Bicycles and Cycle-Rickshaws in Asian Cities: Issues and Strategies

MICHAEL REPLOGLE

An overview of the use and impacts of nonmotorized vehicles in Asian cities is provided. Variations in nonmotorized vehicle use, economic aspects of nonmotorized vehicles in Asia, and facilities that serve nonmotorized vehicles are discussed, and a reexamination of street space allocation on the basis of corridor trip length distribution and efficiency of street space use is urged. The relationship between bicycles and public transportation; regulatory, tax, and other policies affecting nonmotorized vehicles; and the influence of land use and transportation investment patterns on nonmotorized vehicle use are discussed. Conditions under which nonmotorized vehicle use should be encouraged for urban transportation, obstacles to nonmotorized vehicle development, actions that could be taken to foster appropriate use of nonmotorized vehicles, and research needs are identified.

Nonmotorized vehicles—bicycles, cycle-rickshaws, and carts—play a vital role in urban transportation in much of Asia. Nonmotorized vehicles account for 25 to 80 percent of vehicle trips in many Asian cities, more than anywhere else in the world. Ownership of all vehicles, including nonmotorized vehicles, is growing rapidly throughout Asia as incomes increase.

However, the future of nonmotorized vehicles in many Asian cities is threatened by growing motorization, loss of street space for safe nonmotorized vehicle use, and changes in urban form prompted by motorization. Transportation planning and investment in most of Asia has focused on the motorized transportation sector and has often ignored nonmotorized transportation. Without changes in policy, nonmotorized vehicle use may decline precipitously in the coming decade, with major negative effects on air pollution, traffic congestion, global warning, energy use, urban sprawl, and the employment and mobility of low-income people.

As cities in Japan, the Netherlands, Germany, and several other European nations demonstrate, modernizing urban transportation requires not total motorization, but the appropriate integration of walking, nonmotorized transportation, and motorized transportation. As in European and Japanese cities, in which a major share of trips are made by walking and cycling, nonmotorized vehicles have an important role to play in urban transportation systems throughout Asia in coming decades.

Transportation investment and policy are the primary factors that influence nonmotorized vehicle use and can have an effect on the pace and level of motorization. Japan, Germany, Denmark, and the Netherlands have witnessed the major growth of bicycle use despite increased motorization, through policies providing extensive bicycle paths, bicycle parking at rail stations, and high fees for motor vehicle use. China has for several decades offered employee commuter subsidies for cyclists, cultivated a domestic bicycle manufacturing industry, and allocated extensive urban street space to nonmotorized vehicle traffic. This strategy reduced the growth of public transportation subsidies while meeting most mobility needs. Today, 50 to 80 percent of urban vehicle trips in China are by bicycle, and average journey times in China's cities appear to be comparable to those of many other more motorized Asian cities, with favorable consequences for the environment, petroleum dependency, transportation system costs, and traffic safety.

8407 Cedar Street, Silver Spring, Md. 20910.

EXTENT OF OWNERSHIP AND USE

Bicycles are the predominant type of private vehicle in many Asian cities. Bicycle ownership in Asia is now more than 400 million and growing rapidly. Bicycle ownership in China increased more than 50-fold between 1952 and 1985, to 170 million, nearly half of which are in cities (*1*). Since then it has risen to 300 million and is anticipated to grow to 500 million by 2000 (*2*). In many Chinese cities, bicycle ownership rates are one bicycle per household or more. In India there are roughly 25 times as many bicycles as motor vehicles, and urban bicycle ownership is growing at a fast pace. Table 1 shows the number of nonmotorized vehicles in a number of Asian countries and cities.

Most of the world's 3.3 million cycle-rickshaws and goods tricycles are found in Asia. Despite recurrent efforts by some local authorities to suppress cycle-rickshaws in favor of motorized transportation, the number and use of these vehicles is growing in many cities in response to otherwise unmet transportation needs. The Indian Planning Commission in 1979 estimated that the number of cycle-rickshaws in India would increase from 1.3 million in 1979 to 2.2 million by 2001. In Bangladesh the cycle-rickshaw fleet is estimated to grow from two-thirds of a million in 1988 to more than a million by 2000 (*3*). More than three-fourths of Bangladesh's cycle-rickshaws are in urban areas. These urban cycle-rickshaws each account for an average of more than 30,000 passenger-mi and nearly 100 ton-mi of goods movements a year. Together, bicycles, rickshaws, bullock carts, and country boats account for about 75 percent of the value added, 80 percent of the employment, and 40 percent of vehicle assets employed in the transportation sector. On secondary roads, nonmotorized transportation vehicles make up about 85 percent of traffic (*4*,p.16).

The substantial variability in nonmotorized vehicle use in Asian cities is due to many factors, including topography,

TABLE 1 Vehicles in Selected Cities and Counties (*2*;*3*,p.69;*6*;*7*,p.31;*19–23*)

