing countries have experienced several forms of ownership and regulation of urban buses. Typically, urban bus services in developing countries are provided through a system comprising a mix of publicly and privately owned vehicles. Frequently, the conventional-sized buses are operated by a publicly owned corporation, while private firms provide significant minibus services. In recent years, however, public bus services in the majority of large urban areas of the developing world have suffered declining effectiveness and viability, and have been unable to cope with the growing demand for urban transport. In most cities, the gap has been readily filled by private operators, who command a far greater share of the market. The World Bank recently completed a series of studies indicating that the private sector accounts, on average, for more than 75 percent of all bus trips in the developing world, as well as all paratransit trips. In Karachi, Pakistan, for example, the public bus company, Karachi Transport Corporation, is responsible for only 18 percent of all public transport trips, while the remaining 82 percent is provided by private enterprises operating medium-sized buses,

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[6] The following discussion relies primarily on Chapters 3 and 15 of Gómez-Ibáñez and Meyer (1993), a recent and extremely thorough discussion of international experience with transportation privatization efforts.

[7] Beneficiary principles involve requiring those who benefit from or impose additional marginal costs on an urban area to pay for those costs.

[8] The most important modes include conventional-sized buses (with 35 or more seats) and a variety of paratransit modes, including the minibus (which has 30 or fewer seats and sometimes as few as 10 to 15) and several close relatives of the minibus, such as the shared taxi or jitney.

minibuses, taxis, and rickshaws (Armstrong-Wright, 1993). And although public bus corporations continue to supply a large share of transport services in China and India, the importance of private operators is increasing rapidly even in these countries.

Private firms have such a large share of the market mainly because of their ability to hold costs down by reducing waste and overhead, as well as employing a minimum of staff. Public corporations, in contrast, are often dependent on revenue from government subsidies and are burdened with very large workforces, as well as higher wage rates and greater farebox revenue leakage. Consequently, the costs of public corporations are roughly double those of the private-sector bus and minibus operators functioning on the same routes and under the same conditions (Armstrong-Wright, 1993). Even in cases where the private and public entities charge the same low fare, private operators are usually able to make small profits even while the public corporation must absorb substantial losses.

Often governments are aware of the deficit problems facing their public transport companies and attempt to privatize transportation services or, more commonly, allow other, less-regulated and privately operated modes, such as minibuses, fill the gaps not provided for by the public companies. Privatization frequently permits cities in developing countries to eliminate or check growth in transport subsidies while maintaining or expanding service, largely because of the cost differences between private and public providers. In Jakarta, for example, both the public company, the Penang Kutan Penumpand Djakarta, and one private firm operate conventional buses, while the other private firms operate minibuses. The public and private firms all charge the same fares, but the public firm needs a 50 percent subsidy, i.e., US $30 million per year, while all the private firms make a profit (Armstrong-Wright, 1993). In a few cases, such as in Khartoum, Sudan, a private operator of conventional buses apparently charges even less than the public operator. Sometimes, private firms are allowed to charge a higher fare in return for an expansion of service, as in Rabat, Morocco, and Kingston, Jamaica.[9]

Gómez-Ibáñez and Meyer (1993) identify three main types of privatization reform within the bus sector: privatization accompanied by some public regulation (particularly for fares), privatization without fare regulation, and privatization accompanied by maintenance of subsidies for unprofitable routes. Overall, privatization with route and fare regulation can benefit all parties. Taxpayers benefit because the burden of public bus subsidies is generally reduced, while riders probably benefit much of the time, especially where services have been expanded as a result of the introduction of private operators with little or no increase in fares. Finally, labor may not lose much, or it may gain, because service expansion often implies more jobs, though sometimes at lower wages.

Privatization with fare deregulation has been attempted in far fewer countries. Colombo, Sri Lanka, and Santiago, Chile, are the two most commonly cited examples. In 1979, the

[9] Bus service in terms of number of vehicles improved somewhat in Kingston, Jamaica, but still remains inadequate by most other measures or standards of service (Gómez-Ibáñez and Meyer, 1993).

government in Colombo permitted private operators to offer bus services largely free of fare and route regulation, but maintained the existing publicly owned bus company (the Central Transport Board). In Santiago, a publicly owned bus company that shared the market with regulated private operators was disbanded in 1980, while government fare and route regulations covering the private sector were also relaxed. In neither city were subsidies for unprofitable routes made available to private operators, although the Central Transport Board in Colombo continues to receive large subsidies.

