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Urban Transport Priorities

Meeting the Challenge of Socio-economic Diversity in Cities, a Case Study of Delhi, India

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Non-motorized transport is an integral element of urban transport in Indian cities. More than 50% of the city residents cannot afford any other mode of transport unless heavily subsidized. Therefore, non-motorized transport has to be given equal priority in designing the urban infrastructure. This paper uses Delhi, India as a case study to indicate that the existing urban transport infrastructure in cities does not meet the needs of a large number of city residents who remain outside the formal planning process. This leads to sub-optimal conditions for all modes of transport. An efficient bus system cannot be designed without taking care of the slow vehicles (non-motorized vehicles, NMVs) on the road. Since sustainable transport systems in Indian cities demand the movement of large number of people by bus transport and NMVs, planning for the latter is indispensable. Planning for non-motorized transport and integrating it with the other modes of city transport is a prerequisite for creating sustainable transport systems, thus leading to sustainable cities.

Keywords: low income countries, Indian cities, urban transport, non-motorized transport, sustainable cities

Introduction

Most Indian cities are characterized by high densities, intensely mixed land use patterns, short trip distances, and a high share of walking and non-motorized transport. The transport and land-use patterns found in these cities are so influenced by poverty and high level of complexity that it becomes difficult to analyse their characteristics using the same indices as used for cities in highly motorized countries. There is ample evidence to illustrate the mismatch between urban transportation planning methods and the growing transportation problems. Consequently, these cities continue to face environmental decay, congestion, and poor health conditions. Unless we understand the basic nature of problems faced by these cities, the adverse impact of growing mobility on the environment will continue to multiply in the future.

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Changing city profile

The spatial spread of Indian cities has been changing as in other cities across the globe. The city limit is now indicated by urban sprawl. The cities include the old core area, which is usually congested, has narrow streets, old houses, and a mixed and relatively unregulated pattern of land use. Then there are unplanned parts of the city, which have developed spontaneously, are often beyond the municipal limits, but are also found within it, along arterial roads or the main highways going out of the city. These spontaneous developments are of two types: one inhabited by residents of lower and middle classes who, due to mismanagement of the land market, cannot afford to buy land for housing. The other category consists of squatter settlements. These can be spread all over the city. These are largely inhabited by the poorer sections of the society, especially construction labourers and the informal workers of the city. The larger the city, the more we find slums and squatter settlements.

In the 'million plus' and megacities of India, 40 to 50 percent of the population lives in these informal housing colonies (Misra, 1998). The third category of settlements consists of planned residential colonies, built by the public, private or co-operative sectors. These are high-income residential homes and multi-storeyed flats with well-laid out roads, and other urban services. Public transport and private cars give easy access from these locations to the city centre, as well as to shopping areas. A fourth category is commercial. It is planned and has multi-storied buildings. These have been located to create multi-centred cities. A fifth and the final category is the urban fringe where the urban and rural divide becomes blurred. Thus the structure that emerges from the complex interplay of physical, social, economic, cultural and behavioural factors does not follow the classical "rich centre and poor periphery" type of model. There are no clear-cut concentric zones of different activities. Central core areas depict not only commercial activity but also high housing concentrations. The manufacturing activities are spread not only in the peripheral zone but also in intermediate and inner zones. Unlike many Western countries, Indian cities have more than one Central Business District; therefore commercial activities are spatially dispersed. Manufacturing activities are concentrated not only in the earlier old commercial areas but also newly developed industrial areas at the outskirts of the city.

In the spatial structure of Delhi there is significant overlapping of areas of high social status with traditional urbanism. The spatial arrangement of social zones in Delhi shows distinct patches of lower class at the outskirts and in the innermost commercial areas. The innermost areas are characterized by high population density. These areas of Old Delhi have been declared as slums due to old, dilapidated and obsolete structures, while at the outskirts, the lower class resides in resettlement colonies, build by the government. The elite class is mostly concentrated in central planned zones and the peripheral zones, while middle class areas are dispersed all over the city.

