

To develop a framework for modeling the optimal modal mix for urban passenger transport, given considerations of congestion, pollution and lack of safety

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1.0 Introduction

Indian cities of all sizes face a crisis of urban transport. Despite investments in road infrastructure, and plans for landuse and transport development, all cities face the problem of congestion, traffic accidents air and noise pollution. All these problems are on the increase. Large cities are facing a rapid growth of personal vehicles (two wheelers and cars) and in medium and small cities different forms of intermediate public transport provided by the informal sector is struggling to meet the mobility demands of city residents. Several attempts have been made by planning authorities and experts to address these problems. RITES has summarized urban transport policy related studies since 1939 (RITES,1998)¹. A draft urban transport policy has been prepared by the ministry of urban development and poverty alleviation in 2004. Landuse masterplans prepared for most metropolitan cities have a brief chapter on urban transport. However, an integrated urban transport policy based on the present and future needs of the citizens 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 in piece-meal and isolation. Delhi, Mumbai, Kolkatta and Chennai have prepared detailed project reports for rail based mass transport.They 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, and the construction metros and flyovers, travel conditions for an 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. This has led to the development of 'cities within cities'. Each level of the city with its own level of technology and land-use pattern exists in close geographical proximity with others of a vastly different patterns. This is reflected in travel and traffic patterns existing in cities. The same road space is used by modern cars, buses, along with locally developed vehicles for public transport (three wheelers), scooters and motorcycles, bicycles, rickshaws, animal-and human driven carts. This requires careful understanding and innovative planning to meet such diverse demands. A policy framework for an optimal modal mix in this context should promote innovations in road design, institutional modifications, suitable vehicles designs and innovative financial schemes. Therefore the proposed framework for designing an optimal modal mix should include indices and measures to reflect the needs of heterogeneous travel patterns and traffic reflecting mobility, environment and safety concerns to all city residents equitably. This should lead to a modal mix - choice of technologies, which minimises pollution and traffic accidents and maximizes accessibility and mobility.

Section 1 lays down the systems framework to highlight the complexities of urban transport. Section 2 discusses the differentiated demand and heterogeneous traffic existing in our cities. Section 3 presents a comparison of alternate transport solutions for urban transport. Section 4 proposes urban transport priorities for different sized cities which need to ensure accessibility and optimal mobility with a minimum of pollution and the least number of accidents. Section 5 the discusses institutional mechanisms required to achieve the optimal mobility levels in our cities.

1.1 The Systems Framework

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3 *This report was prepared by consultants for the Asian Development Bank. The views expressed in this report are the views of the authors and do not necessarily reflect the views or policies of the Asian Development Bank (ADB), or its Board of Governors, or the governments they represent. ADB does not guarantee the accuracy of the data included in this paper and accepts no responsibility for any consequence of their use.*

Urban transportation system is a complex structure defined by land use and transport policies. Transportation includes all modes of mobility. This includes 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. The travel pattern of different cities shows that around 40-50% of the total urban trips are walking and bicycle trips and are less than 5 kms in length. Mumbai a city of 16 million people has 42% walking trips and Pune with a population of 3 million has 32% walking trips and 13 % bicycle trips, all less than 5 kms in length. As a city expands, trip lengths increase; however the majority remain short trips below 5 km long; about 15 to 20% of the trips are more than 15 kms long. Motorised modes are suitable for these trips.

All elements of the transportation system must be considered - the persons and things being transported; the vehicles in which they are conveyed, the network of facilities through which the vehicles, passengers and cargo move including terminals and transfer points as well as line-level facilities. Facilities at transfer points are crucial for the use of public transport.

All movements and their impacts through the system must be considered. If movement by one mode of transport improves it has a direct or sometimes indirect impact on the other modes. Higher speeds of motorised traffic impose a higher risk to pedestrians and therefore may inhibit walking trips.

For each specific flow, the total trip from the point of origin to the final destination, overall modes and facilities must be considered. Such a comprehensive definition of the transportation system enables the analyst to consider explicitly the assumptions introduced by eliminating individual elements of a highly complex and interrelated system. The complexity of a transport system must be understood at two levels. These are described in sections 1.2 and 1.3 respectively.

1.2 Travel demand and The transport system

The number of trips by different modes that we observe on the network is a result of individual decision to travel to maximize their own utility. This depends on the time and money that an individual is willing to spend. However, it also depends on the availability of modes of travel ranging from walking, bicycling, two wheelers, three wheelers, buses or trains. Often our infrastructure design decides the convenience of using certain modes. For example, current road designs in Indian cities are suitable for cars and two wheelers, and hostile for walking and bicycling. This promotes usage of cars and two wheelers and discourages walking and bicycling by choice. Use of public transport is also influenced by the infrastructure design; for example location and design of bus stops, access to bus stop or the railway(metro) station, is one of the important factors influencing the bus or metro usage along with pricing and institutional structures. The travel demand of people who have limited choices because of their socio-economic characteristics presents another dimension of complexity in the system. The system characteristics in terms of physical infrastructures and institutional regulations have a limited effect on their travel choices. In a hostile physical environment people continue to walk and use bicycles in most Indian cities. Rickshaws and other forms of paratransit exists in many cities defying all regulatory measures.