The results of these two experiences are mixed. In Colombo, while some private operators resorted to overloading and did not serve some of the city's most unprofitable routes, ridership increased greatly, and deregulation stimulated a large increase in capacity and bus frequency. Fares did not increase significantly, apparently because of the Central Transport Board's policy of maintaining extremely low fares on its buses, which limited the private operators' ability to raise their own fares. In Santiago, the reforms brought about a dramatic expansion in public transport capacity, which was initially accompanied by large fare increases for some forms of transport, particularly buses, microbuses, and taxicabs. This occurred because these transport modes were subjected to a series of anticompetitive controls enforced by their very strong route associations. The problem was corrected through the introduction of a competitive bidding process that determines which buses will have the right to service downtown routes. As a result, bus fares in Santiago are currently determined by the market and are close to prices charged prior to deregulation.

While several lessons emerge from the cumulative international experience with privatization of urban bus operations, the most important by far is that the benefits depend critically on whether effective competition can be established and maintained in the industry. When competition exists, privatization can reduce costs and improve the quality of urban bus services; without competition, such reforms may bring little improvement and conceivably even degradation in service, as well as unwarranted increases in fares and excess capacity as route associations abuse their monopoly positions.

The prospects for effective competition among private bus operators are far greater in the developing than the developed countries. The striking feature of bus service and paratransit in the major cities of developing countries is the huge number of small private operators, at least where local governments have not severely restricted entry. Minibus service is usually provided by independent operators. Competition is often further enhanced because the minibus and standard bus operators compete not only with one another, but also with other kinds of shared-ride paratransit, including taxis, jitneys, motorized tricycles, cyclos, and rickshaws.

Although the competitive prospects are greater in developing countries, the public sector is still required to maintain or even create conditions that enhance or mimic competitive situations. Government entities can, unfortunately, be as much at fault in suppressing competition as route associations. Sometimes, governments involved in the management of large cities in the developing world are open to the notion of private conventional transportation at the same time they try to regulate market-based informal transit out of existence. Paratransit vehicles maneuver into areas where standard buses cannot go and provide frequent door-to-door service at a profit. Research indicates that the greatest variety of paratransit modes is found

where there is the least amount of road capacity per capita, and is more prevalent in cities with poor road hierarchies (Cervero, 1991). Given that paratransit addresses a clearly expressed market demand, and given the importance of the informal sector to the transportation sector's competitive environment, it is critical that governments not suppress informal transportation alternatives at the same time they try to privatize formal transport.

Other Opportunities

Privatization of other transportation services in developing countries is less common and more ambiguously successful than is true of urban bus privatization. For example, relatively few developing countries have tried to experiment with private road provision. In general, the experience of developing countries in this area illustrates two problematic issues in infrastructure privatization: the desire of the public sector to access private capital markets and the need to balance investor and user concerns in designing regulatory schemes. Developing countries are somewhat paradoxical in this respect. On the one hand, the argument that privatization might increase overall investment in the economy by providing access to new capital is more credible in developing countries because their capital markets are typically less sophisticated and integrated with world capital markets than is the case in industrialized nations. On the other hand, the regulatory environment is often uncertain and more risky in developing countries, making it difficult to attract new outside investors.

The Mexican Experience with Road Privatization

Mexico has a mixed record of success in road privatization despite devoting considerable resources and attention to the privatization of its federal toll road authority. Mexico had hoped to attract a great deal of new foreign private investment to the country by relying on build-operate-transfer schemes to create a nationwide system of toll roads. Build-operate-transfer agreements require the private firm or firms involved in a project to build and operate the service or facility for a fixed period of time and then transfer it to the public sector. Frequently, such arrangements require government guarantees or subsidies and have had mixed success, although they can also act as isolated arrangements allowing more flexible procurement and contracting in circumstances where a more general reform of public-sector arrangements is not possible. While the build-operate-transfer approach for very large-scale projects, as is now the vogue, is problematic because of the complicated assurances required by multiparty investment groups, it may represent a solution for more modestly sized transit systems.

In Mexico, build-operate-transfer agreements were created to furnish toll road infrastructure. As of 1995, however, only 3 of the 53 road concessions that had been bid out were actually functioning as commercial enterprises. The other 50 projects are being restructured in various ways to sort out problems associated with poor concession practices. As is true for many developing countries, Mexico faces special burdens in the area of medium- and long-term financing and investment instruments because its political and regulatory traditions are not as well developed or understood as those in industrialized countries, especially by foreign investors. Thus the places where access to capital markets might be most improved or enhanced through road privatization are also the places where the regulatory and political environment makes tapping new markets exceptionally challenging.