Spatial integration of different activities and various social groups has occurred because of economic and social factors. The section of the population which has very low income ends up in sub-standard housing on public land owned by various government agencies. The rising cost of transport within the city and long working hours force the workers to live right next to their factories. Violation of laws becomes a pre-condition for their 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. The growth rate of the squatter households, as compared to that for the non-squatters, is nearly four times higher – we see a 54.2% growth in squatter households compared to 12.3% in non-squatter households (Hazards Centre, 2000). Recent estimates show that about 77% of the entire population (more than 10 million people) is living in marginal/sub-standard settlements. It is also well known that the socio-economic and the environmental conditions in these settlements are dismal, but only 50% of the housing stock were allotted to them till 1986 (Hazard Centre, 2000). A socio-economic survey of the people living in these settlements revealed that over two-thirds of the households had small families, lived in substandard housing, and did not have access to municipal water supply or sewerage facilities. The majority of the workers were in service jobs and as daily laborers earned less than Rs. 2000 per month (US$45), and travelled by foot or bicycle. About 75% of the workers were in "temporary" jobs and about 56% were "unskilled" (Hazard Centre, 2000). Infrastructure planning and policies in the city have clearly ignored the existence of this population, and this is most evident in the transport infrastructure and transport policies of the city.

Travel modes

Urban transport in Indian cities is heterogeneous, reflecting the heterogeneity in the socio-economic and landuse patterns. It is dominated by walking trips, non-motorized modes such as bicycles and rickshas, and depending on the size of the city, motorized paratransit and public transport. Generally, in all cities, two wheelers have been growing at a rate of 15–20% p.a. Cars have been growing at a rate of 10–15% p.a. Up to 80% of the registered vehicles are motorized two-wheelers (MTWs). Cars account for 5–20% of the total vehicle fleet (RITES 1998a).

If access trips are ignored, the share of walk trips declines, as population and trip lengths increase with city size. Public transport plays a limited role in cities with population up to 1.5–2.0 million. Intermediate public transport (IPT) or paratransit modes, both motorized (three wheeled tempos) and (non-motorized) cycle rickshas play an important role in intra-city travel. Motorized two wheelers satisfy more than 25% of transport demand in all city sizes except for cities with population 5 million and above (RITES 1998a). The share of bicycle trip reduces with increase in city size, however, absolute number of bicycles have been increasing in even mega-cities like Delhi. Numbers of bicycles and cycle rickshas in the city are estimated to be 1.5 million and 110,000–300,000, respectively. Except in Mumbai, where suburban rail plays a major role in providing public transport, the other mega-cities are primarily served by bus-based transport. Skeletal bus services exist in few other million plus cities also.

The entire vehicle fleet, motorized and non-motorized alike, is growing rapidly. From 1975 to 1998, the car population increased from about 68,000 to almost 800,000, and the motorized two wheelers from about 100,000 to almost 2 million (Table 1) in Delhi. The number of bicycles and cycle rickshas is also very large and increasing. It is estimated that as many as

Table1 Motor vehicles in use in Delhi, 1971–2000 (figures shown refer to 1,000s)

Year	Scooters and motorcycles	Cars/jeeps	Auto rickshas	Taxis	Buses	Freight	All motor vehicles
1971	93	57	10	4	3	14	180
1980	334	117	20	6	8	36	521
1990	1077	327	45	5	11	82	1547
2000	1568	852	45	8	18	94	2584

Source: RITES 1998a,b.
Note: Historical data are from Delhi Statistical Handbook and Transport Department, Delhi. Except for 1971 and 1980, they have been revised downward to reflect scrappage of vehicles over time. There are no registration data for 1971 and 1980 to estimate attrition.

300,000 cycle rickshas currently travel on Delhi roads.

Public transportation

Buses form the backbone of the transport system in Delhi. As a generalization, buses are the most economically and environmentally efficient means of providing transport services to the most people. In Delhi, buses constitute less than one percent of the vehicle fleet, but serve about half of all travel demand.