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

1.3 Mobility, Safety and Pollution

The second level of complexity in urban transport system comes from the conflicting requirements between mobility(faster travel), safety and pollution. Individuals who have access to faster travel perceive benefits of speed enhancement strategies(wider roads, flyovers, elevated roads), however, higher speeds result in higher probability of accidents for vehicle occupants as well as people outside the vehicles. Models based on mobility related indicators such as the number of vehicular trips, average journey speeds, total vehicle kilometre travelled etc., which are easily quantified and analysed cannot lead to an optimal modal mix. These indicators are biased towards mobility provided by motorized travel. Often transportation impact on environment and safety are considered as an afterthought. Bicycle and walking trips are not considered alongside motorized vehicle trips for traffic analyses. This is a major lacuna. Policies based on this limited analyses lead to adverse health impacts on a large section of the population.

Annexure I explains the complexity existing between mobility, safety and the environmental concern in urban transport using Delhi as a case study. Construction of grade separated

junctions and signal free arterial roads may have improved the speeds of motorised vehicles in the short term; however, these measures have imposed higher risks on pedestrians who are forced to use the same infrastructure. In the long term, transport strategies which aim at reducing congestion for cars/ personalised vehicular traffic have been found to be ineffective, because, more people opt for cars and congestion levels increase. Similarly, the conversion of complete public transport fleet to compressed natural gas and limitation on the age of public transport may have reduced public transport fleet in the city and increased use of motorised two wheelers which may contribute to more pollution and accidents in the city.

2. URBAN TRAVEL DEMAND

2.1 Urbanization Pattern in India

Urbanization in India has been relatively slow, yet it is one of the largest urban systems. With the growth in the economy the rate of urbanization is expected to increase. The challenge to meet the future travel demand lies in understanding the character of our cities. These cities are characterized by diversity and heterogeneity in socio economic conditions. Often 10%-50% of the population live in slums. The slum population seems to grow as the city size increases.

The large cities- million plus population- are agglomerations of several small cities having multiple economies, in close proximity to each other. One economy serves the needs of the affluent and features modern technologies, formal markets, and the outward appearance of developed countries. The other serves disadvantaged groups and is marked by traditional technologies, informal markets, has the marks of economic and political deprivation.

The growth of the formal sector is accompanied by the growth of the informal sector. The informal sector develops firstly because of rural-urban migration which is based on better employment opportunities in urban areas. The formal sector in urban areas requires support of unskilled labour provided by the migrants from the rural areas. Construction labour, casual labour in factories and commercial establishments depend on migrant labour. Higher income families require domestic help, gardeners, carpenters, plumbers, electricians etc. for normal functioning. Often in Indian cities squatter settlements develop inside the city close to commercial centers, planned housing developments, and factories. Soon these settlements demand all kinds of services needed by the residents: low cost food, vegetables, tailors, etc. It is a common sight in Indian cities to have street vendors along the roads selling food, toys, flowers, and various handicrafts made by family members. Thus the informal sector provides employment opportunities to each and every family member. The growth of formal sector is accompanied with the growth of informal sector, with the latter showing higher growth rates than the formal sector.

Integration of informal sector in city planning has direct impact on modal shares, trip patterns, risks of traffic accidents and air pollution. Current urban development policies and plans do not address the needs of informal sector adequately. Almost all cities have slum population occupying land which is not earmarked for them.

City	Total population	Slum population(million)/ %
Greater Mumbai	12	5.8 49%
Delhi municipal Corporation	10	1.8 19%
Kolkata	5	1.4 33%
Bangalore	4	0.3 8%
Chennai	4	0.7 18%
Ahemdabad	4	0.4 13%
Hyderabad	3	0.6 17%
Pune	3	0.5 21%
Kanpur	3	0.3 15%
Agra	1	0.1 10%
Varanasi	1	0.1 13%
Meerut	1	0.4 44%

Census of India, 2001²

The city growth is almost always accompanied with the expanding size of the urban 'informal economy'. Larger cities have more slums and squatter settlements. In the millionplus and

megacities of India, 40%-50% of the population lives in these informal housing (Misra, 1998³). The rising cost of transport within the city and long working hours force the workers to live in proximity to their work place. 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 have been planned. The growth rate of the squatter households, as compared to that of the non-squatters is nearly four times higher in Delhi— we see a 54.2% growth in squatter households compared to 12.3% in non-squatter households (Hazards Centre, 1999⁴). Recent estimates show that about 77% of the entire population in Delhi is living in marginal/sub-standard settlements.

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 labourers earned less than Rs. 2000 per month, and travelled by foot or bicycle. About 75% of the workers were in “temporary” jobs and about 56% were “unskilled” (Hazard Centre, 1999). This section of the urban population is captive user of low cost travel modes (walking and bicycles) because many of these residents cannot afford to pay even the low subsidized fares for buses. For the poorest 28% of households with monthly incomes of less than Rs. 2000, 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.

Annexure II describes the impact of eviction and resettlement policies in Delhi. People who have been relocated have reduced access to jobs because the new residential locations are 10-15kms away from their previous residence. All walking trips have to change to motorised trips. Often increased distance from the work place has meant increased travel time and expenses along with increased motorised trips.

