TOWARDS A SUSTAINABLE URBAN TRANSPORT SYSTEM: PLANNING FOR NON-MOTORIZED VEHICLES IN CITIES

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A sustainable transport system must meet the mobility and accessibility needs of people by providing safe and environmentally friendly modes of transportation. This is a complex and difficult task in the mega-cities of developing countries because the needs of people belonging to various income groups are not only different, but also often conflicting in nature. For example, if a large section of the population cannot afford to use motorized transport – private vehicles or public buses – they have to either walk to their place of work or use bicycles. Providing a safe infrastructure for cyclists and pedestrians means either physically segregating road space for cyclists and pedestrians from motorized traffic, or, if that is not possible, reducing the speed of motorized traffic. Both measures imply restricting the mobility of car users to ensure the mobility of bicycle users.

In this paper we show that pedestrians, cyclists and non-motorized rickshaws are the most critical elements in mixed traffic. If infrastructure design does not meet the requirements of these three all modes of transport operate in sub-optimal conditions. It is possible to redesign existing roads to provide a safe and convenient environment for non-motorized modes of transport. This also results in the improved efficiency of public transport vehicles and an enhanced capacity of the transport corridor when measured in number of passengers per hour per lane.

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I. NON-MOTORIZED TRANSPORT IS AN INTEGRAL ELEMENT OF URBAN TRANSPORT

The transport and land-use patterns found in South Asian cities are different from those in the West. Most of these cities can be classified as "low-cost strategy" cities (Thomson 1977). Compared to cities in the West, these cities consume less transport energy. High population densities, intensely mixed land use, short trip distances, and high proportions of pedestrians and non-motorized transport characterize these urban centres (Newman and Kenworthy 1989). Their transport and land-use patterns are so complicated by poverty that it becomes difficult to analyse their characteristics using the same indices as are used for cities in highly motorized countries (HMCs).

A. Urban transport and land use plans

Most of the metropolitan cities of South Asia prepared master plans in the 1960s. Included in these were the following:

(a) Demographic projections and decisions on the levels at which the population should be contained;

(b) Allocation of population to various zones, depending on existing population density level, infrastructure capacity and future density levels;

(c) Land-use zoning to achieve the desired allocation of projected population and activities in various zones as projected;

(d) Large-scale acquisition of land with a view to ensuring planned development.

The planning framework usually adopted in the preparation of master plans was completely divorced from resource assessment. The process also did not include any procedures for involving the community and bringing about consensus on contentious issues. The net effect of the inadequacies of the planning process was that most urban growth took place without formal planning. Informal residential and business premises and developments increasingly dominated new urban areas. Even in South Asian mega-cities, where may economic activities are located in informal settlements, urban planners still rely on traditional master-planning approaches, which serve the minority, high income residents. A few weak attempts have been made to bring some coordination of development and services to informal areas through slum-improvement schemes.

For example, the Delhi Master Plan is a typical example of integrated land-use and transportation planning. The new Master Plan was developed in 1990. The land-use distribution and density patterns proposed in the Plan are intended to minimize average trip lengths. In the Plan a five-tier system of commercial activities is proposed, to accommodate the shopping, commercial office and recreational needs of the population (Delhi Development Authority 1990). The proposal includes the provision of district centres designed to serve as focal points for multi-nodal activities of the community. Seven district centres have already been developed and twenty more have been proposed. Rising land prices have contributed significantly to the growth of mixed land-use patterns and higher population densities. In the past decade, a large number of single-family dwelling units have been converted to multi-storey apartment buildings. Commercial and institutional organizations have rented or bought space by outbidding the residential occupants. Mixed land-use patterns have successfully curbed the number and length of non-work-related trips by motorized modes of transport. The number of trips per household for different purposes remains constant, regardless of whether people live in the "inner area", which has a heavy concentration of employment and commercial activities or the "outer areas", with the planned new developments (Central Road Research Institute 1992).