Since 1992, Delhi has turned increasingly to the private sector to help expand and improve bus services. This decision was a response to the widely acknowledged shortcomings of the public bus service, including escalating costs, poor maintenance, high labour costs, an ageing bus fleet, and erratic service. Service was expanded in 1996 by adding more buses, with buses per route increasing from 0.8 to 1.7 (RITES, 1998b). The regular fixed-route bus system now comprises about 4000 privately operated and 3760 publicly operated buses. 5000 private charter buses that provide point-to-point service during peak hours to subscribers who pay a monthly fee for a guaranteed seat complement it. The schools and tourists use another 5000 buses.

Public buses provide a low level of service and comfort, with passengers often travelling on footboards. Large-scale privatisation has increased capacity but buses continue to be overcrowded and poorly maintained. Even though buses carry half of all passenger travel, they receive no preferential treatment in terms of dedicated lanes or traffic management.

The low quality of service is due in large part to the extreme poverty of so many riders. Many Delhi residents cannot afford to pay even the low subsidized fares. Consider that a single one-way bus fare for people living on the outskirts of the city is \$0.20–\$0.25 (Rs.8–Rs.10), depending on the number of transfers. For the poorest 28% of households with monthly incomes of less than Rs. 2000, about US\$40, a single worker would spend 25% or more of their entire monthly income on daily round trip bus fares. For those with incomes much less than Rs 2000, the already-low bus fare is prohibitively expensive (ORG, 1994).

Rickshas and non-motorized vehicles

Indian cities have many three-wheelers that are either motorized (“auto rickshas”), or not (“cycle rickshas”). All are used for commercial reasons rather than personal use. Most carry passengers, but some occasionally carry freight. Cycle rickshas are registered separately from motorized vehicles. Current policies regarding cycle rickshas and other non-motorized vehicles are restrictive based on a notion held by many that efficient (“modern”) transport systems do not include these vehicles. Traffic management experts and traffic police have proposed area and time restrictions on the movement of cycle rickshas in Delhi. The government fixes the number of cycle rickshas that can be registered in the city (by the Municipal Corporation of Delhi) and at present this is 99,000. The registration procedure requires the owner to have a valid registration card, and to register these vehicles only during stipulated times twice a year. Not surprisingly, a large number of cycle rickshas are unregistered. The true number of cycle rickshas in the city is estimated to be about 300,000. Cycle rickshas are also used for delivery of goods such as furniture, refrigerators, and washing machines. Several case studies have documented the poor, often exploitative, working conditions of cycle ricksha operators. Contractors who demand a fixed rental payment from the pullers, often with little regard to the state of the equipment or the environment in which the ricksha puller has to operate, usually own the vehicles. Even though both types of rickshas (and other non-motorized vehicles) are widely viewed as a principal cause of congestion and chaos, they have been ignored in traffic planning and road design.

Inadequate road infrastructure?

Delhi has an extensive road network with a total length of 26, 582 km (year 1996–97) of which approx. 1148 km has a right-of-way 30 m and above. Nearly 500 km of these roads already exist, and the remaining 852 km is proposed in new developments. The Ring Road and the Outer Ring Road are the most important arterials. In general, most arterials are six-lane divided roads. Average speeds have been reducing over the years. Peak hour traffic on arterial roads crawls through bottlenecks at major intersections. However, at non-peak hours, mid-block speeds tend to be much higher, ranging from 50 to 90 km/h for buses and private motorized vehicles, respectively. This leads to higher fatality rates on one hand and on the other, longer waiting periods at junctions. It seems that the problem lies with the poor management of the corridor traffic flow and speeds, resulting in increased levels of congestion at some spots and in a few corridors at peak hours. The traffic system does not meet the requirements of pedestrians, bicyclists and bus systems.