2.2 Heterogeneous Traffic

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

Characteristics of the urban transport in cities change with the city size. The share of motorised trips increase with city size as shown in Table 2; however, low cost modes which includes walking, non-motorised rickshaws and cycles continue to play an important role. The share of walk trips ranges from 37% in a city of 100,000 population to 28% in megacities with a population of 10 million. The share of cycles and other non-motorised vehicles reduce with increase in city size; however, since each public transport trip involves at least two walking trips the importance of non-motorised trips cannot be minimized. Low cost trips including public transport trips range from 65% to 82%.

This pattern is not expected to change significantly in the near future as is evident from the

Table 2 Modal Share in Different City Size (RITES 1998)

City size	walk	Public Transport	Three WheelT axi	Ricksha w	Cars	MTW	Cycle
A	37	10	7	13	2	15	16
B	38	14	6	11	2	20	14
C	31	18	6	8	7	20	11
D	30	22	4	6	2	28	8
E	29	30	4	2	4	21	11
F	29	44	2	3	4	10	7

City size = A and B: 0.1-0.5, C: 0.5-1, D: 1-2, E: 2-5, F: above 5 million population

MTW: Motorised two wheeler

travel data from Delhi and Mumbai. If Delhi with the highest number of private vehicle ownership (cars and two wheelers) has 82% trips by low cost modes, the dependence on low cost modes will remain much higher in other cities despite growth in private vehicles.

Table 3 : Modal shares in Selected cities

Cities	Walk	Bicycle	Motorised Two wheelers	Cars	Bus	Train	Rickshaw	Three wheeler	Taxi
Delhi 4	14	24	13	11	33			1	
Mumbai 5	43.8	3.1	8.5	2.7	16.1	22.7		1.8	
Pune 6	31	13	28	6	15	.2		7	
Hyderabad 7	22	12*	49	2	11		*	4	

* Includes rickshaw

Table 4: Trip Length Distribution (%) in Selected cities

Cities	< 2 Km	2-5 Km	5-10 km	10-15 Km	> 15 km
Delhi	11	29	35	22	3
Mumbai	43	25	12	8	9
Pune	16	60	20	4	
Hyderabad	32	33	22	6	6

2.3 Captive Users

Travel patterns of people living in informal housing or slums are very different from residents in formal housing (Table 5). Bicycles and walking account for 66% of the commuting trips for those in the informal sector, whereas those in the formal sector are dependent on buses, cars and two wheelers. This implies that despite high risks and a hostile infrastructure, low cost modes exist because users of these modes do not have any choice, as they are the captive users of low cost modes.

Table 5 Commuting patterns of high and low income households in Delhi (1999) and Mumbai(2004)

	High income households ^a		Low income households ^b	
	Delhi	Mumbai	Delhi	Mumbai
Cycle	3	3.5	39	6
Bus	36	15	32	14.5
Car	28	3.6	0	0
SC/MC	29	8.5	3	.7
Auto	2	2.1	1	1.3
Rail		21	2	16
Others		1.1	2	
Walk	2	45	22	61

^a IIT ⁵ survey of high and middle income households (average income Rs. 7000/month).

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

^c Baker, J. et al (2004) ⁶

2.4 Role of Informal Sector and Paratransit

Urban travel in Indian cities is predominantly walking, cycling and public transport including intermediate public transport(IPT) as shown shown in Table 6. The variation in modal shares among these three modes seem to have relationship between city size and per capita income. Small and medium size cities(Kanpur, Ahmedabad) have a lower income than mega cities therefore dependence on cycle rickshaws and cycles is more than in larger cities. Delhi is showing declining trends of three wheeler population because of restriction on fuel and age of public transport vehicles. All three wheelers are required to run on CNG and should be less than eight years old as per the orders of the court.

Table 6 :Existing Modal Split For Intra-City Trips By Mechanical Modes In Various Cities					
City	Percentage of Trips By				
	Public Tpt	IPT Fast	IPT Slow	Private Vehicles Fast	Cycles
Shimla	86	-	-	14	-

4 IIT survey, 1999

5 Baker, J. 2004

6 PMC, 2004, Comprehensive Traffic &Transportation Study for Pune, by SPAN Travers Morgan International, for PMC

7 MMTS Phase-II study, 2004 by L & T Ramboll

Guruvayur	64	6	1	25	5
Agartala	15	16	33	15	21
Panipat	1	9	31	35	24
Tirupur	28	1	-	54	17
Udaipur	6	11	-	49	34
Rourkela	36	5	4	30	25
Guwahati	47	6	9	32	6
Hubli-Dharwad	50	5	5	32	10
Dhanbad	27	21	9	32	11
Vijaywada	34	1	5	35	25
Varanasi	9	9	20	34	28
Vadodara	15	9	-	53	23
Ludhiana	1	12	16	48	23
Visakhapatnam	47	7	4	33	9
Bhopal	30	9	-	53	8
Nagpur	5	2	7	49	37
Kanpur	18	6	13	35	28
Pune	29	9	-	46	16
Ahmedabad	27	9	-	40	24
Calcutta	89	4	2	2	3
Other studies earlier					
Madras(1992)	49	0.5	2.6	32	16
Cochin(1993)	54.4	2.1	1.5	33.1	6.9
Delhi(1994)	62.4	2.9	3.5	24.6	6.6
Source: RITES,1998					

Table 6 shows that cities with poor public transport systems have a higher presence of paratransit and private modes. In some cities, private buses have been introduced recently, but predominantly the bus transport operation is under public sector.

