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Contents

Foreword

The papers in this Record were presented at conference sessions devoted to nonmotorized transportation during the Transportation Research Board's Annual Meetings in 1990 and 1991. For several years Ralph Hirsch and Michael Replogle organized conference sessions on nonmotorized transportation, and as interest built, more presentations were offered and attendance at the sessions increased sharply. For the 1991 Annual Meeting, V. Setty Pendakur, with the aid of Michael Replogle, organized four conference sessions on this topic. Interest had now reached the point where formal papers were solicited, submitted, and reviewed. A combination of the papers presented in 1991 and two papers from the 1990 Annual Meeting resulted in this Record.

The papers fall into three groups. First are those primarily concerned with bicycles. Koike discusses issues and problems of bicycles as an increasingly used mode of transport in Japan. Bicycling experience in a country with a northern climate, Finland, is described by Ojajärvi. Hope describes a community bicycling manual that is used for planning bicycle facilities in Canada.

In the next group, pedestrian characteristics are compared for Sri Lanka and Canada by Morrall et al. and pedestrian movement is analyzed for Bangkok, Thailand, by Tanaboriboon and Guyano.

In the last group, the authors discuss mode choice and the role of nonmotorized transportation. Pendakur and Guarnaschelli are particularly concerned with transport among the poor and use Katmandu, Nepal, to illustrate their conceptual arguments. The importance and role of nonmotorized transportation in India and Indonesia are discussed by Sarna and by Soegijoko and Horthy, respectively. Gibbons describes research done in Kanpur, India, that identified relationships between different travel modes and land uses. This led to land use planning that more effectively accommodates slow-moving vehicles while providing for faster vehicles. Replogle discusses current transportation policies in developing countries, forces shaping these policies, and the implications of current policies for low-income people, the environment, and economic development. This paper provides an overview of some key issues related to sustainable transportation, particularly in developing countries.

Sustainable Transportation Strategies for Third-World Development

MICHAEL A. REPLOGLE

Current transportation policies in developing countries, forces shaping these policies, and the implications of current policies for low-income people, the environment, and economic development are discussed. Current policies favor rapid motorization of transport to the detriment of modal diversity and nonmotorized modes, such as bicycles, cycle-rickshaws, and pedestrians. Such policies, rather than fostering real development, accelerate global climate change, increase air pollution, and weaken petroleum-importing economies, while often increasing inequality, social conflict, and poverty. Economic efficiency is diminished by decreased diversity in urban transportation systems, forcing people to conform to the few higher-cost ways of traveling offered rather than allow these movements to be made by the most appropriate and affordable means. The concept of sustainable transportation calls for a more holistic approach to policy and investment planning to achieve a diverse and balanced mix of transport modes and a sensible arrangement of land use that enables conservative use of energy and capital to fulfill mobility needs. Sustainable transportation strategies are those that can meet the basic mobility needs of all and be sustained into the foreseeable future without destruction of the planetary resource base. An overview of some of the key issues related to sustainable transportation is provided.

A large number of different transportation modes are in use around the world today, meeting in various ways and with varying success the mobility needs of human communities. The World Bank (*1*) estimates that 600 million person-trips per day were made by bus in Third-World cities in 1980. Rail trips and rural bus trips account for a modest increment of several hundred million more daily trips across the Third World. The 50 million automobiles in the Third World (*2*) account for roughly a quarter billion automobile person-trips daily. In contrast, with a half billion bicycles in the Third World, there are several billion bicycle trips per day. Daily pedestrian trips likely number as many as 10 billion per day.

MODAL DIVERSITY

Variations in the level of use of different motorized and nonmotorized transportation modes are a function of many forces. These forces include investment, subsidy, and tax and tariff policies, infrastructure design and planning, regulatory actions, topography, climate, cultural tendencies and habits, income levels and distributions, and land use patterns that evolve in response to long-term transportation system evolution. Many of these forces are strongly influenced by technocrats and social elites who shape investment policies and who direct government planning and policy formation.

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Transportation engineers, planners, and policy makers have tended to focus most of their attention on the higher-cost motorized transportation modes when studying transportation systems, identifying policy options, and offering investment plans. Traditional nonmotorized and low-cost transportation modes—such as bicycles, carts, trishaws, small locally produced boats, and oxcarts—have generally been ignored or dismissed without study as backward and inefficient. Few data have been collected about these modes, reinforcing the impression among many that they are of little consequence. The most basic mode, walking, is similarly neglected.

However, the majority of all trips made in the world are made by foot. In developing countries, most people rely on nonmotorized transportation, occasionally or regularly supplemented by public transportation, often provided by the informal sector of the economy. In most cities, the number of people affected by inadequate facilities for pedestrians and bicycles and by slow and overcrowded public transportation vastly exceeds the number affected by traffic congestion and parking problems.

Many developing countries cannot provide sufficient investment in public transportation even to keep up with population growth. Many of the poor cannot afford even low-cost public transportation and must simply walk. In rural areas, appropriate vehicles and transport services are frequently not available or affordable for the majority of people.

As a United Nations study (*3*) notes, the rural poor are

> locked into a vicious circle involving lack of money, inadequate equipment, time-consuming and health-impairing methods of transport, lack of production flexibility and exploitation by transporters and middlemen. Inadequate transportation in rural areas. . .hampers productivity, limits access to services such as education and health services, and isolates much of the population from political and social life.

The distributional impacts of both rural and urban transport system investments continue to be ignored at huge social and human costs. Even when transport investments are made with an intent to help alleviate poverty, those who are better off in the first place are far better able to capture the benefits of these investments, because the poor often cannot afford to purchase or use available vehicles. The net effect of much current transportation investment in developing countries is to increase social and economic stratification at the expense of the poor while boosting import requirements, foreign debt, and environmental problems.

Reduction in the diversity of transportation modal options within societies often reduces economic efficiency by forcing movements of people or goods to conform to the few higher-cost modes offered rather than enable these movements to be made by the most appropriate and affordable means. More people end up walking long distances or waiting for buses that sometimes never come, or they abandon the idea of moving themselves or their goods to places that they might have been able to reach by an affordable but unavailable mode of transport.

Just as an ecological system is healthiest when it displays great diversity and differentiation, so too is a transportation system healthiest and most robust when diverse modal options are available to those moving people or goods. A transportation system dependent on only one or two modes of transport is far more susceptible to inefficiency, disruption, and system failure than is one in which numerous different modes are allowed to operate within a competitive market environment, regulated to the extent necessary to ensure safety and fair allocation of street space and other infrastructure among the modes serving different market niches.

NONMOTORIZED TRANSPORTATION

Walking is the most fundamental form of human transportation, something most of us do both in developed and developing countries. Many billions of trips are made by foot every day. Walking accounts for two-thirds of total trips in large African cities such as Kinshasa and Dar es Salaam. In relatively prosperous Malaysia, a recent study found that 70 percent of all on-farm trips and 50 percent of shopping trips are made on foot. A survey of one district in India found that nearly 40 percent of rural households spend no money on transport, being totally dependent on walking. In Kenya, surveys have found that more than 90 percent of rural trips were on foot, 4 percent by bicycle, 2 percent by paratransit (small informal public transportation vehicles), and only 0.5 percent by bus (*4*, p.130).

In many parts of Asia, the bicycle is a predominant means of short-distance vehicular transport. In China there are over 270 million bicycles and the urban bicycle ownership rate is about 0.5 bicycle per person and growing. In most Chinese cities, 50 to 90 percent of vehicular passenger movements is by bicycle, with most of the remainder by bus (*5*). In India there are 25 times as many bicycles as motor vehicles (*6*). In Madras one-third of vehicles entering the central business district is bicycles, as is 25 percent of vehicles passing a cordon line 10 mi out from the center. Pedal-powered trishaws constitute a predominant element in the street traffic of cities like Dhaka, Bangladesh, and account for the majority of all goods movements. In Thailand, Indonesia, Pakistan, and many other countries in this region, bicycles and tricycles have attained similar importance.

In many parts of Latin America, the Caribbean, and Africa, however, bicycles and tricycles are far less common. However, opportunities for the transfer of bicycle and tricycle technologies between Asia and these regions appear to be great, especially in the many countries with large low-income populations and inadequate public transportation systems and those undergoing structural adjustment in response to debt problems that have been exacerbated by unsustainable levels of petroleum and motor vehicle imports.

MOTORIZED TRANSPORTATION

Public Transportation

A wide variety of motorized public transportation services operated by both the private and public sectors is found throughout developing countries. The vehicles used include motorized trishaws built on extended motorcycle frames; small trucks; buses; vans, larger buses, and trucks outfitted for passenger hauling; and many types of rail vehicles.

Motorized public transportation in developing countries has been the subject of much research and discussion by transportation professionals. It has an important role in moving people around urban and rural areas with only modest impact on the environment and modest demands on scarce energy and capital resources. However, even if public transportation is relatively inexpensive and efficient, many people still cannot afford it and will seek alternative means to move themselves or their goods.

In many countries, public transport services have failed to keep up with population growth, widening the gap between transport system supply and demand. Levels of investment in public transport have been restrained in many countries in the past decade by capital shortages, especially in nations with severe debt problems.

Private Transportation

Around the world, people dream of owning automobiles and covet their speed, privacy, comfort, and convenience. People everywhere seek access to automobiles for themselves and their societies whenever this goal appears attainable. Achieving an automotive society, however, is well beyond the means of most of the world, at least for the foreseeable future. Worldwide petroleum, capital, and infrastructure are insufficient for this condition to be a near-term global goal. Motorization is a pleasure attainable only by a minority of the world's people.

Motorization is retarding development for the majority of Third-World people. Imports of petroleum and motor vehicles consume one-third to one-half of the foreign exchange earnings of many developing countries, for example, Haiti, Honduras, Kenya, and Thailand. Instead of providing affordable mass transportation, these imports often simply increase debt burdens and budding automobile cultures irrespective of the needs of the majority.

Automobile ownership levels remain low in much of the world. Of every 1,000 people, fewer than 5 are car owners in Haiti, Pakistan, India, and China; fewer than 7 in Indonesia, Ecuador, Zaire, and Honduras; fewer than 12 in Africa as a whole; and fewer than 15 in Thailand and Nicaragua. In Brazil and Mexico, 75 out of 1,000 people own cars compared with 370 in the Western European countries of the Organization for Economic Cooperation and Development (OECD) and 570 in the United States.

Automobile ownership in the Third World increased at an average annual growth rate of 11 percent in the first half of the 1970s and 8 percent in the second half of the 1970s. Decreasing commodity prices and increasing debt burdens limited the annual market growth rate to 5 percent in the 1980s. China and India together own over 600 million bicycles and scarcely 0.5 percent of the world's cars. Recently, however, both countries have changed their priorities to embark on policies to stimulate automobile production and use, with help from some Western transportation experts and corporations (*2*).

Spreading Culture of Motorization

Current trends favor growth in motorization. The automobile has become a central icon of the emerging global culture of the late 20th century. Motorization has proponents, especially among the social elite, in nearly every nation on earth. A variety of institutional structures have been established to defend the interests of motor vehicle users and producers.

International lending institutions, corporations, and Third-World elite groups largely favor transportation policies similar to those that led to the motorization of North America. These policies emphasize maximizing subsidies and government spending to benefit motorization through effective control of transportation investment policies; expanding the formal transport sector while restricting, regulating, or eliminating informal transport sector activities; reallocating street space and infrastructure to restrict nonmotorized transportation; and encouraging the decapitalization of modes that offer an alternative to motor vehicles.

For example, though bicycles provide the primary means of rural and urban mobility in China, the World Bank recently issued a 400-page report (*7*) on China's transportation sector that did not even mention the bicycle. Rather than identifying means for better integrating land use controls, traffic management systems, and the current bicycle-based transport system with more and better public transportation, some Chinese planners, such as Min Fengkui, now call for bicycle traffic to be strictly controlled with the ultimate intent of reducing it to an auxiliary means of short-range transportation. Writing about the bicycle problem in China, Fengkui (*5*) reflects the attitude of many Third-World professionals:

> As has been shown in the developed countries, the traffic role of bicycles will gradually phase out when urban transportation becomes modernized. . . . Their functions there have already been reduced to being tools of sports, recreation and tourism. Such examples should serve as our reference in the planning of our future urban development. Currently efforts should be focused on speeding up road construction, improving public transportation and traffic control and restraining volume of bicycle traffic in the cities, so as to prevent further worsening of urban traffic congestion. . . . Steps should be taken now to restrict overproduction of bicycles. . . . Control on urban bicycle traffic should be tightened by strictly restricting licensing and enforcing safety inspection of bicycles. Bicycles should not be allowed to travel on certain vital or busy urban streets, but be gradually diverted to specially built bicycle lanes in different urban districts. . . . A full-scale development of urban road, public transportation and traffic control systems should be carried out with the ultimate aim of completely modernizing the urban traffic system in the Chinese cities.

Although many transportation decision makers view the United States as a model and equate the modernization of transportation systems with total motorization, other potential models, such as the Netherlands, Switzerland, and Japan, clearly demonstrate the important role that nonmotorized transportation can play in modern transport systems, especially for short trips and for access to public transport services (*8*).

Transportation investments closely reflect systems of power in the world. Former Philippine senator José Diokno understood how transportation investment limited development of local economies in his country while fostering dependency on raw material exports.

> Look at the expressways. Most of the cars that go through are private cars. Who owns the private cars in this country? The elite. And did you notice one more thing? All of these expressways converged in Manila when we should have been building roads connecting the different barrios to the poplacion (town) and one barrio to another so that the flow of goods would not all go in one direction, which is towards an outgoing port, but would have been circulating internally.

Transportation system development is not market driven. Technocratic control is usually in the hands of engineers and economists wealthy enough to own cars, trained in American-style policy solutions, and subject to political control from those who profit from oil import deals, automobile dealerships, construction contracts, or other aspects of motorization. Most transportation investments and subsidies benefit the formal transport sector of motor cars, trucks, aviation, railways, and motorbuses. The prime criteria for most transportation investments in developing countries are the potential benefits to corporations and military security interests, not the potential benefits to communities or informal economic sectors.

International development organizations influence policies adopted by local elite groups. Current World Bank lending for 18 road projects is U.S. $1 billion. The major share of $100 million in annual World Bank spending for urban transport is related to automobile transportation promotion. Between 1972 and 1985, the World Bank spent more than a half-billion dollars on urban road construction, improvement, and maintenance, with about $120 million devoted to urban traffic management and road safety. Of the $2.1 billion spent by the World Bank in 1985 on transportation, minuscule amounts were expended to benefit the nonmotorized informal transportation sector.

The long-term effect of World Bank programs has been to encourage capital and energy-intensive transport systems. In Pakistan, for instance, the World Bank is investing hundreds of millions of dollars to develop a local automobile industry, although less than 1 percent of Pakistanis own cars and walking and cycling account for 60 percent of total trips and 40 percent of work-related trips, even in its former capital city of Karachi.

Little investment has gone into research and development of those modes that are of greatest use to the poor. As an Indian development professional, Hoda (*9*) has noted,

> Our research programs do not have even a remote relationship with the problems of poor people and rural areas of India. We consider research on aeroplanes, aerospace, and automobiles as the real science, whereas research on Indian modes of transport like bullock carts, horse carts, and rickshaws is considered substandard and below dignity. . . . The transport problems

of the bulk of people in this country can be solved by working on these indigenous vehicles and not by working on airplanes, rockets and automobiles.

The leading global lending institutions frequently help reinforce these attitudes. The World Bank's recently updated report on urban transport policy (*1*) refers appropriately to helping "developing countries find inexpensive ways of increasing transport capacity and improving transport flows, with particular attention to the transport needs of the urban poor," but nonmotorized transport is viewed solely as a congestion generator rather than as a part of the solution to urban mobility problems. The report ignores extensive recommendations published in other recent World Bank studies that call for a reorientation to favor such low-cost transportation to meet basic needs (*10,11*), as well as the similar recommendations of the United Nations Center for Human Settlements (*3*) and other experts (*4,12*).

For urban areas in developing countries, the World Bank and many others have advocated better transportation system management (TSM), including restrictions on urban automobile use, and more investment in motorized public transportation services. TSM offers many excellent ideas for more cost-effective and environmentally sound transportation, and buses offer a sound means for low-cost public transport in most circumstances (*13*). However, the effectiveness of many TSM strategies has been limited by political resistance to serious urban automobile restraints. In most cities, shortages of financing have kept the growth rate of public transportation services below population growth rates, leading to low service quality.

In many countries, TSM has been used to reduce the availability of low-cost transport, forcing people to walk, to use already overcrowded public transport, or to defer travel. Too often, the concepts of TSM have been applied solely to improve motor vehicle traffic flow. With this objective, TSM has often focused on getting rid of or displacing in time or space existing pedestrian and pedal-powered traffic. This policy has pushed more people into dependence on motorized transportation, in the end leading to more traffic and a loss of the original improvement in transportation efficiency. Motor-vehicle-biased TSM has been encouraged by policies of the World Bank, which have been generally hostile to human-powered transportation modes. The sole use of the word "bicycle" in the World Bank's 1986 transport policy report (*1*) is in the following statement: "Congestion is often exacerbated when the road network must cope with a mixture of motorized vehicles, other modes of transport (such as bicycles and pedal carts), and pedestrians."

BANNING SLOW TRAFFIC

Following the inference of such statements, many cities have imposed constraints on nonmotorized modes of travel, such as cycle rickshaws, bicycles, and pedestrians, claiming that these cause congestion. This claim is despite the fact that bikeways offer capacities that are far higher than typical automobile freeways and close to the capacities of buses in mixed traffic (*3*).

Transportation policy makers in a number of developing countries have destroyed valuable nonmotorized transportation resources because they see them as symbols of backwardness and hold them accountable for motor vehicle traffic congestion and safety problems. In Kuala Lumpur, Malaysia, and Jakarta, Indonesia, many thousands of cycle rickshaws have been thrown into the sea in the past several years (*14*). In April 1987, the government of Dacca, Bangladesh, announced plans to completely ban pedicabs from the city on safety grounds, although they employed more than 100,000 people (*15*).

The wholesale assault on trishaws and bicycles on safety grounds is simply an expression of the political power of automobile users and motorized public transport interests who resent sharing road space with slow nonmotorized modes used by the poor. This situation has its structural parallel in the removal of slums and squatter settlements by elite groups who wish to displace the poor to favor their own interests. In urban housing policies, slum clearance has been largely discredited in the international development community and replaced by sites and services approaches to community development, in recognition of the lack of resources to provide every household in squatter settlements in the developing world with adequate housing. Similar changes in thinking are needed in transport policy, in recognition of the lack of resources to provide every person in the world with motorized transport. The banning of trishaws is nothing less than slum clearance on Third-World streets. Just as slum clearances destroy real housing resources for the poor, so too do current transport policies destroy real transportation resources, harming millions of people who lack the political power to defend their mobility systems.

NEW DIRECTIONS AT WORLD BANK

The World Bank plays an important role in setting the direction of global development policies. It has begun to respond to criticism that its policies have damaged the environment and harmed low-income people. The Bank's reorganization in 1987 led to shifts in personnel, some decentralization, and possibilities for policy innovation at the project level.

In 1988, the U.S. Congress passed legislation requiring the U.S. representatives to the multilateral lending institutions to press for more attention to low-cost, nonmotorized transportation in development lending. The Congress also requested that the Agency for International Development undertake initiatives in this area. Further legislation is awaiting Congressional action. Concern over global warming and the debt crisis is leading to a changing political climate for transport policy reform.

The World Bank is now funding a project in Ghana that includes a small but important component to build low-cost (U.S. $4,300 per kilometer) feeder village-to-market paths, to provide nonmotorized vehicles to villages served by these paths, and to strengthen a local workshop producing nonmotorized vehicles (*16*). A World Bank–funded project in Mozambique will provide a slow traffic lane as part of a road rehabilitation project in Beira. Transport policy in the Sub-Saharan Africa is undergoing reassessment with potential for greater recognition of the vital role nonmotorized transport must play in economic development. These small elements are indicative of positive changes in World Bank transport policy at the project level. However, whether these changes will result in serious funding for and high-level policies supportive of nonmotorized and sustainable transport strategies remains to be seen.

ALTERNATIVE POLICIES FOR SUSTAINABLE DEVELOPMENT

Infrastructure and Land Use

The safety and congestion problems associated with automobiles and pedal-powered modes have much in common when situations are compared in which one or the other of these has clear local dominance in traffic. Different problems occur when there is a more even mixture of automobiles and nonmotorized traffic.

In the developed world, the response to automobile-induced traffic congestion has been to control land development staging, institute better traffic management, and program additional infrastructure and transit services. In cities where bicycle traffic congestion is a major problem, similar solutions should be adopted. Better traffic management and design might include improved traffic signal systems that are explicitly designed for slow traffic, as in the Netherlands; creation of one-way modally segregated street systems; and where extremely high volumes of bicycle traffic clog intersections—such as in some Chinese cities where up to 50,000 bicycles per hour have been counted passing through a single intersection—grade separation through use of underpasses (*17*).

Transportation investment policies need to be reordered to place more emphasis on making roads and trails suitable for low-cost vehicles. In urban areas, street space needs to be reallocated to enhance the safety and usefulness of nonmotorized modes. Sidewalks, footpaths, and pedestrian and bicycle under- and overpasses crossing congested arterial roads need to be incorporated as standard elements of urban transportation planning. Automobiles should be subject to far greater restrictions and higher user fees in dense central city areas. Area licensing schemes, as used successfully in Singapore, should be more widely adopted, along with more widespread automobile-free zones and strict parking law enforcement. Area licensing requires all private motor vehicles entering an area to either maintain a minimum occupancy level (such as four persons per automobile) or to display an area license that can be purchased on a daily or monthly basis for one to several dollars per day.

Urban land use planning should encourage heterogeneous land use patterns at a small scale and a mix of housing types at different cost levels. Spatial separation of economic activities and residential locations, except for heavy and hazardous industrial uses, should be minimized. Mixed land use patterns with greater decentralization of employment can reduce the need for motorized commuting and foster community integration. When cities grow ever larger, it is desirable to locate employment clusters along rail nodes and in corridors well served by rail or bus public transportation, with affordable, transit-accessible housing nearby.

The development of new roads in rural areas should be accompanied whenever possible by land redistribution and the assurance of secure land tenure to those living near the new roads. Without this, most benefits of the new roads will accrue to those who own the land or who have the capital to take advantage of increased market access. In many countries, rural road programs have simply pushed those at the bottom of the economic heap onto more marginal lands, creating injury rather than benefit as the larger landowners succeeded in driving off subsistence producers from what has often been ancestral land. Major transportation investments without development of an equitable system of land distribution inherently will increase inequality and economic stratification.

In countries where capital is insufficient to meet the basic transport development needs of the poor majority, road construction standards should be reduced to cut costs, and more labor-intensive, lighter-weight motorized and nonmotorized vehicles should be favored over heavy vehicles, except for transport of bulk commodities on selected routes. In many cases, this traffic might be well served by rail.

Road weight standards need to be set and enforced, and the costs of road maintenance should be borne by those imposing the most wear and tear on the roads. Wear and tear on roads varies by the fourth power of axle weight, so most road maintenance costs are attributable to heavy truck traffic. Frequently, only large corporations and those dependent on them (an influential and sometimes sizable minority) benefit from this traffic. It makes no sense to build roads unless they can be properly maintained.

More attention should be paid to the integration of motorized and nonmotorized modes, encouraging bicycle access to express transit services for longer-distance trips. As city size increases, average trip lengths tend to increase, and the usefulness of bicycles and walking in urban areas is diminished. In Western Europe and Japan today, the fastest-growing and predominant access mode to suburban railways is the bicycle, accounting for one-fourth to one-half of access trips to stations (*18*). In India and China, bicycles play a major role in access to commuter railways. Adequate supporting infrastructure, including secure parking at station entrances and safe access routes, is needed to enhance such intermodal integration.

Urban rail passenger transportation has an important role to play in the development of large cities. Modal diversity, as previously argued, is essential to the creation of healthy cities. However, the same forces that have promoted motorization and made use of low-cost, nonmotorized modes of transport marginal have been hostile to new investment in rail transportation systems.

The World Bank has been resistant to most proposals for highly capital-intensive metrorail system development in Third-World cities, arguing that these are not cost-effective and benefit mostly the middle class. However, many capital-intensive road projects funded by the World Bank appear to be vulnerable to the same arguments. The World Bank's aggressive promotion of urban bus alternatives to the exclusion of all forms of rail has failed to address basic needs.

Especially in larger cities, light-rail or commuter rail systems, combined with bicycle access and egress systems in moderate- to high-density suburban areas as in much of Europe and Japan, offer cost-effective investment opportunities.

Surface rail infrastructure on its own right-of-way offers far more reasonable costs than tunneled track, which can likely be justified only in extremely dense central areas.

Investments in rail infrastructure, however, should be accompanied by programs to recapture for the public sector most infrastructure and operating costs. Special real estate assessment districts, public-private joint development of land adjacent to stations, and other techniques are needed to ensure that these major investments do not simply profit a handful of already affluent landowners.

Access to Vehicles for Mobility

In Europe and America, roads are built with the reasonable expectation that users will obtain the necessary vehicles to operate on the infrastructure provided. In developing countries, this expectation persists but results in serious system failure because few can afford vehicles for the infrastructure, and many trips need to be made in places without any infrastructure. In this situation, resources need to be reallocated from infrastructure to providing the poor with better access to low-cost vehicles and efficient carrying devices. Such tools can have a major effect on the labor productivity of the poor and their access to services and local markets. The hauling of produce and collection of water and cooking fuel require many hours of labor each day for millions of people around the world, especially women.

A recent World Bank project design (*16*) estimated the costs of head-loading in rural Ghana at U.S. $8 per ton-mile, some 8 to 12 times more expensive than any other form of transport, and noted that

> the head-loading and foot-path economy not only constrains production and marketing, but also limits other forms of rural mobility and access to schools and health facilities, severely affecting the development of human capital and the quality of life. Extensive head-loading also causes a severe health problem (cervical spondylosis) due to constant trauma to the neck and spine and remains the most burdensome chore affecting the rural woman's life. . . . Head-porterage effectively limits the time and energy available for farm activities, particularly because the peak of transport activity coincides with the peak of farming activity in the harvest season.

This report noted that building motorable roads to reach villages by truck is not a supportable economic solution; the appropriate and recommended solution (*16*) is rather

> low cost "single blade" roads (costing about 8 % of a standard feeder road), *in combination with* the provision of low-cost non-motor transport such as bicycle-trailers and specially designed hand-propelled farm carts—both of which are relatively new to Ghana. This combination will *help mechanize*, and provide a substitute for, human transportation by head-loading.

The provision of low-cost credit for the purchase of bicycles, carts, pack animals, and similar vehicles should be a high priority to ensure that more of the poor have access to affordable mobility. In Hyderabad, India, commercial banks are encouraged to lend to rickshaw operators for the purchase of vehicles. In Santo Domingo, Dominican Republic, a credit union of tricicleros helps finance vehicle purchases and a tricycle assembly project. Such lending programs, targeted at microenterprises, can provide major stimulation to local economic activity.

Those of higher status, such as rural extension agents in health, education, and agriculture, should be afforded bicycles to enhance their productivity at low cost and to counter the low-status associations that human-powered modes have in many countries. For the cost of sending one jeep to the front office of a development project, a whole fleet of new all-terrain bicycles can be sent to provide mobility to project participants, organizers, and agents. Food distribution efforts in famines should incorporate human-powered utility vehicles where appropriate to augment other transport resources, especially where trucks cannot go.

Creation of more modally diverse vehicle fleets can enhance economic efficiency in cities, too. In Bogota, Colombia, a large bakery once used only trucks to deliver baked goods to its 600 retail outlets. Today the bakery uses semitrailer trucks to distribute inventory to six subdistribution centers, from which a fleet of cargo tricycles of 1-m^3 capacity provides final distribution to retail outlets. By recognizing the benefits of modal differentiation, the bakery cut distribution costs by over half while increasing employment (*12*).

The difference in labor and capital intensity between motorized and nonmotorized modes is vital to understanding their appropriate respective roles in low-income countries. A 100,000-rupee (U.S. $12,000) investment in a conventional bus system in Patna, India, for example, enables creation of two new direct jobs. If the same amount is invested in a motorized autorickshaw, six direct jobs are created. The same sum invested in the cycle rickshaw industry creates 75 jobs (*19*). Where capital is scarce and incomes are low, nonmotorized transportation offers far more potential for the creation of microenterprises than motorized transport systems and can thus serve as a powerful engine for sustainable and healthy economic growth at the base of such societies.

Most countries should be encouraged to develop local bicycle assembly and cart production capabilities for domestic use. This policy can create significant employment opportunities. Even if all of the bicycle parts must be imported, these imports can continue to generate productive outputs for some time, rather than being spent on a single trip, as petroleum imports are. Several countries have fostered domestic bicycle manufacturing industries with varying success. Mexico and China both have offered subsidies to their bicycle industries to enhance access of lower-income people to this mode and encourage domestic production. The attempts of Tanzania and Mozambique to establish protected domestic bicycle manufacturing were failures because of low product quality and high costs of local parts manufacture. However, by starting with small assembly workshops of low capital cost and only gradually assuming the production of selected bicycle components, countries with little or no industrial base can begin to develop appropriate domestic transportation vehicle manufacturing capabilities with low risk (*12,20*).

Research, Development, Demonstration, and Policy

More resources should be committed to research and demonstration related to safety of nonmotorized modes. Better traffic management, infrastructure, and vehicle design; the encouragement of bicycle helmet use; and safety education all have a role to play in this area.

Modest investments in the design of cycle rickshaws, for example, could yield substantial increases in their safety and efficiency in traffic. Most cycle rickshaws have only one gear, making them hard to start in motion, particularly at the base of an incline. Most also have only a single, often poor quality brake on the front wheel of the vehicle. A development group working in India has demonstrated that by retrofitting existing rickshaws with three-speed gearing and a three-wheel braking system, vehicle safety, efficiency in traffic, and driver working conditions can all be greatly improved with less than a 20 percent increase in vehicle cost (*9*).