Delhi does not lack in availability of infrastructure in terms of space and length. However, the complexity arises due to the wide variety of vehicle types including humans, animal-drawn vehicles and bicycles that all share the same road space. With the available right of way on arterial corridors in Delhi, a much better level of service and higher throughput can be provided only if the road space available can be used by all vehicles much more efficiently. At present, due to lack of dedicated facilities, bicyclists have to interact with fast moving motorized traffic. Service roads, if present, are not maintained well. Footpaths are either not present or poorly maintained. The road network does not have any facilities for slow moving traffic (bicycles and rickshas), nor are there any dedicated facilities for buses, except sometimes a covered shed for bus stops.

Clearly, the extensive road network has not been developed to serve the mixed traffic present on the roads. Society pays a huge cost in terms of worsening congestion, air pollution and traffic accidents. While the growing congestion and air pollution affect all income groups, the middle and lower income groups who are primarily dependent on public transport, bicycles and walking – the environment friendly modes – have to suffer the unusually high cost of traffic accidents. Commuting patterns of low income and high-income people residing in Delhi are significantly different (Table 2). Since nearly 50–60% of the city population resides in unauthorized slum settlements having an average income of Rs. 2000/month, bicycles, buses and walking will continue to be important modes of transport.

Table 2 Commuting patterns of high and low income households in Delhi (1999)

	High income households[a]	Low income households[b]
Cycle	2.75	38.8
Bus	36.2	31.43
Car	28.35	0
SC/MC	29.29	2.48
Auto	1.74	0.96
Taxi	0.04	0
Rail		1.79
Others		2.34
Walk	1.62	22.12
Total	100.00	100.00

[a]IT survey of high and middle income households (average income Rs. 7000/month).

[b]IIT survey of low income households (average income Rs. 2000/month).

Fig. 1 shows the proportion of trips made by different modes in Delhi (ORG, 1994) and the distribution of fatalities by different road users (Delhi Traffic Police, 1995). These data show that the ratio of fatalities to the proportion of trips is highest for bicycles and the lowest for buses. There are no estimates for the fatalities associated with access to the car or the bus. We can assume that some of the pedestrian fatalities would include those who are bus commuters and only a few who are car users. Therefore, if access to the bus were included in the statistics the proportion of bus commuters getting killed would be more than the 10% shown in Fig. 1. It should be noted that a large proportion of the bus commuters are killed and injured in the process of entering or leaving the bus or when they fall off a moving bus (there are no doors on public buses in Delhi). These injuries and fatalities are frequently reported in the newspapers. The higher risk associated with bus travel must be acting as a deterrent for private vehicle owners to use public transport. These data show that people living in urban poverty, who are heavily dependent on NMVs and public transport, are the main victims of road traffic crashes.

The urban poor, who are also the "transport poor", are responsible for creating environment friendly travel patterns – dependence on non-motorized modes, short trip lengths and a high share of public transport. They themselves do not contribute to the environmental pollution and road accidents; however, they are the victims of road traffic accidents.

Transport infrastructure improvement priorities

Sustainable transportation options rely heavily on promotion of public transport and non-motorized modes. However, the actual policies promoted do not recognize the conflicts inherent in some of the measures suggested. In the name of development, a type of brutalisation of the habitat takes place that sends the already marginalized segment of the population further away to even more remote areas. Investments in transport improvement plans continue to focus on projects that benefit car users, at the cost of environment friendly modes such as NMVs and pedestrians.

The Government of India in 1997 prepared a White Paper on pollution in Delhi (MOE, 1997). Subsequently an Environmental Pollution Control Authority (EPCA) was set up for the city. The policies recommended by EPCA have been driven by environment concerns, aiming to achieve better speeds of motorized vehicles and less polluting fuels. These policies include the following:

