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Urban Passenger Transport: Framework for an Optimal Modal Mix

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Introduction

Indian cities of all sizes face a crisis of urban transport. Despite investments in road infrastructure and plans for land use and transport development, they face problems of congestion, traffic accidents, and air and noise pollution. Large cities are characterized by rapid growth in the number of personal vehicles (two-wheelers and cars). In medium and small cities different forms of intermediate public transport, provided by the informal sector, are struggling to cope with the mobility requirements of the public. Several attempts have been made by planning authorities and experts to address these challenges. A draft urban transport policy has been prepared by the Union Ministry of Urban Development and Poverty Alleviation in 2004. Land-use master plans prepared for most metropolises have a brief chapter on urban transport. However, an integrated urban transport policy based on the citizens' present and future needs has not been formulated. Planning and development of road infrastructure, regulations for private or public vehicles, licensing procedures, and operations of state transport undertakings continue to be done piecemeal and in isolation. Delhi, Mumbai, Kolkata and Chennai have prepared detailed project reports for rail-based mass transport, which are in different stages of implementation. However, the institutional structure required for integrating the system with other modes of transport based on scientific studies that include route and fare rationalization and financial structure of the system has not been developed. Despite increasing investments in road infrastructure, clean-fuel policies, the construction of metro systems, and expansion of roads and flyovers, travel conditions for the average citizen have not changed.

Urban travel demand has to be understood in the context of differentiated urban growth. Large differences in income levels and social disparities characterize our cities, leading to the phenomenon of 'cities within cities'. Each level of the city with its own level of technology and land-use pattern exists in close proximity with others of vastly different patterns. City travel and traffic patterns reflect this. The same road space is used by cars and buses, locally developed vehicles for public transport (three-wheelers), scooters and motorcycles, bicycles, rickshaws, and animal- and human-drawn carts. Such diverse demands require careful understanding and innovative planning. A policy framework for an optimal modal mix should promote innovations in road design, institutional structure, vehicle design, and financial schemes. It should include indices and measures to reflect the needs of heterogeneous travel patterns and traffic, reflecting concerns about mobility, environment, and safety of all city residents equitably.

Key Issues

Travel Demand and the Transport System

An urban transportation system is a complex structure defined by land-use and transport policies. Transportation includes all modes of mobility—pedestrians, bicyclists, rickshaws, two-wheelers, cars, buses, and rail-based systems. As the city size increases, travel patterns change in terms of trip lengths and modal choice.

Our infrastructure design often decides the convenience of using certain modes. For example, around 40–50% of the urban trips are walking and bicycle trips of 5 km or less. But current road design promotes use of cars and two-wheelers and discourages walking and bicycling by choice. Use of public transport also is influenced by infrastructure design. For example, location and design of bus stops and access to bus stops or railway (metro) stations are important factors influencing use of the bus or metro; pricing and institutional structures being other considerations. The travel demand of people who have limited choices because of their socioeconomic characteristics is another complex factor. In a hostile physical environment, people continue to walk and use bicycles in most Indian cities. Rickshaws and other forms of para-transit also exist in many cities, defying all regulatory measures.

An understanding of the individual demand vis-à-vis the system characteristics is necessary for achieving a socially optimal modal mix for a city.

Mobility, Safety, and Pollution

A second level of complexity in the urban transport system comes from the conflicting requirements between mobility (faster travel) vis-à-vis safety and pollution. Those with access to faster travel perceive benefits in speed enhancement strategies (wider roads, flyovers, elevated roads). However, higher speeds increase the probability of accidents. Often, the impact of transportation on environment and safety is considered as an afterthought. Bicycle and walking trips are not considered alongside motorized vehicle trips for traffic analysis. Policies based on this limited analysis adversely affect the health of a large section of the population.

Urban Travel Demand

Diversity and socioeconomic heterogeneity characterize our cities, with 10–50% of the population living in slums. The informal sector grows alongside the formal sector, first because of rural-urban migration, attracted by better employment opportunities in urban areas. The formal sector benefits from the informal sector. Integration of the informal sector in city planning has a direct impact on modal shares, trip patterns, risk of traffic accidents, and air pollution. Current urban development policies and plans do not, however, address the needs of the informal sector adequately. Almost all cities have slum populations occupying land that is not earmarked for them.

Larger cities have more slums and squatter settlements. In the million-plus and mega-cities of India, 40–50% of the population lives in this informal housing. Rising cost of transport and long working hours force the workers to live close to their work place. Relocated people, 10–15 km away from their previous residence, have reduced access to jobs because all walking trips have to change to motorized trips, which implies increased travel time and expense.