There should be more funding for research on transportation problems in developing countries and more work to transfer low-cost human-powered transportation technologies from the countries where they are successful to those in need of low-cost mobility, especially to Africa and Latin America. Relatively small investments could produce significant improvements in traditional carrying devices and vehicles powered by humans, animals, wind, and sun, extending their range and utility at low cost.

Funding is needed to support demonstration projects for the transfer of emergent low-cost transportation technologies. For example, all-terrain bicycles, a recent innovation, offer much greater performance than traditional bicycles. Although multiple barriers impede the diffusion of such new technologies, demonstration projects can help identify and overcome these difficulties.

More encouragement should be extended for the creation of locally responsive appropriate technology research and training centers to study and respond to local needs, including those in transportation, and to build community leadership and skills. Transportation projects should be designed in consultation with representatives of the poor and the users of slow transportation modes to identify alternative strategies for mobility enhancement, unmet travel needs, and ways of making projects most compatible with the interests of all potential users.

Transportation professionals at all levels should be encouraged to take nonmotorized and informal modes of transport seriously in the collection and analysis of data, the design of facilities and policies, and the evaluation of alternative solutions to mobility problems. Textbooks designed for traffic planning in the United States and Europe are inappropriate for Third-World transport planning. Funding is needed to support the development of new textbooks and planning paradigms for sustainable transport system planning and development, especially for low-income countries.

Diverse programs and actions should be undertaken to influence public opinion in favor of less-resource-intensive transportation modes and to promote traffic discipline and safety in the operation of both motorized and nonmotorized modes.

Impact statements should be required for all transportation projects funded by development lending institutions to identify alternatives and anticipated impacts of projects on the environment, on alternative transportation modes, on the poor, and on long-term foreign currency requirements. Such impact statements might be required as part of legislation funding various aid programs. A process for public review and comment on these statements should be required.

Taxes on automobile purchases and operation, particularly for private use, should be increased sharply to reflect the true costs of automobile use on the urban environment. Subsidies for automobile use of urban road space should be eliminated. It is common for private motor vehicle traffic used by a minority of the population to be allocated the majority of publicly provided street space, to the detriment of public transportation, which suffers from severe congestion, and nonmotorized traffic, which often simply loses a safe place to operate. Road pricing and street space reallocation through physical separation of modes can address these problems.

Taxes and tariffs on bicycles, public transportation vehicles, and nonmotorized vehicles should be eliminated or sharply reduced to enhance their affordability by the poor and near-poor. Public transport pricing should encourage economic use of resources while maintaining basic access for the poor. Innovations in services and modes should be encouraged by allowing private-sector competition with regulation to ensure safety and fair access to street space.

CONCLUSIONS

Major changes are needed in the priorities for transportation policy in the Third World if development is to meet human needs rather than benefit only the world's current elite groups. The costs of failing to redirect transport policies today will be paid in the decades to come through a sharply reduced quality of life in the world's cities, increased conflict between the mobile elite and the mobility-restricted poor, and reduced capacity to solve the problems of capital shortages, unpayable debt burdens, toxic air pollution, and global climate change.

Changes in transport policies are needed not only in the Third World, but also in many advanced industrial and post-industrial countries. It will become increasingly difficult in coming decades for policy makers to ignore the global limits on resource consumption, particularly in the burning of fossil fuels. The planet will remain a closed atmospheric system with finite resources and potentials for absorbing man-made pollutants.

The transition to a world that recognizes the need for social as well as economic development and a world that is based on sustainable patterns of production and consumption must begin soon. Nonmotorized transportation cannot be expected to supplant the solidly entrenched motor transport sector in the developed world in the foreseeable future, but it can serve a major portion of local travel needs, as many healthy and wealthy modern communities in the Netherlands, Denmark, and Japan demonstrate.

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Importance of Nonmotorized Transport in India

A. C. SARNA

The urban population in India has been growing rapidly. Although the present levels of urbanization are low compared with those of the developed countries, it is estimated that by the turn of the century 35 percent of the total population in India will be living in urban areas. The number of cities with a population of 0.1 million and greater will increase from 216 in 1981 to 423 by 2001. Cities are growing in size, resulting in more complex transportation problems. Motor vehicle ownership levels, which vary considerably from city to city, are generally low. A considerable proportion of urban population depends on nonmotorized modes for transportation. To improve the transport infrastructure, transportation studies should be conducted in Indian cities of all sizes so that more realistic transportation plans can be prepared in keeping with the prevalent socioeconomic environment. Greater attention has to be paid to nonmotorized modes, pedestrians, and poorer sections of society, which form a majority of the urban residents.

The present-day traffic and transportation problems in urban areas of India result from a wide variety of reasons, and solutions to these problems need to be compatible with the socioeconomic environment that prevails. Some of the important factors that contribute to the traffic and transportation problems of Indian cities are as follows:

- Urbanization patterns,
- Socioeconomic and industrial development,
- Growth in the number of motor vehicles,
- Mixed nature of traffic flow,
- Inadequacy of the infrastructure,
- Growth in transport demand, and
- Lack of effort in urban transportation planning.

URBANIZATION PATTERNS

Since India's independence in 1947, the population has been growing rapidly and has been moving from rural areas into complex and densely populated urban areas. Table 1 presents the population trends in India. The urban population as a percentage of the total population, which was around 24 percent in 1981, is expected to increase to 34.5 percent by the turn of the century. In absolute numbers, the urban population will increase from 159.7 million in 1981 to 326.0 million by 2001, thus accounting for a twofold increase in a span of two decades. Although the urban population in India is increasing rapidly over the years, the urbanization levels are quite modest compared with some developed and developing countries in which the share of urban population ranged between 38 and 86 percent compared with 20 percent in India during 1970/1971.

The Indian census categorizes urban population into six classes of cities and towns designated Class I cities (population more than 10,000) to Class VI cities (population less than 5,000). The population figures of such cities show that although the relative share of Class I cities with a population of 10,000 and above is increasing over the years, that of other classes of cities has either stagnated or registered a decline. The growth in the number of Class I cities is presented in Table 2. Those with >1,000,000 population (metropolitan cities), which numbered 9 in 1971, increased to 12 in 1981 and are expected to increase to 26 by 2001. The total number of Class I cities is expected to increase to 423 in 2001, compared with 152 in 1971 and 216 in 1981.

Transport Systems in Indian Cities

Transportation demand of urban residents in India is met through a vast variety of vehicles. The vehicles may be grouped in the following categories:

1. Private vehicles: cars, jeeps, passenger vans, scooters, motorcycles, and bicycles.
2. Public vehicles: buses, minibuses, passenger tempos, and passenger vans.
3. Hired vehicles: taxis, three-wheeler motorized autorickshaws, three-wheeler nonmotorized cycle rickshaws, and animal-drawn vehicles.
4. Goods vehicles: trucks, minitrucks, goods tempos, tankers, animal-drawn *rehras*, and hand carts.

In addition, in some major metropolitan cities like Bombay, Calcutta, Madras, and Delhi, besides the road-based transport modes, suburban trains and other short- and long-distance trains cater to commuter needs.

Growth of Motor Vehicles

Table 3 presents the growth of motor vehicles registered in the metropolitan cities in India. In most of the cities as well as in India as a whole, the number of motor vehicles has increased significantly over the years. One peculiarity about the growth in motor vehicles is the explosion in the number of two-wheelers like motorcycles, scooters, and mopeds. In

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TABLE 1 POPULATION TRENDS IN INDIA (*1*)

Year	Total Population (millions)	Urban Population (millions)	Percent of Total Population
1901	238.3	25.9	10.8
1911	252.0	25.9	10.3
1921	251.2	28.1	11.2
1931	278.9	33.5	12.0
1941	318.5	44.2	13.9
1951	361.0	62.4	17.3
1961	439.1	78.9	18.0
1971	548.2	109.1	20.2
1981	685.2	159.7	23.7
1991[a]	801.2	230.1	28.7
2001[a]	945.4	326.0	34.5

[a]Central Statistical Organization estimates (1986).

TABLE 2 GROWTH IN NUMBER OF CLASS I CITIES IN INDIA

Year	Number of Cities by Population (millions)			Total
	>1.0	0.5–1.0	0.01–0.5	
1971[a]	9	9	134	152
1981[a]	12	28	176	216
1991[b]	16	56	230	302
2001[b]	26	78	319	423

[a]*Census of India Reports* (*1*).
[b]Central Statistical Organization estimates (1986).

TABLE 3 GROWTH IN NUMBER OF MOTOR VEHICLES REGISTERED IN METROPOLITAN CITIES IN INDIA (*3*)

City	No. of Motor Vehicles (thousands)		Percentage of Growth
	1977	1985	
Calcutta	147 (22.4)[a]	286 (30.1)	95
Bombay	245 (23.3)	432 (31.7)	76
Delhi	389 (61.7)	841 (68.8)	116
Madras	69 (47.8)	139 (51.8)	101
Bangalore	109 (56.9)	279 (68.1)	156
Hyderabad	N.A.	172 (70.9)	—
Ahmedabad	68 (58.8)	177 (67.8)	160
Kanpur	32 (62.5)	89 (77.5)	178
Pune	75 (50.7)	160 (68.1)	113
Nagpur	N.A.	83 (71.1)	—
Lucknow	27 (66.7)	82 (74.4)	204
Jaipur	34 (61.8)	127 (62.2)	273
Total[b]	1,195 (47.0)	2,867 (59.1)	140

[a]Values in parentheses show percentage of two-wheelers (motorcycles, scooters, mopeds, etc.).
[b]Total number of vehicles for all of India: 1977—3,260,000 (43.4 percent two-wheelers); metropolitan vehicles as percent of total in India, 37. 1985—8,796,000 (56.4 percent two-wheelers); percent of total in India, 33.

most of the metropolitan cities (except Calcutta and Bombay), two-wheelers constitute between 50 and 78 percent (with an average figure of about 59 percent) of the registered motor vehicles. In India as a whole, two-wheelers constituted about 56 percent of total vehicles registered in the country in 1985.

Importance of Road System

The transport sector in India has recorded substantial growth during the last three decades both in its spread as well as in the output of its system. Despite the impressive performance, the capacity of the transport system continues to fall short of the demand, resulting in ever-increasing congestion on roads, leading to a decline in productivity and city efficiency.

In view of the large number of cities in India and the prevalent socioeconomic environment, the road-based systems will continue to play an important role in the movement of passengers in cities of all sizes. Not only is the road network inadequate but also the quality of roads is fast deteriorating because of the lack of proper maintenance. This problem has resulted in adverse consequences such as increased fuel consumption, lowering of speed, greater chances of accidents, and increasing discomfort to riders in general.

Transport problems of Indian cities are unique and need to be understood in a systematic manner, and facilities need to be planned for healthier growth of the urban areas.

Urban Transport Planning

Urban transport, which is the most important component of the urban system, has not been given its due so far in India, largely because its role and implications are not clearly understood. Urban transport has to be an integral part of urban planning and is closely linked to land use planning. Comprehensive traffic and transportation studies for major cities in India have been conducted in the past, generating voluminous data bases and complex transport models as well as ambitious transport plans. However, the success in terms of implementation of the proposals so far has been limited. If any success is to be achieved in planning a realistic urban transport system, greater understanding of the travel characteristics of urban residents along with more practical tools will be needed for urban transport planning exercises. It has been argued that motorized and nonmotorized vehicles have to coexist in urban India. However, the proportion of these two types of vehicle streams depends largely on the city size as well as on the economic base of the city. In the absence of any policy on urban transport (including public transport), the growth of traffic in Indian cities is haphazard, which also affects urban development and the environment.

URBAN TRAFFIC AND TRANSPORT DEMAND CHARACTERISTICS

Growth of Road Traffic

Traffic flow characteristics on the Indian road system differ significantly from those in other countries, developed or developing. Hence, in most situations the solutions to traffic problems have to be innovative rather than adapted from other countries. The low level of public transport supply in Indian cities has to a large extent led to the enormous growth of nonmotorized and motorized vehicles, particularly the motorized two-wheelers.

Heterogeneous Nature of Traffic

Traffic flow on roads in urban areas of India consists of a wide variety of vehicles ranging from animal-drawn slow vehicles to motorized fast vehicles. Cycles constitute a significant proportion of the traffic stream in most cities. Heterogeneous traffic is not easy to manage efficiently in terms of quality and quantity of traffic flow. The composition of traffic flow on roads also varies from city to city.

Road Safety

In addition to their ill effects on the environment, motor vehicles kill or injure people and damage property. The road accident trends for 12 metropolitan cities of India are presented in Table 4. The total number of accidents, persons killed, and persons injured has increased over the years. In 1985, as compared with the all-India level, around 29 percent of accidents occurred in 12 metropolitan cities, whereas the proportions of persons killed and injured were around 11 and 19 percent, respectively. From available statistics, the road users killed or injured in road accidents are mostly pedestrians and cyclists who constitute between 50 and 80 percent of the population in most of the cities.

Road accidents, besides creating social problems, also cause economic losses. According to some estimates, the total cost of road accidents in 1978 was INR 2370 million (U.S.$1 = INR 18), which was about 0.3 percent of the national income of India. Again, comparison of fatality rates per 10,000 motor vehicles for India and those for developed countries suggests that there is a wide gap, and considerable work has to be done to make the road system safer in India.

Transport Demand Growth

Passenger transportation demand in urban areas has been growing over the years. Comprehensive transportation studies have been carried out in a few metropolitan cities and are in progress for other selected cities. In addition, limited transportation studies have also been carried out in many other cities. The daily passenger transportation demand in most cities is estimated to nearly double by the turn of the century as compared with 1981 levels (*2*).

Motor Vehicle Ownership Levels

The dependence on public transport and on nonmotorized modes is reflected by the motor vehicle ownership trends in Indian cities. Motor vehicle ownership levels per 1,000 population are low in all cities in India compared with those of developed countries as well as many developing countries. Within India, these ownership levels also vary considerably, largely because of the inadequacy of the public transport system or generally lower income levels.

Socioeconomic Aspects and Mobility Levels

Socioeconomic characteristics of households for five selected cities are presented in Table 5. The following observations can be made:

- The variation in average family size and number of earners per household was not significant in the five cities.
- Average household monthly income varied between INR 1452 in Cochin to INR 2582 in Delhi.
- The proportion of households owning motor vehicles (cars, motorcycles, motor scooters, etc.) varied between 48 percent in Delhi and 65 percent in Ahmedabad.

The effect of household income and type of vehicle owned is presented in Figure 1 and Table 6. Daily one-way trip rates (including walk trips) increase with increasing household income. The mobility levels of households owning motor vehicles are higher compared with levels of households owning bicycles or no vehicles. The trends also suggest higher mobility levels of different population groups in larger cities. The mobility levels of low-income households are low compared with those of higher-income households.

Quality of Transport Services

In many Indian cities, with the exceptions of the three major metropolitan cities of Bombay, Calcutta, and Madras, in which

TABLE 4 ROAD ACCIDENT TRENDS IN METROPOLITAN CITIES IN INDIA (*3*)

	1977			1985		
City	Total Accidents	Persons Killed	Persons Injured	Total Accidents	Persons Killed	Persons Injured
Ahmedabad	1,491	149	1,491	2,279	143	2,077
Bangalore	3,523	247	2,931	4,805	419	3,892
Bombay	25,743	660	9,545	26,759	657	8,002
Calcutta	10,611	358	3,783	8,108	421	3,170
Delhi	4,032	694	3,874	6,254	1,269	6,366
Hyderabad	965	210	879	1,493	221	691
Jaipur	N.A.	N.A.	N.A.	641	133	572
Kanpur	450	73	352	458	130	345
Lucknow	N.A.	N.A.	N.A.	814	150	664
Madras	5,177	199	2,811	5,155	397	4,558
Nagpur	N.A.	N.A.	N.A.	1,303	132	824
Pune	2,136	145	1,255	2,895	250	1,538
Total	54,128	2,926	26,918	60,944	4,322	32,699
Total in India	135,000	20,100	95,600	208,000	39,000	168,900
Percentage in metropolitan cities to total in India[a]	40.1	14.6	28.2	29.3	11.1	19.4

[a]For nine cities.

TABLE 5 SOCIOECONOMIC CHARACTERISTICS OF HOUSEHOLDS IN SELECTED CITIES (*4*)

City	Average Family Size	Average No. of Earners per Household	Average Monthly Household Income (INR)	Proportion of Households Owning Motor Vehicles[a]
Delhi	4.44	1.5	2,582	48
Ahmedabad	4.28	1.3	2,194	65
Lucknow	4.16	1.3	1,955	60
Madurai	3.49	1.4	2,018	49
Cochin	3.60	1.4	1,452	49

[a]Cars, motorcycles, motor scooters, etc.

suburban rail transport plays a vital role, buses are the only public transport mode. Bus transport plays a key role in providing mobility to urban dwellers and, in conjunction with other motorized and nonmotorized modes, serves the transport needs of the cities. Thus, the quality of transport services available in the cities depends largely on the number of different types of vehicle in any particular city.

The per capita availability of various types of transport services varies from city to city as presented in Table 7. The availability of buses per 1,000 population in Delhi is around 2.5 times that of other cities like Vadodra, Jaipur, and Patna. In Vadodra, there is a large number of autorickshaws, whereas in Jaipur and Patna cycle rickshaws ply in large numbers compared with the situation prevailing in Delhi. In other words,

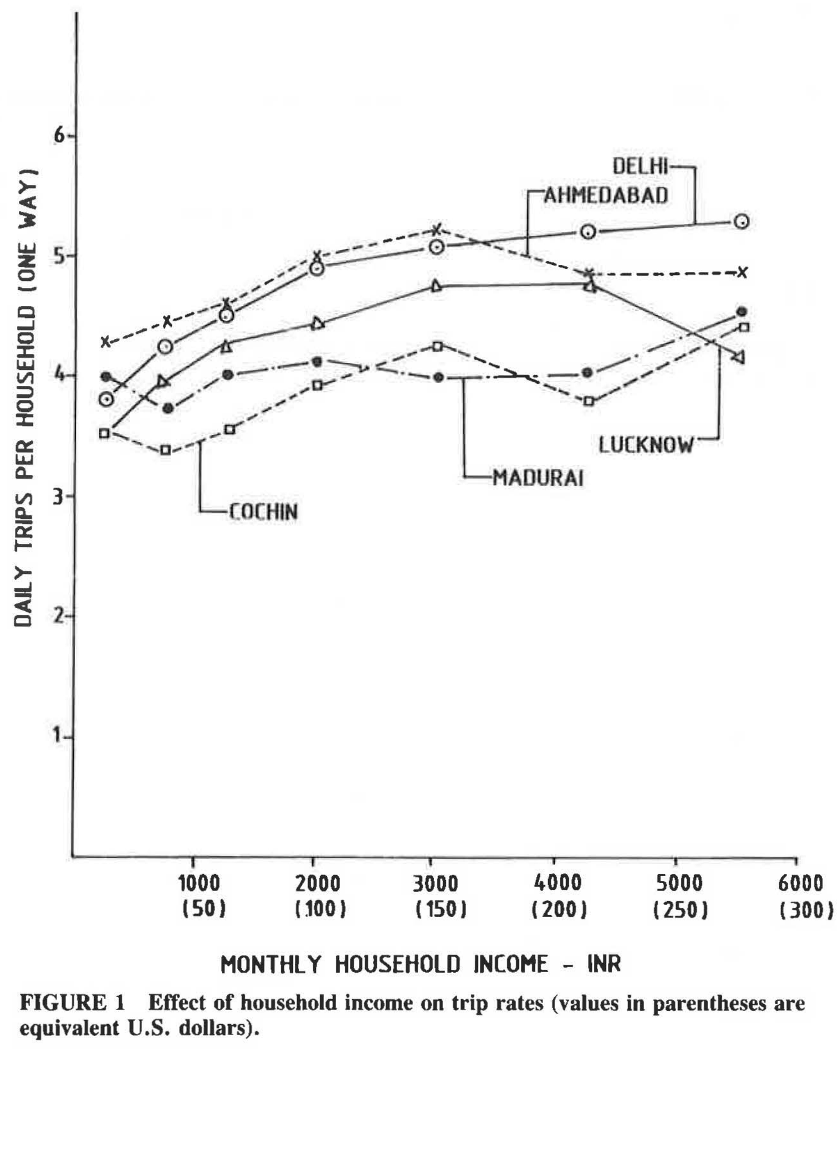

FIGURE 1 Effect of household income on trip rates (values in parentheses are equivalent U.S. dollars).

TABLE 6 EFFECT OF VEHICLE OWNERSHIP ON DAILY TRIP RATES PER HOUSEHOLD (*4*)

	Trip Rate[a] by City				
Type of Vehicle	Delhi	Ahmedabad	Lucknow	Madurai	Cochin
More than one car	5.21	4.23	3.44	4.09	4.74
One car	5.02	5.11	4.10	3.68	3.81
Motorcycle or scooter	5.16	4.89	4.51	4.11	3.67
Cycle	4.65	4.57	4.20	4.04	3.84
No vehicle	4.53	4.30	3.51	3.97	3.40
Average	4.84	4.78	4.26	4.00	3.70

[a]One-way trips.

TABLE 7 AVAILABILITY OF TRANSPORT SERVICES IN SELECTED CITIES OF INDIA (*4,5*)

	Vehicles per 1,000 Population					
	Public Modes			Private Modes		
City	Buses[b]	Auto-rickshaws	Taxis	Cycle Rickshaws	Cars	Scooters and Motorcycles
Vadodra	0.25	7.9	—	—	13	45
Jaipur	0.27	2.4	—	7.1	15	86
Patna	0.17	—	—	39.0	11	52
Delhi[a]	0.61	4.1	1.3	1.1	22	74

[a]From Central Road Research Institute report (*4*).
[b]Conventional bus and minibus.

in medium-sized and small metropolitan cities, the population has to depend mainly on intermediate public transport modes rather than buses. The availability of personalized fast modes like motorcycles and motor scooters is high in most of the cities. Car ownership rates are significant in Delhi.

IMPORTANCE OF NONMOTORIZED MODES

Nonmotorized modes in Indian cities, besides walking, consist of slow modes like bicycles, three-wheeled nonmotorized cycle rickshaws, horse-drawn vehicles, and many other types of slow vehicles. The nonmotorized vehicles share the road space with the motorized modes. The proportion of slow vehicles in the traffic stream varies from city to city (Figure 2). Transportation planning studies conducted thus far in Indian cities have been biased toward motorized modes. In most of the cities, facilities for bicycles have not been developed and pedestrian facilities have been completely neglected.

Walk Trips in Selected Cities

The distribution of trips by walking and vehicular modes, including fast and slow vehicles, as presented in Table 8 shows variations in the proportion of walk trips for different purposes in selected cities. The proportion of trips by walking for "other purposes," which includes social, recreational, and health, is high in all the cities, whereas for "education," it is significant in most of the cities.

Share of Nonmotorized Modes

The nonmotorized passenger transport modes that generally ply the road systems in Indian cities include bicycles, cycle rickshaws, and other slow vehicles. Based on a study (*4*), the modal share of these nonmotorized modes for five selected cities is presented in Table 9. The share of nonmotorized modes is high in Lucknow and significant in Ahmedabad and Madurai.

Traffic Flow in Selected City Corridors

Composition

The composition of traffic flow on arterials of selected cities of different population sizes is presented in Table 10. In major cities like Bombay and Delhi and some smaller cities like Cochin and Mangalore, motor vehicles dominate the traffic flow, but in the majority of the cities studied, the share of nonmotorized modes in the traffic flow is significant.

Modal Share

The modal shares of passenger flows on arterials of selected cities are presented in Table 11. Wherever public transport modes are inadequate, the greater proportion of trips are catered to by fast modes and the nonmotorized modes. The share of nonmotorized modes in catering to transport demand is significant in most of the cities.

CONCLUSIONS AND ISSUES

The analyses presented indicate that nonmotorized modes play a significant role in catering to the transport demand in

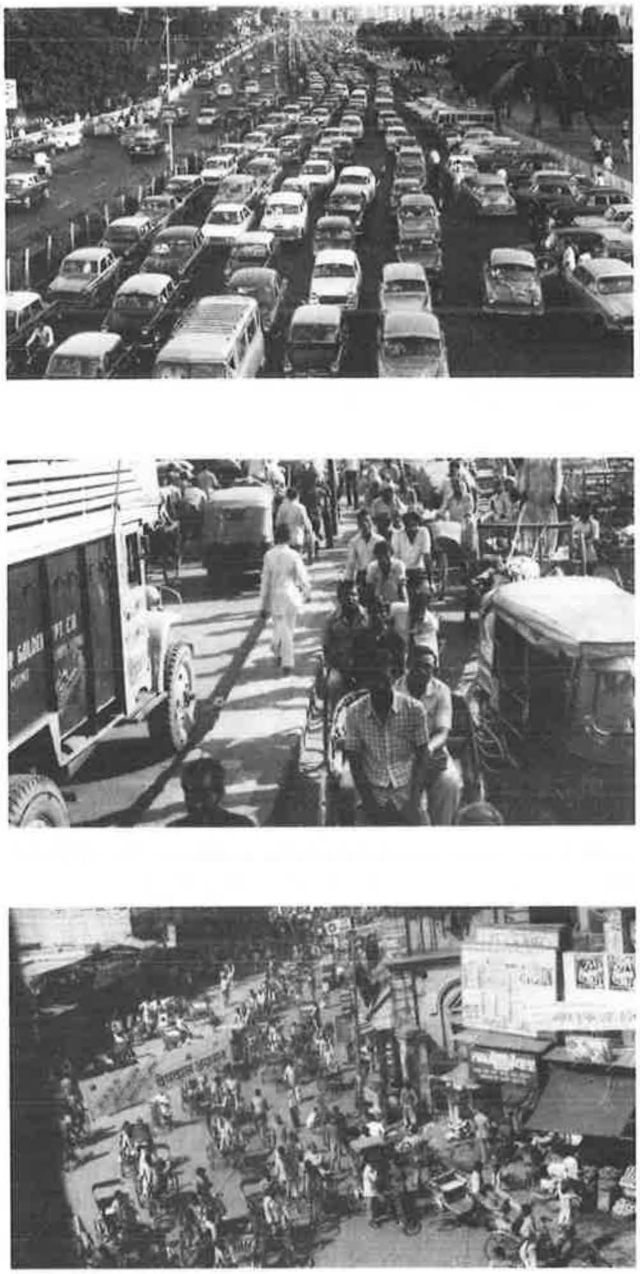

FIGURE 2 Traffic flow composition in Indian cities.

TABLE 9 MODAL SHARE OF NONMOTORIZED MODES IN SELECTED CITIES (*4*)

	Percentage of Trips by Mode		
City	Mass Modes	Other Fast Modes[a]	Nonmotorized[b] Modes
Delhi	62	33	5
Ahmedabad	22	52	26
Lucknow	7	44	49
Madurai	49	32	19
Cochin	56	36	8

[a]Includes cars, motorcycles, autorickshaws, taxis, etc.
[b]Includes bicycles, cycle rickshaws, other slow vehicles.

most of the Indian cities with less than 2.5 million population. Despite the growing economic affluence and fascination for owning motor vehicles in urban areas, the dependence on nonmotorized transportation modes will persist in the foreseeable future. The transportation planning studies conducted so far in metropolitan cities have not paid the attention needed for providing facilities for nonmotorized modes. Some of the issues that need to be addressed relating to Indian cities are as follows:

- For assessing precisely the requirements of nonmotorized modes, transportation studies need to be conducted in medium-sized and small cities to match transport facilities with transport demand patterns. The transport systems to be developed for such cities should have a blend of all transit modes, including facilities for nonmotorized modes.
- Cycle rickshaw is a popular paratransit mode that provides door-to-door service in congested parts of most Indian cities. The requirements of this mode need to be studied and better understood in relation to the socioeconomic environment.
- Pedestrianization schemes, particularly in central congested areas, need to be planned and implemented to improve environmental and safety aspects.
- In the majority of the cities, a large proportion of road users killed or injured in road accidents is composed of users of nonmotorized modes (pedestrians and cyclists). Studies need to be conducted to assess the socioeconomic aspects of these users to minimize fatalities among them.

TABLE 8 DISTRIBUTION OF TRIPS BY WALK AND VEHICULAR MODES IN SELECTED CITIES (*4*)

		Percent of Trips by Purpose							
		Work		Education		Other		All Purposes	
City	Population (millions)	Walk Trips	Vehicle Trips	Walk Trips	Vehicle Trips	Walk Trips	Vehicle Trips	Walk Trips	Vehicle Trips
Delhi	5.7	6	94	50	50	84	16	51	49
Ahmedabad	2.5	9	91	41	59	71	29	46	54
Lucknow	1.0	9	91	28	72	64	36	42	58
Madurai	0.8	17	83	27	73	62	38	34	66
Cochin	0.5	13	87	28	72	60	40	38	62

TABLE 10 TRAFFIC FLOW COMPOSITION ON ARTERIALS IN SELECTED CITIES (*4,6*)

		Percent Range by Mode		
			Nonmotorized Modes	
City	Population (millions)	Motor Vehicles	Slow Vehicles[a]	Bicycles
Bombay	8.2	86–99	0–6	1–11
Delhi	5.7	74–90	0–14	10–19
Ahmedabad	2.5	55–66	0–3	33–44
Kanpur	1.7	29–34	15–21	45–51
Lucknow	1.0	15–40	9–26	49–59
Varanasi	0.8	32–47	23–32	25–40
Indore	0.8	56–62	0–3	30–40
Madurai	0.8	21–51	6–13	40–66
Cochin	0.5	86–89	0–1	10–13
Chandigarh	0.4	49–62	8–11	28–40
Mangalore	0.3	87–94	0–2	6–13

[a]Mostly three-wheeled nonmotorized cycle rickshaws.