In Malaysia, the government has granted a concession for the construction of a major north-south highway, and the concessionaire is relying primarily on loans either directly from or guaranteed by the government. Since the government has limited credit on domestic and international capital markets, the concessionaire's road investments come at the expense of some other government-financed or -guaranteed investments. If the regulatory environment had been less risky, it might not have been necessary to induce private-sector participation through the use of government guarantees. Thailand seems to have done better than Malaysia, although its record is mixed as well. The private developer involved in the construction of a major expressway through Bangkok apparently made investments that provided the Thai economy with access to new capital; nonetheless, a good portion of the expressway was financed by the domestic capital market and not through greater reliance on external capital.

Developer Participation

Most developing-country cities do not apply beneficiary principles, and as a result basic infrastructure is often poorly and inadequately supplied. Within industrialized nations many of the newest urban areas, particularly in Hong Kong and the United States, rely on private developers to supply a substantial portion of urban infrastructure as part of private development projects. The developer is often required to pay not only for the cost of installing roads, sidewalks, water and sewage connections, and the like in a new development, but also for the additional marginal costs the development will impose on the current systems of transportation and other basic public infrastructure. Land impact fees, as these charges are called, often make up part of a mandatory developer contribution that must be paid into the coffers of the municipality before the development is approved. In most instances, these charges or the developer contributions are based on beneficiary principles.

Beneficiary principles can be applied in many different forms. For example, in some settings, urban areas have relied on betterment taxes, which tax residents who benefit from a particular public investment, such as a new road or public transit system, by an amount proportional to the benefit they receive. Often the benefit is based on the amount of appreciation a residence or business is estimated to have undergone as a result of the public expenditure or investment. Other urban areas, primarily in Asia, have used land consolidation schemes to recoup some of the expenses associated with public infrastructure investment. Land consolidation requires that individual property owners give up a small portion of their land to the public sector in recompense for the benefit they receive from the development of their rural property into urban land supplied with adequate infrastructure.

LINKAGE OF LAND-USE PLANNING AND TRANSPORTATION INVESTMENT

The relationship between land use and transportation is a key factor in understanding the nature and evolution of urban spaces and, as such, has extremely important policy implications for megacities. Indeed, a strong linkage between the two can help avoid many of the problems of urban motorized transport that necessitate the other measures discussed in this paper. Transportation investments are among the largest of public investments, and their anticipated impacts play a key role in the both the current and future development within a city. Yet in many megacities, particularly those in the developing world, there is a distinct lack of linkage between land-use planning and the existing or even planned transportation systems.

Institutional weaknesses are a probable cause of the poor linkages between land use and transportation policy in many megacities. Some megacity governments lack the legal and fiscal capacity to guide urban development through transportation investments. In Bangkok, for example, it used to take up to 7 years to expropriate land legally for a transportation investment as common as an extension of a distributor road (Daniere, 1995). Others lack adequately trained staff or the support of policymakers to actually implement urban land-use plans in the face of rapid economic growth. As such, any improvements in the linkages between land use and transportation policy will most likely need to be preceeded by institution strengthening, as well as legal reforms.

Consequences of Poor Linkage

The rapid growth of urban populations, coupled with limited land-use and transportation planning, is responsible for a number of important inefficiencies, including the loss of land through hopscotch development, ribbon development along major urban highways, and extensive unplanned road systems. Urban sprawl increases the cost of all infrastructure, including transportation, and decreases the positive economic gains associated with the agglomeration economies of urban areas.

Weak linkage between land use and transportation is also strongly related to increased congestion within the city center. Congestion in megacities is particularly burdensome for the poor, who often spend 3 or 4 hours a day commuting to their place of employment from homes located in relatively inaccessible parts of the city to or through an increasingly congested city center. On average, households in large urban areas of developing countries devote up to 10 percent of their urban household income on transport. Low-income households often spend even more; in the Saket residential area of New Delhi, for example, low-income groups spend as much as 15 percent of their total income on transportation (World Bank, 1986). Land-use planning to reduce trip lengths can help minimize increases in vehicle miles traveled, thus improving productivity, decreasing the costs of commuting and fuel consumption, and improving the health of urban residents.