City	Year	Bicycles (X1000)	Cycle-Rick-shaws (X1000)	Motor Vehicles (X1000)	Popula-tion	Bicycles per 1000 Residents	Motor Vehicles per 1000 Residents
China	1988	300,000	500	1,200	1,104,000	272	1
Beijing	1982	3,773	na	na	9,231	410	na
Tianjin	1982	3,228	na	na	7,764	420	na
Tianjin	1987	4,500	na	na	8,500	530	na
Shanghai	1980	1,700	na	80	na	152	7
Shanghai	1982	2,243	na	na	11,860	200	na
Shanghai	1988	5,600	na	200	12,400	445	12
India	1985	45,000	1,700	1,500	765,000	59	2
Bangalore	1981	322	na	na	2,900	111	38
Bombay	1981	984	na	na	8,200	120	11
Delhi	1981	945	7	na	5,800	163	54
Hyderabad	1979	800	14	na	2,200	360	na
Jaipur	1979	150	9	na	900	180	na
Madras	1979	272	6	na	4,000	68	16
Indonesia	1985	na	200	na	na	100	na
Jakarta	1985	na	65	na	na	35	
Serang	1983	10	na	3	112	89	29*
Tasikmalaya	1983	16	na	17	159	101	106*
Cirebon	1983	10	na	4	275	35	18*
Surabaya	1976	200	42	144	2,300	na	na
Yogyakarta	1975	44	6	34	400	na	na
Bangladesh	1982	1,500	633	250	na	na	na
South Korea	1982	6,000	na	na	39,000	154	na
Thailand	1982	2,500	15	400	49,000	51	53
Thailand	1988	na	na	6,300	na	na	116
Malaysia	1982	2,500	na	900	14,000	179	64
Japan	1988	1,500	na	250	na	na	na
Netherlands	1985	11,000	na	4,900	14,000	786	350
United States	1988	103,000	na	139,000	245,000	420	567

* includes motorcycles and cars only. Otherwise includes all motor vehicles.

TABLE 2 Percentage of Person Trips by Various Travel Modes (*14*;*24*,p.4;*25*,p.2;*26*,p.2)

<table>
<tr><th>City</th><th>Year</th><th>Walk</th><th>Bicycle &NMV</th><th>Bus & rail</th><th>Motor-cycle</th><th>Auto-mobile</th><th>Other</th><th>Total</th></tr>
<tr><td>Kanpur, India</td><td>1977</td><td>72</td><td>24</td><td>0</td><td>3</td><td>1</td><td>0</td><td>100</td></tr>
<tr><td>Tianjin, China</td><td>1987</td><td>50</td><td>41</td><td>9</td><td>0</td><td>0</td><td>0</td><td>100</td></tr>
<tr><td>Shenyang, China</td><td>1984</td><td>10</td><td>65</td><td>25</td><td>0</td><td>0</td><td>0</td><td>100</td></tr>
<tr><td>Shanghai, China</td><td>1986</td><td>38</td><td>33</td><td>26</td><td>..</td><td>3</td><td>..</td><td>100</td></tr>
<tr><td>Kathmandu, Nepal</td><td>1987</td><td>56</td><td>8</td><td>16</td><td colspan="2">14</td><td>6</td><td>100</td></tr>
<tr><td>Ahmedabad, India</td><td>1981</td><td>43</td><td>20</td><td>29</td><td>6</td><td>1</td><td>1</td><td>100</td></tr>
<tr><td>Bangalore, India</td><td>1984</td><td>44</td><td>12</td><td>36</td><td>6</td><td>2</td><td>0</td><td>100</td></tr>
<tr><td>Bandung, Indonesia</td><td>1976</td><td>40</td><td>16</td><td colspan="4">46</td><td>100</td></tr>
<tr><td>Surabaya, Indonesia</td><td>1984</td><td>20</td><td>25</td><td>13</td><td>26</td><td>9</td><td>7</td><td>100</td></tr>
<tr><td>Delhi, India</td><td>1981</td><td>29</td><td>18</td><td>40</td><td colspan="3">13</td><td>100</td></tr>
<tr><td>Tokyo, Japan</td><td>1988</td><td colspan="2">45</td><td>28</td><td>**</td><td>27</td><td>0</td><td>100</td></tr>
<tr><td>Okayama, Japan</td><td>1982</td><td>23</td><td>30</td><td>7</td><td>**</td><td>39</td><td>1</td><td>100</td></tr>
<tr><td>Matsuyama, Japan</td><td>1982</td><td>27</td><td>23</td><td>12</td><td>**</td><td>34</td><td>4</td><td>100</td></tr>
<tr><td>Jakarta, Indonesia</td><td>1984</td><td>23</td><td>17</td><td>25</td><td>13</td><td>8</td><td>14</td><td>100</td></tr>
<tr><td>Bombay, India</td><td>1981</td><td>15</td><td>11</td><td>58</td><td>1</td><td>8</td><td>7</td><td>100</td></tr>
<tr><td>Melbourne, Australia</td><td>1979</td><td>19</td><td>2</td><td>13</td><td>..</td><td>64</td><td>2</td><td>100</td></tr>
</table>

Notes: ** small amount included with bike/NMV category; .. data not available or included in other categories.

income, metropolitan structure, level of motorization, climate, and transportation policies. Table 2 shows the variation in mode shares for selected cities in Asia. In Indian cities bicycles typically account for 10 to 30 percent of all person trips (including walking) and for 30 to 50 percent of the traffic on primary urban roads. Walking and cycling account for 60 percent of total trips and 40 percent of work-related trips in Karachi, Pakistan. Bicycles have largely replaced buses as the principal means of urban vehicular transportation in Tianjin, an experience repeated in other cities.

Cycle-rickshaws account for 10 to 20 percent of urban freight movement in many Asian cities. Of all land transportation in Bangladesh, nonmotorized vehicles produced 60 percent of all passenger miles and 36 percent of freight ton miles in 1985 (*5*,p.46). Annually, each urban cycle-rickshaw accounted for 32,810 passenger-mi and carried 94 ton-mi of goods (*4*).