TABLE 11 MODAL SHARE OF PASSENGER FLOWS ON ARTERIALS IN SELECTED CITIES (*4,6*)

		Percent by Mode			
				Nonmotorized Modes	
City	Population (millions)	Mass Modes	Other Fast Modes	Cycles	Other Slow Vehicles[a]
Delhi	5.7	62	3	5	—[b]
Ahmedabad	2.5	34	45	21	—[b]
Kanpur	1.7	24	27	30	19
Pune	1.0	59	25	16	—[b]
Lucknow	1.0	29	18	34	19
Varanasi	0.8	39	20	21	20
Indore	0.8	54	30	16	—[b]
Chandigarh	0.4	54	27	15	4
Mangalore	0.3	77	21	2	—[b]
Moradabad	0.3	40	17	25	18

[a]Mostly three-wheeled nonmotorized cycle rickshaws.
[b]Negligible.

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Role of Nonmotorized Transport Modes in Indonesian Cities

BUDHY TJAHJATI S. SOEGIJOKO AND SHARIF I. HORTHY

The importance and role of nonmotorized transport—including walking—in Indonesian cities and the need to provide appropriate infrastructure for nonmotorized modes are discussed. Characteristics, costs, and utility of different Indonesian transport modes are analyzed. Constraints in the development of motorized public transport are determined and problems facing nonmotorized transport users are categorized. Management strategies, policies, and design standards for reducing intermodal conflict and increasing transportation system effectiveness are outlined.

The importance and role of nonmotorized transport—including walking—in Indonesian cities, and therefore the need to provide the necessary infrastructure, are discussed.

Indonesian cities range in size from metropolitan cities with populations of over 1 million to small towns with populations of less than 50,000. In each of these cities, nonmotorized modes are still an important part of the transportation system. Nonetheless, not enough attention is given to this subsector. Planning the development and construction of the city's road network is always oriented toward the needs of motorized transport.

This bias creates a vicious circle. Planning for the city's land use development assumes the provision of a road network for motorized transport only. Distance standards are calculated on the basis of motorized transport. Nonmotorized transport is not included in the planning of the city's transport network. Therefore, as the city grows, people are more and more dependent on transport modes. The lack of special infrastructure and traffic regulation for nonmotorized transport results in conflicts with motorized transport in high-density areas.

Because the majority of the population in Indonesian cities does not have access to motorized transport—financially and sometimes also physically because of the physical limitations of the city—nonmotorized transport still has a major function and in the future will still be an important part of the urban transport system. Therefore, it is necessary to consider it as part of the city's transportation system. Planning and development of Indonesian cities should include nonmotorized transport as an integral part of the city's transport system. Three important conditions need to be met. First, there should be political intent and policy backup from the government to include nonmotorized transport as part of the city's system. Second, nonmotorized transport should be considered in planning the city's structure and transport infrastructure. Where necessary, special infrastructure should be provided. Finally, traffic management and regulation should also be addressed for this transport subsector.

CONCEPTUAL BACKGROUND

Speed-Distance Relationship in Transport Demand and the "Transport Gap"

The strong correlation between trip length and the demand for speed in all forms of travel is familiar both in everyday experience and in transportation theory. Bouladon (*1*) attempted to formulate it as a simple relationship:

$$T = 7.62d^{0.46}$$

where T is the time in minutes that people are prepared to spend on a journey of d kilometers. This relationship includes the access time of the vehicles concerned, that is, the time it takes on average for the traveler to reach the relevant transport mode and attain its running speed.

Although time is money, speed costs money, so the actual speed-distance relationship prevailing in a given community will depend on the perceived relative value of time, which is in turn dependent on cultural and economic factors.

For comparison, origin-destination survey results from Bandung, quoted by Soegijoko (*2*), yield the following relationship:

$$T = 18.34d^{0.411}$$

giving considerably higher travel times for given urban trip distances than those postulated by Bouladon's formula. In terms of speed and distance, this relationship can be written as follows:

$$d = 0.133V^{1.70}$$

where V is the speed in kilometers per hour.

Soegijoko's results indicate a high degree of correlation between speed and distance (correlation coefficient $r = 0.39$). Assuming that the cost of travel increases with the speed of the mode used, this relation seems to indicate that for maximum cost-effectiveness the intrinsic speeds of the transport modes used for trips of a given length should be within the orders of magnitude reflected in these relations.

An automobile, with an intrinsic speed of, say, 80 km/hr is therefore appropriate under the (presumably European)

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conditions assumed by Bouladon's formula up to a trip length of 75 km, and under Indonesian conditions up to one of 230 km, with slower transport modes making trips significantly shorter.

In developed countries, such slower modes generally do not exist and their absence has been described as a transport gap (*3*), which has resulted in the prevalent use of the automobile for most trips that cannot conveniently be made by walking. The urban use of the automobile is therefore predominantly under conditions inappropriate to its intrinsic speed, power, and size characteristics and has led to a number of serious problems.

In Indonesia, as in many developing countries where cost efficiency is the overriding consideration, a variety of transport modes have arisen to fill this gap, creating a transport hierarchy, the lowest levels of which consist of the various kinds of nonmotorized modes. One result is that the converse of the transport gap—the mutual interference of a multiplicity of modes—necessitates a correspondingly different approach to urban road design and traffic management.

Hierarchical Nature of Transport Systems

The concept of a road hierarchy is a familiar one in the field of traffic engineering and traffic management. In a correctly functioning road hierarchy the needs of traffic movement increasingly predominate over the needs of access at successively higher levels of the hierarchy, the efficiency achieved through this specialization of function being the hierarchy's main purpose. In Indonesian cities studied by the authors, reasonably clear road hierarchies exist, although use does not always correspond to function. These road hierarchies consist of the following:

- Primary arteries (intercity roads passing through the city, with road widths usually more than 8.0 m);
- Secondary arteries (main roads linking major activity centers in the city, including the central business district of widths about 7.0 m);
- Secondary collectors (roads connecting the secondary arteries with the residential areas or other urban activity locations, of widths between 6.0 and 8.0 m); and
- Local roads (of width between 4.0 and 6.0 m) and roads within a community consisting of narrow paved streets (width between 2.5 and 4.0 m) and paved and unpaved footpaths, often inaccessible to four-wheeled motorized transport (of widths between 1.0 and 2.0 m).

Conversely, urban transportation demand arises from hierarchies of activities taking place in a hierarchy of urban communities as known in Indonesian cities: the Kecamatan (about 20,000 households), the Kelurahan (5,000 households), the Rukun Warga (250 households), and the smallest community, the Rukun Tetangga (25 households).

The location of these activities generally determines trip distances. Because the destinations of frequent trips on average are closer to the residential areas and those less frequently visited are further away, the demand for shorter trips is generally much greater than it is for long ones. Generally, those less frequent venues serve the whole city and are centrally located, whereas those that people visit more frequently tend to be dispersed throughout the city.

Because most of these short trips are at the bottom of the speed hierarchy and also take place on the lower levels of the road hierarchy, for maximum efficiency the modal mix should be different at different levels of the road hierarchy, as certain modes are more appropriate than others for certain trip lengths. In this respect, traffic conditions in Indonesia differ markedly from those encountered in developed countries.

A working knowledge of how these hierarchies operate and interact in typical Indonesian cities is therefore required as a basis for deducing a rational approach to urban road planning, traffic management, and the selection of the most cost-effective infrastructure designs in terms of road widths, pavement designs, and provisions for public transport and pedestrians.

INDONESIAN URBAN CONTEXT

Physical Structure of Cities

Indonesian cities are similar in basic physical form to cities elsewhere in the world in having a central area and a main street surrounded by residential areas. However, in the course of the cities' development some specific characteristics began to emerge that affected the transportation system. The difference was due to several factors, including the historical factor. In most of the older (and also the larger) cities, specific distinctions could be observed in the city's form and structure between the European and the indigenous sections. The former were characterized by large plots and houses with wide road networks and were generally of low density with many open spaces and parks. These were the areas where the Dutch resided during the colonial period. In contrast, the areas where the Indonesians lived were generally of high density with narrow roads and small housing plots; open space and parks were limited or nonexistent. Cities such as Bandung, Semarang, Malang, and others were the result of this historical development, in which the distinction between the European section and the indigenous section was obvious. In Bandung, the low-density area is in the northern part, whereas the high-density area is in the southern part of the city. In other cities, the situation is more mixed so that there are pockets of high-density areas surrounded by low-density areas. As the cities grew, this distinction tended to disappear. However, because of economic considerations, the newly developed residential areas are mostly high density with small plots and houses and narrow streets. These tend to be located on the fringes of the city—sometimes even outside the city's boundary—where land is still cheap. Following the growth of these new residential areas, new commercial centers started to emerge. In most cases, these new areas are not linked to the central part of the city with adequate roads, creating congestion during the rush hour.

As a result of this city structure, not all areas could be adequately served by motorized public transportation such as buses. Various types of public transport emerged as a response: minibuses with a capacity of 15 to 20 passengers, scooter- or motorcycle-based vehicles (called *bemo* and *bajaj*) with a capacity of 2 to 7 passengers, and *becaks* (pedicabs) with a capacity for 2 passengers. Some high-density areas can barely be served by *becaks*. People travel on foot, using bicycles and, if they can afford it, motorcycles. A multitude of travel modes exists in most Indonesian cities as a result of the cities' physical structure. Tables 1 and 2 present access and street structure in some cities and communities.

Urban Trip Characteristics

As an illustration, some findings of a household survey undertaken in 1985 in three medium-sized cities in Jawa will be described. The profile of the three cities is presented in Table 3. Trip characteristics of household members surveyed are presented in Tables 4 and 5.

In all three medium-sized cities, walking is the dominant mode of transport—for work, shopping, and education trips. The lowest proportion of walking trips is perhaps for Cirebon because of its relatively larger size, and therefore trip distances are longer. However, in larger cities such as Jakarta (population more than 3.5 million) walking still accounts for 40 percent of total trips (1985), whereas in Bandung (population about 1.5 million) and in Yogyakarta (population about 0.6 million in 1976) walking trips account for about 49 and 50 percent of total trips, respectively. This proportion has not changed much in recent years.

Next to walking, bicycles and pedicabs are the other nonmotorized modes in the three sample cities. Although their use is limited, some part of the population is still dependent on these modes. In 1985, even in a city like Jakarta, *becaks* and bicycles account for 4.6 and 2.4 percent, respectively, of the total trips. For some cities like Yogyakarta and Bandung, this proportion is even higher. For example, in Bandung in 1976, 9.7 and 5.8 percent of total trips were made using *becaks* and bicycles, respectively. A later study in some high-density communities in Bandung (*4*) concluded that work trips using *becaks* are even more frequent, about 12 percent of total trips. In that study, there was also evidence that the use of *becaks* is more significant for nonwork trip purposes.

In the three sample cities surveyed, work trips are relatively short. In Cirebon, 72 percent of total work trips are less than 5 km. In Tasikmalaya, 74 percent and in Bandung 78 percent of these work trips are less than 5 km. Most of the work trips in Bandung are between 2.5 and 4.9 km. Only 21 percent are

TABLE 1 ACCESS CATEGORY IN THREE COMMUNITIES IN BANDUNG (*4*)

Access Category	Household % in each category			
	(Jamika %) (460 persons/ha)	(Padasuka %) (460 persons/ha)	(Pasteur %) (460 persons/ha)	All
Walk, cycle, motorcycle	72	54	87	71
Walk plus becak	19	25	3	16
Four wheeled access	9	21	10	13
Percentage	100	100	100	100
Total number of sample household	69	67	70	206

TABLE 2 ROAD NETWORK COMPOSITION AND PATTERN IN FIVE INDONESIAN CITIES (*5*)

CITY	AREA (HA)	POPULATION (00)	TOTAL ROAD LENGTH (KM)	ROAD CLASSIFICATION		ROAD PATTERN
				Arterial	Collector & Local	
Bandung	8,098.0	1,408.0	4,000.0	11.3	85.5	Radial & Concentric
Sole	4,404.0	502.0	367.3	7.6	92.3	Grid iron East-West major arterials
Magelang	1,812.0	123.0	NA	NA	NA	Linear North-South major arterials
Salatiga	1,728.0	84.0	NA	12.9	87.1	Linear North-South major arterials
Banjarnegara	1,510.0	41.0	NA	NA	NA	Linear North-South major arterials

TABLE 3 PROFILE OF THREE MEDIUM-SIZED CITIES IN JAVA (*6*)

CITY	AREA (HA)	POPULATION (000)	NUMBER OF PRIVATE VEHICLES		
			Bicycles	Motorcycles	Cars
Serang	11.6	111.5	10,000.0 (1983)	3,000.0	246.0
Tasikmalaya	19.2	156.7	16,000.0	14,600.0	2,250
Cirebon	60.1	275.0	9,700.0	3.600.0	876.0

Note: Becak, Minibus and other Types of public transport are available in all three cities.

TABLE 4 PERCENTAGE OF TRIP PURPOSES IN THREE MEDIUM-SIZED CITIES (*6*)

CITY	WORK	EDUCATION	SHOPPING	OTHERS	TOTAL
Serang (60 households)	49	29	8	17	100
Tasikmalaya (60 households)	40	28	13	19	100
Cirebon (159 households)	28	30	21	21	100

TABLE 5 TRIP PURPOSE AND TRANSPORT MODES IN THREE MEDIUM-SIZED CITIES (*6*)

CITY	WORK (%)			SHOPPING (%)			EDUCATION (%)		
	S	T	C	S	T	C	S	T	C
W A L K	48	58	29	80	72	57	83	70	53
B e c a k	9	8	6	4	3	1	3	4	7
Bicycle	4	2	12	0	5	6	6	2	7
Motorcycle	12	7	11	0	15	23	0	8	5
C a r	6	0	8	0	0	1	2	0	0
Minibus	21	25	34	16	5	12	6	16	28
	100	100	100	100	100	100	100	100	100

S = SERANG
T = TASIKMALAVA
C = CIREBON

more than 5 km. Shopping trips are mostly less than 2.5 km. Some are even less than 1 km. The proportion of shopping trips that are less than 1 km is 84 percent in Serang, 48 percent in Cirebon, and about 60 percent in Bandung. Education trips are generally even shorter in the smaller cities. But in larger cities like Bandung, education trips are longer, mostly between 1.0 and 5.0 km.

What can be concluded from the above discussion is that in Indonesian cities—from the medium-sized to the larger cities, including metropolitan cities like Jakarta—nonmotorized modes such as walking, bicycle, and pedicab still have an important function as a travel mode. Walking is especially important, perhaps because trip lengths in these cities are short. Shopping trips are especially short trips, less than 1 km. Another fact or might be the limitations of the motorized public transport service in terms of area coverage and services.

Constraints in Development of Motorized Public Transport Service

The low private vehicle ownership rates and the high percentage of work trips indicate the need to develop a more extensive and adequate public transport service. However, the existence of high-density communities with narrow roads and the limited length of wider roads (collectors and arterials) have made difficult expanding the coverage of the present motorized public transport service using regular (standard-sized) buses. Minibuses have been used to complement standard bus service in larger cities such as Jakarta and Bandung. Nonetheless, because of the width of the streets and the structure of the city, minibuses also have limited coverage. Widening of roads can only be done in parts of the city.

Other constraints are the financial and management aspects of the operation. At present, the standard bus service is operated by government companies and is subsidized. If government is to continue this responsibility, covering all large cities in the country will be a major drain on the government budget. Participation of the private sector is expected to increase. Encouragement, coordination, and form of participation of the private sector are aspects that need careful consideration.

Physical constraints that limit the development of motorized transport indicate the need to also use nonmotorized transport modes as part of the public transport service. However, at present there is still a negative attitude toward pedicabs because of the government perception about this transport subsector.

INDONESIAN TRANSPORT MODES

Transport Mode Hierarchy

In order to give an overview of common Indonesian transport modes, a representative member of each of the main categories has been selected and is defined as follows. The numbers in parentheses indicate rated passenger capacity, including driver, values that are normally exceeded by 50 to 100 percent under peak demand conditions.

Private Transport Modes

1. Pedestrian (1),
2. Pedestrian with push cart (*gerobak* or *kakilima*) (1),
3. Bicycle (1),
4. Motorcycle (Honda OC) (2), and
5. Automobile (Toyota Corolla) (5).

Public Transport Modes

1. *Becak*—a three-wheeled, nonmotorized pedicab specific to Indonesia (3);
2. *Andong*—a four-wheeled horse-drawn carriage in a number of varieties, such as the two-wheeled *dokar* (7);
3. *Ojek*—a motorcycle for hire in the manner of a taxi (2);
4. *Bajaj*—a motorized tricycle using a 150-cc scooter engine, steered like a scooter (3);
5. *Bemo*—a three-wheeler with 360-cc engine (8);
6. Mikrolet I—a motorized vehicle using a 1000-cc engine such as the Hijet Zebra (10);
7. Mikrolet II—a motorized vehicle using a 1500-cc engine such as the Toyota Kijang (11);
8. Minibus—a small bus using a 3300-cc engine such as the Mitsubishi FE-114 (26); and
9. City bus—a Mercedes model using a 5675-cc engine (51).

Mode Characteristics

The most important attributes of transport modes in the Indonesian urban context are described in the following paragraphs.

Speed

Table 6 presents the dimensions, capacity, power, fuel consumption, and cruising speed of these transport modes. From the information presented in the table, the modes can be arranged in four speed bands, as follows:

Speed Band	*Mode*
1 (about 5 km/hr)	Pedestrian
	Pushcart
2 (10 to 20 km/hr)	Bicycle
	Becak
3 (25 to 40 km/hr)	*Bemo*
	Bajaj
	Motorcycle (low-power)
4 (50 to 100 km/hr)	Mikrolet
	Minibus
	City bus
	Motorcar

Cost

Table 7 presents the cost per passenger-kilometer in rupiahs (Rp.) for each of the modes listed with the exception of the *andong* (for which no reliable data were available) and walking. The cost was based on an estimation of depreciation, the cost of maintenance, the cost of fuel, and the cost of a driver and a conductor (*kenek*), where appropriate.

Road Space Utilization

A factor not yet covered in the cost calculation is a transport mode's efficiency in the utilization of road space, that is, the obstruction per passenger that the mode offers at different road widths and traffic velocities. A higher efficiency in this regard results in lower traffic volumes per passenger and hence makes possible narrower roads and less disruptive traffic management measures. The road utilization efficiency of a transport mode therefore makes an important contribution to its true economic cost.

This road utilization function depends on more than the plan area or "footprint" of the transport mode; it is a function of vehicle length L, width W, width of the road w, mode's maximum speed V, free flow speed of the surrounding traffic v, number P of passengers, average distance s between stops, and possibly other factors as well, so that

$$\text{RUF} = f(L,W,w,V,v,P,s, \ldots)$$

This function can be thought of as analogous to a mode's PCU value, which is defined in developed countries as a vehicle's contribution to saturated flow compared with that of a standard car. In developed countries, however, because of fairly standard road and traffic conditions, PCU values are conveniently regarded as intrinsic to a transport mode and generally independent of the extraneous factors mentioned earlier. This characteristic makes the concept not very useful in Indonesia except at the higher levels of the road hierarchy.

The RUF is determined empirically by measuring saturated flows with different modal mixes and with different values of the variables. It provides city planners with a useful tool in

TABLE 6 INDONESIAN TRANSPORT MODES: MECHANICAL CHARACTERISTICS

TRANSPORT MODES	LENGTH (m)	WIDTH (m)	OFFICIAL PASSENGER CAPACITY (ng)	EXTRA FREIGHT CAPACITY (kg)	ENGINE DISPLACEMENT (cc)	FUEL CONSUMPTION (km/lt)	CRUISING SPEED (km/g)
Private							
Pedestrian	1.00	0.60	1	30	NA	NA	5
Ped & Pushcart	2.10	0.80	1	200	NA	NA	5
Bicycle	1.75	0.60	1/2	50	NA	NA	16
Motorbike (Honda GC)	1.60	0.80	2	30	125	SUPER 20	80
Automobile (Toyota Corolla)	4.05	1.60	5	100	1290	SUPER 9	100
Public							
Becak	2.25	1.00	3	30	NA	NA	10
Andong	3.50	1.50	7	100	NA	NA	10
Cjeg (Honda GC)	1.60	0.80	2	15	125	SUPER 20	60
Bajaj	2.50	1.20	3	30	150	SUPER 30	40
Bemo	2.90	1.25	8	30	360	SUPER 16	40
Mikrolet I (Hijet Zebra)	3.80	1.80	10	70	1000	SUPER 9	60
Mikrolet II (Toyota Kijang)	4.25	1.25	11	80	1500	SUPER 10	60
Minibus (Mitsubishi FE-114)	5.40	1.90	26	NA	3298	DIESEL 8	60
City Bus (Mercedes)	9.30	2.50	51	NA	5675	DIESEL 5	60

Source: TDC-SA, 1988

calculating road capacity and designing infrastructure at the local and village road level and serves as a means of identifying the traffic levels at which modal conflicts become critical.

It is hoped that the work currently under way on an Indonesian highway capacity manual will shed more light on this aspect of Indonesian transport mode performance.

Safety

At present, insufficient data are available to assess the safety of these transport modes scientifically. Statistical analysis of accident data coupled with extensive mechanical testing will be required in the future to achieve this assessment.

In the context of the role of nonmotorized traffic modes, the provision of adequate infrastructure will have the greatest impact on safety, because these transport modes with their low speeds are inherently safe.

Nonmotorized Modes and Infrastructure Requirements

In the following more detailed discussion of nonmotorized traffic, the cruising speed or speed limit is taken from Table 6, average speed is from the origin-destination survey referred to; ideal trip length is that derived by applying Bouladon's formula to the cruising speed, whereas average trip length is obtained by applying Bouladon's formula to the average speed. The cost per passenger-kilometer is taken from Table 7.

Characteristics of Nonmotorized Modes

Pedestrian Characteristics of the pedestrian mode are as follows:

Characteristic	*Amount*
Cruising speed or speed limit	5 km/hr
Average speed	3.5 km/hr

TABLE 7 INDONESIAN TRANSPORT MODES: ECONOMIC CHARACTERISTICS

TRANSPORT MODES	CAPITAL COST (M Ep.)	USEFUL LIFE (yr)	MAINTENANCE COST (ERp./mc)	DAILY TRAVEL (km/day)	FUEL COST (ERp./mo)	DRIVER & ASSISTANT (KRp.mc)	COST PER PASSENGER (KM) Rp.
Private							
Bicycle	0.15	15	2	20	0	0	6
Motorbike (Honda GC)	0.65	15	10	50	33	0	16
Automobile (Toyota Corolla)	15.00	8	30	50	73	0	35
Public							
Becak	0.70	8	5	20	NA	75	69
Ojeg (Honda)	0.65	10	15	100	66	75	54
Bajaj	3.00	5	20	70	31	100	48
Bemo	5.00	8	25	70	58	100	18
Mikrolet I (Hijet Zebra)	13.50	8	35	100	147	275	22
Mikrolet II (Toyota Kijang)	16.50	8	50	100	132	275	21
Minibus (Mitsubishi FE-114)	31.00	10	75	100	75	275	10
City Bus (Mercedes)	80.00	12	100	100	120	300	8

Source: TDC-SA, 1988

Characteristic	*Amount*
Ideal trip length	400 m
Average trip length	1.1 km
Cost per passenger-kilometer	Nil

Walking is the predominant transport mode for short trips in Indonesian cities. The Bandung study (*7*) found that 40 percent of all household trips were walking trips that constituted 50 percent of all travel time and 32 percent of all traveled distance. Similar results from a number of other studies indicated that walking was the most important urban transport mode, from the point of view of economic and basic needs.

In Indonesian cities, pedestrian problems essentially break down into the following categories:

- At the village community level, the lack of paved surfaces and poor drainage constitute a major lack of amenities in the rainy season.
- In areas where motorized traffic predominates, the lack of continuous networks of footpaths, sidewalks, and adequately enforced pedestrian priority crossings forces pedestrians to compete with motorized traffic for use of the road space.
- At all levels, there is a lack of an adequate standard of design of pedestrian facilities.

In the most congested areas, sidewalks are routinely subordinated to the needs of informal vendors and the parking needs of motorized vehicles.

Pushcart The pushcart mode has the following characteristics:

Characteristic	*Amount*
Cruising speed or speed limit	5 km/hr
Average speed	NA
Ideal trip length	400 m
Average trip length	NA
Cost per passenger-kilometer	NA

These are of two kinds, the *gerobak*, a pushcart for carrying freight and merchandise of all kinds and also solid waste, and the *kakilima*, which mostly serves as a mobile facility for selling food and groceries. These vehicles usually run on bicycle wheels and have various widths, but most are designed to go down the narrowest footpaths.

No surveys were found relating to this mode, but the presence of pushcarts in large numbers in all the cities studied by the authors indicates that they fulfil important economic functions. The *gerobak* and the *becak* are the few means of freight access for the large percentage of houses not served by roads accommodating motorized transport, whereas the *kakilima* is the principal source of meals away from home in Javanese cities.

Bicycle The bicycle mode has the following characteristics:

Characteristic	*Amount*
Cruising speed or speed limit	15 km/hr
Average speed	6.0 km/hr
Ideal trip length	3.3 km
Average trip length	2.8 km
Cost per passenger-kilometer	Rp. 5

The bicycle is the most efficient of the transport modes in economic terms at Rp. 5 per passenger-kilometer. It is therefore comparable with walking, but its long history of mechanical refinement has led to an efficiency in the use of human energy that has permitted an eightfold increase in the ideal trip length (from 0.4 to 3.3 km).

The bicycle does not lend itself to multistage journeys because parking it in public places is not practical. Bicycles also present a high degree of obstruction to fast-flowing traffic. For these reasons, on roads that carry a high volume of motorized traffic bicycles should be accommodated in a bicycle lane or bikeway.

Bicycles do not perform well above a gradient of 4 percent or on roads with potholes or excessive roughness. Indonesian bikes are rarely provided with gears, which would be especially useful when bicycles are adapted for the carriage of freight, as they often are, with the addition of deep baskets on either side of the rear wheel.

In spite of its clear advantages, the bicycle is not in widespread use in all Indonesian cities. This may be caused by a negative social connotation (*7*). There is a tendency for cyclists to disobey traffic regulations.

Pedicab (*Becak*) The characteristics of the pedicab mode are as follows:

Characteristic	*Amount*
Cruising speed or speed limit	10 km/hr
Average speed	5.3 km/hr
Ideal trip length	1.5 km
Average trip length	2.3 km
Cost per passenger-kilometer	Rp. 69

The pedicab, or *becak*, is the public transport equivalent of the bicycle and is the highest-cost transport mode in terms of passenger-kilometers. The reason for this high cost is its unproductive use of the driver's time rather than high capital or running cost, in which respects the *becak* is extremely economical. When alternative employment is scarce and the opportunity cost of the driver is reduced, the *becak* can become more competitive.

The *becak* has been studied in some depth (*7,8*), both from the social and transport points of view. The conclusion of these studies—as well as of this paper—is that the *becak* fills a valuable role in the road transport hierarchy because it has a unique combination of advantages:

1. Its extremely low capital cost and relatively informal licensing arrangements place it within easy reach of the permanently or temporarily unemployed.
2. It can negotiate the narrow village roads and therefore provide services for which there is at present no alternative, such as

- Taking produce to markets,
- Carrying the elderly,
- Transporting small children to school,
- Providing freight and passenger capacity for housewives, and
- Going to market.

3. It uses no scarce economic resources, its maintenance is easy, and it can carry freight.
4. It provides a flexible and personalized service.

The *becak* has come under fire from time to time, mainly from two points of view—it obstructs traffic and it is inhumane. The need for segregating *becaks*, as well as other nonmotorized traffic, from high-speed motorized transport flows is clear, and this segregation can be achieved through *becak*-free corridors (rather than zones) or bikeways along major transport corridors as in Solo.

The issue of inhumanity seems less clearcut, because the sale of personal services involving physical labor is a common and well-accepted element of life in Indonesia, and although the job of a *becak* driver is physically taxing, the surveys mentioned report better-than-average health records among *becak* drivers.

From the point of view of infrastructure, *becaks* require a smooth riding surface. Because of the load they carry, *becaks* are even more sensitive to gradient than the bicycle, and it has been suggested that their effectiveness would drop off sharply above a gradient of 2 percent.

The most useful design improvement to *becaks* would therefore be the addition of gears. Cheap ones manufactured in the region would not add substantially to the capital cost of the vehicle. The addition of a motor would appear to be less useful, however, because this would convert the *becak* into a different type of vehicle, competing with the *bajaj* and the *bemo*. It is not clear whether the mechanical behavior of the traditional *becak* at higher speeds would be acceptable.

Andong The characteristics of the *andong* are as follows:

Characteristic	*Amount*
Cruising speed or speed limit	10 km/hr
Average speed	NA
Ideal trip length	1.6 km
Average trip length	NA
Cost per passenger-kilometer	NA

The *andong* is one of many types of horse-drawn carriage still in use, some of which are smaller, carrying five passengers or fewer. In general, the horse-drawn carriage is increasingly relegated to rural and peripheral urban areas, but it still plays a significant role in small cities.

With its relatively large size and slow speed, the *andong* is not suitable for negotiating narrow urban community roads, whereas the obstruction they present to motorized traffic is considerable. Their value is therefore only in areas with reasonably wide roads where motorized traffic is still sparse.

Infrastructure

The provision of a continuous network of walkways designed for the needs of pedestrians and compact slower-moving transport modes that accommodate the greater part of the demand for short trips would relieve the higher-class roads of modal conflict and much unnecessary traffic.

These networks would typically consist of

- Village footpaths and community roads with no motorized access or restricted access,
- Local roads with a low volume of motorized traffic,
- Sidewalks or nonmotorized lanes along roads with a higher volume of motorized traffic,
- Pedestrian crossings and nonmotorized crossings on roads with higher traffic volumes, and
- Pedestrian bridges or underpasses on roads with the highest traffic volumes.

Greater segregation of fast-moving motorized modes, slow-moving modes, and pedestrians at all levels of the road hierarchy is required, favoring the fast-moving modes at the higher levels and the slow-moving modes at the lower levels, with priority for pedestrians at the lower levels.