1. Construction of expressways and grade separated intersections.

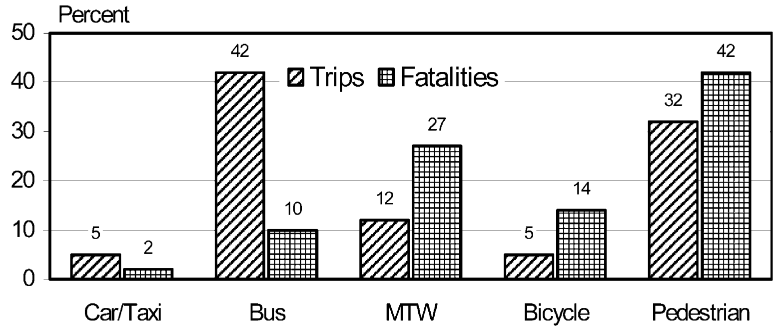

Figure 1 Proportion of trips and road accident fatalities for different road users in Delhi, 1994 (MTW, motorized two-wheeler)

2. Introduction of one-way streets and of synchronized signals and area traffic control systems.
3. Construction of a metro rail transport system.
4. Phasing out of older buses and increases in the number of buses.
5. Entire bus fleet to run on compressed natural gas.

Experiences from several cities suggest that construction of more high capacity roads can have the unintended effect of reductions in public transport and bicycle use without increasing vehicle speeds or reducing congestion on city roads. Reductions in bus and bicycle use would result in higher pollution levels and possible increase in traffic congestion. The experience of large cities in China shows that construction of such high capacity roads has not even improved traffic congestion levels. For example Guangzhou has an orbital expressway and inner ring road and a large number of interchanges. The total number of vehicles is 1 million. However, the average speed on north-south and east-west main roads for 12 hrs in daytime is 18-21 km/h. (Guangzhou Municipal Government, 1999). Beijing has constructed two ring roads and the third ring road is in the process of completion. The city has already constructed 119 flyovers and 202 overpasses. The total number of vehicles is 1.2 million. However, the rush hour average speed on trunk roads is still 13-19 km/h. (Beijing Municipal Environment Protection Bureau, 1999). The road area in Shanghai has been increased by 42% between 1991 and 1997 and 400 roads have been designated as one-way streets. The total number of vehicles is 1.3 million. The average vehicular speeds inside the inner ring road during rush hours are 16 km/h (Shanghai Municipal Government, 1999). Shenzhen has completed construction of 139 km of highways, the total number of vehicles is 250,000, but the rush hour average speed on main roads is 20 km/h (The Municipal Government of Shenzhen City, 1999).

In the past five years, the input to road infrastructure in the large cities has been doubled. Almost all the large city authorities believe that the situation of traffic congestion may be alleviated through road construction. But to date, we are still short of rational study which verifies the relationship between road infrastructure and traffic volume or the ownership of motor vehicles. The traffic volume introduced with road construction may again increase vehicle emissions and cause new traffic congestion, multiplying all the pollutants. So there would be no direct cause-and-effect relationship among infrastructure construction, pollution prevention and environmental protection (Wu Yong and Li Xiaojiang,1999).

Wu and Li's (1999) data show that though the number of public transit vehicles increased in all of the 12 large cities studied in China between 1993 and 1997, while the total number of passengers using public transport decreased in eight of them. Bicycle use has also reduced in cities like Beijing, Shanghai, Shenzhen, Zhuhai, Xiamen and Guangzhou. This could be because bicycle use is being restricted on the major roads in some of these cities in order to promote "smoother" motor-vehicle movement. This decrease in public transport use can be the unintended effect of building of high capacity roads in the city, which increase risks to pedestrians and bicycle users and encourage private motor vehicle use.

No detailed studies have been done to understand the effect of these changes on road user behaviour in Indian cities. However, Mumbai recently completed 52 grade-separated junctions at a cost of Rs. 18 million that have not improved the average speeds of public transport buses. Similarly, in Delhi, completion of 30 new grade separated junctions will not benefit public transport, bicycles or pedestrians. It is possible that in these cities, the construction of high capacity roads at the expense of facilities for public transport and non-motorized traffic may make things worse for everyone. These effects could include a higher incidence of congestion for motorized traffic, higher accident risk for non-motorized traffic, and reductions in public transport and non-motorized traffic.