IPT modes like tempos, autos and cycle rickshaws assume importance as they are necessary to meet the travel demand because of the lower level of bus availability in medium size cities in India like Hubli, Varanasi, Kanpur, Vijayawada, etc.

Public transport is the predominant mode of motorized travel in megacities. Buses carry 20%-65% of the total trips excluding walk trips. Despite a significant share of work trips catered to by the public transport, the presence and interaction of different types of vehicles create a complex driving environment. Preference for using buses for journey to work is high by people whose average income is at least 50% more than the average per capita income of the city as a whole(CRRI, 1998⁷). Whereas increase in fares may or may not reduce the ridership levels, it will certainly affect the modal preference of a large number of lower income people who spend 10%-20% of their monthly income on transport. A survey result shows that nearly 60% of the respondents find the minimum cost of journey to work trips by public transport (less than Rs.2 per trip) unacceptable(CRRI, 1998). Even the minimum cost of public transport trip accounts for 20% to 30% of the family income of nearly 50% of the city population living in unauthorized settlements. This section of the population is very sensitive to the slightest variation in the cost of public transport. In outer areas of Delhi NMVs and pedestrians on some of the important intercity highways with comparatively long trip lengths show that a large number of people use these modes because they have no other options. Since a subsidized public transport system remains cost prohibitive for a large segment of the population, we should note that the market mechanisms may successfully reduce the level of subsidies; however, they would eliminate certain options for city residents.

The RITES(1998) projected modal shares(Table 7) show that in future bicycles and NMVs will continue to carry a large number of trips in all city sizes. Public transport trips will be in the range of 25%-35% of the total trips. Walking trips will constitute 50-60% of total trips. Despite a high share of walk trips and trips by non motorised 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.

Population in million	Share of walk Trips	Vehicular Trips

		Public Transport	IPT		Private vehicles			Total
			Fast	Slow	Cars	Sc/Mc	Cycle	
0.1-0.25	37.11	16.4	10.43	20.08	3.27	24.13	25.68	100
0.25-0.50	37.76	20.55	8.93	17.19	2.6	29.83	20.87	100
0.50-1.0	30.67	25.41	8.15	12.02	9.47	29.1	15.86	100
1.0-2.0	29.62	30.55	6.39	8.09	3.3	39.57	12.09	100
2.0-5.0	28.65	42.33	4.94	2.97	4.99	28.86	15.9	100
>5.0	28.35	62.81	3.29	3.65	6.13	14.75	9.38	100

3. ALTERNATE TRANSPORT SOLUTIONS

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

3.1 Line Capacity: Capacity is the number of people who can be transported per hour. Rail based systems like metro, LRT, sky bus, 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 decides the capacity of the system. Longer trains have a larger capacity, however they require longer platforms. The capacity of road based systems depend 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 180seconds 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 is capable of providing 35,000 passengers per hour. Often in 1-2 km wide stretch there are 2-3 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.

3.2 Commercial Speed: The average speed of public transport system depends on the frequency of stops since the 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, then the expected speed is 35-45Km/h. If the average spacing of stops is changed to every 500m, it increases the catchment area of the system: then the average speed may reduce to 20-25Km/h. This is true with 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 location is integrated with intersection design, an average speed of 20-25 km/h can be achieved with bus stops every 500 m. Higher speeds are possible if express bus services are introduced which do not stop at every bus stop. The trade off between higher speed and higher catchment area is important for deciding upon an optimal public transport system.

3.3 Cost: System cost varies for both fixed and operating cost. Rail based systems have 10-20 times more fixed cost requirements than the road based systems. Rail based system have higher operating cost than the road based systems because of a larger infrastructure to be maintained. The operation of a rail based system requires skilled manpower as compared to a road based system.

3.4 Construction Time :International experience shows that rail based systems require 3-4 times more time for construction than the road based system.

3.5 System Demand: Demand for public transport depends upon the ease of accessing the system, the total trip length and the ticket cost. Commuters prefer shorter walking distances, usually less than half a km. The access time required for a rail based system is higher than that required for a road based system; therefore usually trips which are more than 10-15 km long are suitable for rail based system. In mega cities like Delhi and Mumbai 20% of the total trips are more than 15 Kms. Rail based systems can effectively meet this demand provided that majority of these long trips originate and terminate within half a kilometer of the rail corridor. Otherwise the capacity provided by the rail system cannot be fully utilized.

Table 8 shows optimal trip lengths for different modes based on the desirable access time. Details are given in Annexure 3.

Table 8: Optimal Trip Length for different modes

Mode	2 Wheeler	3Wheeler	Car	Taxi	Bus	Metro
Trip Length, Km	1.8	2.5	4.8	7	6.5	14

For an efficient and successful public transport system, a balance should be achieved between present and future travel demand and the system design. The following indicators may be used to decide the optimality conditions:

3.6 Load Factor: The load factor is defined as the number of actual users versus the available capacity. If the number of actual users are less than the capacity provided, then the system requires higher subsidies. The gap between revenue and cost is large. It also reflects oversupply and waste of scarce resources. The number of actual users depends upon the trip length, access time, and travel cost. The capacity provided should match the existing demand, otherwise the load factor is always less than one, indicating oversupply.