Opportunities for Improved Linkage

A number of observers argue that many transportation problems in the future will be alleviated by the current revolution in telecommunications and information technology. Improved telecommunications has the potential to allow megacities to leapfrog certain infrastructure developments that were required in the West. In particular, megacities may be able to invest in fiber optics at the expense of public roads, highway, and transit, and still compete effectively in the global economy. Others have argued that the telecommunications revolution may well result in increased urban sprawl, raising the costs of urban transportation infrastructure, because people will be less limited in their choice of location than in the past and choose to locate their homes in increasingly remote places.

Presently, the potential impact of telecommunications and information technology on transportation systems is speculative at best. What is much more certain is that in the next 10 years, megacities will become swamped by the use of private automobiles and that most urban residents will remain poor. Transportation policy must be based, at least in the short run, on these two realities. This is not to suggest that the potential impacts of telecommunications should be ignored by policymakers in developing-country megacities, but rather that those impacts should be considered as part of all housing, employment, and transportation strategies that include an element of telecommunications. In addition, land-use plans can be designed to accommodate advances in technology as they become viable and affordable, particularly in terms of impact on transportation needs.

Planning, which includes consideration of low-income housing, roads, public transit, and potential employment sites in advance of private-sector-led initiatives, also represents a potential long-run improvement in urban form. For example, research by Maunder in India suggests that restructuring land use by locating the place of work as close as possible to the workers' residences (or vice versa) could lead to a 30 percent reduction in the number of trips by bus and more than a 100 percent increase in trips by bicycle and walking. Improved land-use patterns can thus enhance some of the basic objectives of governmental policy, including improving both productivity and environmental conditions.

In some urban areas, the central business district has faded from overall importance in urban activity. As people move from the city to the outskirts, many jobs, industries, and shopping centers follow the migration, leading to completely new living environments and travel patterns. Indeed, some of the most recently formed urban areas have bypassed the formation of a traditional central business district; instead, these areas comprise a series of small-scale urban centers linked by roads that shuttle people and goods. The new trip patterns evolving from these decentralized urban areas have often overwhelmed existing transport networks designed for traditional central business district commutes.

Although dispersed urban forms can result in new and complex traffic congestion problems, they offer the opportunity to create highly transport-efficient communities. If

multiple-center, polynucleated urban areas comprise mixed land uses at relative high densities, walking/bicycling for short trips and mass transit for longer trips can become the major travel modes. Planners and analysts suggest that such urban structures, if planned in conjunction with public transport, housing, and labor markets, as well as the established characteristics of the existing urban area, can strengthen regional employment centers and reinforce commuting patterns supportive of mass transit (Haines, 1986). Megacities, in particular, could be guided by or planned with a polynucleated urban structure, with each nucleus as a self-sufficient center and clearly emphasized satellite centers as the nodes in the public transport system. Land-use planning and density patterns affect not only the travel mode people choose, but also their travel habits. Research suggests, for example, that people traveling to and from higher-density mixed-use areas tend to spread out their trips over the entire day, thereby minimizing peak traffic periods, more than people traveling to and from homogeneous employment centers or housing suburbs (Replogle, 1991).

A polynucleated system concentrates travel demand and facilities high-capacity modes of transportation. In addition, planned polynucleated urban centers can lead to more efficient land development because this form facilitates access to rapid transit. Few cities in the developed, let alone developing, world have been successful at implementing planned polynucleation, but the first step in such a process is to acquire the legal and fiscal authority to acquire land in advance of urbanization. A project in Bangkok, Thailand, for example, has resulted in significant strengthening of the agencies charged with land-use planning and the planned purchase of land for the development of transit-based transport systems, as well as a new urban center (Hack, 1994). Notwithstanding recent successes in Thailand, planned polynucleation is probably more achievable in countries where there is a high degree of civic discipline, such as Singapore or China. It has been quite difficult, for example, to implement such schemes in industrialized nations despite the widely recognized benefits associated with managed growth, mixed-use zoning, and greater reliance on public transit.

Linking land use and transportation investments may, in the long run, also alleviate the air pollution experienced in many megacities. There is no doubt that the use of motorized vehicles in megacities of the developing world will continue to grow rapidly. Evidence suggests that even if megacities are able to provide efficient and convenient public transportation service, private automobiles will eventually prove to be the least costly alternative for many individual households.[10] Simply relying on technological improvements to solve the problem of air pollution in urban areas is probably naive, and thus there is all the more reason to rely on good prevention rather than a good cure.