The Delhi government has approved the construction of 30 new flyovers (grade separated intersections) along several arterial roads at a cost of Rs. 30 million to 300 million each, depending on the design of the flyover. Pedestrians, bicycles and other non-motorized vehicles would not use these facilities. Buses may also avoid using them because commuters who have to change buses would be inconvenienced.

Therefore this major capital investment is expected to benefit only the car user. Ironically, the benefit to car users is also temporary because often the junction following the flyover becomes congested as large volume of traffic is dumped on to it. Similarly, while phasing out older buses and the introduction of compressed natural gas buses may reduce pollution levels in the city initially, new clean technology buses would be more expensive, which may force many bus commuters to shift to using two wheelers, which is more polluting and less safe. At a marginal cost of using a two-wheeler of about 75 paise a km (US$0.015), the monthly expenditure amounts to about Rs. 450 (US$10) per person, assuming 20 km per day for 30 days. Obviously, any public transportation cost higher than this would be resisted by commuters. Since the commuters are already paying this maximum amount, any increase in fares would shift people away from buses. Seven to ten two-wheelers pollute as much as one bus and four occupy as much road space as a bus when in motion. Since each bus carries 50–60 persons, if only 10% of the bus user population start using two-wheelers, it will have the effect of introducing another 10,000 buses on the roads of Delhi in terms of pollution and congestion. If there is more congestion, then all other vehicles will also pollute more. In addition, an increase in numbers of two wheelers could increase the number of road accidents. This means that if all the new buses emitted only clean air, even then the pollution load in Delhi would remain the same or even increase. Therefore, no policy which results in the increase in bus fares is likely to have a beneficial effect on air quality in Delhi, unless arrangements are made to subsidize public transport through innovative local taxation policies.

Socio-economic burden to urban poor

Low-income households spend larger shares of their income on transport, thus affecting their other needs such as food, shelter and health. In a recent survey in selected slums of Delhi, 70% of the residents responded that commuting to work is the most dangerous aspect of their work (Hazards Centre, 1998). They are more vulnerable to events like traffic accidents, because in the absence of any other social network they often have to give up their temporary jobs to get to the hospital to get their relatives treated. In the absence of savings, the economic and emotional costs of traffic accidents to this group of people can be disastrous and may destroy the family economically. There have been instances where families have been forced to sell their meagre assets, give up their temporary jobs and take loans, which take a lifetime to repay.

The “critical” element in city transport systems

Meeting the specific needs of the most vulnerable groups in the city becomes crucial for the efficient performance of all traffic. For low-income people commuting to work, walking, bicycling or affordable public transport are not a matter of choice but a necessity for survival. Therefore, whether the roads have any specific facilities for these modes or not, they continue to be used by them. Delhi traffic laws do not segregate bicycle traffic and enforcement of speed limits is minimal. Motor vehicles (MVs) and non-motorized vehicle (NMVs) have different densities at peak traffic hours at different locations in the city. The existing traffic characteristics, modal mix, location details, geometric design, landuse characteristics, and other operating characteristics present a unique situation where economic and travel demand compulsions have overwhelmed the official plans.

On the two and three lane roads, bicycles primarily use the outermost lane on the left, i.e. curb side lane, and MVs do not use the left most lanes even at low bicycle densities. Bicyclists use the middle lanes only when they have to turn right. Even at one-lane sites, the bicyclists occupy the left extreme, giving space to the motorized vehicular traffic. A study of fourteen locations in Delhi shows that maximum mixing of NMVs and MVs occurs at the bus stops. (Tiwari et al, 1998a). Their interaction with other MVs is minimal at other locations. On three lane roads, the MV flow rates are close to or less than 4000 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 2000 passenger car units per hour per lane (Indian Road Congress; IRC, 1990). Though the peak volumes are not exceeding saturation capacities, we find the average speed remains in the range of 14–39 km/h. This shows that the left most lane (in India traffic keeps to left) is only partially used. However, if this space were exclusively available for bicyclists, throughput would increase because the MV traffic lane is 3.5 m wide and it can accommodate flow rates of at least 6000 bicycles per hour (Replogle, 1991).