In other metropolitan cities transport and urban planners have followed similar standard procedures in dealing with urban sprawl and traffic congestion. Large-scale integrated land-use transport models have supported policies and plan documents. These policies and plan documents recommended high-density planned neighbourhoods, and capacity expansion of arterial corridors to meet future travel demands. Despite these efforts to promote mixed land-use planning, the presence and growth of "unauthorized settlements" and pavement dwelling defy the master plans. Nearly 40 to 65 per cent of the population of South Asian mega-cities live in sub-standard living areas, which are notified slum areas and slum rehabilitation colonies, with minimal supplies of drinking water, sewage disposal and electricity. It is mainly, migrant workers who have set up these dwelling units in places not designated for residential units. Even in the Delhi Master Plan there is no living area envisaged for workers earning low wages in Delhi's industries. Many factories and small-scale production units operating in Delhi work entirely outside the law. The government agencies themselves admit their failure and powerlessness to enforce the current minimum wage, which does not account for housing costs. Therefore, the low-income section of the population, ends up in sub-standard housing on public land owned by various government agencies. The rising cost of transport within the city and the long working hours force workers to live right next to their factories. Violating the law becomes a precondition for survival in the city. A large number of people living in these units are employed in the informal sector, providing various services to the outer areas of the city where the new developments had been planned. However, due to the lack of employment opportunities, people living in these areas have to commute long distances across the city in search of employment. Unlike the traffic in the cities of high-income countries, bicycles, pedestrians and other non-motorized modes of transport are present in significant numbers on arterial roads and intercity highways. Their presence persists, despite the fact that engineers designed these highway facilities for fast-moving, uninterrupted flows of motorized vehicles.

B. Captive ridership

The share of bicycle trips as a proportion of total trips has declined over the years. However, a large number of commuters are still using bicycles and other non-motorized modes of transport in spite of long trip lengths. For example, in the outer areas of Delhi, non-motorized vehicles and pedestrians are present on most intercity highways and have comparatively long trip lengths (Tiwari 1995). This shows that at present a large number of people use these modes not out of choice but owing to the absence of other options.

Increasing numbers of the poor continue to live without services in slums and unauthorized colonies in Delhi. It is estimated that there are currently over 1,500 unauthorized colonies without civic amenities and that as much as 60 per cent of the population lives in sub-standard housing. Recent sample surveys from these colonies indicate that these citizens are largely dependent on walking (20 per cent) or cycling (44 per cent) to work. This is true for people employed in the informal sector, with household income of less than Rs. 2,000/month (US$ 50).

Table 1 gives indicators for selected Indian cities. In large cities such as Mumbai, Delhi and Madras, more than 60 per cent of people are employed in informal sector. For this population walking and cycling to work are the only modes of transport available. A sustainable transport system must cater for this captive ridership of non-motorized transport users in the cities of the south.

Even a subsidized public transport system remains beyond the means of a significant segment of the population. Assuming a minimum of four trips per household, per day, at a cost of four rupees per trip, a household would need to spend Rs. 320 per month on transportation. For low-income people living on the outskirts of the city, the cost per trip may be between 4 and 6 rupees, depending on the number of transfers. On average, a low-income household cannot spend more than 10 per cent of its income on transportation. This implies that a household’s income must be at least Rs. 3,200 for it to be able to use the public transport system at minimum rates. According to “Household travel surveys in Delhi” (Operations Research Group 1994), approximately 28 per cent of households in Delhi have a monthly household income of less than Rs. 2,000. For these people cycling and walking are the only logical choices.

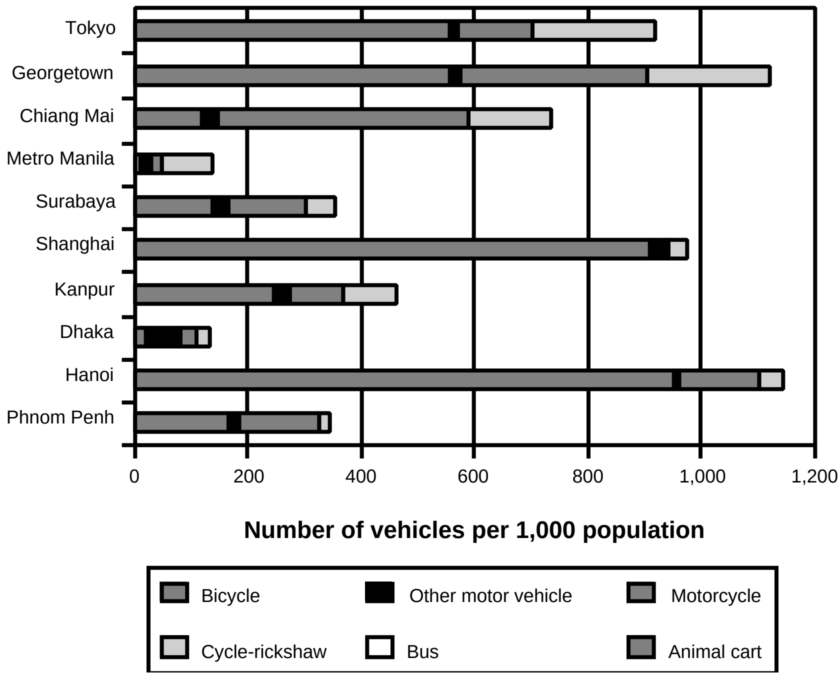
C. Traffic and travel characteristics in South Asian cities