The cutoff traffic volume at which mode separation is required (which is a function of road width) needs to be studied further.

Junctions of footpaths and local roads frequently serve as pick-up and set-down points of informal motorized public transport services and act as focal points around which *becaks*, fulfilling a feeder function, cluster. The resulting obstructions can only be avoided if suitable parking areas are provided for this function.

PREREQUISITES TO ACTION

Political Will and Policy Requirements

As discussed earlier, nonmotorized transport is still important and can have a function in the total urban transport system. However, to optimize its role requires some action such as providing special infrastructure where necessary, modifying present road design standards to accommodate the operation of these nonmotorized transport modes, and including them in the design of traffic management and traffic regulation. The prerequisite for this action clearly is the support and political intent of the government. It is important for the government to appreciate the role of these nonmotorized modes and the need to include them in the total urban transport system.

Policies are required at the national level to indicate the government position on this subsector and to formulate national policies supporting the use of nonmotorized transport modes in relevant situations. Policies at the local level deal mostly with the operational aspects: regulating their operation, management, and integration with the motorized transport system.

Another set of policies are those dealing with safety aspects, which are also important for motorized transport. Safety aspects that need to be dealt with are protection for riders and passengers and traffic safety measures. The latter is especially important in areas of high population density and of high traffic density where there will be competition for road space with motorized transport (and sometimes even with nontransport activities such as sidewalk vendors).

Traffic Management Approaches

The second aspect necessary to optimize nonmotorized modes is a traffic management approach, including traffic safety aspects, efficient and convenient routing, and the interface with motorized traffic. The basic issue with regard to traffic safety is trying to minimize competition and conflict with motorized traffic. One of the options is to separate their service areas. For example, nonmotorized traffic together with low-speed motorized modes is to serve short-distance trips, and therefore its area of operation is mainly on local or community streets and in residential areas and other areas of low traffic-generating activity. This policy is also in line with the role or function of nonmotorized travel in the urban transport system. Another option is to provide special infrastructure facilities such as special lanes separated from the motorized transport, pedestrian sidewalks and crossings, traffic lights, and parking space. Low-cost design is available for this without reducing the main function of the nonmotorized modes.

Infrastructure Design Standards

The third aspect is the design standards for transport infrastructure. This aspect is to accommodate the need for special lanes in areas where it is necessary to separate the motorized transport from the nonmotorized traffic. In areas where the two can be mixed—usually in areas of low population and traffic density—street width should be sufficient to accommodate the operation of both the motorized transport and nonmotorized traffic so that they interfere least with each other.

Pedestrian areas and sidewalks should be included to allow people the choice of walking. An important factor is the need for continuity of the special lanes for pedestrians and motorized transport modes. Pedestrian crossings could be made above grade level, but for nonmotorized traffic modes they should be at grade level.

Specifically, it is essential that local authorities be provided with countrywide design standards for pedestrian and nonmotorized traffic modes. This will involve the following:

1. Investigation into the cutoff traffic levels at which traffic in the various speed bands needs to be segregated.

2. Investigation into the transport infrastructure needs at the community level corresponding to various trip purposes and trip lengths, with special focus on the needs of pedestrians, nonmotorized traffic, and motorcycles; the collection of quantitative data to enable benefit-cost and economic return calculations for such infrastructure provision to be carried out.

3. Countrywide standardization of appropriate design details for pedestrian and nonmotorized traffic provisions, to include

- Standard drainage ditches;
- Low-cost footpaths and community roads of various widths appropriate to the smooth riding surface and light wheel loads of bicycles, *becaks*, and pushcarts;
- Waiting areas for *becaks* at intersections of community roads and village roads;
- Stopping places for microlets and minibuses;
- Low-cost sidewalks for pedestrians and pushcarts;
- Low-cost bikeways for bicycles, *becaks*, and animal-drawn vehicles;
- Standard intersection design incorporating pedestrian and bikeway crossings; and
- Standard details for communal areas to accommodate *kakilimas* and food vendors' stalls.

These designs should preferably be tried out and assessed in the form of pilot projects at the community level and involving the future users in decision making.

Finally, in areas where it is necessary to have an interface between the two subsectors, facilities should be provided to accommodate this interface. Among others, these facilities would include parking places, stalls, and waiting areas.

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Motorized and Nonmotorized Transport in Katmandu, Nepal: Where Do the Pedestrians Fit?

V. SETTY PENDAKUR AND MARCO GUARNASCHELLI

Conceptual aspects of mode choice determinants regarding nonmotorized transport in developing countries are described. The influence of city size, trip length, and income is discussed with particular reference to the poor. Nonmotorized modes will be important for a long time, and planners need to devise methods that recognize the majority of trips made using these modes. Mode choice and various factors influencing it in Katmandu are presented to illustrate the importance of nonmotorized modes, particularly walking. Traffic studies in three different areas indicate that exclusive pedestrian and bicycle precincts in old areas of central business districts with narrow streets can be quite successful. This success could be replicated in other Asian cities. Examples of inefficient use of street space are given to indicate a lack of application of normal traffic engineering techniques and enforcement of traffic discipline. Experience in Katmandu indicates that exclusive nonmotorized mode precincts provide large volumes of person-trips, particularly by walking. These precincts must be related to street geometrics and adequate bypass routes must be provided.

Basic conflicts between motorized and nonmotorized urban transport in developing countries are described and analyzed. Policy analysis and mitigation measures are based on studies in Katmandu, Nepal (*1,2*). People in poor developing countries resort to nonmotorized transport primarily because they have no money and often because there is lack of adequate and cheap motorized transport.

Analytical methods and intellectual technology formulated in developed countries are based on the value of time and the assumption that capital and maintenance resources are available to provide adequate urban transport supply. Nonmotorized modes (walking, bicycling) are considered negligible and quite often are not included in data collection and policy analysis except in special circumstances such as recreational walkways and bicycle paths. Mixed traffic (motorized and nonmotorized) is not seen as a planning or engineering problem. Recent research emphasizes that under these circumstances, the transfer of intellectual technology from the west to the east (or from the north to the south) without drastic modification is dangerous and distorts the planning process, policy analysis, and investment priorities in developing countries (*3–7*).

In recent years, some progress has been made in including and emphasizing the nonmotorized modes used by the urban poor. Examples and studies have been conducted with the assistance of the International Development Research Center (IDRC) of Canada (*1,8,9*) in India, Nepal, the Philippines, and Indonesia. However, the use of data collection and analysis without the inclusion of nonmotorized modes persists. For example, in a recent study of 12 major cities in India conducted by the government of India there is no mention of pedestrians, although the pedestrian trips could vary from 40 to 70 percent of average daily traffic (*5,10*).

International technical assistance and lending agencies have a major influence on the thrust and focus of urban transport investment priorities in developing countries. Bilateral assistance agencies such as the Canadian International Development Agency (CIDA), Agency for International Development (AID), and Japan International Cooperation Agency (JICA) have, in the past, emphasized high-technology motorized and rapid transit solutions without any reference to the nonmotorized modes (*11–13*). Slowly, though, a more enlightened approach is being taken by agencies such as the IDRC, Transport and Road Research Laboratory (TRRL) of the United Kingdom, and the Swedish International Development Research Agency. These agencies are slowly awakening to the importance of nonmotorized modes in mixed traffic (*14*). However, the nonmotorized transport modes have been neglected in investment priorities. Only 1 percent of World Bank lending supports urban transport by pedestrians, as shown in Figure 1.

Until recently, there was little recognition of the importance of, and consequently little attention paid to, nonmotorized transport by planners in developing countries. In general, the origin-destination surveys and planning models were based on experience in developed countries. Many major transpor-

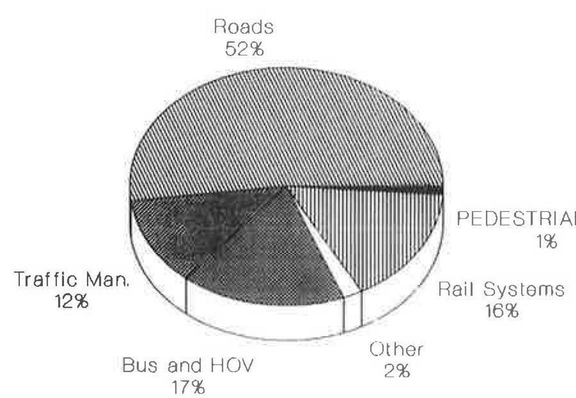

FIGURE 1 Urban transport lending of the World Bank (1972–1985).

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tation studies involving local and international funding were concerned only with cars, trucks, and buses and indirectly relegated nonmotorized transport to nuisance status (*10–12,7*). However, in recent years planners have begun to pay attention to nonmotorized transport because of a variety of reasons, which include their inevitable presence, the difficulties of handling mixed traffic, and their significance in urban transport (*15–17*).

MOTORIZATION

The desire for increased personal mobility is universal. Motorization, which occurs in all the major cities of developing countries to varying degrees, is influenced by a large number of factors, including the following:

1. National policies regarding motor vehicles and taxation,
2. City sizes and trip lengths,
3. Incomes, and
4. Availability of alternative modes with differing costs.

To a large degree, these factors also influence the role, survival, and success of nonmotorized modes.

Income is a major determinant of mode choice among the poor. Because of their affordability, walking and bicycling trips are common among the poor even when trip lengths are high. The data in Figure 2, derived from a number of studies in India and Nepal, show the decrease in nonmotorized mode use as incomes increase.

City size has a major influence on motorization. Larger cities involve a larger proportion of longer trips, especially for the poor. Figure 3 shows the changes in nonmotorized mode use in relation to city size.

As incomes increase, so does motor vehicle ownership (cars, motorcycles, mopeds). However, there is unlikely to be high vehicle ownership in poorer countries. Figure 4 shows car ownership rate versus income for several cities in Asia. Low car ownership rates correspond to low incomes. National policies regarding ownership and use of private cars have significant influence in spite of income. For example, Singapore (with higher incomes) has lower car ownership rates than Kuala Lumpur because of high taxes and import duties. Empiric forecasts based on average and high growth rates for Katmandu and typical low-income countries are shown in Figure 4.

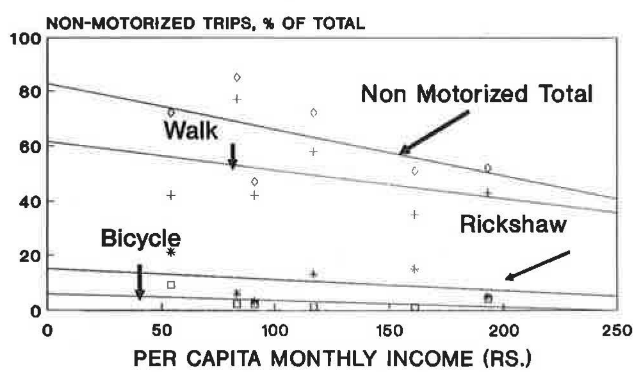

FIGURE 2 Urban travel patterns, mode choice versus income.

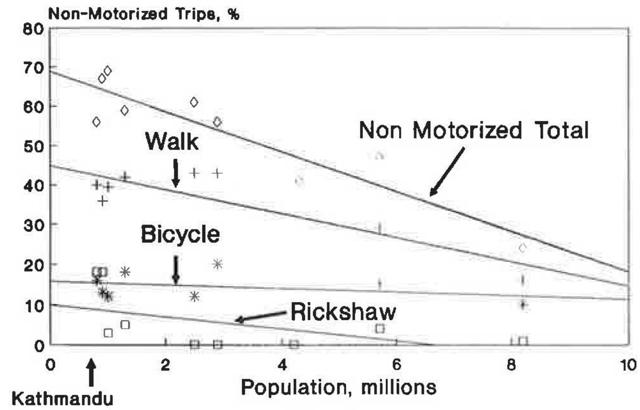

FIGURE 3 Nonmotorized trips in South Asian cities.

The availability of public transport in relation to income for several Asian cities is shown in Figure 5. Again, forecasts for Katmandu and for typical low-income cities are included. The forecasts shown in Figures 4 and 5 are based on assumptions presented in Table 1.

Given the slow growth rates of the lower-income economies, rapid increases in per capita income cannot realistically be expected and as a consequence neither can rapid increases in either private vehicle ownership or public transport availability. Table 1 indicates future income scenarios both for Katmandu and a typical South Asian city with a less-developed economy. These forecasts have been applied to Figures 4 and 5 with the aim of estimating car ownership and public availability. It can be seen that even in the best case (the high-growth scenario for the typical lower-income economy), car ownership and public transport availability estimates remain low. Car ownership could be expected to double from 20 to 40 cars per 1,000 persons but to remain far below the typical 400 to 500 cars per 1,000 persons typical of the industrialized economies. Public transport availability would also remain low at approximately 1.2 buses per 1,000 persons, similar to availability in lower-middle-income economies.

Although it is recognized that motorization will continue to increase in developing countries, it is postulated that nonmotorized modes will remain important for the 20- to 30-year planning horizon. This condition is more pronounced for the very poor countries like Nepal. Under these circumstances,

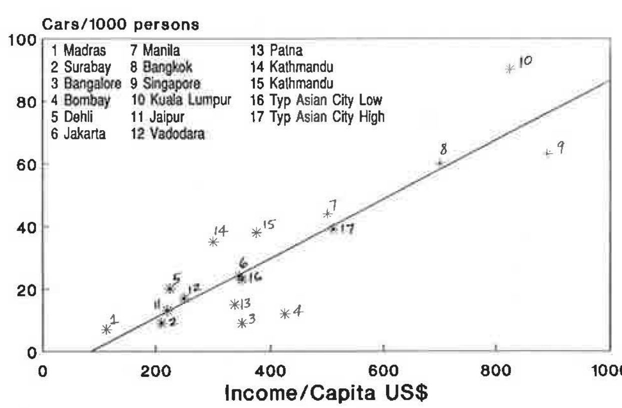

FIGURE 4 Automobile ownership versus income in South Asia.

TABLE 1 EXPECTED INCOME GROWTH

Location	Scenario	Growth* (%)	Present Income ($US)	20 Yr. Forecast Income ($US)
Kathmandu	Expected	0.2	300	312
	Hi Growth	0.9	300	359
"Typical" Low Income	Expected	0.9	300	359
	Hi Growth	2.8	300	521

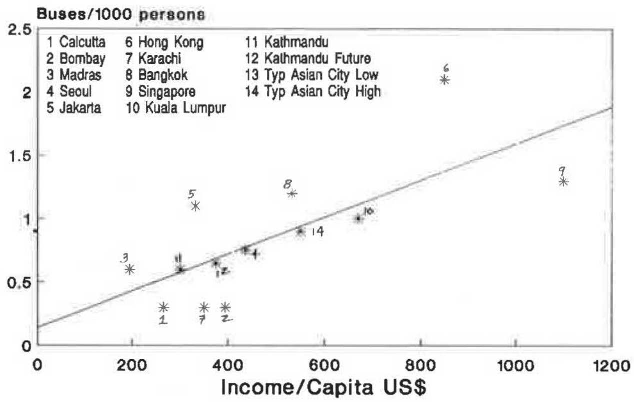

FIGURE 5 Public transport availability in South Asia.

there is an urgent need for further research into the efficient planning, design, and control of nonmotorized modes.

MODE CHOICE

Income is a major determinant of mode choice, especially among the poor. The poor walk and bicycle simply because they cannot afford to pay for other modes (*5*). In some instances, accessibility measures for these modes are either equal to or better than measures for motorized modes (*16*). Depending on the availability, quality, and cost of public transport, walking and bicycling can be as efficient or better depending on trip lengths, terrain, and climate.

Urban transport policies and priorities also have a major influence on mode choice. These policies cover pricing, regulation, enforcement, and safety aspects. Quite often, nonmotorized modes except walking are banned from the central business district (CBD). There is often inadequate provision of safe footpaths or sidewalks. In many developing countries, the supply side (technology and economics) and the regulation side (enforcement, economics, and availability) favor motorized transport. Planning, design, and road space allocation are heavily weighted in favor of motor vehicles. The intellectual technology relies heavily on equivalents of passenger-car units (PCUs). This one-sidedness would change enormously if the professional and research basis were person-trips and not vehicles.

Mode choice differences are probably the most important factor in the reduction of the effectiveness of the models transferred from industrialized to developing nations. Many local economic, cultural, and geographic factors combine to create a different set of mode choice conditions in the less-developed countries (LDCs), for which new mode choice models must be calibrated. An understanding of the set of parameters relevant to developing nations and, more important, of the values attached to the parameters by the particular population is essential.

Generally, the personal modes of travel such as bicycle, motorbike, and automobile provide greater convenience and flexibility but require an initial investment of capital. The passenger modes such as the low-cost transport modes (LCTMs) and the bus are less flexible but may offer more comfort in the guise of protection against the elements and possibly greater speed at a similar cost in continual smaller payments.

The treatment of time as a parameter in mode choice models is probably the major source of difference between the LDCs and the more industrialized nations. In general, the traveler in the developed world can be concerned with optimizing the travel time, whereas the traveler in the developing nation is more concerned with the immediacy of ensuring survival. As a result, income, passenger transport availability, trip distance, and terrain have greater significance.

The most critical parameter affecting mode choice in the developing nations is income. At the most basic level, income may inhibit choice by causing mode captivity. The very poor with minimal or no income may have to walk for the simple reason that all other modes have associated financial costs that the very poor may be unable to bear. Even the poor with a small income may be captive to a low-cost passenger transport mode such as the rickshaw or minibus if distance prohibits them from walking and capital outlay prohibits them from use of the cheapest of the personal transport modes, the bicycle. Aside from causing mode captivity, income versus cost is also one of the strongest factors in the balancing of values by the traveler comparing the relative merits of each mode.

Trip distance is also a strong factor in mode choice for the traveler in the LDCs. This factor, as well as mode type, affects energy expenditure, travel time, and protection from hot weather. The cost of these effects to the passenger is also often linked to trip distance, limiting the availability to the poor of these modes when they have to make long trips.

The availability and cost of passenger transport also have a strong bearing on the choice of mode. As in the developed nations, especially with fixed-route modes, transfer point proximity to both origin and destination and convenient scheduling are factors considered. These factors are less important in the case of the more flexible LCTMs, although for reasons of economics even these modes will still tend to congregate on the more highly frequented routes, and a premium may be paid for deviation from such routes.

The climate, terrain, and available infrastructure also affect the choice of mode. Poor weather conditions such as heavy rain or extreme heat or cold may inhibit the use of nonmotorized modes such as walking and cycling, putting a premium on covered passenger transport modes. Rough terrain and steep hills may also inhibit cycling, whereas poor roads may inhibit the use of motorized modes.

Finally, there are many cultural and historic factors that may enhance or inhibit certain mode choices. For example, religious beliefs may preclude any contact between women and unknown men in public, such as in bus use by women. Frequent past bicycle use by a family will enhance this mode for other family members because of familiarity, availability, and past route choice experience. These effects may prove the most difficult to discern, especially for expatriate specialists with little knowledge of the customs and culture of the developing country.

KATMANDU EXPERIENCE

Background

Nepal is a small landlocked country completely surrounded by India and China. It is a very poor country with a per capita gross national product (GNP) of U.S. $160 in 1984, the seventh lowest in the world. Its economic base is mainly agricultural, which provides employment for 93 percent of the labor force (*18*). Motor vehicles and parts are not manufactured in Nepal and are imported at significant cost. In contrast, nonmotorized transport in the form of bicycles and bicycle rickshaws is often manufactured and repaired locally.

Nepal's 16.5 million inhabitants are mostly rural with only 7 percent living in urban areas. However, between 1973 and 1984 the urban growth rate was very high, 8.4 percent annually. Katmandu, with a population of 235,000, has approximately one-fourth of the urban population of the country and is the largest and principal city (*1*).

As with most LDCs, unemployment and poverty are prevalent in Nepal. There is a significant amount of both unemployment and underemployment, especially among the educated. Shah (*1*) reports that various surveys have found unemployment among the educated to be between 25 and 65 percent. Income statistics for Katmandu are not readily available; however, given a poor income distribution in combination with the extremely low per capita GNP cited, a fairly high level of poverty is apparent. In fact, between 40 and 60 percent of all households are considered poor (*2*). Unlike in most Asian cities, though, the poor in Katmandu have been relatively well dispersed spatially; therefore the city has, to date, avoided the usual problems with slums and squatter settlements (*1*).

Transportation: Description and Observations

The following description of the transportation system of Katmandu stems from two separate studies as well as the personal experience in Katmandu of the principal author. The first study was carried out by Tribhuvan University during 1984 to 1987 under the guidance of the principal author and was funded by the IDRC (*1*). The second study was a miniature traffic study conducted in 1988 (*2*).

The transport system of Katmandu is typical of low-income Asian cities, with a heavy emphasis on nonmotorized transport. Walking is the dominant mode; Figure 6 shows that 56 percent of daily trips were walking trips. Fortunately, as indicated earlier, the poor in Katmandu are relatively well dispersed and thus seem able to keep their travel distances short, a necessary condition for the pedestrian travel mode. Figure 7 shows the large number of trips shorter than 5 km; two-thirds of these trips are by walking.

As it is in most lower-income nations, bicycle use is minimal in Katmandu. This low use is due in part to the hilly terrain

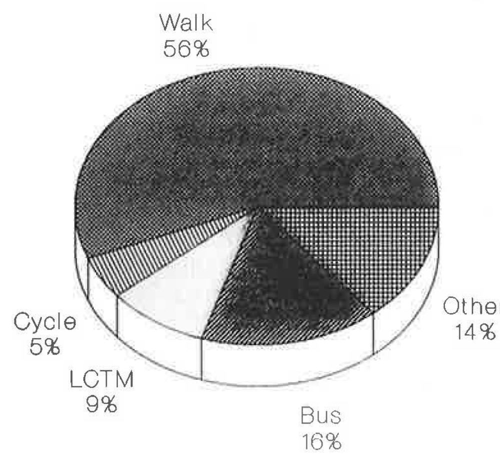

FIGURE 6 Mode split in Katmandu (percentage of total trips).

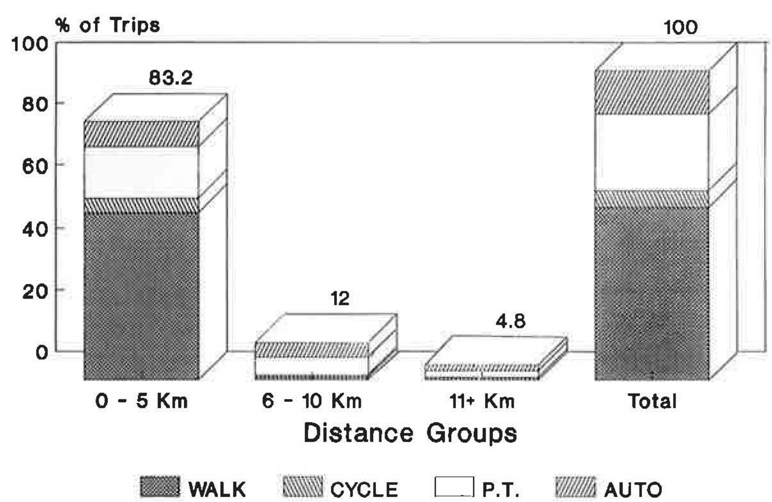

FIGURE 7 Trip mode split characteristics in Katmandu.

and in part to the low availability of bicycles. The hiring of bicycles is restricted somewhat by the lack of an identification system for clients. In addition, only 18 percent of all households own a bicycle, significantly less than in many other lower-income nations. Local production and access to financing may induce travel mode upgrading from walking to the more comfortable and efficient bicycling mode. There are two areas in which nontransport solutions may have significant impacts on travel patterns.

Other modes used in Katmandu are buses and LCTMs. These LCTMs include cycle rickshaws, tempos, meter tempos, and minibuses. Figure 6 shows the popularity of LCTMs and buses, with a total patronage of 25 percent of all trips. Figure 8 compares these two modes, indicating that the actual use of buses is higher than for other for-hire modes in relation to seat capacity. However, from a social perspective LCTMs provide employment to a greater number of people, resulting in additional social benefits.

Nepal is one of the poorest countries and nearly half of Katmandu's residents are poor. The effect of income on mode choice is shown in Figure 9. In addition, the dependency ratio is very high and incomes are very low. Under these circumstances, the majority chooses to walk or to use other, cheaper nonmotorized modes of transport.

Because of the hilly terrain and very cold climate during 6 months of the year, trip distances have a significant influence on mode choice, even by the poor. Figure 10 shows that walking is the predominant mode when trip length is less than 5 km. When trip length exceeds 5 km, there are major shifts to buses and other modes. In the range of 6 to 15 km, terrain, climate, and fatigue are major factors influencing mode choice. Beyond 16 km, walking is not a practical choice.

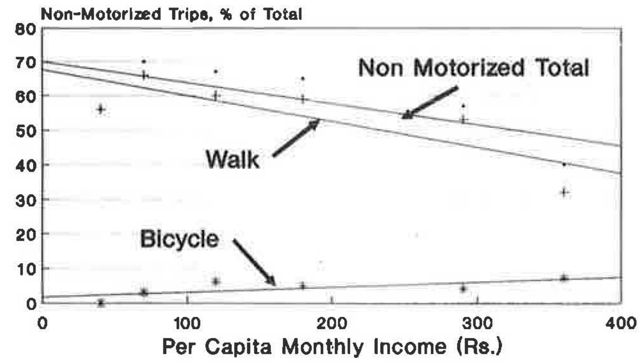

FIGURE 9 Mode choice versus income in Katmandu.

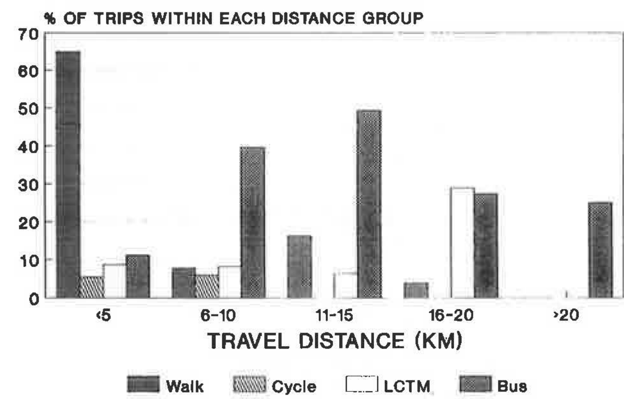

FIGURE 10 Distance versus mode choice in Katmandu.

Conflict Mitigation and Capacity Enhancement

Traffic patterns in three specific areas of Katmandu were studied by the authors in 1988 (*2*). These areas were Bhotahity, Lainchaur, and Ratna Park. The map in Figure 11 shows these three areas in detail within the overall traffic network. The purpose of this study was to observe and analyze traffic volumes and modes during peak hours.

Bhotahity is an ancient inner city core with narrow streets that contain thriving retail businesses and much informal vending on the streets themselves. This area is quite typical of the many older cities in developing countries. The street widths from building line to building line are very narrow at 8.12 m. The retail market area is thriving, dynamic, and economically successful.

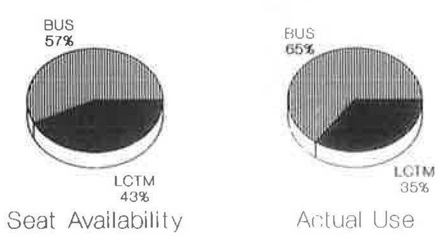

FIGURE 8 Passenger travel in Katmandu.

Expansion of these streets to allow for all modes is economically prohibitive. As a result, instead of allowing motorized transport during peak periods at the expense of pedestrian capacity, motorized traffic has been restricted. From 8 a.m. to 8 p.m., only bicycles and pedestrians are allowed. Motorized personal vehicles are not permitted except when the owners live in the area. Goods vehicles are allowed access for delivery purposes. The result is a nonmotorized precinct allowing for relatively free and safe pedestrian and cyclist flow. Obstructions to capacity had been apparent, especially in the form of sidewalk vendors. The informal sector may have been a significant source of income to the poor, and enforcement of street vending restrictions could have proved to be difficult. In this instance, once the motorized traffic was removed, capacity was adequate for use of the street both as a nonmotorized traffic route and as a vending area constituting an integral part of the economic system. Creative interaction of transport and land use planning can optimize the use of the minimal infrastructure available in developing nations.

In Bhotahity, the number of cycle rickshaws, delivery vehicles, and personal motorized vehicles was small. The traffic consisted primarily of pedestrians and cyclists. The peak-period mode split is shown in Figure 12 and the pedestrian flows in Figure 13. Traffic flows were 5,015 pedestrians per hour and 286 bicycles per hour.