On two lanes roads, the MV flow rates are close to or less than saturation values. It is only on the one-lane roads that we find flow rates of 726 bicycles/h and 616 PCU/h. Both these values are approximately one third of their respective saturation capacity values for one lane. Though de facto segregation takes place on two and three lane roads, an unacceptable danger exists to bicyclists because of impact with MVs. At two- and three-lane locations, it is a waste of resources not to provide a separate bicycle lane because bicycles, irrespective of bicycle density, occupy one whole MV lane.

Our data show that bicycle fatalities on two and three lane roads are relatively high when traffic volumes are low but conflicts between MVs and NMVs have very little correlation with fatalities during peak flows. In these locations of “integrated” traffic on two and three lane roads, fatalities during peak hours are low but not eliminated. On the other hand, during non-peak hours vehicles travelling at speeds around

50 km/h or greater kill a large number of bicyclists (Tiwari et al, 1998a).

Since bicycles and other non-motorized vehicles use the left side of the road, buses are unable to use the designated bus lanes and are forced to stop in the middle lane at bus stops. This disrupts the smooth flow of traffic in all lanes and makes bicycling more hazardous. Motorized traffic does not use the curbside lane even when bicycle densities are low. Providing a separate bicycle track would make more space available for motorized modes and bicycling less hazardous.

Infrastructure for buses

Public transport buses are the major mode of transport in Delhi. Approximately 10,000 buses carry 6 million commuters along 600 routes everyday. However, the road design, traffic signals, and traffic management policies are not specifically designed for bus transport. The design and location of the bus shelter itself does not meet the commuters' requirements of providing convenient interchange between bus routes and spaces for hawkers. Therefore, often bus stops and bus shelters result in a major conflict zone between commuters and moving buses while hawkers "encroach upon" the carriage-way, and bicycles and other slow moving vehicles occupy the designated bus stops.

Roadside vendors and services for road users

Bicycles, pedestrians and bus traffic attracts street vendors. Often the side roads and pedestrian paths are occupied by people selling food, drinks and other articles, which are demanded by these road users. Vendors often locate themselves at places that are natural markets for them. A careful analysis of location of vendors, number of vendors at each location and type of services provided them shows the need of that environment, since they work under completely "free market" principles. If the services provided by them were not required at those locations, then they would have no incentive to continue staying there. However, road authorities and city authorities view their existence as illegal. Often the argument is given that the presence of street vendors and hawkers reduces road capacity. If we apply the same principle that is applied for the design of road environment for motorized traffic (especially private cars), then vendors have a valid and legal place in the road environment. Highway design manuals recommend frequency and design of service area for motorized vehicles. Street vendors and hawkers serve the same function for pedestrians, bicyclists and bus users. As long as our urban roads are used by these modes, street vendors will remain inevitable and necessary.

Costs avoided due to investments in pedestrian, bicycle and public transport friendly infrastructure

It is possible to redesign roads to meet the needs of diverse modes existing in Indian cities. This requires not only altering road geometry and traffic management policies but also legitimizing the services provided by the informal sector. The road network has to be designed from the perspective of the pedestrians, bicyclists and public transport vehicles. If the infrastructure designs do not meet the convenience of these users, they are forced to use facilities that are not designed for them, and all users are forced to operate under sub-optimal conditions.

A segregated bicycle lane needs 2.5-m space in Delhi, and this would be used by rickshas also. Since most of the major arterials in Delhi, as well as other Indian cities where planned development has taken place after 1960s, have a service road, the existing road space is wide enough to accommodate a bicycle track. This would not require additional rights of way for the road. A detailed study completed in Delhi shows how existing roads can be redesigned within the given right of way to provide for an exclusive lane for NMVs (bicycles and three wheeled rickshas), a separate pedestrian path, service road and a dedicated bus lane (Tiwari *et al*., 1998b).