[10] Baumol (1986) argues that as the cost of labor increases as a result of economic development, the cost of labor-intensive activities, such as transportation, becomes very high. Consumers come to prefer substituting their own labor in the provision of transportation services, and the private automobile offers them this opportunity. Private transport thus has major economic and service advantages because it does not require hired labor, and this means it will play an increasingly important role even in countries that are currently relatively nonmotorized.

The industrialized nations have generally chosen to address the problem of transport-related air pollution very late in the process, when pollutant concentrations have reached intolerable levels for the urban population. By this time, the existing land-use patterns and the modal dominance of the automobile are difficult to undo or even influence. A cost-effective and long-term strategy for the megacities of the future involves identifying and implementing policies and measures designed to manage the process of motorization and its associated environmental impacts. Such a strategy must pay substantially greater attention to preventive actions, such as strategic land-use planning, as well as to the appropriate pricing of different transportation modes (as discussed earlier). Curitiba, Brazil offers a well-known example of the successful implementation of a strategy linking land-use planning and transportation investment with the intent of minimizing the congestion and air pollution associated with economic growth and urban expansion (Cervero, 1995; Rabinovitch and Hoehn, 1995).

MULTIMODAL TRANSPORTATION SYSTEMS

One way to avoid the problems associated with motorized transport is to foster the use of nonmotorized modes. As noted earlier, developing countries have a greater prevalence and range of nonmotorized transport than do industrialized countries. This is attributable to differences in income, as well as deficiencies in the transit services available in large cities of the developing world (Shimazaki et al., 1994). Nonetheless, many large cities in the industrialized world are seeking ways to encourage commuters and others to walk and bicycle more frequently. Ironically, many developing countries have implemented policies that encourage motorized transport, or even prohibit certain nonmotorized modes.

Importance of Nonmotorized Transport

While a much higher percentage of the population relies on nonmotorized transport in the developing than in the developed countries, it is also true that the prevalence and use of nonmotorized transport differ almost as much across the spectrum of developing countries. In particular, nonmotorized transportation, including walking, bicycles, cycle-rickshaws, and carts, plays a major role in the urban transportation systems of many Asian countries. Nonmotorized vehicles, for example, account for 25 to 80 percent of vehicle trips in many Asian cities, particularly in China, India, and Indonesia (Replogle, 1992). As Table 1 indicates, the average number of bicycles per 1000 people in Tianjin, China, was 530 in 1987, compared with only 163 in India and 35 in Jakarta in 1985. In addition, as shown in Table 2, the percentage of person trips that rely on nonmotorized vehicles in Asian cities varies from a high of 65 percent in Shenyang, China (in 1984) to a low of 8 percent in Kathmandu, Nepal (in 1987). As of 1991, nonmotorized vehicles made up 90 percent of all the vehicles in Hanoi, Viet Nam, while a mere 53.5 percent of all vehicles are nonmotorized in Phnom Penh, Cambodia (Bell and Kuranami, 1994). A recent United Nations survey shows that in several large cities in Africa, walking accounts for at least half of all trips, and bicycles make up more 70 percent of all vehicles owned

by the population (Philpott, 1994). Although in comparative terms, bicycles and tricycles are far less common in many parts of

Latin America, the Caribbean, and Africa, there are opportunities for the transfer of these modes between Asia and those regions.

Most cities in the developing world make investments that emphasize the car and conventional means of public transportation, such as buses and metros, over nonmotorized or nonwestern means of public/private transportation. Indeed, despite the critical role played by nonmotorized transport modes in many cities, some governments have imposed constraints on nonmotorized vehicles, particularly cycle-rickshaws, claiming that they cause congestion, unfairly exploit human labor, or represent backwardness. In Jakarta, for example, authorities have seized some 100,000 cycle-rickshaws in the past 5 years, dumping at least 35,000 into Jakarta Bay as they seek to eliminate these vehicles from the city. Such strategies can reduce economic efficiency in that motorized transport is more expensive than nonmotorized modes, causes more environmental damage, and is associated with undesirable urban forms. For a given amount of road space, for example, the most efficient modes of transportation are generally rail or buses operating on their own dedicated rights of way. The least efficient use of road space is low-occupancy private cars. Bicycles fall in between this range, with road space use approaching that of buses in mixed traffic.[11] Moreover, these strategies ignore the role that paratransit modes, such as cycle-rickshaws and tricycles, can play in alleviating the deficiencies of modern bus and rail services. Furthermore, cities with a full variety of modes, such as Jakarta, Indonesia, are likely to have better mobility than those, such as Cairo, Egypt, where some modes are systematically excluded.