In the Lainchaur area, traffic counts were made on Kanti Path, an arterial street just outside the CBD. In Ratna Park, the counts were made on Ratna Park East and Ratna Park

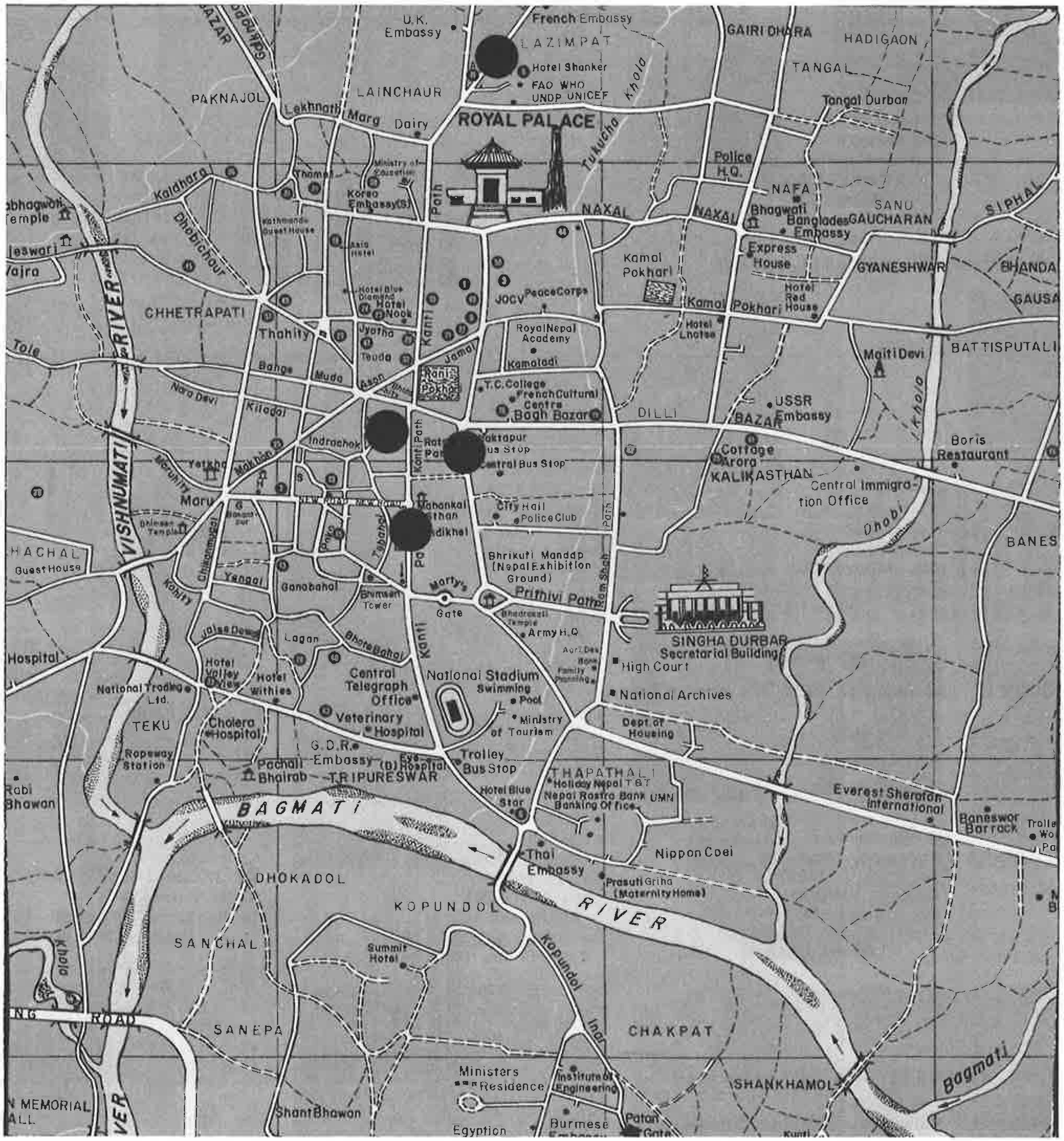

FIGURE 11 **Map of Katmandu (areas studied indicated by ●).**

West, two one-way streets designed originally as ceremonial streets. The locations of the counts are shown in Figure 11.

Mode split and traffic volumes for Lainchaur are shown in Figures 14 and 15. Similar data for Ratna Park are shown in Figures 16 and 17. On these two arterials, there are no capacity problems. However, visual observations suggest inefficient traffic controls; insufficient enforcement of pedestrian use of the vehicular roadway; and unregulated use of space at bus stops, tempo stops, and intersections. These problems can easily be rectified by normal traffic engineering practices, at the same time paying attention to all modes and person-trips.

Despite the fact that more than 60 percent of all trips in Katmandu were by nonmotorized modes, the arterials showed less than 15 percent of nonmotorized trips. This low number may indicate that nonmotorized traffic on other arterial routes is reduced by the use of nonmotorized precincts such as Bhotahity. The reduction of nonmotorized traffic on the arterial routes increases the capacity of these routes by reducing the effects of the slower cyclists on the speeds of the faster mo-

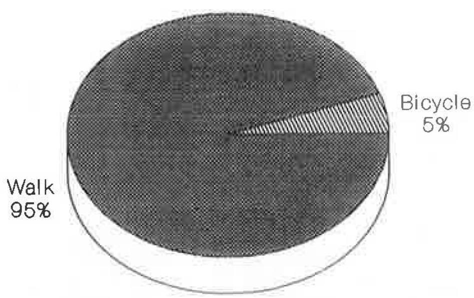

FIGURE 12 Mode split in Bhotahity.

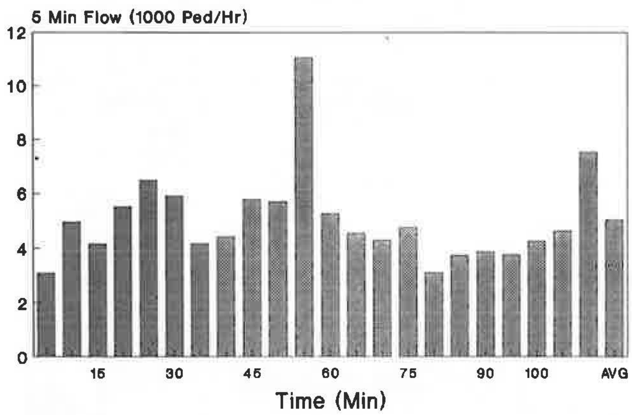

FIGURE 13 Five-minute pedestrian flow rates in Bhotahity.

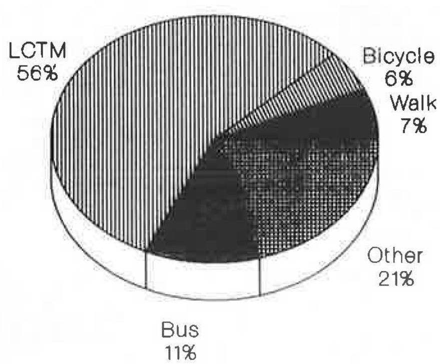

FIGURE 14 Mode split in Lainchaur.

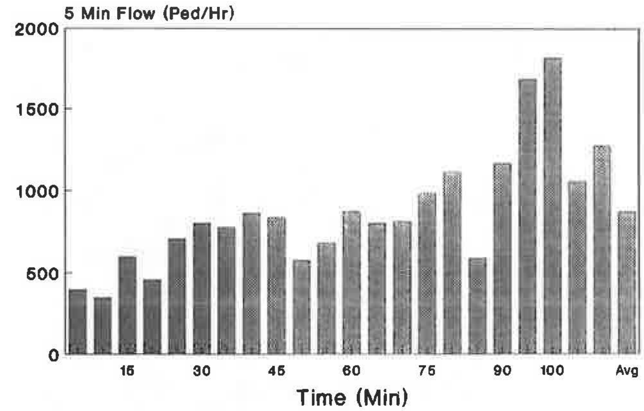

FIGURE 15 Five-minute pedestrian flow rates in Lainchaur.

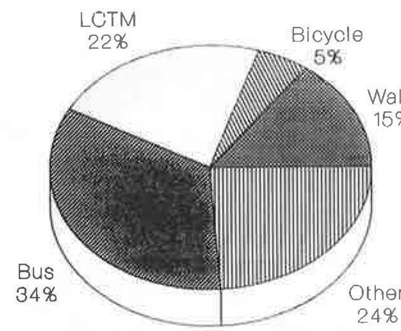

FIGURE 16 Mode split in Ratna Park.

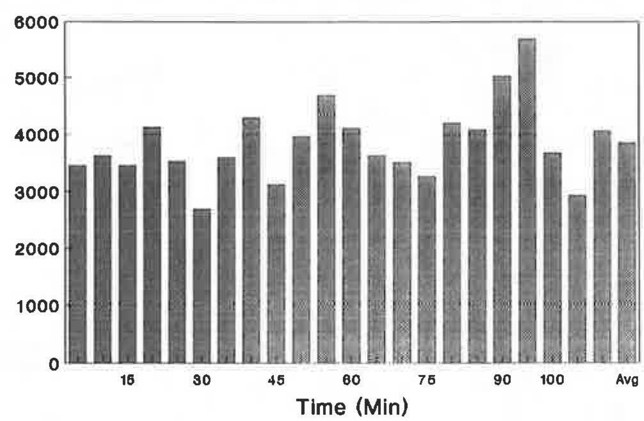

FIGURE 17 Five-minute pedestrian flow rates in Ratna Park.

torized modes, allowing for possible additional roadway width through smaller pedestrian flows, and reducing conflicts (Figure 18).

Such efficient use is possible only when planners focus on total person-trips (not on vehicles only) and allocate appropriate exclusive and mixed precincts for various modes. This allocation must be done by recognizing the important role of nonmotorized modes in developing countries.

CONCLUSIONS

The data and analysis presented here lead to several conclusions. The more important conclusions are as follows:

1. Developing countries and major international lending agencies have previously ignored the nonmotorized modes, particularly pedestrians, in planning and investment strategies. These attitudes appear to be changing as planners begin to recognize that a majority of the people in poor countries are dependent on nonmotorized transport, particularly walking.
2. Income is a major determinant of mode choice. Because rapid increases in personal incomes are not predicted for Katmandu, the majority will continue to walk.
3. It is unlikely that there will be a significant increase in bicycle trips in Katmandu because of the constraints of terrain and climate. Currently, the available bicycles are all single speed.

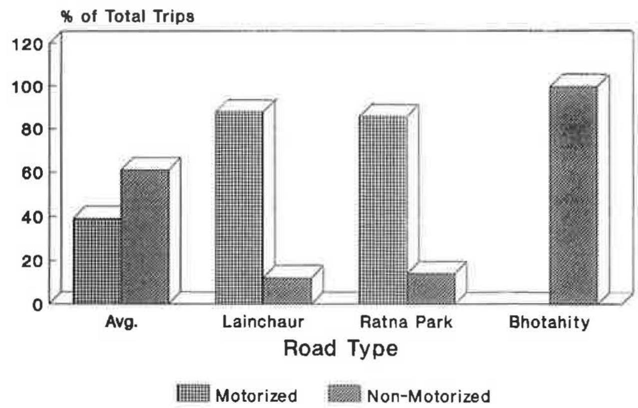

FIGURE 18 Mode separation effects in Katmandu.

4. The number of bicycle and cycle rickshaw trips in Katmandu is significantly lower than that in cities of similar size. This is attributed to terrain, climate, and cost versus income factors.

5. Although it is recognized that motorization will continue to increase, considering the predicted GNP and income increases for Nepal, it is estimated that motorized vehicles and motorized trips will remain proportionately insignificant during the next 20-year period.

6. Bus availability is a function of both regulation policies and urban transport investment (which is dependent on the strength of the national economy), especially when it involves foreign currency expenditures. Katmandu is likely to increase its bus fleet but unlikely to do so in substantially large measure.

7. Car ownership in Katmandu is now higher than it is in other Asian cities with similar economic status.

8. Fifty-six percent of all daily trips in Katmandu are by walking and another 5 percent are by bicycle. Other low-cost transport modes account for 9 percent of the total.

9. For trips of up to 5 km, walking is the mode choice for a variety of reasons including cost and unavailability of other cheap transport. Beyond 5 km, walking appears to be impractical even for the poor.

10. There is a pronounced shift from walking to public transport for trips longer than 5 km.

11. The public transport system is overloaded and there is an adequate supply of other for-hire transport.

12. Katmandu planners have successfully used exclusive pedestrian precincts within the CBD to relieve congestion, create additional capacity on other arterial streets by diverting pedestrians to these precincts, and achieve higher safety levels.

13. On certain arterials, apparent crowding may be the result of capacity obstructions such as trees and an unregulated mix of traffic including pedestrians; inadequate traffic controls; and unplanned bus, tempo, and taxi stands and stops.

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Urban Land Use and Nonmotorized Transport in Kanpur, India

SCOTT GIBBONS

In the United States, considerable priority has been placed on the segregation of land uses and the relatively free flow of motorized vehicles on urban streets and roads. This policy has allowed considerable economic benefits. In less developed countries, as in earlier U.S. experience, streets and roads are an integral part of the urban marketplace. Most of the economic activity in that marketplace is conducted with slow-moving vehicles or on foot. Research in Kanpur, India, has identified relationships between different travel modes and land uses that could lead to land use planning that would more effectively accommodate slow-moving vehicles and accord fast-moving vehicles their appropriate importance in the transportation hierarchy.

In the 20th century, American urban land use has become more formal and segregated as the scale of economic activity has increased. Large American cities at the turn of the century suffered from encroachment on streets and sidewalks by small-scale hawkers. This patten is still visible today in such isolated locations as the Italian Market in Philadelphia. However, increased affluence has resulted in strict building codes and segregated land uses. These characteristics have promoted the use of motorized vehicles, which has expanded the potential service area for commercial enterprises and introduced horizontal rather than vertical economies of scale. That land use environment has been characterized by declining density. This dispersion of development is a sharp departure from previous industrial age trends. Today the density of land use is again increasing. However, ideas about land use and transportation planning are still firmly rooted in the concepts of segregation and motorization.

Land use and transportation planning in less developed urban environments such as those found in most of the cities of the Indian subcontinent have been influenced to a large extent by the ideas prevailing in the United Kingdom and the United States. Motorization, in particular, was seen as a key indicator of economic progress, as was land use segregation to a lesser extent. However, almost no consideration was given to the relationship between small-scale enterprises and nonmotorized or slow-moving vehicles. Small-scale enterprises tend to be located in areas of high traffic volumes. This situation presents a fundamental conflict in urban areas with limited roadways. The limited road space, coupled with increased traffic of all types (i.e. potential customers), encourages the location of even more small-scale enterprises. When motorized vehicles increase their share of the traffic composition, their greater space requirement causes congestion to increase dramatically. In addition, their lack of maneuverability compared with that of other modes reduces their operating speeds to near those of nonmotorized vehicles.

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In this environment, the greatest concern seems to be that motorized vehicles are operating inefficiently because of the road congestion. The first solution considered is often the removal of slow-moving vehicles and encroachments. Because many central area roads suffer the same types of congestion, small enterprises are encouraged or forced to relocate to areas where there is less congestion—exactly the opposite of their natural inclination and economic necessity. In the case study of the Indian city of Kanpur, motorized vehicles constitute less than 10 percent of person-trips. Although it is appropriate to improve their operating speeds, it does not logically follow that roads with the best potential operating surface should be cleared to serve their needs to the exclusion of those of others. Research conducted in Kanpur shows important relationships between land use and transportation that must be considered before any land use or traffic management decisions are made involving nonmotorized vehicles.

KANPUR URBAN ENVIRONMENT

Kanpur, located in north India's state of Uttar Pradesh, was a group of villages until the late 1700s. From then until 1857, Kanpur developed as an army camp for the British. It was chosen as a camp because of its nearness to both Avadh (a rich cultural and agricultural state) and Delhi and its location on the Ganges River. As is typical of many north Indian towns, Kanpur was partitioned into three parts: the cantonment, the civil lines, and the native town. The cantonment housed the military and its supplies, and the civil lines was the office and residential area for administrative personnel. The native town was the locus of all support activity.

The municipal boundaries were changed after the unsuccessful rebellion of 1857 but have remained fixed since that time. Even though it has ceased to be an army camp, the cantonment remains a key and active part of Kanpur's environment. Under military jurisdiction, the cantonment remains outside the control of city authorities. Geographically, it acts as a barrier to northeastern expansion of the native town. The civil lines is an integrated part of Kanpur and has no legal protection from urban growth. However, it has retained much of its distinct character because of the design of its structures and its low density. The principal change in its land use has been the conversion of many residential units into offices.

Kanpur, the native town, has grown from the cantonment in the east along the Ganges toward the northwest. Railroad lines and major roadways have left a narrow funnel for development along their transportation corridor. The railroad lines and the Grand Trunk Road (both with rare trans-Ganges bridges built to facilitate the transport of raw materials, particularly cotton, to the major industrial market in Kanpur) and the Ganges itself have linked Kanpur to the entire region. In the late 1800s, industries were established there with a regularity that quickly made Kanpur the principal industrial city of north India. Industries there were established along the Ganges or close to the railroad lines. However, because of the physical constraints of the narrow transportation corridor, the Ganges, and the cantonment, it was much more difficult to move within the city than into and out of it.

URBAN DEVELOPMENT

Much of the village form has been replicated in the Indian urban environment. This is in large part due to traditional Indian values that are substantially different from contemporary Western values. Contrary to Western urban economic behavior, many Indian families seek to minimize their total outlay of money rather than to reach optimal utility levels. Most people prefer to pay higher rent in crowded conditions in order to avoid travel, even when living conditions outside the central area could be obtained with only a small increase in total expenditure. It is not uncommon to find wealthy families in the same densely settled areas where the poor inhabit dormitory units in up to three shifts per day.

In Kanpur residential, commercial, office, and even light industrial land uses may be found in different rooms of individual buildings in the central areas. Heavy industry is also located there. The great demand by all land uses for space in the central areas results in direct competition between residential and nonresidential uses. Commercial and office uses have been able to outbid residential land uses for space near industrial facilities, forcing many workers to live farther away. With limited roadway facilities and inadequate public transportation, this results in an expansion of the high-density area with serious congestion.

In Kanpur the street network has remained essentially unchanged since 1930, whereas the population and traffic have grown considerably. The entire central area is generally under intense use, particularly the road frontage along major streets. The increases in traffic destined for central areas and in local commercial strip-based traffic remain only along narrow corridors. Thus, the limited existing transportation network reinforces strip development and the pattern of dense settlement in the central areas.

The severely limited access to transportation facilities is evident from the horizontal stacking of commercial activities along major streets. For example, it is common for stores to encroach on part of the sidewalk, *pattiwallas* to sell their wares from a cloth spread on the sidewalk or at the street edge, and hand carts and animal-drawn vehicles to conduct business on the street itself. With the myriad vehicle types parking on the street (parking space occupancy from 9 a.m. to 9 p.m. averages 200+ percent) added to the direct commercial encroachment, the strain on the streets becomes most severe. Even where sidewalks are relatively unoccupied by nonpedestrian uses, their awkward design height causes pedestrians to prefer the street. As a result, as little as 30 to 50 percent of the road right-of-way is available for vehicular traffic (Pradeep Tiwari, unpublished data).

Industrial production in Kanpur peaked in the 1940s when its mills, tanneries, and ordnance factory produced wartime supplies and drew additional rural labor. During this period, major urban infrastructure was not built, nor was industrial differentiation undertaken to broaden the city's economic base. Shortly after the war, Kanpur's economy slumped. The lack of raw materials nearby for heavy industry resulted in low priority for development for Kanpur based on the Five-Year Plan (*1*). The number of industrial workers, which had increased from 55,814 in 1939 to 116,252 in 1945, decreased to only 68,832 in 1953 (*2*). The population continued to grow at 3.1 to 4.0 percent and reached 1 million in the late 1960s and 1.74 million in 1981 (*2*) (see Table 1).

The increased population was not needed in the industrial sector, so instead many found casual jobs, plied rickshaws, or became hawkers. New residents did not generate the wealth that could even maintain, let alone expand, urban transportation services. Moreover, the occupations taken up by these new residents were dispersed throughout the city rather than being in factories at discrete locations that could be efficiently served by public transportation.

In the 1940s and 1950s, housing construction was only 1.2 units per 1,000 population per year (*1*). This situation resulted in increased crowding of existing *ahatas* rental housing and in residential densities of up to 800 persons per square kilometer in some slum and squatter settlements (six times the maximum government standard). By 1975 the total population in such housing reached 0.5 million. Unlike other Indian cities such as Ahmedabad, Bombay, and Calcutta, these settlements in Kanpur are centrally and not peripherally located.

Slums and squatter settlements in Kanpur often encircle a commercial district or factory but rarely abut major roads (*1*). In 1977 two-thirds of those settlements were within 1 km of transportation, education, shopping, and banking services, and 58 percent were within 1 km of the workplace, but only 13 percent had access by *pucca* (macadam or paved all-weather) roads. One of the largest such areas, Gwaltoli, is not accessible by vehicular traffic. The Uttar Pradesh Town and Country Planning Organization recommends that the distance to work for residents of *ahatas* should be no more than 1 mi. In practice, that standard prevails, primarily because of the initial urban settlement pattern of workers living adjacent to employment opportunities. However, in the peripheral sites and services schemes the 1-mi standard does not apply.

The Second Five-Year Plan states that slums will remain a problem until steps are taken to prevent the establishment of new ones and until land use regulation is exercised to check unplanned growth (*1*). Both the Second and Third Five-Year Plans provided for slum clearance and improvements. A study team for the Third Five-Year Plan even went so far as to recommend the provision of paved streets and good approach roads to slums and squatter settlements. Most planning efforts for these settlements have involved plans to displace the residents to distant developments away from their social and economic contacts. As a result, there has been much resistance to most programs.

Various plans for slum improvement and upgrading have ignored a critical factor. In Kanpur, as in the rest of urban

South Asia, there is an acute shortage of affordable and economically viable commercial space. Planned space is available in peripheral developments but finds few takers, as has been observed in Lahore and Chandigarh. It is precisely because of the commercial land shortage that the squatter and slum settlements have been packed into areas that are both close to jobs and lacking in access to the street network. The low percentage of urban space devoted to streets (6.8 percent in the central area, 2.6 percent in the metropolitan area) in Kanpur causes acute competition for road frontage with high traffic volumes (*2*). Thus, workers often find housing directly behind commercial establishments, because the area away from the main streets has little or no commercial value.

Little employment is found within the slum. Of all slum and squatter units, 83 percent were residential, 15.4 percent residential with commercial use, 0.5 percent residential with industrial use, and only 1.1 percent commercial (*1*). After their first move to Kanpur, 75 percent of slum dwellers have not moved again. In a survey conducted by the Indian Institute of Public Administration, of the 32.9 percent of slum and squatter settlement residents who would not relocate under any conditions, 48 percent would not relocate because of increased difficulty in job-based travel. These data seem to indicate an individually optimized residential location pattern.

The problem with this type of optimization is that as population grows, the density will increase in previously established residential areas. It is difficult to establish new settlements farther out of town because of the separation from markets and employment opportunities. Any peripheral settlement would have to provide either affordable public transportation or densities high enough to sustain adequate internal employment. In the absence of either of these two requisites, it is likely that central area slums will become even more overcrowded and that commercial and manufacturing density will also increase in the central areas, thereby appropriating more road space and further constricting traffic flow.

KANPUR TRANSPORTATION ENVIRONMENT

The residence of both rich and poor in the early days of American industrialization was in the crowded business district (CBD) (*3*,p.28).

> When the only transportation was by horse, almost everyone lived within walking distance of his job in the central business district. Even afterward, when they could take a trolley to work, factory workers and office and store clerks generally preferred to pay relatively high rents for crowded quarters from which they could walk to work rather than spend the time and money to commute from neighborhoods where rents were lower.

In the United States, the movement of affluent urban residents farther out along transportation corridors has resulted in a continuous filtering down of housing stock from the more to the less affluent and a general outward movement of population from the CBD. Once transportation corridors had been established, the affluent could continue to move farther out, and transportation lines were extended to serve them. From this movement, better housing was constantly made available to the less affluent who lived nearer the CBD. The transportation system was already in place for them, having been subsidized earlier by private trolley companies serving affluent customers. In addition, radial growth allowed more central area space for commercial use and transportation facilities.

Significantly, this pattern took hold while economic scales were increasing. More people worked in factories or offices in large buildings located in areas with little residential land use. It was easy to go from a residential area to a commercial area by public transportation, and less of the population needed to protect their financial interests by living close to their place of work.

The improved transportation technologies that led to the gradual movement of the affluent urban population along transportation corridors in the United States have largely not materialized in Kanpur. Instead, large numbers of merchants and other affluent persons continue to live in the Kanpur CBD.

In contrast to the development of the North American urban environment, which has resulted in higher scales of economy, development in Kanpur has moved toward lower scales of economy. As a result, travel destinations are dispersed and continuous along major streets. It must be stressed that some entire streets, and perhaps a large part of the CBD, are work and shopping destinations. It was previously pointed out that commercial land uses have outbid residential land uses for road frontage. The result is that bus service along these corridors is not efficient because it does not directly serve significant residential areas or offer the frequency or short stop spacing needed in this environment. As a result, ad hoc transport modes dominate.

In 1977 fast vehicles made up only 3.8 percent of total person-trips in Kanpur. The rest were delivered by pedestrian (72.3 percent), cycle (17.7 percent), and slow modes (4.3 percent). Trip length ranged from 1.1 km (pedestrian) to 3.12 km (fast vehicles) with an average of 1.43 km. Travel times ranged from 19.9 min (pedestrian) to 26 min (cycle) (*2*). In Kanpur fast-moving vehicles average only 7.9 km/hr and cycles, 5.4 km/hr. The minor variation in travel times and speeds is indicative of the acute congestion in the city and has also been noted in the case of Delhi's Walled City.

More than 9 out of 10 person-trips in Kanpur are either by foot or by cycle. These trips have negligible costs to the individual and can be considered free. Of the remaining 10 percent, bicycle rickshaws make up 62.5 percent, scooters, 31.9 percent; cars, 5.4 percent; tempos, 3.3 percent; and buses, 0.8 percent. The remaining direct-cost outlay modes are buses, tempos, and cycle rickshaws. Their shares in total vehicle movement are rickshaw, 6.3 percent; tempo, 0.3 percent; and bus, less than 0.1 percent (*2*).

Among these three modes, design speed is highest for buses, followed by tempos and rickshaws. Operating frequency is the reverse, with rickshaws first, followed by tempos and buses. Comfort is difficult to define, but strictly in terms of occupant space the order would be the same as that for frequency. Fare pricing per kilometer is lowest for buses, then tempos, and highest for rickshaws. According to the Kanpur Traffic and Transportation Plan, trip length increases from 1.1 km for pedestrian traffic to 1.8 km for slow vehicles and 3.12 km for fast vehicles (*4*,p.208). The bus and tempo have significant service level overlap, as do the cycle and rickshaw.

The result of the congestion in Kanpur is that operational speeds and efficiencies are lowered in proportion to design speed. This means that a bus will be more adversely affected than a tempo and a tempo more than a rickshaw. Operational efficiency is directly related to the attainment of design speed and loads, which are much lower for a tempo than for a bus. Similarly, design speed and loads are lowest for the rickshaw. Tempos and buses both depend on passenger turnover to maintain the load factor. A rickshaw normally carries one or two passengers directly to a single location. As congestion increases, the operational efficiency of the rickshaw increases relative to that of tempos and buses. This efficiency is even greater for bicycles. Yet, ironically, as congestion has increased, the removal of cycle rickshaws and bicycles from certain roads has been considered, to increase the travel speeds of automobiles and buses.

Data in terms of aggregate percentages for different travel modes are available for a number of Kanpur intersections. Volume counts were taken in 1963–1964, 1974–1975, and 1982–1983. The four key intersections of Bakr Mandi, Bara Chauraha, Deptyka Parao, and Afim Kothi reveal the change in traffic composition over time. The composition of automobiles has declined drastically from over 6 percent to just 2 percent of the total intersection traffic during the 20-year period. At the same time, buses have declined from 1.3 percent to only 0.4 percent. Trucks, as well, have declined from 2.3 to 1.4 percent. Scooters and motorcycles have increased rapidly from 3.7 to 15.4 percent (*4*,p.208).

Between 1963–1964 and 1974–1975, the percentage of rickshaws decreased but by 1982–1983 it had increased to more than the 1963–1964 level. (This increase was also observed in New Delhi and was attributed to increases in petroleum prices.) Cycle composition decreased, probably because of the increase in scooter use. Use of animal-drawn vehicles showed a slight increase similar to that for rickshaws, although use of handcarts declined throughout the period. The introduction of three-wheeled motorized tempo paratransit was evident for the first time in the 1982–1983 counts, with 1.6 percent of traffic composition (*4*,p.208).

In 1984 there were nearly 500,000 bicycles and 50,000 cycle rickshaws in Kanpur (Pradeep Tiwari, unpublished data). The Kanpur urban bus service of the state monopoly Uttar Pradesh State Road Transport Corporation (UPSRTC) consisted of only 92 buses (*5*). With a population of almost 2 million, Kanpur may be the largest city in the world without an independent urban bus service. The buses used were not designed for urban areas and cannot load and unload passengers efficiently because of narrow doors and high loading heights. Routes and timings are largely unknown and it is common for people to board any bus that comes before they inquire about the route. This is not surprising, because bus drivers have been known to abort trips because of congestion. Because buses have been commandeered by students, a driver may avoid bus stops with large numbers of students.

LOCATIONAL CHARACTERISTICS IN KANPUR

The urban slum population in India grew from 20 percent in 1951 to 35 percent in 1976. In Delhi, the squatter settlements grew 12 percent annually compared with a total city population increase of 3.4 percent (*1*). In Kanpur, the population is expected to grow from the present nearly 2 million to 3.2 million in 2001, of which 70 percent will be low-income earners. The principal characteristic of these squatter settlements is their location in any available space when affordable housing is not provided.

Transportation planning for this urban population, whose economic activities are confined to the lowest levels of organization and are often called ad hoc or informal, requires an understanding of their behavioral patterns and economic needs. In order to identify these key factors, a random, nonscientific survey was conducted with Raka Sharan of the Department of Humanities and Social Science at the Indian Institute of Technology, Delhi. In the survey, 350 workers from six employment groups were interviewed (S. Gibbons and R. Sharan, unpublished data).

In the survey, all groups showed a preference for residential locations near large wholesale markets (*mandis*). It is not surprising that this preference was greatest among the wholesalers themselves. Even when the option of living near a small market was raised as a possibility, the respondents continued to prefer the *mandi*. Considerable mode split existed for different trip purposes and varied among occupational groups. Cycles and rickshaws were preferred for all trip purposes except visiting relatives.

This survey again confirmed the residential proximity to work place shown in earlier surveys in Kanpur. The preference of many respondents for residential locations in areas around large wholesale markets could be caused by employment there or by the lower cost of goods in those markets as compared with smaller neighborhood stores. Nevertheless, the results do not indicate much potential for a less congested urban environment.

A bus passenger survey was conducted in Kanpur in 1980. The most interesting information contained therein is that 35 percent of trips could not be attributed to standard trip purpose categories (S. L. Dhingra, unpublished data). This finding tends to support the observation that many trips are, in fact, miscellaneous in that people travel to check things out or to spend time. Eastern cities are in fact oriented this way, and it is not surprising that people settle densely to facilitate this behavioral preference. Many of the miscellaneous trips could have been made in search of job or business opportunities. Nevertheless, public transportation is least able to serve precisely these trips.