3.7 Cost/passenger: For achieving low cost per passenger, the load factor should be close to one. Similarly for lower fuel consumption and emissions per passenger, the actual number of users should be close to capacity.

Optimality of a system can be summarized by the following indicators:

- Least space consumption/passenger-km
- Least energy consumption/ passenger- km
- Least emission/passenger-km
- Least accidents/passenger-km

Table 9 shows that the bus and the train perform much better in terms of optimality indicators than the car or the two wheeler. However these estimates are based on the capacity provided, and not the actual use of the system. Therefore the challenge is to provide a public transport system which has the same capacity as the number of users willing to use the system.

Table 9: Comparison of alternate modes of transport

Mode of transport	Occupancy persons	Energy consumption Kj/pass-km	CO emission gm/pass-km	Fatalities/million pass-km
Scooter	1.3	706	9.2	19.21
Car	2.2	1825	6.5	3.17
Bus(Diesel)	40	267	.26	.4
Train(EMU)	1080	88	.12	.001

Source: TRIPP, 1995⁸

Table 10: Summary of Alternate Mass Transport Systems

Characteristics	LRT	Metro	BRTS	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
Avg 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	15 km	15km	5 km	10-15km
Catchment area	Medium-low	low	high	Medium-low
Segregation	At grade- elevated	Elevated-u'ground	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	No where
Flexibility	Low	Very low	Very high	low
Integration	Integration with buses/	Integration with buses/	Integration with buses/ paratransit desirable	Integration with buses/

	paratransit required	paratransit necessary		paratransit required
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The optimal capacity is one which fulfils the travel demand. Travel demand depends upon city size, trip lengths, location and density of jobs and residences and other socio economic conditions. A high capacity system requires that within walking or easily accessible distance demand for high capacity system should exist. This requires a very high density development within the catchment area of the rail system. In Hongkong and Singapore highrise buildings along the metro corridor provides a high density of residences as well as jobs.

Therefore the capacity provided by the metro can be well utilized. Indian cities have high density developments in the form of urban slums. Even a subsidized metro system is too expensive for slum dwellers. Therefore the demand for metro systems in Indian cities is low. This is the reason that the Kolkatta, Chennai and Delhi metro systems are carrying less than 20% of the available capacity. The metro and the LRT have low social cost in terms of energy consumption and pollution only when the system runs to its capacity. Since the supply exceeds the demand, the system runs at a loss. System demand is dependent on the ease of access, low fares, and dependability. The metro is a capital intensive system (~Rs.200-300 crores/Km). It is suitable for meeting the mobility requirements of less than 20% of the city residents because Indian cities have a medium density development of middle income groups. For the same price a 30-50 km of bus net work can be developed including modern buses. This would benefit 30-50 times more people than a metro system. The cost of single metro trip is at least Rs.45 compared to Rs 15 for a bus trip. Since car and personal two wheelers provide flexible door to door service, it is not easy to attract these users to a metro, even if they can afford the cost. Metro ticket has to be subsidized at least 10-15 times more than a bus ticket for the same journey.

The efficiency and viability of these systems have to be judged in terms of how well they can serve the individual trip, how many people can benefit for the same investment, and how flexible the system is in meeting the changing demands of the city.

The metro, the LRT and the sky bus all capital intensive systems cannot match the extensive coverage provided by road based systems. All three require a high density of population who can afford the price of rail based systems living along the corridor. This is not the case in most Indian cities, therefore such technologies will have to depend on buses, three wheelers and rickshaws to increase their catchment area. Metro systems are successful in cities with a high density central business district or a very high density residential and commercial development; often high rise developments along the metro line as in HongKong. A large number of people should be able to access the metro without depending on a feeder mode. Only long distance travelers(trip length at least 15 km) are likely to use a feeder mode. Therefore, in order to realize the social benefits of metro systems the city structure has to change completely. 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. The advantage of a road based mass transport system is that at a cost of 1/10th -1/20th of the cost of other mass transport systems, a high quality public transport system can be provided within walking distance. Since the catchment area of a road system depends on the extent of the road network, road based systems are capable of reaching almost 80% of the city population. Access to this system includes improved and safe pedestrian paths. Because of this it can match the convenience and flexibility provided by private modes. Therefore, we can expect a high demand and therefore better capacity utilization of this system. One of the major drawbacks of rail based systems all over the world including Kolkata, Chennai and Delhi has been its low capacity utilization. Even if better feeder trip systems are planned, capacity utilization is not expected to change because only long trips (longer than 15 km) will benefit from these systems. Bogota and Curitiba, both considered model public transport systems, have decided to expand their BRT system in order to cover the whole city by public transport which does not require subsidy, restricts car usage, and has made major impacts on safety, pollution and energy consumption. A summary of these systems is given in Annexure III .