Asian cities are characterized by heterogeneous traffic (a mix of non-motorized and motorized modes of transport) and mixed land-use patterns. Non-motorized vehicles are owned and used by a large section of the population (figure 1). Car ownership rates in Asian countries are low compared to those of North America and Organisation for Economic Cooperation and Development countries. In 1993 car ownership was 29 cars per 1,000 residents in East Asian countries, compared to 561 cars per 1,000 residents in North America, and 366 in OECD countries (AAMA, 1995). Although the growth rate in motor vehicles ownership is expected to be greatest in many Asian countries, most of these increases in absolute numbers of vehicles will result from increases in the numbers of motorized two- and three-wheelers (World Resources Institute 1996). In Thailand, Malaysia, Indonesia and Taiwan, two- and three-wheelers make up more than 50 per cent of all motor vehicles. The number of two- and three-wheeled vehicles is expected to grow most rapidly in China and India.

Table 1. Indian city indicators, 1993

Indicator / *City*	*Mumbai*	*Delhi*	*Madras*	*Bangalore*	*Lucknow*	*Varansi*	*Hubli*	*Mysore*	*Gulbarga*	*Tumkur*
Population (million)	10.26	8.96	5.65	4.47	1.80	1.08	0.68	0.70	0.33	0.19
Household income distribution (Quintile boundaries US$)										
I (poorest 20 per cent)	374	290	347	385	291	268	284	373	258	287
II	620	679	531	670	482	426	698	746	660	433
III	939	1 082	772	1 144	762	634	845	1 176	1 052	641
IV	1 553	1 496	1 492	1 437	1 331	1 230	1 473	1 511	1 435	923
V (richest 20 per cent)	2 497	3 292	2 781	2 487	2 181	2 084	2 009	2 372	1 951	1 761
Informal Employment (percentage)	68	66	60	32	48	49	31	31	27	63
Motorized vehicles (per 1,000 population)	51	205	102	130	130	85	49	123	60	63

Source: World Resources Institute, 1996. *World Resources: A Guide to the Global Environment*, (Washington DC, World Resources Institute).



Note: Animal carts and buses are negligible.

Source: World Bank, 1991, *Urban Transport in Asia* (Washington DC, World Bank).

Figure 1. Comparison of vehicle populations

In Indian cities the share of non-motorized transport (NMT) at peak hours varies from 30 to 70 per cent. The proportion of trips made by bicycle ranges between 15 and 35 per cent, the share tending to be higher in medium- and small-sized cities. The patterns of NMT use vary according to city size. In most NMT-dependent, low-income cities, bicycles are used for the entire trip (for example, commuting, shopping). In a high-income city like Tokyo, bicycles are increasingly used as a feeder mode to rail stations as well as for shopping and other purposes (World Bank 1995:27). Every motorized public transport trip involves access trips by NMT at each end. Thus, NMT, including walking, continues to play a very important role in meeting travel demand in Asian cities.

In addition to bicycles, non-motorized rickshaws are used for the delivery of goods such as furniture, refrigerators and washing machines. Semi-skilled workers, carpenters, masons, plumbers, postmen, and courier services use bicycles. The demand for bicycles and rickshaws is therefore considerable at present and is likely to continue to be so. This situation is not explicitly recognized in policy documents and very little thought is given to improving facilities for non-motorized modes of transport.