A large portion of cycle-rickshaw trips are of a nature not readily replaced by overcrowded buses. Surveys on several main roads in Dhaka, Bangladesh, found that 22 percent of cycle-rickshaws were carrying goods and nearly as many were carrying passengers with small children. Nearly one-third of all cycle-rickshaws carried female passengers, and nearly one-fifth carried females alone. Many of the remaining trips were made by males traveling as passengers without goods, often for short-distance trips on irregular routes (*3*).

In many Indonesian cities, becaks (cycle-rickshaws or pedicabs) play an even greater role in urban mobility than the bicycle. In Bandung, cycle-rickshaws accounted for 12 percent of all work trips and an even higher share of nonwork trips in 1985, whereas bicycles accounted for about 6 percent of trips (*6*). In Jakarta, where the government is forcefully suppressing becaks through banning and confiscation, these vehicles accounted for 4.6 percent of all trips in 1985; bicycles held only a 2.4 percent mode share.

RELATIONSHIP OF INCOME TO BICYCLE USE

Income plays a significant role in influencing the choice of transportation that people have. People with low incomes face extremely limited choices. Where there is extensive poverty, it is vital to ensure that the modes used by the poor continue to remain available as travel options. Despite rising incomes in many cities across Asia, the distribution of wealth and income remains skewed in much of the region. Rapid urbanization and economic growth throughout much of Asia has left behind hundreds of millions of people who continue to live in desperate poverty. Indeed, two-thirds of the poorest of the world's poor live in India, Bangladesh, Pakistan, and China.

Many low-income people in Asian cities cannot afford even subsidized public transportation fares and have no choice but to walk or cycle, even for 10 to 20 km. For most poor households, walking accounts for the majority of all trips. When incomes are low, the value of time relative to cost for travelers is low as well. Although walking costs nothing, it takes much time for all but short trips. Cycling can be four or five times faster than public transportation, and it is cheaper once a bicycle is in hand. When a bicycle that will last years costs the equivalent of 6 or 8 months of bus fare, a poor person profits in having and using one. Thus, for the poor in Asia, increases in personal mobility are most commonly expressed in expanded use of bicycles. Increased mobility for goods movement and the transportation of children and families is often expressed in greater use of cycle-rickshaws, where they are available, or public transportation, where it is available.

Low-income households must spend a higher share of their income on transportation than higher-income households. The poor often must live far from their jobs to find cheap housing, they often hold several part-time jobs, and, because their income is so small, a single bus fare represents a larger share of their earnings than it does to others. The poor in general make fewer trips than higher-income people and engage in little discretionary travel. Irrespective of city size, the poor will continue for now to be dependent on nonmotorized transportation modes for mobility in Asian cities.

However, it is not only the poor who use bicycles. 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 have been taken to facilitate cycling. As traffic congestion in Asian cities increases, the reliability of public transportation schedules and the average travel speeds both decrease, making bicycles competitive at longer trip lengths because of their flexibility, convenience, and greater reliability.

EMPLOYMENT GENERATION BY NONMOTORIZED VEHICLES

The manufacturing, servicing, and repairing of nonmotorized vehicles generates substantial employment in Asia. Nonmotorized vehicles also form the foundation for a large informal sector providing goods or services on the street or transporting people and goods on a for-hire basis. In Dhaka, Bangladesh, for example, about 380,000 people are directly employed as cycle-rickshaw pullers, and another 80,000 are employed in ancillary services related to cycle-rickshaws. In all of Bangladesh, cycle-rickshaws in 1988 were estimated to provide employment for more than 1 million people and ancillary employment to another 250,000, representing about 3.5 percent of the nation's labor force (*7*).

An investment of 100,000 rupees ($8,000 in 1984 U.S. dollars, $5,000 in 1991 U.S. dollars) in a conventional bus system in Patna, India, was estimated to produce two new direct jobs. If that sum was invested in the motorized auto-rickshaw system, it was estimated to create six direct jobs; if invested in cycle-rickshaw transportation, it was estimated to create 75 jobs (*7*).

Promoting the nonmotorized transportation sector can stimulate employment growth and microenterprise development, especially in low-income cities, particularly benefiting the poor. Where cycle-rickshaws are suppressed by regulation, taxes, licensing requirements, bans, and even confiscation, many low-income people lose their livelihoods.

Most developing countries depend heavily on imported oil. More than half of low- and lower-middle-income countries import more than 90 percent of their commercial energy, with most of these imports in the form of petroleum (*8*). Low-income developing countries (excluding China) spent an average of 33 percent of their merchandise export earnings in 1985 on energy imports; many spent more than half (*9,10*).

In non-oil-exporting Asian cities, consumer expenditures on motorized private and public transportation usually require more foreign exchange and less local labor than expenditures for alternative nonmotorized modes. Thus, a shift from nonmotorized to motorized modes may have significant impacts on regional economies and foreign exchange requirements.

NONMOTORIZED VEHICLE FACILITIES

In many low-income Asian cities in which nonmotorized vehicles predominate, there has been little need to create a separate cycle network because large numbers of nonmotorized vehicles define their own legitimacy to right-of-way. However, as motorization increases, or as traffic congestion worsens, it becomes more important to develop modal separation in corridors of high traffic flow. This is particularly vital in mixed-traffic cities in which nonmotorized vehicle use is declining because of competition from growing motorized traffic. Motorized modes are heavier, faster, and often higher in social status than nonmotorized vehicles. When street space is scarce, nonmotorized vehicles are vulnerable to displacement from mixed-traffic streets unless they are present in sufficient numbers to assert an almost continuous claim to their share of road space. A key function of bicycle or nonmotorized vehicle facilities is to protect the legitimacy and safety of nonmotorized vehicles in the transportation system where they would otherwise be threatened by motorized traffic. Isolated bikeways and fragmented segments of bicycle paths cannot be expected to overcome the problems that urban cyclists face. Comprehensive networks of bicycle-safe roads and paths are needed to attract less-skilled cyclists to use the bicycle for a significant share of their short daily trips in motor vehicle–dependent cities and to avoid the diversion of cyclists to motorized modes in mixed-traffic and nonmotorized transportation–dependent cities.