Several Indian cities have constructed and made plans for new flyovers. The justification for flyover construction is to reduce long delays at intersections and provide uninterrupted movement to long distance traffic. Flyover construction cannot provide long term solutions because it improves journey time at a small section of the road for cars which are only 20%-25% of the total commuter trips in a city like Delhi. In other cities car trips are less than 20%. It does not have any benefits for bus commuters because bus stop locations are shifted away from the intersection increasing the walking distance for changing the buses going in different directions. With an increase in speed of vehicles on the road bus commuters as well as other pedestrians find it difficult to cross the road. Thus flyovers result in short term benefits to the

car users at the cost of increasing traffic hazards and inconvenience to the other road users. It also encourages people to use cars and two wheelers and move away from public transport, walking and bicycling. This results in more vehicles, congestion and pollution on the roads. There is ample evidence and documentation from several Chinese and other Asian cities showing the futility of these measures. The congestion levels in the city have worsened over the years in many of these cities(Guangzhou Municipal Government., 1999)⁹

4.0 FRAMEWORK TO MODEL THE OPTIMAL MODAL MIX

4.1. The urban transport system must meet the demands of the affluent people dependent on motorized vehicles and at the same time meet the mobility needs of the poor who are dependent on walking and cycling. Often, even a subsidized motorized public transport system is too expensive for at least 20-30 percent of the population.

4.2 The use of the existing network must be optimized by giving priority to more efficient modes of transport which include, buses, bicycles and walking.

4.3 Since the users of low cost modes pedestrians, bicyclists and public transport commuters are captive users(people without choice), their presence on the network is inevitable. If the infrastructure design ignores their needs, and traffic laws restrict their movements, these users are often forced to defy laws and continue to use the road infrastructure exposing themselves to a high risk. Motorised vehicles are forced to operate in sub-optimal conditions despite huge investments in a car oriented infrastructure. Therefore the needs of non motorised users must be given priority.

Table 11 shows that the majority of the cities will have a travel demand which can be met by road based mass transport system. In cities having 8.5 million population only 3% of the network may have demand which is more than 40,000 persons per hour. This too can be met if two 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.

PHPDT	Proportion of Transport Network Length in city of Population size				
	1-5 Lakhs	6 Lakhs	10 Lakhs	35 Lakhs	85 Lakhs
<4000	95	80	60	40	34
4000-8000	5	18	20	20	26
8000-12000	-	2	12	9	16
12000-20000	-	-	8	9	10
20000-30000	-	-	-	15	7
30000-40000	-	-	-	5	4
More than 40000	-	-	-	-	3

Table 12 shows desired modes for different trip lengths based on access time and total travel time.

Table12: Desired modes for different trip lengths

Trip Length, Km	0-2 Km	2-5 Km	5-10 Km	10-15 Km	> 15 Km
Share of trips (%)	25-50	20-25	15-20	10-15	5-15
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

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 system. 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 which are more than 10 million people, 15% translates to 1.5 million trips. Therefore there may be a case for exploring the feasibility for a rail based system provided the corridor has the required density of residences and jobs within the catchment area of the transport corridor. However, a rail based system must be complemented by other modes, otherwise 85% of the trips will remain outside the catchment area of a rail based system.

4.4 Minimum steps required to address the immediate needs of urban commuters are

Infrastructure for nonmotorised vehicles

Streets must be returned to pedestrians not only because they are the majority of road users, but also because, the efficiency of the overall system, including the performance of motorised vehicles depends on meeting the demands of the captive pedestrians. The experience from environments where captive pedestrians are present makes a very strong case for rethinking the conventional hierarchy of road users.

It is possible to design pedestrian, bicycle and public transport friendly urban roads without increasing the right of way of existing arterial roads in cities. The guiding principle of such a design lies in meeting the needs of pedestrians, bicyclists and public transport commuters in that order. It should integrate services provided by vendors and the informal sector as legitimate, productive economic activities.

If pedestrian friendly paths and a separate segregated lane along with spaces for hawkers are constructed for slow NMVs, the curbside lane, which is currently used by bicyclists and other NMVs, becomes available to motorised traffic. This requires a relatively small investment in pedestrian and bicycle friendly infrastructure; however, this needs a major shift in planning methodology and paradigm shift in street design principles. This leads to multiple benefits(Tiwari, 1999)¹⁰. Motorised vehicles benefit because of the improved capacity of the road and improvement in speeds. Major beneficiaries of speed improvement are buses and two wheelers because the curbside lane becomes available to them without interference from pedestrians and slow vehicles. The cost of such a measure is less than the capacity enhancement measures meant for car users only.

Roadside vendors and services for road users integrated with NMV infrastructure:

Bicycles, pedestrians and bus traffic attracts street vendors. Vendors often locate themselves at places, which are natural markets for them. A careful analysis of the location of vendors, the number of vendors at each location and the type of services provided demonstrates the need for their presence(Gandhi, 1997)¹¹. If the services provided 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 motorised traffic, then vendors have a valid and legal place in the road environment. Highway design manuals recommend frequency and design of service area for motorised vehicles. Street vendors and hawkers serve the same function for pedestrians, bicyclists and bus users. Therefore, there is a need for evolving standards for road designs which integrate location and area requirement for vendors.