Eliminating the diversity of transport options reduces economic efficiency by forcing the movement of people or goods to conform to a few higher-cost modes, rather than allowing choice of the most appropriate and affordable means. A transportation system in which a variety of modes function within a regulated but competitive market can serve different market niches more effectively than a system that has been forced to rely on one or two modes (Cervero, 1991; Replogle, 1991).

In addition, maintaining diversity in the paratransit sector is crucial to maintaining good mobility for the poor. The choice of transportation mode in developing-country cities is very sensitive to income. While most people prefer private transport to public and motorized to nonmotorized, even a bicycle, the least expensive form of mechanized transport, is beyond the means of most in many cities. In Delhi, India, for example, 65 percent of the people living in squatter areas walk to work, while only 10 percent of low-income and 3 percent of middle-income workers rely on walking. Furthermore, the average walking and cycling trip in developing countries is five times longer than in developed countries (Gwilliam, 1995). The high level of dependence of the very poor on nonmotorized transport implies that one of the best ways to improve their quality of life is to invest in the nonmotorized transport sector.

[11] These estimates are obviously subject to substantial variation in different cities and towns, depending on vehicle occupancy, level of traffic congestion and traffic mix, topography, frequency of public transportation stops, quality of the track or road surface, and other factors.

For most poor households, walking accounts for the majority of all trips because when incomes are low, the value of time relative to cost for travelers is low as well. Although walking is free, it takes too much time for all but the shortest trips, and the poor must use either public transportation or bicycle for longer trips. Typically, a bicycle that will last at least 10 years costs the equivalent of 6 or 8 months of bus fare. Thus for the poor, particularly in Asia, but in other areas as well, increases in personal mobility are most commonly expressed in expanded use of bicycles and nonmotorized transport. Increased mobility for goods movement and the transportation of children and family also often relies on the greater use of cycle-rickshaws, where they are available.

It is not only low-income urban residents who rely on bicycles, however. The travel time and convenience offered by the bicycle attracts people of all income levels to bicycles in many cities, particularly those in which measures are taken to facilitate cycling. As traffic congestion in Asian cities increases and the schedule reliability and average travel speeds of public motorized transport both decrease, bicycles become a more competitive mode for longer trips because of their flexibility, convenience, and greater reliability.

While there is relatively little knowledge or expertise among transportation experts in North America about how to plan for the traffic problems posed by multimodal transport, a number of industrialized countries have had a great deal of success in combining motorized and nonmotorized transportation modes. Cities in Japan, The Netherlands, and Germany demonstrate that modern urban transportation does not necessarily require total motorization, but rather the appropriate integration of walking, nonmotorized transport, and motorized transport. In Holland, for example, bicycles account for 30 percent of all urban passenger transport and walking for another 18.4 percent (Pucher, 1988).

Multimodal Transportation Strategies

Determining the most efficient modal mix for a city requires consideration of a host of variables, including income levels, the value of time, and the price and speed of various transportation modes, as well as the externalities related to transportation. Given the wide variation in these factors, multimodal transportation strategies must be customized for different types of cities and should be an integral part of both transportation and urban development planning and policy.

One way to accommodate different modes of transportation within roads is to allocate scarce road space more efficiently. In most travel corridors, demand for transport services comprises different trip lengths, implying that a complementary combination of modes should be accommodated to meet the needs of diverse travel markets. When road space is scarce, as in most megacities, traffic management should be the first step in dealing with traffic congestion

problems. As discussed earlier, improved traffic management can include such measures as restricting turns at intersections and introducing one-way street systems.

The segregation of different modes of transportation can result in even greater system efficiency. Experience in Chinese cities suggests that motorized and nonmotorized lanes must be physically separated because otherwise the conflicts at intersections become insurmountable. If street space is insufficient to accommodate demand even with separation, it is often possible to dedicate different streets to different modes and to impose or expand restrictions on private automobiles. Even in cities where streets are generally congested, it is often possible to find underused street space; an example is the use of alleys in Shanghai to provide right-of-way for a bicycle network.