D. Buses: principal means of transport in Asian countries

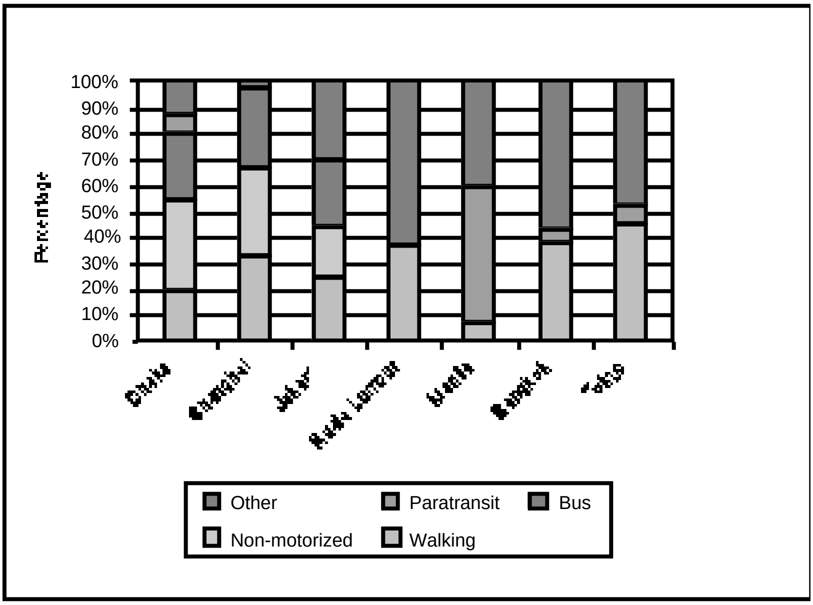
The populations of most cities in low-income countries (as defined by the World Bank in its World Development Reports) are heavily dependent on buses. They are the major means of mobility, particularly for the low-income population (World Bank 1991:38-39). The share of public transport trips is shown in table 2.

Table 2. Modal split of passenger traffic in selected European and Asian countries, 1996

Country		*Private road transport (percentage)*	*Public transport (percentage)*	*Rail transport (percentage)*
Europe	France	5.4	86.4	8.1
	Germany	8.7	84.0	7.2
	United Kingdom	6.3	89.0	4.6
	Spain	12.1	81.5	6.3
Asia	Japan	6.9	61.9	31.1
	Hong Kong, China	51.8	22.5	25.7
	Republic of Korea	36.3	40.0	23.6

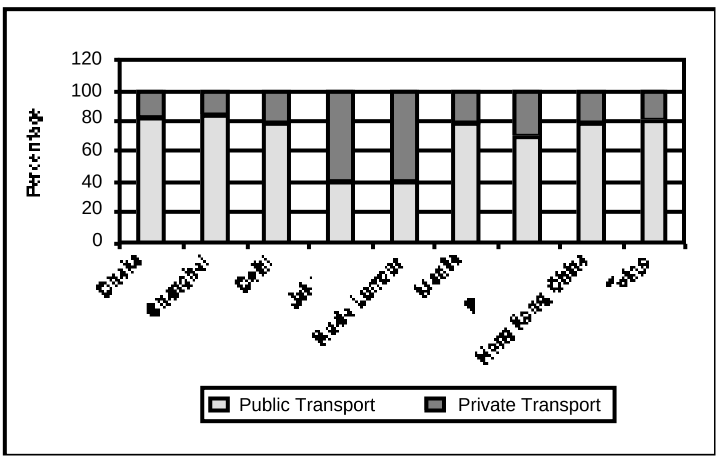
Source: International Road Federation, 1998. *World Road Statistics 1998* (Washington DC, International Road Federation).

In most cities in low-income countries walking and non-motorized vehicles are the main travel modes (figure 2) and public transport is the predominant mode of motorized travel (figure 3). Walking and non-motorized modes of travel are less significant in middle-income Asian countries and bus use predominates.



Source: World Bank, 1991, *Urban Transport in Asia* (Washington DC, World Bank).

Figure 2. Distribution of trips by travel mode in selected Asian cities



Source: World Bank, 1991, *Urban Transport in Asia* (Washington DC, World Bank).