Table 13 presents a summary of policy initiatives required to develop optimal modal mix in different size cities

Table 13 Priorities for optimal modal mix for different city sizes

City Size	Priorities for optimal modal mix		
Population in million	Short term	Medium and long term	Actions required
0.1-0.25	NMV (public and private)	NMV, Motorized IPT	Road planning, traffic calming, regulatory mechanisms for safe and clean IPT
0.25-0.50	NMV (public and private)	NMV, Motorized IPT, PT (Buses)	All the above and planning for formal bus system
0.50-1.0	NMV, Motorized IPT, PT (Buses)	NMV, Motorized IPT(feeder trips), HCBS PT (Buses), rationalize private vehicle parking	All the above and planning for High Capacity Bus systems
1.0-5.0	NMV, Motorized IPT(feeder trips), HCBS PT (Buses), rationalize private vehicle parking	NMV, HCBS expansion and integration with rail based system serving intercity trips with satellite towns	All the above and planning for one or two rail corridor to be implemented in future
>5.0	NMV, Motorized IPT(feeder trips), and taxi systems, HCBS PT (Buses), rationalize private vehicle parking	NMV, taxi system with IT support, HCBS expansion and integration with rail based system serving intercity trips with satellite towns, congestion pricing	All the above and planning for one or two rail corridor to be implemented in future

Table 14 Action Priority for Optimal Modal Mix

City Size	Strategies		
Population in million	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 required for creating NMV infrastructure.	Master plans and target setting for NMV, Regulatory authorities required for setting performance standards. Public transport authorities for formal bus system
0.50-1.0	All the above and planning for High Capacity Bus systems	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), rationalize private vehicle parking
1.0-5.0	All the above and planning for one or two rail corridor to be implemented in future	NMV, Motorized IPT(feeder trips), HCBS PT (Buses), rationalize private vehicle parking	NMV, HCBS expansion and integration with rail based system
>5.0	All the above and planning for one or two rail corridor to be implemented in future	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 rationalize private vehicle parking	Urban transport authority for integrating landuse 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 institutes.

5.0 REQUIRED INSTITUTIONS AND POLICY PROCESS

A well-planned and coordinated effort is necessary to overcome the emerging problems of city transport. At present, multiple agencies, working under the Central Government, State Government, or local municipality are involved with various aspects of transport planning within a city, as shown in Table 15. Each agency has its own focus. One of the important requirements to ensure an optimal modal mix that results in increased mobility and accessibility with the least adverse health effects is a continuous interaction and coordination amongst these agencies. Very often these agencies work at cross-purposes, with little or no coordination among them. Such overlapping multiplicity does not lend itself to effective planning or monitoring and leads to an erosion of accountability.

Table 15 Allocation of Responsibility Amongst Different Agencies

Central Government		State Government	
Agency	Responsibility	Agency	Responsibility
Ministry of Railways	Own and operate urban rail transit systems.	Department of Transport	License and control all road vehicles, collect motor vehicle taxes, fix fares.
Ministry of Surface Transport	Administer the Motor Vehicles Act and notify vehicle specifications	Public Works Department	Construction and repair of major roads
Ministry of Urban Development	Overall responsibility for urban transport policy and planning	Local municipality	Construction and repair of smaller roads, road signage, traffic lights, licensing and control of non-motorized vehicles, clearing of encroachments and land use planning.
Ministry of Environment & Forests	Recommend the emission norms for motor vehicles and administer the Environment Protection Act	Police	Enforcement of traffic laws and prosecuting violators
Ministry of Finance	Responsible for fiscal policies	Department of Environment	Monitoring air quality
Ministry of Industries	Responsible for the Industrial Policy	Land Revenue administration	Allocation of land and land acquisition
Ministry of Petroleum	Controls all the oil refining	State Transport	Operation of bus services

	companies	Undertaking	
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Changes in institutional arrangements, processes, methodologies and expertise are necessary if an optimal modal mix leading to a sustainable transport systems is to be promoted. This change requires plans based on participatory processes with representation from all stakeholders in the city. One of the major weakness in the current institutional arrangement and administrative procedure is a poor mechanism for ensuring the participation of all stakeholders in general and vulnerable groups like informal sector and low income groups in particular. Some of the measures that can be instituted in the short term are:

5.1 Legislative Requirements: Legislations are required to ensure that the rights of pedestrians and bicyclists are honoured 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 will be required for introducing 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 a legislation for all travel data collected by local, state or central government to be made publicly available. This would improve the quality of data collected and researchers using the data may highlight the shortcomings of the data. Similarly, traffic accident data and air pollution data should also 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 incentive schemes for local governments in terms of offering matching funds if the city government schemes satisfies a set of criteria requiring the participation of all stakeholders, impact on pedestrians, bicyclists, and public transport users .

5.2 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. Linking landuse plan with transport plans, implementing regulations pertaining to environment and safety should be the responsibility of this level of institution. 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 organisations, or city level institutions like development authorities should be reorganised to deal with the complexities of urbanization and transport systems. They should have targeted capacity building programmes, linkages with state level or national level academic institutes. Surveys and studies undertaken by these should be made publicly available so that the process of survey and findings can be discussed by all. This is needed 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 landuse plans, road development and geometric standards for implementing agencies. At least 5 -6 interdisciplinary groups should be setup in academic institutes to work on urban transport related issues like transport economics, public transport systems, public private partnerships in urban public transport, transport management, traffic safety.

5.3 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, transport department, and the public works department should have cell that have expertise in modern road design, traffic management systems, and management of transport services.