Important factors to be considered in nonmotorized vehicle facility planning include continuity, facility standard and function, degree of separation of modes, anticipated traffic flows by mode, and available rights-of-way. The concept of network functional hierarchy used in classifying highways and evaluating their spacing is equally useful in planning and designing cycle networks. Conditions for cyclists and other slow traffic can be optimized if nonmotorized vehicles have available a fine-grained network of collector facilities (often shared with pedestrians and slow motorized traffic); a coarser network of primarily slow traffic facilities, some shared with pedestrians and slow motorized traffic and many reserved for exclusive nonmotorized vehicle use; and a coarse network of exclusive regional facilities designated for nonmotorized vehicles (*11*).

Although the spacing of networks must be adjusted for city patterns and densities, this network concept has been used successfully in a number of highly motorized cities, mostly in Europe, to arrest and often reverse the decline of nonmotorized vehicle use during times of rapid motorization. Many cities in the Netherlands, Denmark, and Germany have developed effective cycle networks: Delft, the Netherlands; Copenhagen, Denmark; Malmö, Sweden; and Hannover, Germany, clearly stand out as successful examples (*12*). Several cities in developing countries are noteworthy for their cycle networks, including Curitiba, Brazil, and Tianjin, China. Pune, India, has been working to develop an extensive cycle network for a number of years.

In many nonmotorized vehicle–dependent cities, bicycle networks can best be preserved by keeping cars and motorcycles out of many existing streets in neighborhoods. Creation of environmental districts—areas in which motor vehicles are restricted and traffic is calmed—can be a most effective strategy for supporting the use of nonmotorized vehicles, walking, and public transportation. Such districts are increasingly common in many affluent cities in Europe and Japan. In some cities extensive alley systems offer opportunities for creating nonmotorized vehicle networks while improving traffic management, as in a World Bank project in Shanghai, China.

Officially dedicated nonmotorized vehicle facilities are common in Chinese and Japanese cities but not found widely elsewhere in Asia. Instead, where nonmotorized vehicles make up a major portion of traffic flows, they frequently define nonmotorized vehicle "lanes" through their physical presence in large numbers. However, especially where nonmotorized vehicle lanes are not well defined by physical separation, the extensive mixing of nonmotorized and motorized traffic often fosters poor traffic discipline among all modes, which exacerbates traffic congestion and safety problems.

CAPACITY OF NONMOTORIZED VEHICLE FACILITIES

The rapid growth of bicycle traffic in Chinese cities in the 1980s has led to serious traffic congestion problems in many cities. Peak-hour flows at many main intersections in Beijing and Tianjin exceed 15,000, with 29,000 per peak hour observed at one main junction in Beijing. As a result, interest in assessing the capacity of bicycle facilities has been a serious matter for Chinese planners. In China, the practical saturation capacity of separated bike tracks has been estimated at 0.5 bicycle per second per meter width, or 1,800 bicycles per hour per meter width. Cycle-rickshaws typically require 1.5 to 3.0 times the capacity of a single bicycle, depending on size and weight (*13*). Mixed-traffic streets typical of Beijing, China, show a saturation capacity of about 0.37 bicycle per second per meter width, or 1,330 bicycles per hour per meter width (*13*).

ALLOCATION OF ROAD SPACE BETWEEN MOTORIZED AND NONMOTORIZED VEHICLES

The capacity of different types of rights-of-way to move people at different speeds in different modal mixes is an important consideration in analyzing travel management strategies. Proper analysis of transportation modal efficiency must differentiate on the basis of trip length, cost, and function.

For a given amount of road or corridor space, the most efficient modes of transportation are generally rail or bus operating on their own dedicated rights-of-way. The least efficient use of road space is low-occupancy automobiles. Bicycles fall in between this range, with road space use approaching that of buses in mixed traffic (*14*). Motorcycles, scooters, and other two-wheeled motorized vehicles fall between automobiles and bicycles in their road space utilization (*15*). All of these estimates are subject to a great deal of variation in the real world, depending on vehicle occupancy, level of traffic congestion and traffic mix, topography, frequency of public transportation stops and other details of public transportation operations, quality of track or road surface, and other factors.

The function of modes and distribution of trip lengths that must be accommodated within travel corridors is an important consideration in evaluating the ways in which scarce road space should be most efficiently allocated. If a large share of traffic is of short to moderate trip length, rail modes are not likely to be cost-effective or practical for these trips. If a large share of traffic is of long trip length, bicycles and walking are not likely to be the most efficient or practical modes. If resources are unavailable to provide bus transportation sufficient to meet demand, bicycles may be more efficient than an overburdened public transportation system, even for longer trips. In most travel corridors, demand is in fact composed of a spectrum of trip lengths, meaning that a complementary combination of modes should be accommodated to meet the needs of diverse travel markets, recognizing limitations on road space, affordability of transportation modes in the community, and the required speed and distance of trips made in the corridor. Where road space is most scarce, traffic management should be the first step in dealing with traffic congestion problems. This can include restricting turns at intersections, introducing one-way street systems, improving traffic signalization, and managing encroachments on transportation rights-of-way. These steps can all affect the relative efficiency of different modes in using road space.