Figure 3. Trips by public transport and private transport in selected cities

The travel characteristics of large cities in high-income countries differ from those in low- and middle-income countries in the use of mass rapid transit and commuter rail systems. Throughout Asia buses form the backbone of urban public transport services. However, overcrowding, the increased incidence of breakdowns and poor service frequency have resulted in a decline in general levels of service and comfort. Consequently, a large number of indigenously designed vehicles are operating as paratransit modes in Asian cities. This service is mostly provided by the informal sector. Paratransit operations provide an important service in cities throughout the region, with the notable exceptions of China and high-income countries such as Australia, Japan and Singapore (World Bank 1991).

E. Vehicle ownership in Asian countries

Asian countries have low rates of vehicle ownership: 50 per cent of the world's population live in Asia, but they own only 11 per cent of the world's cars and 28 per cent of its trucks and buses (World Bank 1990:35-36). In the low-income countries of Asia, vehicle availability rates range from a high of 63 persons per vehicle in Sri Lanka to 250 persons per vehicle in India. In the middle-income countries, they range from a high of 10 persons per vehicle in Malaysia to 124 persons per vehicle in the Philippines, and in the high-income countries they range from 2.3 persons per vehicle in Japan to 18 persons per vehicle in Hong Kong, China.

Economic growth, urbanization and population trends in Asian cities indicate that the urban populations of Asian cities will have to depend heavily upon public transport for their travel needs, unlike people of European cities, who are heavily dependent on private transport.

Though average income levels in Asian countries are expected to rise, these countries will still have 53 per cent of the world's poor people by the year 2000 (World Bank 1990). Thus, travel demand is likely to increase in low-income Asian countries having 50 per cent of the world's poor. Ownership of private vehicles and the availability of public transport vehicles will continue to be low, despite an increase in the number of vehicles.

As is evident in high-income Asian countries, the existence of large public transport demand on the main travel corridors of large urban areas leads necessarily to the implementation of high-capacity systems.

These have been successfully operating in the cities of high-income countries (World Bank 1991:25-27). Since most Asian countries have a scarcity of resources and low income levels, operating a bus-based public transport system is the only option which is economically and financially viable.

II. TRAFFIC FLOW CHARACTERISTICS

The road network of Delhi is used by at least seven categories of motorized and non-motorized vehicles. Vehicles ranging in width from 0.60 m to 2.6 m and capable of maximum speeds ranging from 15 km/h to 100 km/h share the same road space. All these vehicles, which have varied dynamic and static characteristics, share the same carriageway. This traffic is characterized by a lack of any effective channelization, mode segregation or speed controls. To the formally-trained traffic planner it looks like chaos moving toward total gridlock. Yet the people and goods keep getting through and may by some measures actually be doing better than in some controlled conditions.

Detailed traffic studies in Delhi show that all modes of transport use one-, two- and three-lane roads all over Delhi. Delhi traffic laws do not segregate non-motorized and motorized modes, and the enforcement of speed limits is very limited. Motor vehicles (MVs) and non-motorized vehicles (NMVs) have different densities at peak traffic hours at different locations. A study of mid-block conflicts in Delhi gives information regarding the use of road space by different road users (Tiwari et al. 1997). Data from the fourteen sites studied show that maximum mixing of NMVs and MVs occurs at bus stops, but at other locations interaction is minimal. A natural segregation of slow and fast traffic occurs on three- and two-lane roads. On three-lane roads, MVs use the two right lanes and the kerb-side lane is used almost exclusively by NMVs (traffic in India drives on the left).

Since the MV traffic lane is 3.5 m wide, it can accommodate flow rates of at least 6,000 bicycles per hour (Replogle 1991). On three-lane roads, the MV flow rates are close to or less than 4,000 passenger car units per hour. This is much less than the expected capacity of three-lane roads. The flow for these urban localities can be taken as 2,000 passenger car units per hour, per lane (Indian Road Congress 1990). Though peak volumes do not exceed saturation capacity values, we find average speeds remain in the range of 14 to 39 km/h. On two-lane roads the MV flow rates are close to or less than saturation capacity values. It is only on the one-lane roads that we find flow rates of 726 bicycles/hr and 616 passenger car units/hr. Both these values are approximately one third of their respective saturation capacity values for one lane.