Heterogeneous Traffic

The share of motorized trips, for example, increases with city size (see Table 1). Nevertheless, low-cost modes, which include walking, nonmotorized rickshaws, and bicycles, continue to play an important role. The share of walk trips ranges from 37% in a city of 100,000 population to 28% in mega-cities with a population of 10 million. Though the share of bicycles and other nonmotorized vehicles declines with increase in city size, they still remain important since each public-transport trip involves at least two walking trips. Low-cost trips, including public transport trips, range from 65% to 82%. This pattern is likely to persist in the near future, to go by the travel data from Delhi and Mumbai.

Bicycles and walking account for 66% of the commuting trips for those in the informal sector, whereas those in the formal sector depend more on buses, cars, and two-wheelers. Despite high risks and a hostile infrastructure, users of low-cost modes of transport lack choice.

Table 1. Model Transport Share in Different City Sizes

City size (Population in million)	*Walk*	*Public Transport*	*Three-wheeler Taxi*	*Rickshaw*	*Car*	*MTW*	*Bicycle*
A (0.1–0.5)	37	10	7	13	2	15	16
B (0.1–0.5)	38	14	6	11	2	20	14
C (0.5–1)	31	18	6	8	7	20	11
D (1–2)	30	22	4	6	2	28	8
E (2–5)	29	30	4	2	4	21	11
F (>5)	29	44	2	3	4	10	7

Note: MTW = Motorized two-wheeler
Source: RITES, 1998, *Traffic and Transportation Policies and Strategies in Urban Areas in India*, final report prepared for the Ministry of Urban Affairs and Employment, Government of India.

Role of the Informal Sector and Para-transit

Urban travel in India comprises predominantly walking, cycling, and use of public transport, including intermediate public transport. Cities with a poor public transport system have a higher presence of para-transit and private modes. Though in some cities private buses have been introduced recently, bus transport operation is predominantly in the public sector. In medium cities like Hubli, Varanasi, Kanpur, Vijayawada, etc., a lower level of bus availability necessitates intermediate public transport modes like tempos, autos, and cycle-rickshaws.

Since subsidized public transport systems remain cost-prohibitive for a large segment of the population, market mechanisms may successfully reduce the level of subsidies. On the other hand, that would restrict transport options for city residents.

In the future, bicycles and nonmotorized vehicles will continue to carry out a large number of trips in cities of all sizes. Public transport trips will be in the range of 25–35% and walking trips will constitute 50–60% of total trips. Despite a high share of walk trips and trips by nonmotorized modes, the transport infrastructure does not include any facilities for these modes. With the exception of a few cities, most of the major road networks have not been provided with footpaths.

Policy Options

Different Indian cities are either implementing or looking at new transport systems, be it metro, high-capacity buses, or the skybus. The argument given for introducing new technologies is to serve the high-density demands expected in a few corridors in the city. The following characteristics of various systems are important in deciding the optimal system.

Line Capacity

Capacity is the number of people who can be transported per hour. Rail-based systems like metro, light rail transit (LRT), skybus, monorail, etc. have an exclusive line, not interrupted by traffic signals. The capacity of each carriage, the number of carriages in each train, and the frequency of trains decide the capacity of the system. Longer trains have a larger capacity but require longer platforms. The capacity of road-based systems depends on the number of buses that can pass through each signal cycle. If the bus-shelter design allows 10 buses to simultaneously board and alight and pass through in one cycle, then for a 180-seconds cycle, the bus system can have a capacity of 20,000 passengers per hour. With modified road design, bus-shelter design and signal systems, the bus system can cater for 35,000 passengers per hour. Often, in a 1–2 km wide stretch there are two or three arterial/major roads. If each road provides a bus system giving 20,000 passengers per hour, a 40,000 to 60,000 passengers-per-hour capacity can be provided by a road-based bus system.

Commercial Speed

The average speed of a public transport system depends on the frequency of stops, since acceleration cannot exceed 1m/sec/sec because in peak hours the public transport system is expected to carry standing passengers. If rail-based systems (metro, LRT, skybus, etc.) have stops at an average spacing of 1 km, the expected speed is 35–45 km/h. If the average spacing of stops is changed to every 500 m, it increases the catchment area of the system but the average speed may reduce to 20–25 km/h. This is true of bus systems also. Buses have to move on roads with other traffic, therefore the average speed depends upon the frequency of stops and intersections. If bus-stop locations are integrated with intersection design, an average speed of 20–25 km/h can be achieved with bus stops at every 500 m. Higher speeds are possible if express bus services are introduced that do not stop at every bus stop. The tradeoff between higher speed and higher catchment area is important for deciding upon optimal public transport systems.