The segregation of different modes of transportation can result in far greater system efficiency. If street space is insufficient to accommodate demand even with separation, it is often useful to dedicate different streets to different modes and to impose or expand restrictions or costs for private automobiles, the most inefficient mode. Even in cities in which streets are generally congested, it is often possible to find underused street space, such as the use of alleys in Shanghai to provide right-of-way for a dedicated bicycle network. Similar opportunities exist in other cities, such as Bangkok. If space cannot be found, nonmotorized vehicles and public transportation should be favored in allocating street space.

The design of transportation facilities can greatly affect traffic safety. Segregating slow from fast traffic and designing intersections to maintain good sight distances, to reduce turning conflicts, and to channelize traffic to enhance predictability of flows can all reduce safety problems while improving operational performance. Poorly designed and improperly maintained separate cycle facilities can increase safety problems, particularly if many intersections or driveways cross the cycle paths and sight distances are poor. In some countries, design standards from highly motorized countries have been used with insufficient tailoring to local traffic conditions and economic realities. This has often led to unsafe designs that threaten nonmotorized travel.

INTEGRATION OF BICYCLES WITH PUBLIC TRANSPORTATION

Bicycles used in combination with public transportation offer a strong potential competitor to private motorized transportation for many types of trips. To reduce long-distance bicycle commuting and free congested road space, the Chinese have been establishing bicycle-subway and bicycle-bus exchange hubs in Beijing and other cities. Bicycle access to railways is also important in India, where many hundreds of bicycles can be seen parked at some stations.

Bicycle access expands the market area of high-speed public transportation services at low cost. This is one of the most valuable potential functions 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 transportation mode shares in rapidly motorizing cities with mixed-traffic systems, for reintegrating nonmotorized vehicles into motor vehicle–dependent cities, and for dealing with network capacity saturation in nonmotorized vehicle–dependent cities.

In Western Europe and Japan today, the fastest-growing and predominant access mode to suburban railways is the bicycle; it accounts for one-fourth to one-half of access trips to stations (*16*). Between 1975 and 1981 the number of bicycles parked at Japanese rail stations quadrupled to 1.25 million. By the end of the 1980s nearly 3 million bicycles were used daily to access suburban railway stations in Japan. Use is heaviest in the lower-density suburban fringe areas of large cities, in which 15 to 45 percent of rail station access is by bicycle. Japanese and European transportation policy and investment has encouraged bike-and-ride system development with secure parking at station entrances and safe access routes. In Japan more than 2 million bicycle parking spaces have been built at rail stations since the mid-1970s, including automated multistory structures (*17,18*).

Bike-and-ride strategies offer opportunities for increased public transportation system efficiency when factored into public transportation network and operations design. With expanded station catchment areas, interstation spacing can be greater, creating higher line-haul public transportation speeds and efficiency in equipment use, with a level of service comparable to that obtained with denser station spacing relying on pedestrian access. In the long-run, increased interstation and interline spacing may permit public transportation networks to concentrate more frequent service on fewer lines for the same size vehicle fleet, reducing average waiting time for public transportation services and increasing efficiency in use of rights-of-way. This is particularly important in megacities, in which average trip lengths are long and resources for express public transportation service provision are insufficient to meet demand. By reducing average point-to-point travel time throughout metropolitan areas, bike-and-ride systems can improve the competitiveness of public transportation with private motorized transportation. In cities in which public transportation services are inadequate to meet demand, it may be productive to shift some less-efficient short-distance public transportation trips to nonmotorized vehicles, allowing the concentration of public transportation resources on longer trips, with bike-and-ride access systems expanding market catchment areas.

REGULATIONS AND POLICIES INFLUENCING NONMOTORIZED VEHICLE USE

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, regulations and policies have been used to discourage or suppress the use of nonmotorized vehicles, especially cycle-rickshaws, while fostering motorization.

Import duties frequently favor motorized transportation. Bangladesh, for example, has discouraged the import of bicycles and their parts to protect local bicycle manufacturers while offering concessions to affluent buyers of private motor vehicles. In 1989 Bangladesh taxed imported bicycles and most bicycle parts at 150 to 170 percent, whereas motor vehicles faced tariffs of only 5 to 50 percent. Although such taxes are intended to protect domestic bicycle producers, two-thirds of the bicycle parts needed in Bangladesh must be imported, which significantly raises the costs of owning and operating bicycles and cycle-rickshaws (*3*). Such stiff protectionist policies aimed at aiding domestic nonmotorized vehicle producers impose a high cost on cyclists and cycle-rickshaw users while often failing to create viable industries. When combined with low taxes on motor vehicle imports, such policies foster economically inefficient choices.

Vehicle licensing is commonly used to raise revenue, ensure vehicle safety, and regulate vehicle use. In many cities, however, it has been used to suppress cycle-rickshaws and other informal sector public transportation services, such as jeepnies, jitneys, motorized auto-rickshaws, and pirate taxis. In Karachi cycle-rickshaws were banned in 1960 and replaced by auto-rickshaws, which in turn were subjected to restrictions on new registrations from 1986 onward. In Manila, Philippines, the motorized tricycles that replaced cycle-rickshaws in the 1950s were later banned from main roads and now operate mostly on smaller roads as feeder services (*3*). Only in Singapore have restrictions been placed on private motor vehicle registrations, beginning in 1990, although such vehicles are the least efficient users of road space in Asian cities. In several cities in India, Indonesia, and Bangladesh, restrictions have been placed on the number of cycle-rickshaw registrations that will be permitted, often freezing registrations at a fixed level for many years. Restricting licenses creates a lucrative black market in duplicate or falsified licenses. It also makes cycle-rickshaw drivers and owners vulnerable to extortion and abuse from local police, who can threaten to seize their vehicles and cause the loss of, at a minimum, a full day's pay or, at worst, their livelihood. Indeed, Jakarta 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. Thousands more cycle-rickshaws were seized and destroyed in Delhi in the late 1980s.