The design of transportation facilities can greatly affect traffic safety. Segregating slow- from fast-moving traffic, designing intersections to maintain good sight distances and reduce turning conflicts, and channeling traffic to enhance flow predictability can all improve safety and operational performance (Thom and Clayton, 1992). On the other hand, poorly designed and improperly maintained separate cycle facilities can increase safety problems, particularly in instances where numerous intersections or driveways cross the cycling paths and sight distances are poor. In some countries, design standards from highly motorized countries have been implemented without being tailored to local traffic conditions and have contributed to the dangerous driving conditions.

Use of bicycles in combination with public motorized transportation can also be effective, as in Japan and China. To reduce long-distance commuting by bicycle and free up congested road space, the Chinese have established bicycle-subway and bicycle-bus exchange hubs in Beijing and other cities. Bicycle access to trains is also important in India, where many hundreds of bicycles can be seen at some stations. Bicycle access to public transit expands the cachement area of high-speed public transportation at a very low cost and represents the most valuable potential function of nonmotorized vehicles in megacities where average trip lengths are long. Integration of bicycles with public transportation is also an important strategy for sustaining nonmotorized and public transport mode shares in rapidly motorizing cities with mixed-traffic systems.

Regulations and policies, including taxes and import duties, fuel taxes, vehicle registration and licensing fees, and credit financing systems for vehicle purchase, have a major influence on the cost and availability of various transportation modes. Frequently, import duties favor motorized transport. In Bangladesh, for example, the government has discouraged the importation of bicycles to protect local bicycle manufacturers while offering concessions to private car buyers. In 1989, the tax rate on imported bicycles was about 150 percent, while motor vehicles faced tariffs of only 5 to 50 percent. Such stiff protectionist measures have the effect of increasing bicycle costs significantly while failing to create viable automotive industries.

On the other hand, a number of countries have implemented projects that assist low-income households in purchasing or acquiring nonmotorized vehicles. As noted above, bicycles and other nonmotorized modes remain prohibitively expensive in much of the world despite their relatively low cost. The average cost of a bicycle in West Africa, for example, is approximately 60,000 CFA or US $120 (assuming US $1 = 500 CFA), depending on the model and import taxes levied (Philpott, 1994). A domestic servant in Senegal earns approximately 500 to 1000 CFA a day and undoubtedly finds it very difficult to save enough to purchase a bicycle without some form of assistance.

The World Bank has sponsored a project in Lima, Peru, that has resulted in the construction of bicycle lanes in downtown roads and involves lending money to individuals to buy bicycles. In Santo Domingo, Dominican Republic, a credit union of tricicleros helped finance vehicle purchases and a tricycle assembly workshop. In Hyderabad, India, commercial banks are encouraged to lend money to cycle-rickshaw operators for the purchase of vehicles (World Bank, 1990). These programs represent a way to increase the mobility of the poor quickly and effectively as long as they are accompanied by transportation designs that accommodate multiple transportation modes. Credit arrangements based on such successful models could be designed and promoted by researchers in the industrialized nations.

Recent research has shown that long- and short-term transportation strategies will differ depending on the city's stage of development and regional location (Dimitriou, 1993). Transportation system management strategies should be developed with consideration of appropriate choices of modal mix for various population groups and different planning horizons. These strategies should also include nontransport planning to reduce trips and trip lengths, increase energy efficiency, and retain environment-friendly transportation systems. A sample transportation system management model indicating appropriate policy and investment strategies over a 20-year time frame has been developed, which takes into account city size and degree of motorization (Pendakur, 1992). Although this model was developed for China, it is generally applicable to a wide class of low-income countries.

DISSEMINATION OF KNOWLEDGE AND TECHNOLOGY ADVANCES

In addition to the various options discussed throughout this paper, an essential element in improving megacity transportation systems is the dissemination of knowledge and recent advances in research and technology. There has been great progress in both technology and implementation of transportation policy that could, if adopted by national and municipal governments, dramatically affect the transportation situation in many large cities. One impediment to better dissemination of knowledge in the field of transportation is a lack of institutions to promote international research and share the findings of such research with practitioners and policymakers.

The United States has a successful record in disseminating knowledge and setting operational and safety standards within the transportation sector. The U.S. Department of Transportation and its predecessor agencies have played a key role in sponsoring the development of transportation-related technologies and planning techniques and in standardizing technologies and evaluations, and have also been able to insist upon the general use of their successful innovations. The Transportation Research Board, one arm of the U.S. National Academy of Sciences (NAS), is charged with responsibility for advising the U.S. government on major transportation policies and issues. In addition, it serves as a transportation research management and information service, with the objective of producing reports that disseminate transportation research results and technology worldwide, address major national transportation policy issues, and analyze research needs. Much of the board's actual work is accomplished through the volunteer efforts of experts in the field and academia who actively participate in forums for the exchange of information with their peers.