These observations indicate that on two- and three-lane roads, bicycle traffic will naturally segregate itself into the kerb-side lane. Integration of MV and NMV traffic will only take place if the bicycle flow rate exceeds 6,000 bicycles per hour for one MV lane, or if the MV flow rate exceeds one lane capacity on two-lane roads, or two-lane capacity on three-lane roads. Though natural segregation takes place on two- and three-lane roads, the danger to cyclists because of conflicts with MVs is unacceptable. At two- and three-lane locations, it is a waste of resources not to provide a separate bicycle lane, because one whole MV lane gets used by bicycles and other NMVs irrespective of bicycle density.

Since the kerb-side lane is primarily used by bicycles and other NMVs, buses are unable to use the designated bus lanes and are forced to stop in the middle lane at bus stops. In the absence of facilities for NMVs all modes of transport move in suboptimal conditions. This disrupts the smooth flow of traffic in all lanes and makes cycling more hazardous. Therefore, providing a separate bicycle track or lane for NMVs would make more space available for motorized modes and make cycling less hazardous. It is also obvious that in the absence of segregated NMV lanes on arterial roads, it is not possible to provide designated lanes for buses.

III. SEPARATE BICYCLE LANES FOR NMV: ESSENTIAL FOR SUSTAINABLE TRANSPORT SYSTEMS

A sustainable transport system must provide mobility and accessibility to all urban residents with safe and environmentally friendly modes of transport. For example, if a large section of the population can not afford to use motorized transport – either private vehicles or public buses – they either have to walk or cycle to their place of work. If cyclists and pedestrians are to be provided with a safe infrastructure, either road space for them must be physically segregated from motorized traffic, or the speed of the motorized traffic must be reduced. The major arterial roads of the city must be made NMV-friendly. Dedicated NMV routes through parks, green belts and narrow city streets could serve as additional network capacity for cyclists.

Pedestrians, cyclists and non-motorized rickshaws are the most critical elements in mixed traffic. If the infrastructure design does not meet the requirements of these elements, all modes of transport operate in suboptimal conditions. It is possible to redesign existing roads to provide a safe and convenient environment for non-motorized modes, especially if the right of way is 30 m or more (Tiwari 1999), and this can also result in the improved efficiency of public transport vehicles and the enhanced capacity of the corridor when measured in number of passengers per hour, per lane.

A. Bus lanes

Segregated bus lanes are necessary to meet increasing travel demand and to improve public transport. In many cities around the world the kerb-side lane is reserved for buses. This has been attempted in Delhi, but without success. In the absence of segregated cycle lanes, cyclists use the kerb-side lane. This makes it impossible for buses to use the kerb-side lane, in spite of repeated attempts at enforcement by the Delhi Police. If separate lanes were available all cyclists would use them and that would make the curbside lane available for buses. Segregated cycle lanes must be established before dedicated bus lanes can be implemented.

B. Increased capacity

If a separate segregated lane were constructed for bicycles, the kerb-side lane, which is currently used by cyclists, would become available to motorized traffic. This relatively small investment in cycle lanes could increase the road space for motorized traffic by 50 per cent on three-lane roads. Cycle lanes also result in better space utilization. For instance a 3.5 m lane has a carrying capacity of 1,800 cars per hour, but 5,400 bicycles per hour (Replogle 1991). The average car occupancy is 1.15 persons (Indian Road Congress 1990) and a bicycle carries one person. This implies that in order to move the same number of people by car we would need 2.6 times the road area that would be required for cyclists. Given the fact that there is not much space available to expand existing roads, future mobility needs can only be met by increasing the capacity of the existing road network. This can only be achieved by encouraging modes of transport which are more efficient in terms of space utilization.

C. Reduced congestion

Congestion has long been recognized as an environmental problem. Other than causing delays, it causes noise and fumes and increases health risks to road users and residents. Congestion and cycling policies are interconnected in two ways. First, because congestion leads to poor air quality and a poor environment, it may act as a deterrent to cyclists. Second, policies which promote cycling would in themselves help to relieve congestion because cyclists require so much less road space than motorists do, both when travelling and parking.