ANALYSIS OF TRANSPORTATION AND LAND USE RELATIONSHIPS

The high use of cycles, scooters, and rickshaws allows spontaneous decision making during travel, which is not possible with more organized modes. Commercial activity location promotes and is encouraged by this behavior. As a result, the lowest level of commerce (hawkers) is especially dependent not only on population concentration but also on absolute volumes of traffic. To explore these relationships, land use and demographic information was collected and analyzed together with work trip origin-destination survey data.

Raw data that have been collected for all urban areas of India document the population, economic activities, and economic characteristics at the enumerator-block level. This information is contained in the *1980 Economic Census of India* and the *1981 Census of India* unpublished data sheets. Also contained therein is the breakdown of commercial activities into eight broad categories with their ownership and operational characteristics. Especially interesting is the separate listing in the *1980 Economic Census of India* of economic enterprises without premises (i.e., hawkers). Thus, for the first time, information is available that shows location patterns at the metropolitan level. For Kanpur, the data are available at three levels: 45 wards, 190 *chaks*, and 2,800 enumerator blocks (*Economic Census of India*, unpublished data).

During the course of this study, other significant unpublished transportation information was collected. This included an origin-destination survey conducted in the mid-1970s, which gives a breakdown of trips by mode and purpose as well as by origin and destination. Even pedestrian trips (70 percent of the total) were included.

For purposes of data analysis, the census data were aggregated to the ward level and the origin-destination map was adjusted to match the city ward map. Information for eight different types of enterprises with permanent (*pucca*) facilities was available. These types include retail and wholesale, manufacturing, hotels and restaurants, business services, agricultural, personal services, transport, and warehousing enterprises. For each of these enterprise types, the level of organization was given by three categories: directory (five or more persons employed), nondirectory (fewer than five persons employed), and own-account (no hired employment). Enterprises with temporary or no facilities (hawkers, etc.) were aggregated for all types. Population and employment figures were also available from the same source.

Densities were then calculated for each of 45 wards, or analysis zones. The highest densities for population, employment, and all activities except transportation and agricultural enterprises were found in the central areas. This result follows site observation and quantifies the concentration of commercial activities along transportation corridors and in central areas.

The origin-destination survey conducted previously was considered to be of poor quality except for the home-to-work data, which were considered to be of fair quality. However, the survey results were never used to develop a travel model and as a result were never verified. In addition, there were possible errors in conversion to analysis zones and in spreadsheet entry from hand tabulation sheets. In light of these factors, regression analyses were performed with special attention to the goodness of fit as well as the relationships among variables. The results observed in the models were encouraging from both points of view.

Population can be predicted from a model using only information on the number of the six enterprise types in each zone ($\bar{R}^2 = 0.893$). It is positively correlated with manufacturing, warehousing, and personal services and negatively correlated with retail and wholesale, hotels and restaurants, and business services. This location near more organized employment land uses such as manufacturing and warehousing confirms earlier observations and survey results that indicated the strong desire of workers to live near their places of employment. The results show the strong relationships between various enterprises and population that occur in an environment characterized by mixed land use. This reinforces the need to investigate further the relationships between the economic land uses themselves.

Attracted trips can be predicted from a similar model in which population, employment, and number of agricultural enterprises is added. The need for this relatively awkward model shows how difficult it is to identify the impact of individual variables on trip generation and attraction. Normally, employment-related variables would be sufficient for trip attraction and population-related variables for trip generation. However, the nature of the mixed land use environment is much more complicated than that of the segregated land use environment. Case studies and surveys may be the only approaches that will produce reliable disaggregated rates.

Level of enterprise employment is not sufficient to predict trip attraction ($\bar{R}^2 = 0.26$). It is possible that the narrow distinctions among the three categories is not adequate to identify the contribution of truly large businesses such as factories. It may also be true that the categories simply do not reflect significant differences in trip attraction. However, own-account enterprises can be predicted from a model that includes directory and nondirectory enterprises ($\bar{R}^2 = 0.757$). Own-account enterprises are positively correlated with nondirectory enterprises and negatively correlated with directory enterprises. This result indicates a greater similarity between the two lower levels in location pattern.

Hawkers tend to be positively associated with trip generation ($\bar{R}^2 = 0.49$) and negatively associated with trip attraction ($\bar{R}^2 = 0.32$). The positive and negative coefficients for hawkers are more than four times larger than those of permanent establishments. This finding is one of the most important of the analysis. It would indicate that hawkers were more likely to be found around residential than employment concentrations. It may also be represented in the relative absence of hawkers around a factory and their substantial presence in commercial strips near residential concentrations. Because the relationship between commercial enterprises and residential units has not been explored in a rigorous way, it is difficult to draw definite conclusions from these relationships. However, it is possible to infer that as the scale of economic activities becomes larger and more organized, lower levels of economic enterprise such as hawkers are less significant.

The association of hawkers with trip generation four times as great as enterprises with permanent facilities indicates their much greater need for large traffic volumes. This agrees with visual observation of hawkers in the most congested areas of Kanpur. It also suggests the need for a level of location analysis that is in common use in the United States and other parts of the world. Such analysis, which is often used to determine the location of gasoline stations, eating establishments, and other service facilities, considers the likelihood of passing trips (not vehicles) to stop at a given enterprise. In this case, four times the passing trips appears necessary to sustain a hawker than are needed for a fixed enterprise. Analysis by mode has not yet been possible, but it is likely that all the transport modes associated with hawkers are nonmotorized or scooters, simply because of their ability to make quick decisions en route.

CONCLUSIONS

Kanpur is representative of many cities in developing countries. Once a center of more advanced economic life, it is now assuming more characteristics of the traditional village as the rural poor continue to settle in the city. The growth of the percentage of poor people in Kanpur prevents land use segregation and its supporting transportation infrastructure. As a result, increased numbers of slow-moving nonmotorized vehicles serve enterprises with low levels of organization along limited transportation corridors and cause congestion in central areas.

This study has identified the need of hawkers for heavy traffic volumes. Currently, those volumes are composed mainly of nonmotorized vehicles and pedestrians. Traffic regulation to restrict nonmotorized vehicles in the most congested areas would have serious adverse consequences for the economic survival of hawkers and probably other small-scale enterprises. If hawkers and others who need the heavy passing traffic are moved to peripheral locations lacking access to streets with sufficient traffic volumes, they will inevitably return to the central areas.

The intensive use of urban commercial space in Kanpur and other developing cities is associated with lower-level economic organization. The human face of this economic organization is represented by hawkers and squatters, who usually find nonmotorized vehicles to be their only usable source of business and transportation. Until the overall level of economic organization can be raised to allow more segregated land use, more efficient use of urban commercial space can be obtained. For example, in Calcutta at Sealdah Station, two-level stalls have been constructed for sidewalk vendors to double the density of commercial activities while freeing sidewalks for pedestrians (*6*,p.106). The results of this study, demonstrating empirically that in Kanpur entrepreneurs without premises have pass-by trip requirements four times higher than those with premises, indicate the need for more dense commercial development and the analysis of traffic volumes to ensure adequate potential for new commercial developments.

All materials indicate that fewer informal-sector workers and entrepreneurs will emerge in the years to come. Now is the time to organize commercial land planning that will be more intensive in space use and for transportation system management techniques that will distribute traffic more equitably. This planning may begin with an understanding of the role and importance of nonmotorized vehicles in the urban transportation hierarchy. As a result, wherever lower-level economic activities are concentrated, nonmotorized vehicles should be given priority, and motorized vehicles should be diverted to other less congested areas where less operational flexibility is needed and they can operate most efficiently.

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Current Issues and Problems of Bicycle Transport in Japan

Hirotaka Koike

The number of bicycles in Japan has been increasing steadily, and there are now more than 66 million bicycles in use, or one bicycle for every 1.8 persons. However, facilities to accommodate bicycle transport, such as bicycle roads and bicycle parking spaces, are either nonexistent or limited, and so are laws and regulations to deal with bicycle transport. The lack of bicycle facilities and poor bicycle transport policies generate various problems associated with bicycles such as illegal parking in the vicinity of railway stations and traffic accidents involving bicycles. The historical background and current issues of bicycle transport in Japan are reviewed with regard to traffic laws and regulations, bicycle road conditions, parking facilities, education, and the public attitude toward bicycles. Case studies involve reduction of illegally parked bicycles and field observations of cyclist performance that resulted in intersection design changes.

As the most important nonmotorized transport mode, bicycling has gradually gained popularity in Japan, especially after World War II. Although motorization in Japan has been in rapid and constant progress, the bicycle ownership rate has always been higher than the car ownership rate. The two oil crises in the 1970s particularly accelerated the rate of bicycle increase. There are now about 66 million bicycles in Japan, or one for every 1.8 persons, and the number is increasing (Figure 1). This ownership rate is higher than that in most countries in the world except the Netherlands, Finland, Sweden, Denmark, and West Germany. In terms of the volume of ownership, Japan is the third largest bicycle-owning country following China and the United States (*1*,p.234).

There are several reasons why bicycles have become so popular in Japan since the 1970s. One reason is that the bicycle was rediscovered as an alternative transport mode to the increasing numbers of automobiles, which presented many problems such as traffic congestion and air pollution. The energy- and ecology-conscious general public turned to bicycles, which were becoming less expensive and more convenient, and were good for one's health. The convenience factor of a bicycle is increasingly being recognized as urbanized areas expand and people have to travel longer distances to railway stations or shopping districts. People buy bicycles as an inexpensive and convenient means of transport. The prices of bicycles are becoming relatively low because of domestic mass production and increased imports from abroad. This is especially true with the lightweight minicycle, which is popular among students and housewives.

However, the increase in bicycle ownership in Japan is accompanied neither by corresponding policy guidance from the government nor by facility provision from the public sector. Despite the fact that bicycles are favored by the general public, they still remain of secondary importance in the Japanese transport community.

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CHARACTERISTICS OF BICYCLE USE

Surveys indicate that the major trip purposes of cyclists in urban areas in Japan are commuting to schools and workplaces, followed by shopping and business trips. The national census of 1980 indicates that about 15 percent of total commuting trips are made by bicycle between homes and workplaces or schools, although this ratio varies by size and type of city. Commuting trips using a bicycle are divided into two types. In one type the bicycle is used for an entire trip from home to destination such as school or workplace. In the other type a bicycle is used as a means of access to and from public transport terminals such as railway stations. Generally speaking, the average bicycle trip length of the former use pattern is longer than that of the latter, in which the bicycle ride is only a part of the commuting trip. Most commuting trips using a bicycle are in the single-mode pattern. But in large urban areas, the dual-mode commuting pattern using a bicycle as an access means to a railway station is more frequently found. Parking duration is generally long, from half a day at the home-side station to overnight at the destination station. In addition, some persons own two bicycles for use at both ends of a railway trip route.

Shopping and business trips using a bicycle are predominantly single mode, and these trips are less frequent and over shorter distances. The capability of carrying goods on a bicycle is sometimes cited as a reason for using the bicycle. Parking time at the destination is generally short.

Other uses of the bicycle are for pleasure, sports, or sightseeing. The use pattern in terms of location, time, or trip length of a recreational bicycle trip is different from other trip purposes discussed earlier, and the volume of such trips is not significantly large or concentrated.

BICYCLE ROADS

In 1970 the Act Pertaining to the Construction of Bicycle Roads was passed, accompanied by design standards. Bicycle roads are officially classified into four categories: (a) exclusive bicycle road, (b) exclusive bicycle and pedestrian road, (c) bicycle road, and (d) bicycle and pedestrian road. The first two are built mainly in suburban and rural areas to accommodate recreational bicycle traffic, and the latter two are

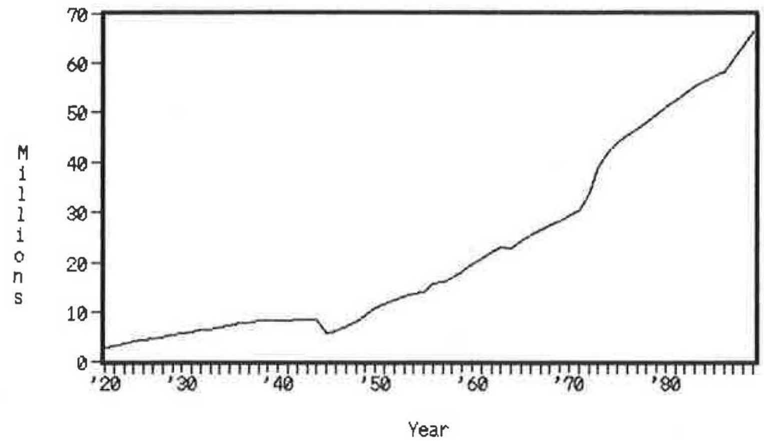

FIGURE 1 Number of bicycles in Japan.

found in urban areas as a part of roads and streets. The lengths for these facilities and ratios to the total length of roads in Japan (1.09 million km) as of 1988 are as follows (*Ministry of Construction statistics*):

Category	*Length* *Kilometers*	*Percent*
Exclusive bicycle road	1,392	0.13
Exclusive bicycle and pedestrian road	3,025	0.25
Bicycle and pedestrian road	54,032	4.92

In the last category, only 2 percent are bicycle roads that have separate bicycle lanes, sidewalks, and automobile lanes. These figures are extremely low compared with those in west European countries, especially the Netherlands and West Germany, whose exclusive bicycle road ratios to total road length are 8.6 and 4.7 percent, respectively (unpublished data from Ministries of Transport in West Germany and The Netherlands, 1985). About 90 percent of bicycle roads in Japan are the so-called "sidewalk bikeway." Bicycle and pedestrian roads are defined as the portions of sidewalk where both pedestrians and bicycles use the same right-of-way. This policy to accommodate bicycles on the sidewalk was originally established in 1978 to curb the increase in traffic accidents involving bicycles. The tentative separation of bicycles from automobile traffic by allowing bicycles on the sidewalk became a part of traffic law that is still in effect.

The use of sidewalks as passages for bicycles (sidewalk bikeways) presents some undesirable problems, as pointed out by Smith (*2*), such as the conflict between bicycle and pedestrian or automobile. Poor visual relationships between cyclists and motorists at intersections and driveways increase the accident potential. Also, sidewalk bikeways are likely to be used bidirectionally despite signs and markings to the contrary. Furthermore, the relatively high speed of bicycles and unpredictable movements of pedestrians generate serious potential for conflict. Small children, older people, and physically handicapped persons are particularly vulnerable to such conflicts.

From the standpoint of cyclists, the sidewalk is not always a safe and comfortable path to ride. There are roadside trees, electric poles, signal signs, street furniture, parked bicycles, and many other hazards. Cyclists may find it difficult to use some narrow sidewalks. Where the sidewalk crosses a driveway, sidewalk elevation may not be even and pavement is often poorly maintained. Cyclists may find it easier to pedal along the street with automobiles, which is legally permitted in most streets.

Bicycle lanes are another means of providing usable space on the street for bicycles. They have an advantage over sidewalk bikeways, in that they can lead bicycles to conform to the directions of automobile traffic. However, bicycle lanes are usually delineated as leftover spaces after automobile lanes have been set aside. This procedure results in use of the narrow and often poorly maintained space next to regular automobile lanes. Furthermore, many illegally parked automobiles make it virtually impossible for a bicycle to stay within the bike lanes. Quite often, bicycles are involved in sideswipe accidents that are caused by passing or turning automobiles. Another problem is the lack of continuity of bike lanes, which may suddenly end at an intersection, causing confusion for the cyclist.

Exclusive bicycle roads are generally found in suburban or rural areas. Their primary purpose is to accommodate recreational bicycle trips. Riverbanks and abandoned railway rights-of-way are commonly used for this purpose. The traffic volume is not high except during holidays and the tourist season. In recent years, construction of these recreational bicycle paths has been increasing. However, such paths do not necessarily form networks to accommodate continuous riding from one system to the next, nor are they provided with access roads.

BICYCLE PARKING PROBLEMS

Recently, bicycles have begun to present serious problems in the urban transport environment in Japan. One problem is the proliferation of illegally parked bicycles around railway stations and shopping areas that become hazards to pedestrians and automobiles. As was mentioned previously, one of the most common uses of bicycles in urban areas is to gain access to railway stations. At the station, bicycles are parked in garages, if any, or left on the sidewalk and in the street.

Traditionally, the residential suburbs of large urban areas in Japan were developed in conjunction with railway construction. Therefore, it is a common commuting pattern to gain access to a railway station by automobile, bus, or bicycle, or on foot. Bus and bicycle are in a competing relationship as far as access to the railway station is concerned. Increasing automobile traffic has resulted in road congestion, so that buses cannot operate on schedule at normal cruising speeds. This, in turn, brings about fare hikes, unreliable service schedules, reduction of operating frequency, overloading, and as a result, sharp decreases in bus ridership.

Statistics indicate that in Japan bus patronage has dropped to one-third of that in the peak era two decades ago. Most of these former bus passengers changed to automobile, bicycle, or walking. But the bicycle is preferred over the other two modes because it is (a) faster than the car in congested urban streets and does not have the parking problem, (b) more flexible to use at any time without need of waiting for the fixed-time schedule of a bus, (c) economical to purchase and maintain, and (d) pollution-free, healthier, and environmentally more acceptable. Therefore, there is always a large population of potential bicycle users who are willing to use bicycles for various trip purposes. Even those who used to walk now tend to ride bicycles even for short distances because they can afford to buy their own bicycles, and bicycle riding requires less effort than walking.

Because of the extremely high land cost around railway stations and major shopping areas and the lack of responsibility for provision of adequate parking facilities on the part of those who operate railway services or stores, bicycles are left on sidewalks near railway stations and in front of stores. Some railway stations in the suburbs of Tokyo have several thousand illegally parked bicycles on the sidewalks near each station. These bicycles prevent other cyclists, pedestrians, and even cars from traveling safely and smoothly and also become hazards in the cae of fire or emergency. In addition, they become an eyesore on the urban landscape.

To remove these illegally parked bicycles, local public authorities have tried various measures, among which the three discussed in the following paragraphs are commonly being tested by a number of local governments. Successful parking control by public authorities depends on a combination of these three measures, taking the psychology of bicycle users into consideration.

Zones To Restrict Illegal Bicycle Parking

There is no authority to confiscate bicycles that are illegally parked in public space not designated for bicycle parking under the present Road Traffic Act. Therefore, to discourage citizens from parking their bicycles illegally, many local governments enact bylaws to restrict illegal parking in the areas surrounding railway stations, for example, within a 200- to 300-m radius. The problem with this measure, if enforced, is that people tend to park their bicycles adjacent to the zone, thereby spreading illegal parking to an even wider area.

Removal, Storage, and Return of Illegally Parked Bicycles

An effective way to demonstrate that public authorities should strictly impose such bylaws is by removing those bicycles left on sidewalks to a temporary storage area. To some extent, successful removal discourages cyclists from parking illegally on the street. However, it requires personnel and money to move bicycles to storage areas. Once the bicycles are stored, the chances of owners' claiming them is relatively low, particularly if removal and storage charges are imposed on the owners. Sometimes as many as 50 percent of the removed bicycles are unclaimed.

The price of bicycles is low in Japan and people tend to leave their bicycles in the public road without much fear of their being stolen. The low price also induces a psychological attitude among many cyclists that they can buy another bicycle if one is stolen while parked on the sidewalk or street. Therefore, those whose illegally parked bicycles are removed often buy new ones without claiming the old ones.

The removed and unclaimed bicycles, together with other abandoned bicycles, cause other problems for local authorities. Even though the bicycles are not claimed by the owners, recycling or scrapping other people's property is illegal. Even if the bicycles were recycled, their market value would be much lower than that of new bicycles, and they would likely be abandoned again. Last, to scrap and dump a large number of unclaimed bicycles would be ecologically undesirable.

Provision of Bicycle Parking Facilities

Along with the two measures first mentioned, it is necessary to provide parking facilities within or near the restricted zone. A parking facility could be provided either publicly or privately, and it could be with or without charge, depending on various circumstances. Usually, the price of land near a station is high, and it is thus acceptable to charge bicycle users, just as it is to charge for automobile parking. However, the low price of bicycles incurs an attitude that bicycle parking should be free. Another dilemma in providing parking facilities is that they encourage those who previously walked or rode the bus to a station to switch to the use of bicycles. An increased number of bicycle users will soon create a shortage of parking spaces in the newly created parking capacity.

CASE STUDY: BICYCLE PARKING FACILITY AND RENT-A-CYCLE

Among many attempts by local authorities to solve illegal bicycle parking problems, a successful case of clearing illegal parking around a railway station is presented. Ageo, located 35 km north of Tokyo, is a typical bedroom community for the Tokyo metropolitan region; its population has increased to 180,000. A large number of commuters travel to Ageo station by bicycle. In 1980 Ageo station became the 12th-worst railway station in Japan, with 4,400 illegally parked bicycles around it. The municipal government provided parking spaces jointly with privately operated parking garages. By 1983 more than 8,000 pay bicycle parking spaces had been constructed. Then a strict bylaw was enacted to restrict illegal bicycles. The result was the drastic reduction of illegal bicycles to a few hundred (Figure 2)(*3*).

Another strategy by this city was to introduce a rent-a-cycle system. Registered commuters and students could rent bi-

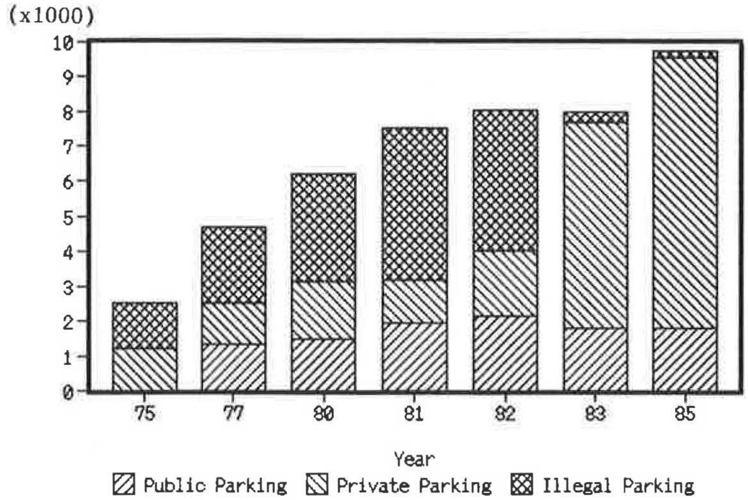

FIGURE 2 Bicycle parking near Ageo station.

cycles to go home, to school, or to the workplace. Under this system, bicycles were used by more than one person. For example, one bicycle would be rented by a student who came to Ageo by train and went to school in the city. After this bicycle had been returned in the afternoon, it would then be rented to a worker who lived in the city. The bicycle would be kept overnight at the worker's home and returned to the station next morning. In this manner, a bicycle would be used two or more times a day, and hence efficient use of bicycles and parking spaces would be achieved. The actual operation of renting out and returning is done with a computer-controlled card system suitable for a station where two kinds of trips, home-based and non-home-based, exist at a similar level.

BICYCLE TRAFFIC ACCIDENT PROBLEMS

Another major problem is the increasing number of traffic accidents that involve bicycles, especially among students and older people. Japan experienced a serious traffic accident increase that peaked in 1970. Total deaths were 16,765 with injuries of 981,096 in 1 year. In those days, the majority of victims were pedestrians and cyclists. However, since then the number of traffic accidents has been steadily decreasing thanks to massive investment of capital in traffic safety facilities such as guardrails to separate cars and pedestrians, grade-separated pedestrian crossings, signalized intersections, and various safety operational countermeasures. One of the countermeasures was to permit bicycles on sidewalks.

The number of deaths halved to 8,466 in 1981, and during the 1980s the number of traffic accidents and deaths was stable despite the ever-increasing automobile traffic. However, since 1987, traffic accidents have started to increase again. For the first time since 1974, the number of traffic deaths exceeded 10,000 and it was increasing at a rate of close to 10 percent per year.

The number of traffic accidents involving bicycles has been consistently correlated with the number of total accidents. For the past two decades, the ratio of cyclist deaths to total traffic deaths has remained about 10 to 12 percent, whereas that of injuries has been about 14 to 15 percent (Figure 3).

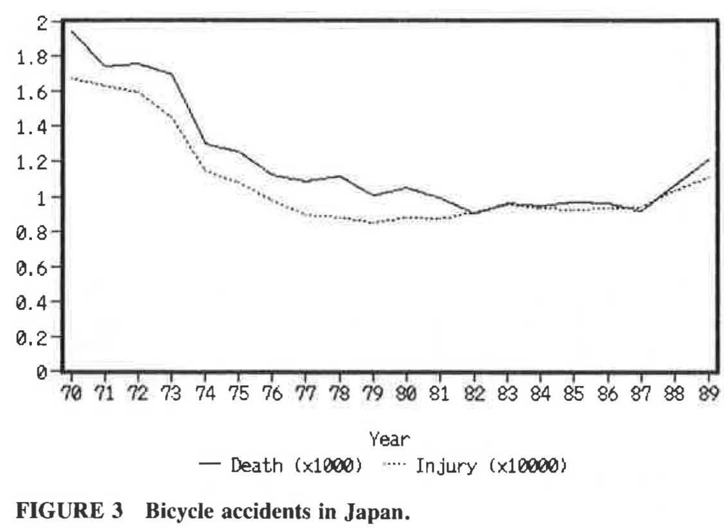

FIGURE 3 Bicycle accidents in Japan.

Two age groups have higher accident rates than others, those between 13 and 19 years old and those over 60. The younger group has a higher injury rate (over 200 injuries per 100,000 population), but the older group shows a higher death rate (3 to 5 deaths per 100,000). The national average is 95.2 injuries and 1 death per 100,000 people. The age group between 25 and 35 shows the lowest injury and death rates (0.1 death, 43 injuries) (Figure 4) (unpublished statistics from the National Police Agency).

As for the increase of total traffic accidents in recent years, the accidents involving bicycles are also increasing. Finding the cause for and taking measures to curb the increasing trend are urgently needed. The high accident rates in the two age groups mentioned above are attributed to lack of education or training as well as inadequate traffic laws, which are discussed next.

EDUCATION AND LAW

The bicycle has not been accepted as a legitimate mode of transport in the Japanese transport hierarchy. Although the bicycle is defined as a light vehicle in the same category as rickshaw, horse-drawn cart, and other nonmotorized vehicles, little is mentioned about the bicycle in the current Road Traffic Act. One reason may be the ambiguity that is inherent in a bicycle. A bicycle is categorized as a light vehicle if it is ridden by a cyclist. However, if a cyclist is walking while carrying a bicycle, the same cyclist is regarded as a pedestrian. These two modes are easily interchangeable, depending on the cyclist's will. The possibility of dual states of a bicycle makes it difficult to strictly enforce the traffic law.

Cyclists do not observe traffic rules any more than do pedestrians. The revised Road Traffic Act of 1981, which permits bicycles to share the sidewalk with pedestrians, contributed to this general attitude of disregarding traffic rules. At present, there is no requirement for a rider's license to ride a bicycle. However, one can ride a bicycle at a fairly high speed, which is dangerous to pedestrians and other bicycles and makes the rider vulnerable to automobiles.

The general lack of adequate education or training opportunities in bicycle riding leaves many cyclists to ride at their own risk. Some introductory education or training may be given in elementary schools, but it is far from satisfactory compared with the training courses given in some European countries. An example of an advanced training program is that in Germany established by the Allgemeiner Deutscher Automobil Club (ADAC) to increase bicycle riding skills.

In Japan, traffic safety training in junior high and high schools is not popular among students, who take for granted that they know enough about traffic rules and possess sufficient bicycle riding skills. However, simple tests of traffic law reveal the contrary, and students' higher accident rates indicate that their skill levels are not high enough for safe bicycle riding.

As for the older generation, they believe strongly that they have been riding bicycles all their lives with sufficient knowledge and skills, and they are reluctant to accept the suggestion that their physical capabilities such as alertness, attentiveness, and correct judgment in case of conflict on the road have deteriorated. It is necessary that some kind of training program be offered to them. This is increasingly important as the number of older people continues to increase because of their longer life span, and their opportunities to engage in outside activities also increase.

An example of the ambiguous nature of the bicycle in the present Road Traffic Act is found in the method of crossing at a signalized intersection. Two methods of bicycle crossing are widely used. One is the provision of a pedestrian crossing where cyclists are expected to alight from the bicycle and to walk with pedestrians subject to the pedestrian crossing signal light or run along the left side of the automobile lane following the signal for automobiles.

The other type of crossing has a narrow exclusive bicycle crossing strip along with a pedestrian crossing, and bicycles can be ridden within this strip. In this case, they have to follow the pedestrian crossing signal light (Figure 5).

Few cyclists realize the difference between these two types of crossing or can use them correctly. Together with the convention of permitting bicycles to be ridden on sidewalks, this

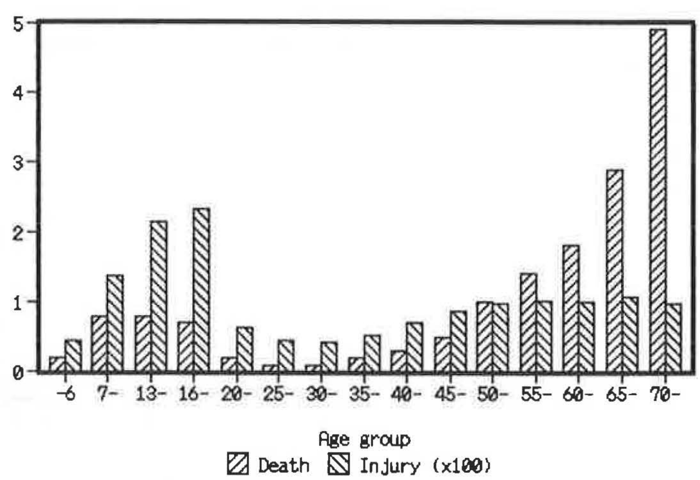

FIGURE 4 Bicycle accident rates by age group for 100,000 population.