Organizations such as the NAS and its research bodies represent a valued and independent advisor to government and the private sector on matters of science and technology. Given that most of the megacities of the future will be in the developing world, it is inevitable that many of the most problematic transportation situations, as well as promising innovations, will occur in developing countries. Thus, it is vital that developing nations look toward the development of counterpart universities and research organizations to focus on their own national policies and agendas. It is just as important for universities, governments, and research organization to sponsor research by academics from industrialized countries on developing-country transportation issues. In this connection, it may be noted that the developed world has much to learn from developing countries, such as how to integrate commercial and residential activities more closely or how to better integrate a richer variety of transport modes, and opportunities to study these successes are few and far between. Transportation policy in the industrialized nations has a mixed record of success and failure. One can argue, however, that the developed world has been relatively successful at sharing information between scientists and researchers at universities, policymakers, and the private sector.

SUMMARY AND CONCLUSIONS

Many more urban residents of developing-country megacities rely on nonpolluting technologies to reach their destinations, are served by a far richer range of both motorized and nonmotorized vehicles, and are less reliant on public subsidies for transit than is true of their counterparts in the West. In addition, the integration of commercial, industrial, and residential activity in many developing-country cities is extremely high and might be envied by many a North American city.

Nonetheless, for a number of reasons, megacities in the developing world face an immediate crisis in dealing with rapid motorization. This paper thus draws on transportation lessons learned more generally from both developing and developed countries that point to

options and strategies appropriate to the urban landscapes of megacities. There are several key lessons or themes that can be drawn from the analysis presented here.

1. Congestion in developing-country cities can be ameliorated in the short run through the comprehensive implementation of traffic and demand management strategies. Developed nations have been quite successful at implementing some aspects of these strategies, such as improved road signs and traffic signals, enforcement, and education, but have been less successful at demand management, particularly in the case of private automobiles. As a result, the flow of traffic in developed countries, while relatively smooth and reliable, is associated with unnecessary urban sprawl and a higher reliance on the automobile than might be warranted.

2. Health dangers posed by motorized vehicles in developing-country megacities are severe and of larger magnitude than those in many industrialized nations. The environmental cost of widespread reliance on private automobiles is a lesson developed countries have learned quite late in the motorization process. It is an experience that does not necessarily have to be repeated in the developing world, where fuels can be cleaner, technologies can be adopted earlier on in the process, and fuels and roads can be priced according to the environmental costs they impose.

3. Megacities should begin to rely more on market mechanisms to provide signals about the need for transportation investments, and these facilities should be commercialized to the greatest extent possible and with the participation of the private sector. Private financing and management can better ensure that services are priced at their full cost, thereby minimizing capital and operating costs and giving proper market signals for capacity expansion. Key to the successful inclusion of the private sector have been public practices to ensure fair and adequate competition in bidding for new facilities and for the management or operation of existing facilities.

4. Better land-use planning is an imperative for most of the world's megacities. It is particularly crucial in the context of developing countries because urbanization is occurring so rapidly and with so little guidance in these settings. An example of guidance through land-use planning is provision for a regional polynucleated development pattern, with relatively high-density outlying nodes connected to the center by high-capacity road and bus service. Such a strategy can reduce land consumption while accommodating reduced population densities at levels high enough to support mass transit.

5. The number and variety of transport modes observed in developing-country megacities present both different problems and opportunities than the modes prevalent in industrialized nations. One cause of the extreme diversity in modal choice in developing countries is income; because much of the population is unable to afford private or motorized transport, walking and other means of nonmotorized transport need to be an integral and key part of transportation policies and investment strategies in the developing world. Traffic systems must also be accommodating of typically unregulated transit modes such as rickshaws, becaks, and jeepneys because in many cities, such modes represent a significant share of passengers. Planning for efficient multimodal transport is difficult for both institutional and systemic

reasons, but some cities have made important contributions to multimodal integration through single-fare arrangements and compatible scheduling between pairs of modes. In addition, the inhabitants of developing-country cities are generally more reliant on less-polluting modes, and building on this history represents a distinct advantage in terms of the environmental costs of future development.

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