D. Increased safety

Figures show that even at per capita income levels of US$ 3,000, car ownership levels remain low and the proportion of motorized two-wheelers can be more than 50 per cent (Mohan and Tiwari 1998). Most least motorized countries (LMCs), including India and China, will not reach the income level of US$ 3,000 in the next decade. As incomes increase, the poorest people in countries like India and China will be able to own bicycles, and those who own bicycles today may opt to buy motorcycles when they become richer. As the number of poor and lower middle-class people in these countries is larger than that belonging to the upper class, we are likely to witness greater increases in absolute numbers of bicycles and motorcycles than cars in the next decade or so. Road safety policies and countermeasures used in societies where cars constitute about 80 per cent of vehicles will not be suitable for most LMCs, where motorized two-wheelers comprise more than 40-50 per cent of the total number of vehicles.

The high rates of pedestrian, bicycle and motorcycle traffic in LMCs (proportions differ from country to country) result in vulnerable road user fatalities constituting 60-80 per cent of all traffic fatalities (Mohan 1992).

Table 3 shows the proportion of road traffic deaths by mode of transport as a percentage of all fatalities in different countries. The data show that vulnerable road users constitute almost 75 per cent or more of fatalities in most LMCs. This flows logically from the fact that this class of road user forms the majority of those using the road space along with fast motorized vehicle, without specific facilities for NMVs. In addition, because vulnerable road users are not protected by metallic or energy-absorbing materials, they sustain relatively serious injuries even at low velocity crashes. A study shows that in LMCs buses and trucks are involved in a greater proportion of crashes than they are in HMCs (Kajzer et al. 1992). The majority of fatal crashes take place

Table 3. Road traffic deaths by mode of transport (Percentage of all fatalities)

	Pedestrians	*Cyclists*	*Motorized Two-wheelers*	*Motorized four-wheelers*	*Others*
Delhi, India (1994)[a]	42	14	27	12	5
Thailand (1987)[a]	47	6	36	12	–
Bandung, Indonesia (1990)[a]	33	7	42	15	3
Colombo, Sri Lanka (1991)[a]	38	8	34	14	6
Malaysia (1994)[a]	15	6	57	19	3
Japan (1992)[b]	27	10	20	42	1
The Netherlands (1990)[b]	10	22	12	55	–
Norway (1990)[b]	16	5	12	64	3
Australia (1990)[b]	18	4	11	65	2
United States of America (1995)[b]	13	2	5	79	1

Source: Mohan, D., and G. Tiwari, 1998. *Reflections on the transfer of traffic safety knowledge to motorizing nations,* Global Traffic Safety Trust.

Note: [a] LMCs [b] HMCs

mid-block. A detailed study done in Delhi shows natural segregation takes place on two- and three-lane roads, with cyclists occuping the kerb-side lane. However, natural segration does not ensure the safety of cyclists.

By creating segregated cycle lanes and ensuring the proper design of intersections, conflicts between motorized traffic and cyclists can be reduced substantially, leading to a sharp decrease in the number of accidents and fatalities for cyclists and motorized two-wheelers.

E. Reduced pollution and energy consumption

Motor vehicles are reported to be the single biggest source of air pollution, causing 70 per cent of the total air pollution in Delhi (Central Pollution Control Board 1993). This is a serious concern to cyclists, pedestrians and motorists, as air quality is worse in or near roads in built-up areas. Cyclists suffer the adverse affects of pollution because of heavier breathing whilst exercising close to the source of exhaust pollution. A dedicated infrastructure can reduce this problem to some extent. While motorized transport is one of the most polluting of all human activities, however, cycling is the least polluting mode of all. Cycling generates no noise pollution or toxic emissions. Therefore, there is a need to make cycling more popular. A better bicycle infrastructure can play an important role in increasing the modal share of bicycles and thus reduce air pollution and health risks.

IV. CONCLUSION

It is clear from the above discussion that non-motorized modes of transport which include bicycles and rickshaws are an integral part of the transport system in all South Asian cities. Existing socio-economic patterns and land-use distribution ensure the presence of NMVs in the whole city and on the complete road network. The densities and modal shares of NMVs in total traffic may differ from one part of the city to the other. However, as long as NMVs are on the road, regardless of their numbers, all vehicles move under suboptimal conditions. Efficient bus systems cannot be designed without taking account of the slow vehicles on the road. Since sustainable transport systems in South Asian cities have to move large numbers of people by bus transport and NMVs, planning for NMVs is indispensable.

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