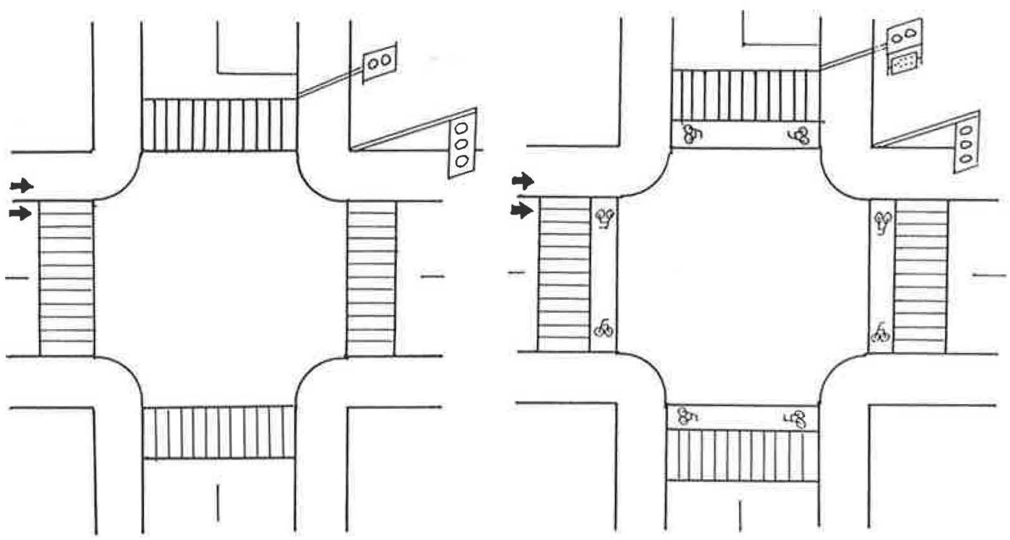

FIGURE 5 Two types of intersections: *left*, pedestrian crossing only; *right*, with bicycle crossing strip.

difficulty further confuses most cyclists. This is one example that warrants a review of the Road Traffic Act from the standpoint of the bicycle.

CASE STUDY: INTERSECTION IMPROVEMENT

In a case study that resulted in the improvement of intersection design (*4*), dangerous conflicts between pedestrians and bicycles were observed at a scrambled intersection. After various analyses, the recommendation to change the intersection system resulted not only in resolving conflicts, but also in improving vehicle traffic flows.

The purpose of this study was to point out the shortcoming of the present traffic law and to demonstrate an improved method of modifying pedestrian crossing at an intersection. The scrambled intersection is located in the busy street of Utsunomiya City, a prefectural capital that has about half a million population. Because this intersection is situated on the commuting route of several high schools, there are a large number of students who ride bicycles. During the commuting period, the majority of pedestrian and cyclist traffic is students traveling to and from school.

A scrambled intersection is designed to allow pedestrians to cross in any direction within the intersection while all car traffic is stopped. During this period, cyclists are expected to get off their bicycles and to walk as pedestrians. However, in actual traffic few cyclists walk to cross. Almost all cyclists continue to ride on bicycles at high speeds while crossing the intersection. This causes a dangerous situation of possible conflict and accident potential between pedestrians and cyclists.

A survey method was developed using a video camera to take pictures of the intersection from a high location (*5*). Then each video image was combined with a microcomputer to record the spatial coordinates of bicycles and pedestrians. The system recorded conflicts between bicycles and pedestrians, their relative locations, traces of movements, speed, density, and so forth. By analyzing the videotaped observation, it was found that this particular intersection had a low diagonal crossing rate. Usually, 20 to 30 percent of pedestrians cross diagonally in a typical scrambled intersection, but this one showed only a small percent.

Therefore, it was recommended that the pedestrian scramble phase be discontinued and the intersection be converted to a regular signalized intersection with a wide bicycle crossing zone where a cyclist could cross without getting off the bicycle. The result was a smoother and safer intersection crossing for both cyclists and pedestrians. In addition, the automobile traffic congestion was reduced because the omission of the pedestrian-only phase increased the green light time for automobiles. Although review of the traffic law is warranted, this small example indicates that it is possible to modify the operating method of a facility to improve traffic safety and reduce congestion.

CONCLUSION

In Japan, bicycles are accepted as a convenient, economical, and environmentally sound mode of transport indispensable to many people. This is especially true for students and commuters in local cities and suburban metropolitan areas as well as for housewives with shopping and personal needs. However, the increase of bicycles generates problems in the urban transportation scene. Among them are the proliferation of illegally parked bicycles in the vicinity of train stations and increasing bicycle accidents, especially among young and old people.

Some of the solutions to the current bicycle problems in Japan include providing facilities such as bicycle roads and bicycle parking spaces, reviewing and restructuring of traffic laws and regulations to ensure safe and smooth bicycle transport, and providing adequate safety education and skill training to bicycle users. It is necessary that society accept the bicycle as a legitimate mode of urban transport and give appropriate rights as well as responsibilities to bicycle users.

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Cycling in a Northern Country

MIKKO OJAJÄRVI

Finland is one of the northernmost countries in the world. Despite the climate, Finland may be called a country of cycling. The number of bicycles per capita in Finland is the third highest in the world, exceeded only by the number in the Netherlands and in Denmark. The high automobile density (440 cars per 1,000 residents) has not limited the number of bicycles. There are numerous cycling roads in Finland, totaling about 8000 km including approximately 1,300 underpasses and about 400 overpasses. The construction of roads for pedestrian and bicycle traffic in general was begun in the 1970s. Thereafter, the numbers of cyclists and pedestrians killed in traffic annually has been reduced by more than half. To further improve cycling conditions in the future, accident statistics should be transformed on the basis of hospitalization statistics, and methods for better counting of pedestrian and bicycle traffic should be developed and implemented.

In northern countries, the use of bicycles for commuting as well as for exercise is usually considered a summer preoccupation feasible on a large scale. Finland is an example of a country in which, despite the short summer and cool or cold weather in winter (Figure 1), cycling is a relatively popular sport and much has been done to promote it.

However, not enough is generally known about the positive aspects of cycling and therefore much can still be done to increase its popularity. Negative aspects to such an increase would be few.

VOLUME OF CYCLING IN FINLAND

In Finland, the volume of cycling can be evaluated on the basis of the number of bicycles and survey research. Of the world's almost 1 billion bicycles, 3.2 million (0.4 percent) are in Finland (*1*). In relation to population, Finland has the third largest number of bicycles in the world, surpassed only by the number in the Netherlands and in Denmark. Because the population of Finland is 5 million, in theory a bicycle is available to every person able to ride one.

The significance of bicycle travel is indicated by the following statistics (*2*):

- The number of trips made by bicycle in Finland is over 12 percent of all trips made in Finland,
- The time consumed in bicycle travel represents 9 percent of all time used in personal transport, and
- The number of traveled kilometers in cycling (number of persons) is 3 percent of all personal transport.

A closer investigation of the status of pedestrian and bicycle traffic would require the development of appropriate measuring devices for the counting of pedestrians and cyclists. This investigation would be required to determine possible accident risks and the overall significance of the need for roads for pedestrian and bicycle traffic.

PEDESTRIAN AND BICYCLE TRAFFIC ACCIDENTS

In Finland, 1972 was the worst year in history for traffic safety (Figure 2). At that time, nearly 1,200 persons died in traffic. Over 600 of the fatalities were pedestrians or cyclists. Of the pedestrian and bicycle traffic fatalities, over half were pedestrians, about one-third were cyclists, and the remainder were drivers of mopeds (Figure 3)(*3*).

During the 1970s, Finland improved traffic safety to the extent that in the 1980s the number of fatalities was less than half of the peak figures. Pedestrian and bicycle traffic fatalities fell to even less than half of their peaks. Development similar to Finland's occurred in many other industrial countries as well, but Finland's development was perhaps the most rapid.

On roads maintained by the government, fatalities in pedestrian and bicycle traffic fell to as much as one-third of their peaks. The most important reasons for this development were the implementation of automobile speed limits on all roads and the rapid construction of roads for pedestrian and bicycle traffic. At present, the portion of pedestrian and bicycle traffic fatalities of all traffic fatalities has stabilized at approximately 30 percent (*3*).

In a northern country like Finland, icy conditions in winter present a special problem for pedestrian and bicycle traffic. According to a Swedish study, pedestrian accidents caused by icy conditions (including falls by single pedestrians) accounted for 70 percent of all days in the hospital or away

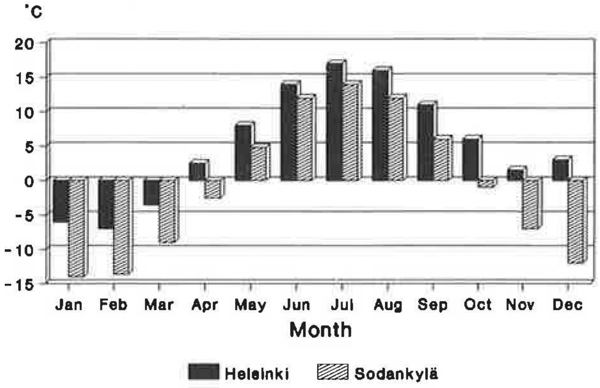

FIGURE 1 Average monthly temperatures in Finland, 1881 to 1980.

Road Safety Division, Finnish National Road Administration, P.O. Box 33, Helsinki 00521, Finland.

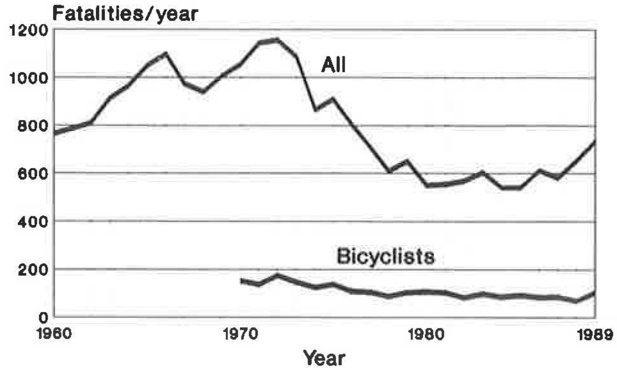

FIGURE 2 Traffic fatalities in Finland, 1970 to 1989.

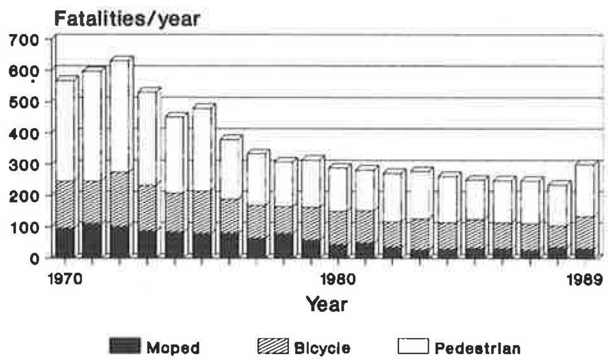

FIGURE 3 Bicycle, moped, and pedestrian fatalities in Finland, 1970 to 1989.

from work. The corresponding proportion for bicyclists was 20 percent. The largest group of injured pedestrians was elderly persons and the largest group of bicyclists was young bicyclists (*4*). In response to icy conditions, car traffic routes are given priority over pedestrian and bicycle traffic routes. Statistics on pedestrian and bicycle traffic accidents will be deficient as long as hospitalization data are not used to define the number of pedestrian and cyclist accidents. The experience in Nordic countries is that perhaps only 20 percent of cycling accidents are recorded in the statistics taken from police reports. In Finland, the equivalent figure for all personal injuries is approximately 60 percent (*5*).

It has been calculated that building roads for pedestrian and bicycle traffic in Finland has prevented accidents involving personal injury on government roads that cost 0.5 to 1 million marks. The figure is quite high but represents only 30 to 50 percent of the expense required for construction of freeways to prevent personal injury. These calculations are based on the service life of 30 years for pedestrian and bicycle roads and on the expected decrease in accidents on roads that are planned to be equipped with a separate pedestrian and bicycle road. For municipal road networks, the cost-benefit relationship of pedestrian and bicycle traffic routes is much more advantageous than for state roads.

CONSTRUCTION OF PEDESTRIAN AND BICYCLE TRAFFIC ROADS

In Finland, construction to meet the needs of pedestrian and bicycle traffic began in earnest in the 1970s. The stimulus was

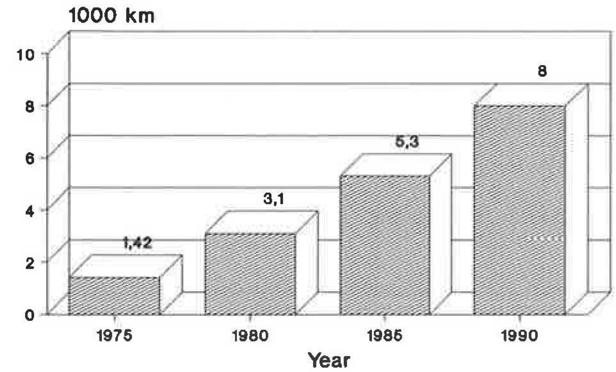

FIGURE 4 Length of bicycle and pedestrian roads in Finland, 1975 to 1990.

the sharp increase in pedestrian and cyclist fatalities. The length of these roads has developed as shown in Figure 4.

Roads for most pedestrian and bicycle traffic are in built-up areas, but an estimated 2000 km is along state roads outside built-up areas.

In the state budget, construction of routes for pedestrian and bicycle traffic accounts for 3 to 4 percent of the entire annual budget of the road administration. With this amount (almost 200 million marks), about 200 km of new pedestrian and bicycle traffic routes is constructed annually.

THE FUTURE

Cycling and pedestrian and bicycle traffic in general will become increasingly significant in the future. Of all the forms of ground transport, bicycles use the least energy per journey, and energy is expended beneficially for travel and for improving the physical condition of the traveler. Cycling is also a pollution-free form of transport. There are no exhaust gases, and the manufacture of a bicycle requires only 1/70 of the natural resources required for the manufacture of an automobile.

The construction of new routes for pedestrian and bicycle traffic in the future will not be as much for safety considerations as in the past. As roads are built in the most dangerous places, the number of roads for pedestrian and bicycle traffic needed for safety reasons will decrease unless there is an increase in the present level of pedestrian and bicycle traffic. Besides safety, there are other reasons for pedestrian and bicycle roads. In the future, more emphasis must be placed on better service for pedestrian and bicycle traffic by building more comprehensive pedestrian and bicycle traffic networks and improving the quality of routes in summer and especially in winter.

The growth of cycling requires changes in prevailing practices in addition to new route networks and improvement in the quality of old networks. Changes are required to improve safety by better determination of the number of accidents, to develop the needed network of pedestrian and bicycle roads by knowledge of the traffic volumes of pedestrians and bicyclists, and to enhance pedestrian and bicycle traffic by more positive attitudes of employers. Specifically, these changes would include the following:

1. The determination of pedestrian and bicycle traffic statistics must be changed so that they are based on hospitalization data;

2. Pedestrian and bicycle traffic recording equipment must be developed so that it is operational and used in a manner similar to automobile traffic recording devices; and

3. Employers should encourage commuting by bicycle by arranging shower facilities and permitting employees to shower upon arrival at work.

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Abridgment

Community Cycling Manual—Planning and Design Guide

DAPHNE A. HOPE

In recognition of the importance of cycling and the needs of cyclists, Fitness Canada, a directorate within the federal Ministry of Fitness and Amateur Sport, established the Canadian Task Force on Cycling. Led by the Canadian Cycling Association, the task force has prepared the *Community Cycling Manual*, a guide for planning, design, and construction of bicycle facilities. The objectives of the project were to establish the concept of the bicycle as a valid means of transportation, undertake activities to increase participation in cycling, enhance public awareness of cycling as both a recreational and utilitarian activity, and provide a safe environment for cyclists across Canada.

Cycling is a physical activity pursued by millions of Canadians. This level of participation not only increases the fitness of many Canadians but also increases their concerns for safety, education, and the provision of bicycle facilities.

Recognizing the needs of cyclists, Fitness Canada, a directorate within the federal Ministry of Fitness and Amateur Sport, established the Canadian Task Force on Cycling under the leadership of the Canadian Cycling Association. One of the projects of this task force was the preparation of the *Community Cycling Manual.* The project was funded by Fitness Canada and managed by the Canadian Institute of Planners.

The objectives of the task force with respect to the *Community Cycling Manual* were to

- Establish the concept of the bicycle as a valid means of transportation,
- Undertake activities to increase participation in cycling,
- Enhance public awareness of cycling as both a recreational and utilitarian activity, and
- Provide a safe environment for cyclists across Canada.

This manual is a guide for planning, design, and construction of bicycle facilities. It also addresses education and enforcement. These are key to the creation of a safe cycling environment for all types of users.

The *Community Cycling Manual* provides sufficient technical information for the expert. At the same time, it provides the basic groundwork for those less familiar with cycling. It also serves as an introduction to the process of translating the needs of the community into actions. The manual provides the basis for reassessing the facilities, both physical (roads, parking, signals) and nonphysical (safety and enforcement programs), in the community. Used along with local expertise, it can provide the framework for developing a more user-friendly environment for cyclists.

The *Community Cycling Manual* is designed primarily for the planners, designers, engineers, and landscape architects who will be involved with bicycle facilities. It provides planning process outlines and design standards. An emphasis is placed on the importance of integrating planning, engineering, education, and enforcement.

Many government organizations, from federal to local levels, are in the process of reassessing their transportation priorities for the 1990s. The environment is a major focus of government, industry, and the public. Planning for bicycles in urban centers and planning for linear corridors in rural areas should be part of any transportation review for the following reasons:

- Bicycles are a practical and economic means of local transportation,
- Bicycle use can make existing transportation systems more efficient as intermodal linkages complement existing public transit systems,
- Capital and maintenance costs for bicycle facilities are reduced when they are designed as part of the overall system,
- Pollution is reduced and energy conservation is increased, and
- Bicycles are already an existing and widely used means of transportation, making it easier to adapt present systems to accommodate them.

Planners and engineers should work to fully integrate the bicycle into the existing transportation system and to encourage the use of the bicycle as a safe and convenient mode of transport by applying the following basic principles:

- Every street is a potential bicycle route,
- Bicycle facilities are part of the whole picture and should be considered as an integral component of any planning decision,
- Existing barriers to bicycles should be overcome,
- Bicycle facilities should be incorporated into long-range capital works planning by adopting design standards, and
- Links between routes should be encouraged to make use of the routes more effective, efficient, and attractive to the cyclist.

Most of these principles can be summarized by the four Es of bicycle planning—engineering, education, enforcement, and encouragement. One important aspect to consider is user preference. The best bicycle route by planning and design

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standards may not be the one that will be used by cyclists. Thus, it is essential to consult with the user group and identify their needs and preferences early in any planning or design process. Cyclists may not necessarily prefer the most direct route if that route follows heavily used motor vehicle roads, has many controlled intersections or frequent stops, or runs through an area considered undesirable from the point of view of personal safety. Many planning jurisdictions are recognizing the issue of women and urban safety. Identifying areas that are considered unsafe for women should be part of the initial planning process. Bicycle facilities that incorporate trails through remote areas or away from lighted areas may pose a threat to such individuals.

The basic planning process may follow an outline similar to Schedule A of the *Community Cycling Manual.* This can be used as a generic model that can be modified to suit individual situations or projects.

The use of bicycles in North America in past decades has had an interesting association with the use of automobiles. During the 1930s and 1940s, the bicycle was viewed as a useful mode of transportation. Automobiles were costly and gasoline rationing during World War II discouraged extensive use of them. In the 1950s, a different trend emerged. Cities expanded, becoming less compact and therefore less attractive for short-trip commuting by bicycle. The general populace was more affluent, the price of automobiles decreased, and the attraction of the bicycle as an economic means of transportation waned. It was not until the 1970s that there was a general revival in cycling. This revival was in part born of the energy crisis of the mid-1970s. Most of the existing bicycle facilities today were built during this period. Design tended to focus on separate pathways that quickly took on a recreational nature.

The current approach to bicycle facility design is based on the premise that bicycles are recognized as vehicles and that every road is a potential bicycle route. This concept endorses cyclists as legitimate road users. With this concept in mind, the idea of integrating existing transportation system and bicycle facility planning and design makes eminent sense.

The term "bicycle facility" is understood to mean any facility designed to accommodate bicycles or bicycle travel. Thus, bicycle facilities include roads, paths, bridges, tunnels, parking racks, garages, and signage. In order to design facilities that accommodate the many types of bicycles and cyclists, it is necessary to be familiar with the characteristics of both vehicle and user. Physical parameters as well as user parameters must be taken into consideration.

The typical multispeed bicycle is 0.6 m wide, 1.75 m long, and stands up to 1.25 m high. It can weigh between 10 and 20 kg. Mountain or city bicycle handlebars can be up to 0.8 m wide, 0.2 m greater than the drop handlebar style of bicycle. Adult tricycles and trailers used to tow children are both 0.8 m wide. If mirrors or a side mount safety flag is added, the vehicle can be 1.0 m wide. In addition to these specifications when not in motion, the bicycle requires approximately 0.3 m of clearance at each side to allow for the side-to-side motion when ridden. Overall, this gives a design width of 1.6 m.

Although the bicycle itself may be up to 1.25 m high, the total height of a bicycle and cyclist can exceed 2.0 m. An additional 0.5 m is needed for clearance. This gives a design height of 2.5 m.

If a bicycle is towing a trailer or baby buggy, the total length can be 2.5 m. A tandem can be more than 2.0 m long. The turning radius and parking requirements of these vehicles are different from those of a standard bicycle. These exceptions should be noted. As more new designs appear on the market, these design parameters must be reviewed and adjusted accordingly.

If the bicycle is to be successfully integrated into the transportation system, both its similarities to and its differences from other road users must be understood and considered. Specific situations require appropriate solutions. Whether a bicycle route, designated lane, or path is considered, the generic models must sometimes be modified to meet the needs of the users.

For the purpose of establishing consistency of design and terminology, the *Community Cycling Manual* recognizes three categories of bikeways:

- Bicycle route—any road so designated by signs or road markings, usually providing continuity with other cycling facilities or being a preferred route;
- Bicycle lane—a separate lane designated for bicycles; and
- Bicycle path—a separate facility for nonmotorized vehicles only, a single-use (bicycles only) or multiuse recreational pathway.

The following factors must be considered in the design of bicycle routes, lanes, or paths: access; attractiveness; continuity; delays; destinations; directness; surface quality; topography; traffic type, volume, and speed; and user conflict. In addition to these general criteria, specific considerations apply to each of the three categories of bikeways. These are identified and addressed in the *Community Cycling Manual.*

Cycling is not a passing fad. For many, it is part of their way of life—a vital transportation link or an enjoyable recreational activity. With this in mind, communities, agencies, and organizations must recognize and work toward the goal of providing a safe environment for all cyclists. Whether bicycles are ridden on the road or on separate pathways, provision must be made for the safety of the cyclist, which would also ensure the safety of other road or pathways users. The *Community Cycling Manual* can provide the framework and design standards to assist in achieving this goal.

Analysis of Pedestrian Movements in Bangkok

YORDPHOL TANABORIBOON AND JOCELYN A. GUYANO

Walking rates of pedestrians in Bangkok, Thailand, are analyzed. Data were collected using a photographic technique with the aid of a video camera on selected walkways such as sidewalks, stairways, and crosswalks. Walking rates on the pedestrian facilities in Bangkok were determined and compared with those of Western standards as well as with findings obtained in other Asian countries. The findings of the study confirmed that Asian pedestrians walk slower compared with their Western counterparts, so local design standards are needed for pedestrian facilities in Asian countries.

Facilities provided for pedestrians should be well planned to ensure pedestrians against overexertion, vehicular-pedestrian conflict, and accidents. These physical facilities must support the physiological, psychological, and social needs of pedestrians to encourage walking, especially in central business districts (CBDs) where vehicular congestion has arisen. Although pedestrian facilities are present in Bangkok that serve the needs of the Thai people, most of these facilities are either designed with reference to Western standards or arbitrarily designed by the concerned officials.

The necessity for adopting standard design parameters for planning and design of transportation facilities is not in doubt, but, unfortunately, not all developing countries have determined their own suitable standard parameters. Often, parameters and values recommended for the design of transportation and traffic facilities are simply adopted from other countries and used in Asian countries. These parameters have been well defined, tested, and deemed acceptable as design standard values specifically for Western countries. Because of environmental and local conditions together with the various cultural differences affecting these parameters, not all of these design standard values should be used directly by Asian countries.

This recommendation does not imply that the authorities concerned in the Asian countries did not use correct design standard parameters, but rather that they lacked their own suitable design values. In some cases, this lack may not have resulted from the unavailability of locally known parameters but from lack of confidence in using anything but Western design standard values. In other cases, no attention had been paid to these parameters. Even in Bangkok, there has been no attempt yet to study the local characteristics and behavior of Thai pedestrians that could justify the plausibility of adopting Western standards. Before local design standards are formulated, research on the characteristics of local pedestrian movement and the environments of local pedestrian facilities should be carried out. Thus, the intent here is to present an analysis of the walking rates of Thai pedestrians, which later can be compared with Western walking standards to determine which rate is slower. The existing pedestrian facilities in Bangkok and the manner in which the facilities affect the pedestrians are also taken into consideration.

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DATA COLLECTION

Movements of Thai pedestrians were studied in the concentrated areas of the Bangkok CBD. A photographic technique was used to gather the speed data with the aid of a video camera placed in a fixed elevated position (e.g., overpass and building canopy) to obtain an overall view of the selected areas. Random observations were made of pedestrian movements along the major walkways—sidewalks, overpasses, stairways, and a signalized intersection (Table 1). In the areas selected, lengths were measured that served in the analysis of pedestrian walking speeds. The data gathered were then processed on each cassette tape and all timing was counted to 0.01 sec using the timer installed on the screen of the monitor. Pedestrian walking speed was calculated by dividing the length of the area traversed by the time it took the pedestrian to cross the marked-off length. That time was measured directly from the timer shown on the perspective view of the monitor.

RESULTS AND DISCUSSION

Speed Measurements

Speeds reported were the mean walking speeds of pedestrians crossing the measured length marked off. The traffic density and conflicts between pedestrians were minimal, and conditions were considered as free flow in which pedestrians could select their desired normal walking speeds.

Sidewalks

The overall average adult walking speed of male and female Thai pedestrians on three selected sidewalks and an overpass was 72.94 m/min. Young Thai pedestrians had a significantly faster walking speed of 74.05 m/min, most likely because of their more energetic movements. The young pedestrian group was selected at random from secondary school students on an overpass in front of their school. In contrast, the average

TABLE 1 OBSERVATION SITES AND DIMENSIONS ON SIDEWALKS, STAIRWAYS, AND SIGNALIZED INTERSECTIONS

Site No.	Site Description	Length (m)	Riser Height (m)	Tread Width (m)	Stair Width (m)	Stair Length (m)	Angle (deg)
Sidewalks							
1	Rachaprarop Road (in front of Thai Daimaru Department Store)	4.0	—	—	—	—	—
2	Phaholyothin Road						
	In front of Northern Bus Terminal	8.0	—	—	—	—	—
	Beside Sunday Market	6.0	—	—	—	—	—
3	Sanam Luang Sidewalk (near Grand Palace)	6.0	—	—	—	—	—
4	Vipawadee Road (overpass in front of Surasak Montri School)	10.0	—	—	—	—	—
Stairways							
1	Phayathai Road (Stairway at Mahboonkrong Overpass)	—	0.20	0.30	1.20	5.00	34.00
2	Phaholyothin Road (Stairway I in front of Northern Bus Terminal)	—	0.15	0.30	3.00	5.00	35.00
3	Phaholyothin Road (Stairway II in front of Chatuchak Park)	—	0.14	0.30	1.20	4.40	28.61
4	Ratchaprarop Road (Stairway at Indra Overpass)	—	0.13	0.30	1.40	4.50	27.57
Signalized Intersection							
Phaholyothin-Yan Phaholyothin Intersection near Sunday Market		11.13					

walking speed of the elderly Thais (49.54 m/min) was much slower than that of both the adult and the young pedestrians. The elderly pedestrians were those who appeared to be over 60 years old and thus were chosen subjectively in this study.

Further analysis on the basis of sex showed that Thai adult as well as young male pedestrians generally walked faster than female pedestrians. These results were significant at the 5 percent level. To verify the findings between the adult and young pedestrian mean walking speeds, tests of significance (t-tests) at the 5 percent level were carried out for men and women of both pedestrian groups. It was known that young female pedestrians walked significantly faster than adult female pedestrians. However, the same was not true for male pedestrians. Tests indicated that there was no significant difference between the walking speeds of young and adult male pedestrians. No significant difference was found at the 5 percent level between male and female elderly pedestrian walking speeds (50.77 and 48.06 m/min, respectively). Table 2 shows the results for all pedestrian walking speeds.

Stairways

Because of the soon-to-be-constructed rail rapid transit system in Bangkok, it has become essential to study stairways as well as other vertical pedestrian modes such as elevators and escalators. Information pertaining to the proper design of stairways being urgently needed, movements on stairways were analyzed and compared with those of Western countries. As mentioned in previous studies (*1,2*), pedestrian walking speeds varied depending on the direction (up or down) and the riser height. Thus, four selected stairway sites with different riser heights were chosen for this study.

Results of the findings are presented in Table 3 for the ascending and descending directions. As in previous studies conducted in the United States, Thai pedestrians also walked faster when descending the stairway than when ascending. These findings held true for all four study sites and were significant at the 5 percent level. Walking speeds also varied from 27.91 to 33.78 m/min for the ascending direction and 34.97 to 37.17 m/min for the descending direction for various riser heights. The t-test at the 5 percent level indicated that even a 1-cm (0.01-m) difference in riser height has a significant effect on the walking speed for both ascending and descending directions. Thus, it can be concluded that riser heights have an effect on Thai pedestrian walking speed.