Cost

System cost varies for both fixed and operating cost. Rail-based systems have 10–20 times fixed-cost requirements more than road-based systems. They also have a higher operating cost because of a larger infrastructure to be maintained and the requirement for more skilled staff.

Construction Time

International experience shows that rail-based systems require three to four times the construction time that road-based systems require.

System Demand

Demand for public transport depends upon the ease of access, total trip length and ticket cost. Optimal trip lengths for different modes based on desirable access time vary from 1.8 km for two-wheelers, 2.5 km for three-wheelers, 4.8 km for car, 7 km for taxi, 6.5 km for bus and 14 km for metro. Commuters prefer shorter walking distances, usually less than half a kilometer. The access time required for a rail-based system is higher than for a road-based system; therefore, usually trips that are more than 10–15 km long are suitable for a rail-based system. In mega-cities like Delhi and Mumbai 20% of the trips are more than 15 km. Rail-based systems can effectively meet this demand, provided that the majority of these long trips originate and terminate within half a kilometer of the rail corridor.

Load Factor

Load factor is defined as the number of actual users as a ratio of available capacity. The number of actual users depends upon trip length, access time, and travel cost. If load factor is much less than one, the gap between revenue and cost is large, necessitating higher subsidies. It also means waste of scarce resources.

Cost per Passenger

A load factor close to one achieves low cost per passenger. It also leads to least space consumption, least energy consumption, least emission, and least accidents per passenger kilometer.

Comparative Assessment

Table 2 presents the various parameters for selected mass transport

Table 2. Summary of Characteristics of Alternative Mass Transport Systems

Characteristics	*LRT*	*Metro*	*BRT*	*Skybus*
Line capacity (Passengers/hr)	20,000–25,000	40,000–70,000	20,000–35,000	20,000?
Commercial speed (km/h)	15–40	24–55	25–30	30–60?
Infrastructure cost (Rs. crore/km)	100	150–300	10–20	50
Average cost/trip (Rs.)	30	45–50	10–15	20–25
Required corridor density (Persons/ha)	Medium (150–200)	High (250–300)	Medium (current Indian cities)	Medium
Required minimum trip length (km)	15	15	5	10–15
Catchment area	Medium-low	Low	High	Medium-low
Segregation	At grade-elevated	Elevated-underground	At grade	Elevated
Space required	2–3 lanes from existing traffic	2 lanes for elevated	2–4 lanes	2 lanes
Impact on road traffic	Policy dependent	No impact	Reduced congestion for buses	Policy dependent
Current applications	European cities	N. America, Europe, limited in Asia	Extensive in Latin America	Nowhere
Flexibility	Low	Very low	Very high	Low
Integration with buses/para-transit	Required	Necessary	Desirable	Required

Note: LRT = light rail transit; BRT = bus rapid transit.
Source: Author.

systems. The utility of any of these systems has to be judged in terms of how well it serves the individual trip, how many people can benefit for the same investment, and how flexible it is in meeting the changing demands of the city. Optimal capacity is one that best fulfils travel demand. Travel demand depends upon city size, trip lengths, location, density of jobs and residences and other socioeconomic conditions. System demand depends upon the ease of access, low fares, and dependability. A high-capacity system succeeds if there is demand for it within walking or easily accessible distance. Only long-distance travelers (trip length at least 15 km) are likely to use a feeder mode for the metro as a viable travel option. Therefore, improving access to the metro requires a very high-density development within its catchment area. In Hong Kong and Singapore high-rise buildings along the metro corridor provide a high density of residences as well as jobs, which promotes the use of the metro. Indian cities have high-density development in the form of urban slums. Since even a subsidized metro system is too expensive for slum dwellers, the demand for the metro system in Indian cities is low. The Kolkata, Chennai, and Delhi metro systems carry less than 20% of the available capacity. The metro, the LRT and the skybus are all capital-intensive systems. For the cost of constructing a kilometer length of the metro system (~Rs. 200–300 crore/km), a 30–50 km long bus network can be developed, including modern buses. This would benefit 30–50 times more people than a metro system. The cost of a single metro trip is at least Rs. 45 compared to Rs. 15 for a bus trip. Metro tickets have to be subsidized by at least 10–15 times the cost of a bus ticket. The system will need subsidies to earn operating cost from fare box revenues if the users' (household) income is less than Rs. 40,000–50,000 per month.