Many cities have imposed constraints on nonmotorized modes of travel, particularly cycle-rickshaws, claiming that they cause congestion or unfairly exploit human labor, or that they represent backwardness. But these officials overlook far more degraded labor conditions that are hidden behind factory gates and in garbage dumps. The suppression of cycle-rickshaws is comparable to the removal of slums and squatter settlements: just as slum clearances destroy real housing resources for the poor, cycle-rickshaw bans eliminate real transportation resources for the poor, hurting hundreds of thousands of people who frequently lack the political power to defend their mobility systems and jobs.

CONDITIONS UNDER WHICH NONMOTORIZED VEHICLES SHOULD BE ENCOURAGED

Nonmotorized modes are the most efficient means of mobility over short distances in cities, and motorized modes offer greater efficiency for longer trips. The distance at which motorized modes become more efficient than nonmotorized modes for consumers depends on income levels, the value of time, and the price and speed of various transportation modes. For societies as a whole, it depends as well on how environmental costs, social costs, and other externalities related to transportation are assessed. Determining the most efficient modal mix for a city also requires consideration of constraints on street space, patterns of land use, existing investments in transportation vehicles and infrastructure, and funds available for new investment and transportation operations. It should also take into account current and anticipated problems in the overall transportation and land use system, such as traffic congestion, air pollution, economic impacts of growing petroleum use, access of housing to employment, motorization trends, and goals for poverty alleviation. Given the wide variation in these factors, urban nonmotorized transportation strategies must be tailored for different types of cities. The integration of urban development and transportation planning and policy is vital to expanding opportunities for nonmotorized transportation.

Bicycles should be encouraged as the most efficient transportation mode for short trips in cities of all types and income levels, particularly for trips too long for walking and too short for express public transportation services, particularly where travel demand density or economics do not permit high-frequency public transportation services. Bicycles are most important for personal transportation, but they also accommodate light goods hauling, being capable of carrying loads of 100 to 180 kg. Bicycles should be considered an integral part of urban transportation planning and management for cities across the world, just like public transportation, private motorized transportation, and walking. In smaller cities, bicycles should have a primary role on their own for work, shopping, and other travel. In larger cities, where trips are longer, bicycles should be seen as most important in providing access to efficient public transportation services for work trips and in serving some short-distance shopping and other trips. The integration of bicycles with public transportation can facilitate efficient polycentric metropolitan development patterns. By linking multiple urban centers by public transportation on its own right-of-way and expanding the service areas of public transportation stations with bicycle access, such strategies can favor the evolution of megacities into more manageable constellations of small cities.

The primary market for efficient bicycle use is generally from 600 to 800 m to distances of 5 to 7 km. The utility of bicycles is reduced, but not entirely eliminated, in cities with many hills or steep topography, where they may still serve a role, especially following waterways. Bicycles should be encouraged as a key element in access and egress to and from public transportation, particularly for intrametropolitan express services in large cities of all types. The catchment area for convenient and efficient access to rail or bus stops and stations can be enlarged by a factor of 20 to 40 by encouraging bicycle-based access systems. Bike-and-ride strategies offer an important means for improving public transportation system efficiency, performance, and use. In large, low-income cities in which public transportation services are insufficient to meet demand, and in low-income areas of more affluent cities, bicycle use should be encouraged as the most efficient mode for trips of up to 10 km, at least until public transportation service provision can catch up with demand. The diversion of some public transportation travelers making trips shorter than several kilometers from buses to bicycles can permit a larger portion of public transportation vehicles to be concentrated on longer distance, limited stop, express services, where they can operate at higher efficiency. In nonmotorized vehicle-dependent cities in which public transportation is insufficient to meet demand, street space is saturated, and a large number of cyclists ride distances of more than 10 or 15 km, such as in some Chinese cities, express limited-stop public transportation services should be upgraded and long-distance cyclists should be encouraged to use bike-and-ride. The diversion of such cyclists to public transportation should be achieved not by suppressing bicycle use or constricting street space for nonmotorized vehicles, but by improving public transportation to provide more competitive travel time. When scarce street space in cities is allocated to different modes, less-efficient private automobiles should be restricted rather than bicycle traffic in setting aside added space for high-efficiency public transportation and pedestrians.

In cities of all types, sizes, and income levels, bicycles should be encouraged as a means of reducing air and noise pollution, petroleum use, global warming, and traffic congestion, and as an important means of increasing the mobility of low-income people. By meeting a larger share of urban mobility needs using low-cost bicycle transportation, cities can reduce total transportation system costs or free resources for other unmet needs.