In a comparison of the walking speed of Thai pedestrians with that of American pedestrians found in previous studies (*1,2*), the results obtained were similar to those for walking speeds on sidewalks. Thai pedestrians walked more slowly than their American counterparts on stairways. Results obtained in the United States (Table 4) indicated that for the

TABLE 2 PEDESTRIAN WALKING SPEEDS

	Adult			Young			Elderly		
Characteristic	Men	Women	Both	Men	Women	Both	Men	Women	Both
Mean walking speed (m/min)	76.44	70.21	72.94	75.96	72.15	74.05	50.77	48.06	49.54
Standard deviation (m/min)	8.71	6.94	7.77	7.1	5.53	6.37	8.52	7.02	7.75
Range									
High	99.34	93.75	99.34	103.5	93.75	103.50	67.80	67.37	67.8
Low	54.55	50.55	50.55	56.00	52.45	52.45	35.12	31.16	31.16
Sample size	238	304	542	298	298	596	51	43	94
Significance at 5% level between sexes of age group	Significant			Significant			Not significant		

TABLE 3 PEDESTRIAN WALKING SPEEDS ON STAIRWAYS

	Study Site			
Characteristic	1	2	3	4
Ascending				
Mean walking speed (m/min)	27.91	29.81	32.30	33.78
Standard deviation (m/min)	2.29	3.42	3.27	4.13
Riser height (m)	0.20	0.15	0.14	0.13
Range				
High	45.76	40.76	42.04	45.76
Low	20.90	20.39	23.46	23.77
Sample size	222	561	168	202
Descending				
Mean walking speed (m/min)	34.97	35.90	36.58	37.17
Standard deviation (m/min)	4.31	4.37	3.62	3.90
Riser height (m)	0.20	0.15	0.14	0.13
Range				
High	52.45	49.18	48.91	53.59
Low	23.29	26.11	26.37	27.55
Sample size	205	307	140	215

TABLE 4 SPEEDS OBSERVED IN UNITED STATES FOR ASCENDING AND DESCENDING DIRECTIONS (*2*)

	Ascending		Descending	
Stairway Characteristic	Speed (ft/min)	Speed (m/min)	Speed (ft/min)	Speed (m/min)
7-in. (0.178-m) riser and 11-in. tread	96	29.26	121	36.89
6-in. (0.1524-m) riser and 12-in. tread	108	32.92	144	43.89

6-in. (0.1524-m) riser heights, walking speeds of American pedestrians were 108 ft/min (32.92 m/min) and 144 ft/min (43.89 m/min) for ascending and descending directions, respectively. Although it may not be valid to compare walking speeds for which the riser heights are not exactly the same, at the selected study site in Bangkok (Site 2) the riser height was 0.15 m, which was close to the 6-in. riser height used in the U.S. studies. Results found at Site 2 (Table 3) indicated slower walking speeds for Thai pedestrians of 29.81 m/min (97.8 ft/min) and 35.90 m/min (117.8 ft/min) for ascending and descending directions, respectively.

Effect of riser height on the design of the stairway should be given more serious consideration, especially in Bangkok. The riser height of 0.20 m (7.87 in.) for the stairway at Site 1 resulted in the lowest climbing speed, 27.91 m/min. This riser height was greater than the maximum height recommended by Fruin (*1*), who in one of his studies, recommended for the design of stiarways that "riser height should be kept below 7 in. (0.178 m) to increase the traffic efficiency. "Although one could argue that Thai pedestrians have the same ability to climb stairs as do Westerners, design of suitable riser heights should not be ignored.

Signalized Crossings

Planners and engineers must address the problem of pedestrians at intersections in which the primary concern is to provide adequate walking time for crossing the street safely. A walking speed study was conducted at crosswalks in Bangkok. A total of 525 observations was made; the results are presented in Table 5.

The mean speed of pedestrians crossing the signalized crossing was found to be 76.52 m/min, which was relatively faster than normal walking speed on walkways. The reason for this difference could be the greater danger involved in crossing the road. Likewise, results also indicated that men walked faster than women (significant at the 95 percent confidence level).

The *Highway Capacity Manual* (*3*) recommends a walking speed of 82 m/min (4.5 ft/sec) to calculate the crossing time in the design of pedestrian traffic signals. Although it is believed that these values are applicable throughout the United States, they may not be valid locally. Thus, only local practitioners and designers can affirm or deny them, and this must be taken into consideration in the design of a pedestrian traffic signal system.

Comparison of Walking Speed Among Countries

Table 6 presents the walking speeds of pedestrians from different countries in Asia and in England, the United States, and Canada (*4–8*). Walking speeds are ranked from as slow as 65 m/min in Saudi Arabia (*9*) to as fast as 88 m/min in Pittsburgh (*8*). Except for Israelis, Asians walk slower than do their Western counterparts. Caucasians may walk faster because of their cultural attitude and their generally bigger size. However, Israelis (*10*), who with a walking speed of 78.8 m/min are perhaps similar physically and in walking characteristics to Western pedestrians, walk faster than Asians. On the other hand, the slower walking speeds of Saudi Arabian pedestrians are caused by the extreme daily temperatures prevailing during at least 6 months of the year. Higher average temperatures are expected to be experienced by the Saudis, especially during the summer months, compared with those in other Asian countries. Those who walk long distances are traveling in pursuit of their daily activities when other means of transportation are unavailable.

The mean free flow walking speed of Thai pedestrians, which is 73 m/min, was found to be relatively comparable with the walking speeds of other Asian pedestrian walking speeds [72, 74, and 75 m/min in India (*11*), Singapore (*12*), and Sri Lanka (*4*), respectively]. This pedestrian movement study conducted in Bangkok has further confirmed the findings in other Asian countries that Asians walk slower than their Western counterparts. It is therefore recommended that walking rates of the Thai and other Asian pedestrians be further examined to derive suitable pedestrian design standards solely for Asian needs.

TABLE 5 PEDESTRIAN WALKING SPEEDS AT SIGNALIZED CROSSINGS IN BANGKOK

Characteristic	Men	Women	Both
Mean walking speed (m/min)	78.45	73.99	76.52
Standard deviation (m/min)	7.10	6.28	6.76
Range			
High	95.25	87.87	95.95
Low	60.27	57.57	57.57
Sample size	298	227	525

GENERAL COMMENTS AND SUGGESTIONS

In the foregoing section, the most common speed measurements that are used in the analysis of pedestrian movements on sidewalks, stairways, and crosswalks were discussed.

In the CBD of Bangkok, it is common to witness traffic jams when pedestrian and vehicular movements are at their peak. On sidewalks, the walkway width has been tremendously reduced, mostly by the presence of sidewalk vendors or vending stands, and pedestrians spill onto the road. Obstructions such as planting boxes and trees used to beautify the sidewalk have been left untended and also reduce the width of the sidewalk, resulting in inconvenience to pedestrians. Inappropriate installation of traffic signs also causes interference and blocks the walkway available to pedestrians. Other obstacles such as type of walking surface, pavement obstructions, and amount of vehicular traffic along the pavement also affect the safety and convenience of pedestrians.

Lack of coordination in the proper placement of telephone booths on pathways has hindered and confused pedestrians, sometimes causing them to take a crooked or meandering path.

Traffic safety devices and improvements for pedestrian facilities should be planned. On sidewalks, barriers are needed in areas of high pedestrian-vehicular conflict to discourage pedestrians from crossing the road. Alternatively, an attractive and safe overpass or underpass should be provided. Corrective measures are also needed for obstacles such as unsafe pavement surfaces, unnecessary trees and planting boxes, and inappropriate placement of traffic signs.

Increased attention is also required to foot placement and maintenance of balance on stairways. Stair dimensions and configurations are important elements of stairway designs that have received very little attention, despite the greater demands on human energy and concerns for the safety of pedestrians. Inadequacy of stairways in and around transport terminals and other trip generators affects the entering and exiting capacity of other traffic.

Likewise, pedestrians crossing the road often run at crosswalks, especially on the Go signals, and some vehicles stop

TABLE 6 COMPARISON OF PEDESTRIAN WALKING SPEEDS IN DIFFERENT COUNTRIES

Country	Mean Walking Speed (m/min)
Asia	
Riyadh, Saudi Arabia	65.0
Madras, India	72.0
Thailand	73.0
Singapore	74.0
Colombo, Sri Lanka	75.0
Israel	78.8
England	78.6
United States	
Columbia	79.0
New York	81.0
Pittsburgh	88.0
Calgary, Canada	84.0

in the center of the crosswalk area, thus threatening the crossing pedestrians. In this respect, a nationwide effort should be made to encourage the enforcement of pedestrian and traffic laws.

CONCLUSION

Although a simple study was carried out, it is hoped that the results will have more far-reaching effects, especially as a base guideline for the more serious consideration of the design of pedestrian facilities. From these results, it is concluded that Bangkok pedestrian facility design standards should conform with local standards and authorities should try to refrain from directly adopting Western pedestrian design standards.

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Comparison of Central Business District Pedestrian Characteristics in Canada and Sri Lanka

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Characteristics of pedestrians in the central business district of Colombo, Sri Lanka, are described. The characteristics measured included walking speed, flow, and density for sidewalks of varying widths. Comparisons are made with results from Calgary, Canada, and from other Asian studies. The findings indicate that Asian speeds for all groups are significantly lower than those observed in Calgary, Canada. Implications of the findings with respect to the technological transfer of pedestrian planning techniques between the two countries are also discussed. The differences in pedestrian characteristics are caused not only by differences in speed, flow, and density relationships, but also by cultural differences. Problems common to both countries are lack of pedestrian data and difficulties involved in collecting pedestrian data. Suggestions concerning low-cost methods of updating pedestrian count data are provided.

A study was undertaken with the main objective of developing facility planning and design standards for Colombo, Sri Lanka. Basic pedestrian movement characteristics such as walking speed were compared between Colombo and Calgary to determine and explain differences that would affect the direct transfer of Western planning practices and design standards to Asian cities. Calgary was chosen for comparison purposes for three principal reasons. First, both Colombo and Calgary have concentrated central business districts (CBDs). Both cities have active plans to develop a system of elevated walkways. Calgary (*1*), for example, has 44 pedestrian bridges totaling over 9 km of elevated walkways that provide access to office, retail, and cultural facilities as well as to indoor and outdoor public spaces. Colombo has plans for an elevated walkway network in the CBD and in the vicinity of congested arterials. Both cities have been assembling a data base of pedestrian characteristics. The second objective of the study was to compare the pedestrian characteristics of Colombo with those of other Asian cities.

DATA COLLECTION

Pedestrian speed and flow characteristics were measured at three different locations in Colombo during peak and off-peak periods in July 1988. Walking speeds were determined by manually timing pedestrians over a test section. In Calgary, walking speeds were measured on six different facilities using time lapse photography, manual observations, and the moving-observer technique. In Colombo, sidewalk widths at the observation sites varied from 1.65 to 3.73 m, whereas in Calgary sidewalk widths varied from 3 to 4 m.

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WALKING SPEED STUDIES

Tables 1 and 2 present the results of the speed measurement studies in Colombo and Calgary (*2,3*), respectively. The walking speeds for both cities were measured for 3-m sidewalks. Walking speeds for Singapore (*4*) and Bangkok, Thailand, (see paper by Tanaboriboon and Guyano in this Record); are presented in Tables 3 and 4, respectively. Mean walking speeds for Riyadh, Saudi Arabia, are as follows (*5*): men, 70 m/min; women, 53 m/min; both, 65 m/min.

COMPARISON OF WALKING SPEEDS

Average Walking Speeds

A comparison of mean walking speeds for Colombo and Calgary, as well as for Singapore, Bangkok, and Riyadh, is as follows:

City	*Mean Walking Speed (m/min)*
Riyadh	65
Bangkok	73
Singapore	74
Colombo	75
Calgary	84

The mean walking speed of 75 m/min for Colombo is considerably lower than the value of 84 m/min shown for Calgary. However, the Colombo walking speed is similar to the values of 73 and 74 m/min reported for Bangkok and for Singapore by Tanaboriboon (*4;* paper in this Record). Although the mean walking speed for Calgary is not intended to represent the range of walking speeds in North American cities, it does indicate that walking speeds in Western cities are higher than those in Asian cities.

Walking Speeds of Men and Women

In both Colombo and Calgary, men were observed to walk faster than women. In Colombo, the average walking speed of men was measured at 81 m/min, or 3 m/min faster than women. In Calgary, the corresponding mean walking speeds

TABLE 1 COLOMBO WALKING SPEEDS FOR 3-m SIDEWALKS

	Statistics (m/min)			
Group	Mean	Standard Deviation	High Value	Low Value
Men	81	5	87	71
Women	78	4	84	68
Total	75	14	87	66
Elderly	72	4	78	66

TABLE 2 CALGARY WALKING SPEEDS FOR 3-m SIDEWALKS

	Statistics (m/min)			
Group	Mean	Standard Deviation	High Value	Low Value
Men	86	13	123	50
Women	81	11	120	43
Total	84	12	123	43

TABLE 3 SINGAPORE WALKING SPEEDS (*4*)

	Statistics (m/min)			
Group	Mean	Standard Deviation	High Value	Low Value
Men	79	12	123	44
Women	69	11	101	38
Total	74	12	123	38
Elderly	54	8	69	36

TABLE 4 BANGKOK WALKING SPEEDS

	Statistics (m/min)			
Group	Mean	Standard Deviation	High Value	Low Value
Men	76	9	99	55
Women	70	7	94	51
Total	73	8	99	51
Elderly	50	8	68	31

SOURCE: Preceding paper in this Record.

were 86 and 81 m/min for men and women, respectively. The difference was determined to be significant at the 1 percent level. Compared with Singapore's mean walking speed of 79 m/min for men and Bangkok's mean of 76 m/min, Colombo has the highest average walking speed. Similarly, the highest average walking speed for women was recorded in Colombo at 78 m/min, compared with Singapore and Bangkok at 69 and 70 m/min, respectively.

Walking Speeds of the Elderly

The elderly were observed to walk more slowly than the general population. The walking speeds of elderly people were 72, 54, and 50 m/min for Colombo, Singapore, and Bangkok, respectively. Comparisons of walking speeds of elderly people were difficult to make, because age was not recorded during the field surveys.

Walking Speed Summary

In the tabulation of mean walking speeds reported above for five cities, the mean walking speed ranges from 65 m/min in Riyadh, Saudi Arabia, to 84 m/min in Calgary, Canada. Mean walking speeds for the three Asian cities of Bangkok, Singapore, and Colombo were observed to be 73, 74, and 75 m/min, respectively. The differences in walking speeds between Calgary and Colombo are attributed to the physical differences among pedestrians (e.g., in height), cultural differences (e.g., in dress and shopping habits), and attractions (such as pavement hawkers) located along sidewalks. Similar findings have been reported for Singapore (*4*), Bangkok (see preceding paper in this Record), and Riyadh, Saudi Arabia (*5*).

SPEED, RATE OF FLOW, AND DENSITY

Speed, rate of flow, and density measurements were made at all three survey sites in Colombo.

Speed Versus Rate of Flow

Figure 1 shows speed versus rate of flow. Over the flow range of 2.0 to 16.0 ped/m-min, speed varied between 70 and 80 m/min. However, no discernible relationship was observed over the range. The independence of speed and flow was also observed in Calgary (*2*). Attempts to fit linear models to the data were unsuccessful for Colombo data.

Speed Versus Density

Figure 2 shows speed versus density for Colombo. Off-peak travel has a density range of 0.1 to 0.2 ped/m^2 and speed varies from 70 to 80 m/min, without a decrease in speed as density increases. This is because off-peak travel is mainly for shopping. However, during the peak the speed drops from 80 to 50 m/min for a density range of 0.2 to 0.3 ped/m^2, because these trips are mainly for business.

Rate of Flow Versus Density

The rate of flow versus density is shown in Figure 3. At densities from 0.20 to 0.25 ped/m^2, the flow rate decreased from 8 to 3 ped/m-min. The rate of flow was measured at 2 ped/m-min and density was about 0.1 ped/m^2. Again, off-peak and peak travel have different purposes (shopping and business, respectively) and the values should be considered separately.

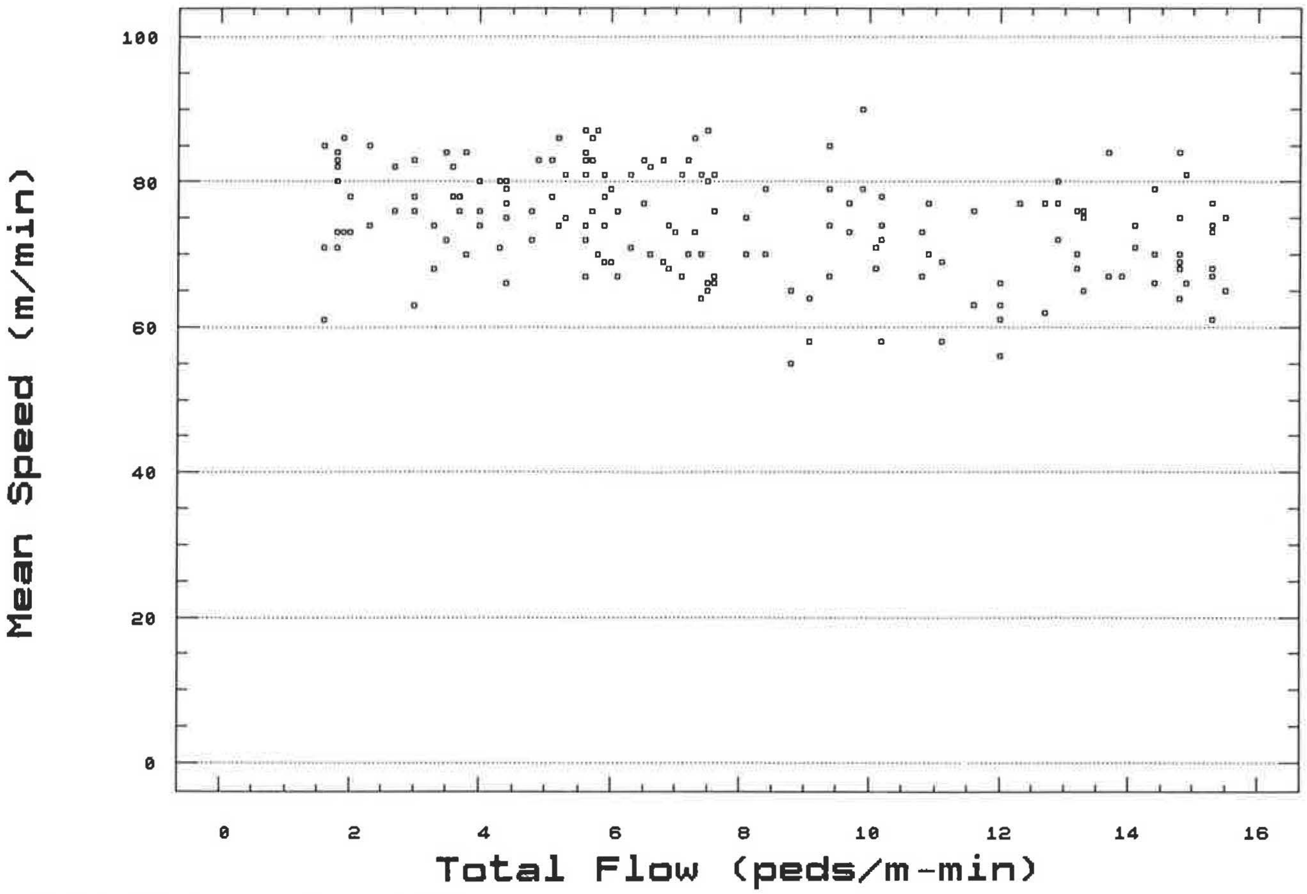

FIGURE 1 Plot of mean speed versus total flow.

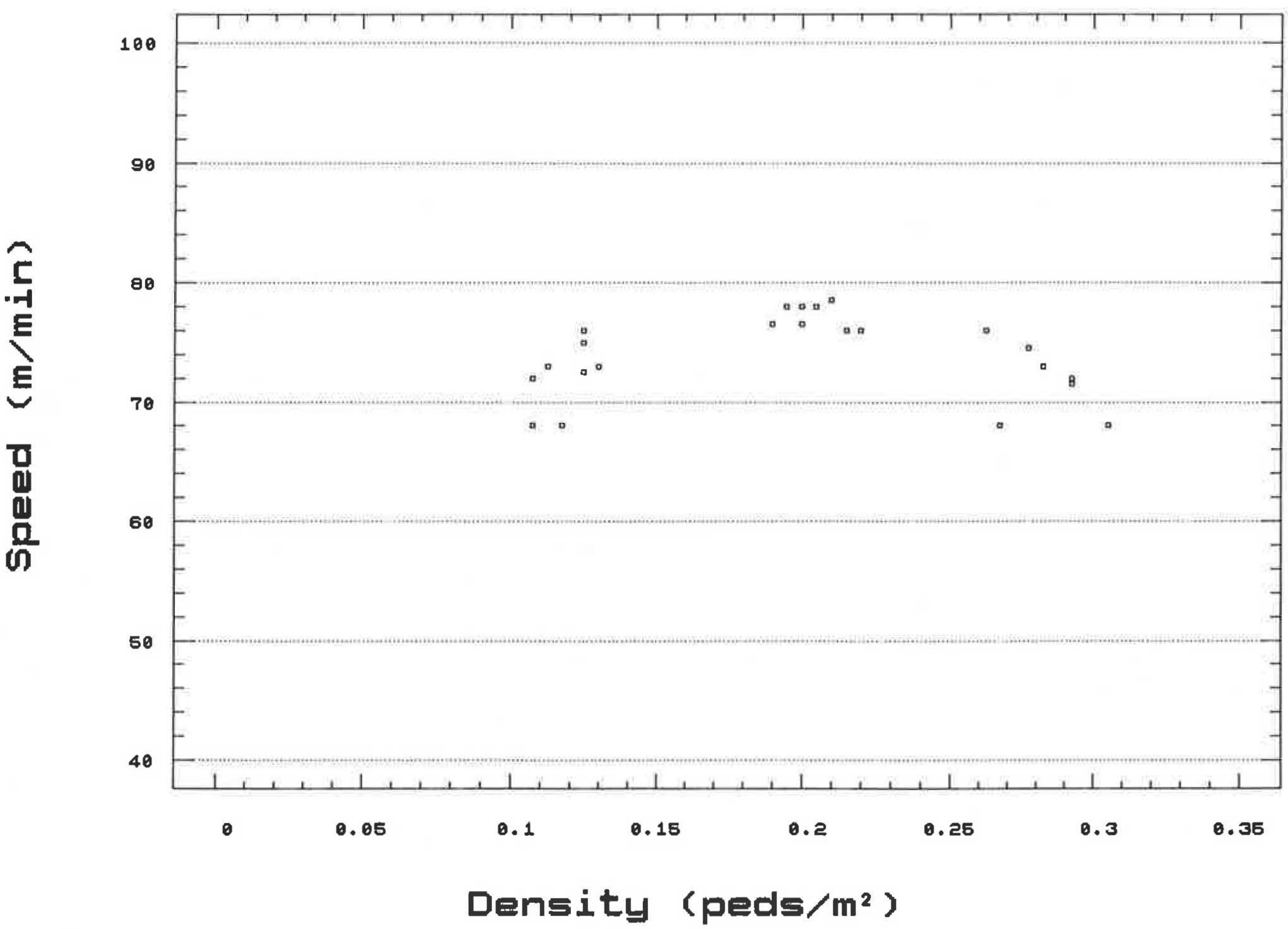

FIGURE 2 Plot of speed versus density.

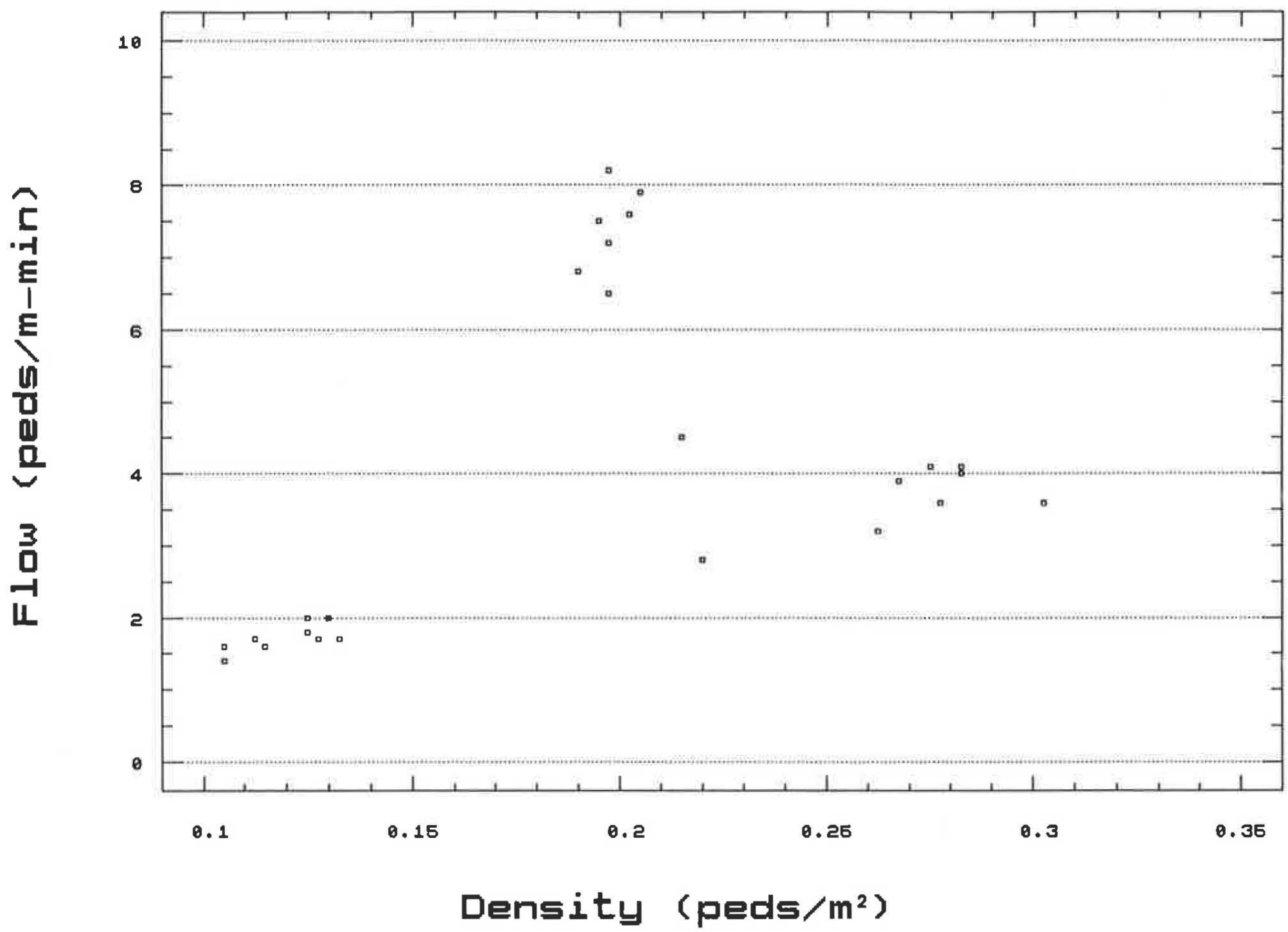

FIGURE 3 Plot of flow versus density.

ESTIMATION OF PEDESTRIAN FLOWS, CHARACTERISTICS, AND SAMPLING TECHNIQUES

As noted at the outset, the difficulties associated with collecting pedestrian data have limited the ability to establish standard pedestrian planning procedures. The collection of pedestrian flow data, which are fundamental for evaluating facility performance, is usually done manually and hence is highly labor-intensive. Even though this may not pose severe problems in developing countries, the costs of data collection in industrialized countries are substantial.

In order to minimize manpower costs, several estimation procedures have been used in previous studies. One of these is the method of expansion factors proposed by Seneviratne and Morrall (*6*). This procedure enables the expansion of long-term flow data. However, sufficient information is required to identify the appropriate short-term count to be expanded.

Pedestrian flow data collected in Calgary and Montreal have demonstrated that counts during periods as short as 5 min are sufficient for estimating hourly volumes. Nevertheless, the short-term variations render it difficult to obtain a representative 5-min count. Bayesian estimates, which recognize the variations in flow, are obtained by combining sample counts during very short time periods using the experience and judgment of the analyst.

SUMMARY AND CONCLUSIONS

1. Free flow pedestrian speeds for all groups in Asian countries are significantly lower than those observed in Calgary.
2. The main explanation for the difference in speeds between Colombo and Calgary may be physical (e.g., height) and cultural (e.g., dress) differences, and attractions (such as pavement hawkers) located along sidewalks. Similar findings have been reported for Singapore (*4*), Bangkok (see preceding paper in this Record), and Riyadh, Saudi Arabia (*5*). The lower walking speeds for Singapore were partially attributed to physical and cultural characteristics, whereas dress and extreme temperatures were cited as reasons for lower walking speeds in Riyadh.
3. Pedestrian planning techniques for Asian countries such as Colombo should be based on local pedestrian characteristics rather than on pedestrian characteristics from cities with dissimilar cultures such as Calgary.
4. Despite the importance of the pedestrian mode in large cities like Colombo or Calgary, pedestrian data collection has been largely ignored because of the cost of data reduction.

A sampling technique based on Bayesian theory for obtaining the best estimates as well as updating short-term counts is suggested as one additional means of enhancing pedestrian flow data banks.

5. The pedestrian mode is the most important means of travel in Sri Lanka, yet it has been largely neglected in urban transportation studies conducted in Colombo. Neglect of planning for the pedestrian mode is manifested in terms of the lack of sidewalks and poor maintenance of existing walkways. In many areas of Colombo, pedestrian and vehicular traffic must share the same roadspace. In view of the neglect of the pedestrian mode, future urban transportation studies should include pedestrian studies and facilities on an equal footing with the vehicular modes.

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