The guiding principle of the proposed design is to meet the needs of pedestrians and bicyclists in terms of convenience, safety, and comfort. This enables the existing space to be reorganized for giving priority to public transport – exclusive bus lanes, better designed bus shelters, spaces for vendors, and ricksha parking. These designs benefit all road users.

Benefit estimation

Increased capacity

If a segregated lane is constructed for bicycles, the curbside lane which is currently used by bicyclists becomes available to motorized traffic. This relatively small investment in bicycle lanes can increase the road space for motorized traffic by 50% on three lane roads. Bicycle lanes also result in better space utilization. For instance a 3.5 m wide lane has a carrying capacity of 1800 cars per hour whereas it can carry 5400 bicycles per hour (Replogle, 1991). Average occupancy of a car is 1.15 persons (IRC, 1999) and a bicycle carries one person. This implies that in order to move the same number of people we would need 2.6 times the road area that would be required for bicyclists. Given the fact that there is not much space available to expand existing roads, the future mobility needs and projected trips can only be met by increasing the capacity of the existing road network. This can only be achieved by encouraging modes that are more efficient in terms of space utilization. Motorized vehicles benefit because of improved capacity of the road and improvement in speeds. Capacity estimations of a typical arterial road in Delhi (Tiwari, 1999) show improvement in corridor capacity by 19–23% by providing an exclusive cycle track. If the full capacity of the corridor is utilized, i.e., provision of a high capacity bus lane in the left most lane, it can lead to capacity improvement by 56–73% (present

Figure 2 Competition for space on Delhi's roads between different modes (author)

carrying capacity of 23,000 passengers/h to 45,000 passengers/h).

Improved speeds

Improvement in speeds of motorized vehicles will be experienced until the corridor is full to capacity due to realization of induced demand. Major beneficiaries of speed improvement are buses and two wheelers because curbside lanes become available to them without interference from slow vehicles. Estimations of time savings experienced by bus commuters, car occupants and two wheeler commuters on a typical arterial corridor in Delhi show 48% reduction in time costs due to 50% improvement in bus speeds (from present 15 km/h to 30 km/h) and 30% improvement in car and two wheelers (Katarzyna, 1999).

Reduced congestion

Congestion has long been recognized as an environmental problem. Other than causing delay, it causes noise and fumes and increases health risks to road users and residents. Delhi as well as other Indian cities have invested in grade separated junctions and flyovers as one of the major congestion relief measures at an average cost of Rs. 100 million to 300 million for each intersection. However, detailed simulation of a major intersection in Delhi shows that re-planning the junction to include separate NMV lanes and bus priority lane can bring in 80% improvement over the present level of delays. Cost of this measure is 25 times less than the proposed grade-separated junction (Kartik, 1998).

Increased safety

By creating segregated bicycle lanes and re-designing intersections, conflicts between motorized traffic and bicyclists can be reduced substantially leading to a sharp decrease in the number of accidents and fatalities for bicyclists and motorized two-wheelers. Safety benefits estimated for a typical arterial in Delhi show 46% reduction in accident costs. This is because a segregated facility reduces injury accidents by 40% and fatalities by 50% (Katarzyna, 1998) (Fig. 2).

Conclusions

It is clear from the above discussion that non-motorized modes, which include bicycles, and other modes like rickshas, are an integral part of the transport system in all Indian cities. Public transport vehicles and non-motorized modes are the major modes of transport for the majority of the city residents. The existing socio-economic patterns and landuse distribution ensures the presence of NMVs throughout 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 present on the road, regardless of their numbers, all vehicles move under sub-optimal conditions. Efficient bus systems cannot be designed without taking care of the slow vehicles (NMVs) on the road. Since sustainable transport systems in Indian cities demand moving a large number of people by bus transport and NMVs, planning for NMVs is indispensable.

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