In a road-based mass transport system, at a cost of a tenth or 1/20th of the cost of other mass transport systems, a high-quality public transport system can be provided within walking distance. Since its catchment area depends on the extent of the road network, it is capable of reaching almost 80% of the city population. Since access to it includes improved and safe pedestrian paths, it can match the convenience and flexibility provided by private modes. Bogota and Curitiba, both considered cities with model public transport systems, are expanding their bus rapid transit (BRT) system to cover the whole city by public transport which does not require subsidy, restricts car usage, and has made a major impact on safety, pollution, and energy consumption.

Several Indian cities have constructed or are planning flyovers. The justification for flyover construction is to reduce delays at intersections and provide uninterrupted movement to long-distance traffic. But flyover construction improves journey time at a small section of the road for cars, which are only 20–25% of the commuter trips in a city like Delhi and less than 20% in other cities. On the other hand, flyover construction adversely affects bus commuters. Because bus-stop locations are shifted away from the intersection, their walking distance to change buses going in different directions increases. The increase in the speed of vehicles on the road also makes it difficult for bus commuters and pedestrians to cross the road. A result is that flyovers encourage people to use cars and two-wheelers and move away from public transport, walking and bicycling, leading to more vehicles, congestion, and pollution on the roads. Experience from several Chinese and other Asian cities bears this out.

Recommendations

Nonmotorized Vehicles Infrastructure

Users of low-cost transport modes like pedestrians, bicyclists, and public transport commuters are captive users (people without choice). If the infrastructure design ignores their needs, and traffic laws restrict their movements, they are often forced to defy laws and continue to use the road infrastructure, exposing themselves to high risk. This also forces motorized vehicles to operate in sub-optimal conditions. Therefore, the needs of nonmotorized users must be given priority.

Public Transport System

Desired transport modes for different trip lengths based on access time and total travel time are shown in Table 3.

Regardless of city size, half of the trips are less than 5 km long. Nearly 70% of the trips are less than 10 km long. Therefore, priority must be given to the infrastructure required for walking, bicycling, and road-based public transport systems. A majority of the cities will have travel demand that can be met by road-based mass transport systems. In cities having 8.5 million population only 3% of the network may

Table 3. Desired Transport Modes for Different Trip Lengths

Trip length (km)	0–2	2–5	5–10	10–15	> 15
Share of trips (%)	25–50	20–25	15–20	10–15	>15
Desired travel modes	Walk, bicycle, two-wheeler, cycle rickshaw	Bicycle, two-wheeler, car, cycle rickshaw	Bicycle, two-wheeler, car, three-wheeler, bus, taxi	Car, bus, taxi, metro/rail based	Car, express bus, metro/rail based system, taxi

Source: Author.

have demand exceeding 40,000 persons per hour. This too can be met if two or three parallel road corridors are available for the bus system. Therefore, modern bus systems have to be planned and implemented as a priority in all cities.

Infrastructure, both physical and institutional, which enables efficient three-wheeler and taxi systems, will reduce dependence on private modes like car and two-wheelers, which have a very high social cost. Only 15% of the trips are more than 15 km long. For mega-cities that have more than 10 million people, 15% translates into 1.5 million trips. This may be a case for exploring the feasibility of a rail-based system provided the transport corridor has the required density of residences and jobs within its catchment area. Such a system, however, must be complemented by other modes, otherwise 85% of the trips will remain outside its catchment area.

Priorities for optimal modal transport mix for different city sizes, summarized below, are also tabulated in Table 4.

- *City size 0.1–0.25 million population*: In the short term nonmotorized vehicles (public and private) infrastructure is required, and in the medium and long term nonmotorized vehicles and motorized intermediate public transport. This needs road planning, traffic calming, regulatory mechanisms for safe and clean intermediate public transport.
- *City size 0.25–0.50 million population*: In the short and medium term, in addition to the strategies for city size 0.1–0.25 million population, bus systems are required. Future actions should include planning for a formal bus system.
- *City size 0.50–1.0 million population*: In the short term nonmotorized vehicles, motorized intermediate public transport, and public transport (buses) are required. Medium- and long-term strategies include nonmotorized vehicles infrastructure, motorized intermediate public transport (feeder trips), high-capacity bus system, and rationalization of private vehicle parking. Future actions include planning for high-capacity bus systems.
- *City Size 1.0–5.0 million population*: In the short term nonmotorized vehicles, motorized intermediate public transport (feeder trips), high-capacity bus system, and rationalized private vehicle parking strategies are required. Medium- and long-term strategies include nonmotorized vehicles infrastructure, and high-