Cycle-rickshaws are not as efficient as bicycles for personal transportation, but they should be encouraged to complement motorized goods transportation and to serve as a passenger paratransit mode, particularly in countries in which wages are low and there is substantial surplus labor. These vehicles are a major source of jobs; in some Asian cities they account for more than 10 percent of total employment. They provide many useful services to urban residents that cannot always be readily replaced by motorized modes, acting as a nonmotorized taxi, school bus, ambulance, delivery service, and small freight hauler in some cities. Cycle-rickshaws are quiet, do not pollute, use no petroleum, and can traverse very narrow streets. Improvements should be encouraged in vehicle design and patterns of vehicle ownership and operation, however, to improve safety, vehicle performance, the quality of working conditions for cycle-rickshaw drivers. Where they are in use, they should be accepted as a useful part of the transportation system that fills market-expressed needs, not as a nuisance or a barrier to modernization. They are a thoroughly 20th century, efficient, and sustainable mode of transportation, used even today in aerospace factories in North America. Even in high-income, motor vehicle–dependent cities, there are opportunities to use cycle-rickshaws for moving people and goods for short distances and as the basis for microenterprises providing goods and services at dispersed locations. There, they will find greatest utility where slow modes are allocated right-of-way separate from motorized traffic, in dense pedestrian-oriented neighborhoods or central areas with slow traffic speeds, in large factories and shopping districts, and in areas where private motor vehicles are restricted.

Cycle-rickshaws should be separated from motorized traffic when possible, except in areas in which traffic speeds or motor vehicle volumes will remain low. On higher-speed roads, the speed differential and combined vehicle width of motor vehicles and cycle-rickshaws can produce unsafe conditions. Where traffic congestion is most serious in cities and there are large volumes of cycle-rickshaws, it may make sense to enhance bicycle or bus modes to gain greater efficiency in the use of street space. However, the wholesale banning of cycle-rickshaws from large areas of cities where they fill market needs is inadvisable on economic, environmental, and social grounds.

KEY BARRIERS TO NONMOTORIZED VEHICLES

The key barriers to nonmotorized vehicle use include the affordability of vehicles, street environments hostile to nonmotorized vehicles, vehicle theft, negative social and government attitudes toward nonmotorized vehicles, and excessive and inappropriate regulation of nonmotorized vehicles. Overcoming these barriers may require changes in transportation investment patterns, infrastructure design standards, street space allocation, credit and financing systems, regulatory policy, public education, and marketing, depending on local circumstances. Such changes should be part of much larger efforts to manage the modal mix of cities to favor greater efficiency of resource utilization in the transportation sector while enhancing accessibility. However, few institutional structures focus on nonmotorized transportation and few data are collected on its attributes or problems. Many national and local transportation planning organizations are indifferent or hostile to nonmotorized transportation and focus solely on motorized transportation issues. Training and institutional reform is needed to address these problems. Many of these factors can be changed only over several years, and some are difficult to control. However, actions by multi- and bilateral development finance organizations, governments at various levels, and nongovernmental organizations can influence the direction and nature of change in many of these factors. Such actions should be accomplished through development and implementation of a nonmotorized transportation strategy by such organizations and by individual countries and cities in Asia and elsewhere.

FORMULATION OF NONMOTORIZED TRANSPORTATION STRATEGY

A nonmotorized transportation strategy, whether for a city, county, a region, or an international development agency working in various contexts, should be developed to establish and support the appropriate use of nonmotorized vehicles to maximize transportation system efficiency, equity, and environmental quality. Some elements described in the following are undertaken in transportation sector and project appraisal studies today, but many aspects related to nonmotorized vehicles are often neglected.

Such a strategy should identify the extent, pattern, and current trends related to nonmotorized transportation availability and use, including variations based on income, cost, trip length, and other factors. It should assess the overall pattern of travel demand for different modes of transportation for low-, moderate-, and high-income groups to identify particular trip lengths where modal options are limited to inefficient transportation choices. A key focus should be on road safety problems, particularly those facing pedestrians and bicyclists. Road safety improvements offer the potential for widespread social and economic benefits in terms popular with all classes of society.

An urban nonmotorized transportation strategy should identify key traffic congestion locations and gather data on the composition and attributes of traffic flows, their trip length distributions and patterns, and the extent of encroachment on the transportation rights-of-way by nontransportation activities and uses. This information should be used to identify opportunities for improved traffic management in congested locations, including separating or channelizing different modes within the right-of-way or on parallel routes to separate slow and fast traffic; improving intersection design and operation to reduce turning movement conflicts and delays; and using turn prohibitions, one-way systems, grade separations, traffic signalization, and grade-separated under- and overpasses where appropriate. It should consider restricting private motor vehicle traffic in congested areas by limiting peak-hour entry or by creating automobile-restricted areas, streets, or traffic cells that discourage short trips by private motor vehicles. It should consider pricing changes for public and private transportation to influence travel demand. Where poor traffic discipline or encroachments are problems, stepping up enforcement, public education, and advertising campaigns and providing low-cost off-street market areas should be considered.

An urban nonmotorized transportation strategy should also identify and evaluate opportunities for shifting longer-distance trips made by private motorized and nonmotorized vehicles to bike-and-ride systems, with express public transportation operating on reserved rights-of-way. It should identify strategies for reducing average trip length in the long run through changes in land use patterns and the distribution of housing, markets and shops, and employment both in relationship to each other and to the public transportation system. It should identify appropriate networks for nonmotorized vehicle use to strengthen their utility for short to moderate-length trips within cities and evaluate the appropriateness of shifting long walking trips and short public transportation trips to nonmotorized vehicles.

Barriers to the nonmotorized vehicle manufacture and ownership and strategies for overcoming these should be identified as part of strategy work. These may include nonmotorized vehicle-related trade barriers, local nonmotorized vehicle industry structure and performance, affordability of nonmotorized vehicles to the population, credit systems for nonmotorized vehicle purchase, and licensing and registration requirements. Regulatory policies inhibiting nonmotorized vehicle use should be identified along with strategies for influencing them, including changes in traffic regulations, parking policies, and licensing requirements.