Table 4. Action Priority for Optimal Modal Mix

City Size (Population in million)	*Strategies*		
	Actions required	*Short term*	*Medium and long term*
0.1–0.25 and 0.25–0.5	Road planning, traffic calming, regulatory mechanisms for safe and clean IPT	Road design standards to be provided by PWD and development authorities; capacity building for creating NMV infrastructure	Master plans and target setting for NMV; regulatory authorities for setting performance standards; public transport authorities for formal bus system
0.50–1.0	In addition to the above, planning for HCBS	Special design cells in development authorities and municipalities, NMV and safety audit mandatory	Master plans with targets for achieving safe accessibility; public transport authority for planning NMV, motorized IPT (feeder trips),HCBS PT (buses), rationalized private vehicle parking
1.0–5.0	In addition to the above, planning for one or two rail corridors	NMV, Motorized IPT (feeder trips), HCBS PT (buses), rationalized private vehicle parking	NMV, HCBS expansion and integration with rail-based system
>5.0	Same as above	NMV audit mandatory for all infrastructure construction, SPC for preparing master plans and priority implementation for HCBS PT (buses), regulatory authority for motorized IPT (feeder trips), and taxi systems; rationalized private vehicle parking	Urban transport authority for integrating land use with transport plans; planning taxi system with IT support; HCBS expansion and integration with rail-based system; congestion pricing; interdisciplinary research groups established in 5–6 research institutions

Notes: PWD = Public Works Department; NMV = nonmotorized vehicles; HCBS PT = high-capacity bus system public transport; IPT = intermediate public transport; SPC = special purpose company (set up by the government for project implementation and management).

Source: Author.

capacity bus system expansion and integration with rail-based system serving intercity trips with satellite towns. Planning for one or two rail corridors to be implemented in future may be required.

- *City size > 5.0 million population*: In the short term nonmotorized vehicles, motorized intermediate public transport (feeder trips), and taxi systems, high-capacity bus system, and rationalized private vehicle parking strategies are needed. In the medium and long term nonmotorized vehicles, taxi system with information technology (IT) support, high-capacity bus system expansion, and integration with rail-based system serving intercity trips with satellite towns, congestion pricing strategies are required.

Required Institutions and Policy Processes

Current institutional arrangements and administrative procedures do not adequately ensure the participation of all stakeholders in general, and vulnerable groups like the informal sector and low-income groups in particular, in ensuring an optimal modal mix leading to a sustainable transport system. Changes in institutional arrangements, processes, methodologies, and expertise are necessary to ensure participatory processes with representation from all stakeholders in the city. Some of the measures that can be instituted in the short term are given below.

Legislative Requirements

Legislation is required to ensure that the rights of pedestrians and bicyclists are honored when any new transport scheme is implemented. This means that every transport project in the city should show that distance, time, and opportunities for pedestrians and bicyclists will improve because of the project.

Legislation is also required to introduce a city-level authority to plan, operate, and run public transport systems like high-capacity bus systems or rail-based systems in partnership with all stakeholders. There should be legislation for all travel data collected by local, state, or central governments to be made publicly available. Public scrutiny would improve the quality of data collected. Similarly, traffic accident data and air pollution data should be made public. Legislative reforms should be carried out by the central government and locally notified by each state as in the case of the Motor Vehicle Act. Central and state governments may introduce incentives of offering matching funds to city governments if their transport scheme satisfies a set of criteria that ensure the participation of all stakeholders and take into account the impact on pedestrians, bicyclists, and public transport users.

Institutional Requirements

New institutions are required at city and state levels. State-level institutions should coordinate the policies and plans required at regional levels, beyond city boundaries. They would be responsible for linking land-use plan with transport plans, and implementing regulations pertaining to environment and safety. State- and city-level institutions for urban transport should set targets and prepare resource plans for achieving the desired level of accessibility and safety. City-level institutions are required for planning, implementing, and operating public transport systems. Existing state-level institutions like town and country planning organizations, or city-level institutions like development authorities should be reorganized to deal with the complexities of urbanization and transport systems. They should have targeted capacity building programs, and linkages with state- or national-level academic institutions. Surveys and studies undertaken by these should be made publicly available to ensure that the interests of the informal sector and vulnerable groups are adequately represented in them. State-level institutions should produce standards and manuals for land-use plans, road development, and geometric standards for implementing agencies. At least five or six interdisciplinary groups should be set up in academic institutions to work on issues related to urban transport such as transport economics, public transport systems, public-private partnerships in urban public transport, transport management, and traffic safety.

Administrative Requirements

Cities must use the enabling clauses from the 74th amendment of the Constitution to bring governance and decision-making to the local level. This will ensure meaningful participation of all stakeholders in transport planning and policies. The administration of city-level implementing agencies like traffic police, the transport department, and the public works department should have cells that have expertise in modern road design, traffic management systems, and management of transport services.