CONCLUSIONS

The transportation systems of many Asian cities are at a crossroads. If they continue on their current path of rapid and uncontrolled motorization, they may face very high long-term economic and environmental costs with diminishing benefits. If they instead follow the models of China, Japan, and the Netherlands, they may be able to stabilize or increase the appropriate use of nonmotorized vehicles with large positive long-term economic and environmental consequences.

Nonmotorized vehicles offer no panacea to growing problems of traffic congestion, air pollution, energy use, global warming, and regional economic development, but they should be seen as a potentially important element in addressing these problems. As we enter the 21st century, nonmotorized vehicles, instead of decline, may play a growing role in urban transportation systems worldwide.

ACKNOWLEDGMENTS

The author would like to acknowledge the support of the World Bank and to thank its staff—especially Peter Midgley, who was responsible for managing the Asia Urban Transport Sector Study—for their assistance in preparing this study. Gracious thanks are also due to Setty Pendakur, of the University of British Columbia, and Marcia Lowe, of the Worldwatch Institute, for their comments on early drafts of this material.

REFERENCES

1. City Lights. *The Economist*, Feb. 18, 1989.
2. Z. Wang. Bicycles in Large Cities in China. *Transport Reviews*, Vol. 9, No. 2, 1989, pp. 171–172.
3. R. Gallagher. *The Cycle Rickshaws of Bangladesh*. Interim report. Wiltshire, England, March 1989.
4. Bangladesh Country Paper. *Proc., Workshop on Non-Motorized Transport*. U.N. Economic and Social Conditions for Asia and the Pacific, Bangkok, Thailand, March 1983.
5. Asian Development Bank. Bangladesh Country Paper. *Proc., Transport Policy Regional Seminar*, Vol. 2, Manila, Philippines, Feb. 1989.
6. B. T. S. Sugijoko and S. Horthy. The Role of Nonmotorized Transport Modes in Indonesian Cities. In *Transportation Research Record 1294*, TRB, National Research Council, Washington, D.C., 1991, pp. 16–25.
7. V. S. Pendakur. Formal and Informal Urban Transport in Asia. *CUSO Journal*, Dec. 1987, pp. 18–20.
8. *Energy in Developing Countries*. U.S. Office of Technology Assessment, 1991, pp. 96–97.
9. *Monthly Energy Review*. Energy Information Administration, U.S. Department of Energy, March 1989.
10. J. J. Erickson, D. L. Greene, and A. J. Sabadell. An Analysis of Transportation Energy Conservation Projects in Developing Countries. *Transportation*, Vol. 1, No. 5, 1988.
11. A. Wilmink. The Effect of an Urban Bicycle Network: Results of the Delft Bicycle Project. *Proc., Velo City '87 International Bicycle Congress*, 1987, pp. 233–238.
12. D. H. ten Grotenhuis, P. J. Jarreman, and A. D. Pettinga. *Fietsen in Delft: Planning for the Urban Cyclist*. Public Works Services, Traffic Department, Municipality of Delft, the Netherlands, 1984.
13. Z. Song. *Capacity of Signalized Intersections: A Study Carried Out in Beijing, China*. Report 53. Institute of Roads, Transport,

and Town Planning; Technical University of Denmark, 1987, pp. 41–47.
14. M. Replogle. *Non-Motorized Vehicles in Asian Cities*. Technical Paper 162. World Bank, Washington, D.C., 1992.
15. H. S. L. Fan. Passenger Car Equivalents for Vehicles on Singapore Expressways. *Transportation Research*, Vol. 24A, No. 5, 1990, pp. 391–396.
16. M. Replogle. The Role of Bicycles in Public Transportation Access. In *Transportation Research Record 959*, TRB, National Research Council, Washington, D.C., 1984, pp. 55–62.
17. M. Replogle. *Bicycles and Public Transportation: New Links to Suburban Transit Markets*. Institute for Transportation and Development Policy, Washington, D.C., 1983.
18. M. Replogle and H. Parcells. *Linking Bicycle/Pedestrian Facilities with Transit*. National Bicycling and Walking Study. FHWA, U.S. Department of Transportation (in preparation).
19. W. Thornhill. Nonmotorized Transport in Tianjin, China. Presented at the 70th Annual Meeting of the Transportation Research Board, Washington, D.C., 1991.
20. S. Chen. Major Issues in Transport Planning of Shanghai. *China City Planning Review*, Sept. 1990, pp. 17–26.
21. D. A. C. Maunder. *Comparison of Cycle Use in Delhi, Jaipur, and Hyderabad*. U.K. Transport and Road Research Laboratory, Crowthorne, Berkshire, England, 1980.
22. M. Lowe. *The Bicycle: Vehicle for a Small Planet*. Worldwatch Paper 90. Worldwatch Institute, Washington, D.C., 1989.
23. United Nations. *Bicycles and Components: A Pilot Survey of Opportunities for Trade Among Developing Countries*. United Nations Conference on Trade and Development/General Agreement on Tariffs and Trade, Geneva, Switzerland, 1985.
24. K. Uchida. Current Issues in Tokyo Regional Transport Planning. *The Wheel Extended*, No. 77, Toyota Motor Corp., Tokyo, Japan.
25. *Research Report on Strengthening the Bicycle Network Function* (in Japanese). Japan Bicycle Road Association, Tokyo, 1988.
26. *Traffic in Melbourne Study: State of the System*. Vic Roads, Melbourne, Australia, Nov. 1990.

Publication of this paper sponsored by Committee on Bicycling and Bicycle Facilities.