8	5500	23 km
9	4500	20 km
10	1000	15 km
11	4000	18 km
12	50	8 km
13	65	35 km
14	20	40 km
15	1200	25 km

Table 2 gives distance of the main road and bus stop at the original site and the relocated sites.
Table 2: Distance from the main road and bus stop

	Main Road		Difference from the original location	Bus Stop	
	Original	Relocated		Original	Relocated
1	10	2500	2490	10	1000
2	20	2500	2480	30	1000
3	30	2500	2470	30	1000
4	30	2500	2470	200	1000
5	30	2500	2470	200	1000
6	20	2500	2480	100	1000
7	1000	2500	1500	30	1000
8	1500	2500	1000	20	1000
9	500	2500	2000	500	1000
10	50	2500	2450	500	1000
11	1000	1000	0	1000	1500
12	30	1000	970	500	1500
13	10	3000	2990	50	1000
14	10	10	0	20	1000
15	1000	2000	1000	100	1000

Table 2 is summarized as the following:

- Average distance to main road before relocation < .5 km.
- Average distance to main road after relocation > 2 km
- Average distance to bus stop 200 m before relocation
- Average distance to bus stop 1 km after relocation
- Minimum distance to bus stop before 10m, after 1km

Travel cost, travel time and risk to exposure is increased as a result of relocations.

The Indian Scenario

The following characteristics may be noted for all Indian cities (except Mumbai for some characteristics):

1. Relatively low rise development with planned multiple business districts.
2. Maximum per capita income of about US \$ 1,000 (say in Delhi) which is not likely to exceed US \$ 4,000 in 2025. Therefore, all cities in India are likely to remain at "low income" levels by international standards for the next 20 years.
3. Very high ownership of motorised two wheelers. It appears that about 70 percent of families in Delhi own a motorised vehicle (Delhi has about 3 million families and 2 million vehicles⁸). This is relatively new development internationally. When the metro systems were originally developed in Europe, USA and Japan (in the first half of the 20th century), vehicle ownerships were very low. For example, in United States only 70% of the families had a car in 1955 and less than 70% of the families owned vehicles in most European cities even in the 1960s.
4. The marginal cost of operating a motorised two-wheeled vehicle is about Rs. 0.50 to 0.70 at 2004 prices. This determines the maximum fare box levels for public transport.
5. If we assume that at least 30% of families in Indian cities earn less than Rs. 5,000 (2004 prices), then these families are not likely to spend more than Rs 5.00 per trip on transport (assuming that they can allocate only 10% of their income to transport, and that they need only 2 round trips per day). Low income individuals are not likely to use public transit for short distances. Long distances trips on the metro would cost 3 to 4 times this amount. Therefore, metro transit is not likely to be affordable for a significant segment of urban Indian populations for some time to come.
6. Most Indian cities are expanding in a radial mode and are not likely to develop one concentrated high density business district in the foreseeable future. Most city plans include decentralising of many trade activities!
7. Most Indian cities have mixed land use patterns and we are not likely to succeed in implementing strict zoning for land use, even if it were desirable.

The above issues have serious implications for the kind of public transportation systems we should develop in our cities. These are discussed in brief below.

Public transport and city character

Transport systems and city character are interlinked. Land use characteristics of a city can determine the type of transport system it needs, and once a transport system is put in place, it influences land use characteristics of the city over time. Therefore, the type of public transport system you want in a city will depend on the vision you have for the future for your city. An economically vital central business district (CBD), which is the main centre for both employment and retail, is likely to contribute to the success of an urban rail system (if the system serves the CBD) because it can generate and attract trips onto the system, however, low-income neighbourhoods may be unsuitable for urban rail operation.⁹

High rise dense city

If you want your city to develop as a dense city with a large proportion of high rise buildings and one very large central business district, then you should think of introducing very high capacity transport systems that can carry more than 40,000 people per hour per direction. This can usually be done by elevated or underground rail systems.

On the other hand, if you put in place a high capacity rail system in a city that is not yet high rise, then the rail system will ensure that over time a very dense high rise city develops where the rail lines converge. This happens because space becomes very expensive and the economics dictate that buildings go high rise. In India, Mumbai is a good example of how the existence of the rail system has resulted in south Mumbai going high rise and developing into a very dense business district.

Low rise, multiple business centre cities

Cities which have multiple business districts and in which buildings are 2-5 stories high cannot feed very high capacity mass transit systems. Such cities do not need and cannot sustain very high capacity systems. Transit systems capable of transporting 15,000 to 25,000 passengers per direction per hour should be adequate. Such systems would not alter the character of the city. Such a demand can be met by modern bus rapid transit systems.

Observations stated above are supported by international experience.

International experience

Table on the right shows share of public transport in four metropolitan cities around the world.¹⁰ These cities are considered to be most successful in providing rail based public transport. However, only Tokyo and Hong Kong are able to capture close to 50% or more of trips in the city. This shows that it is not easy for public transport systems to cater for a majority of urban trips if

City	Public Transport Market Share
Hong Kong	61.11%
Tokyo	48.98%
Singapore	31.21%
Paris	26.98%
London	26.33%

people own private vehicles. For people to use public transport, short access trips, safety from accidents and crime have to be ensured. In addition, both the origin and destination need to be close to the transit stops. This is why density and land use issues become important. It is only when a city has a large and dense central business district that a large number of people who happen to live on a particular corridor need to travel in the same direction. Figure below shows modal shares in cities by different modes around the world.¹¹ It is interesting that even though European cities have built many rail based systems, they have not been successful in having higher modal public transit shares than Asian cities, many of

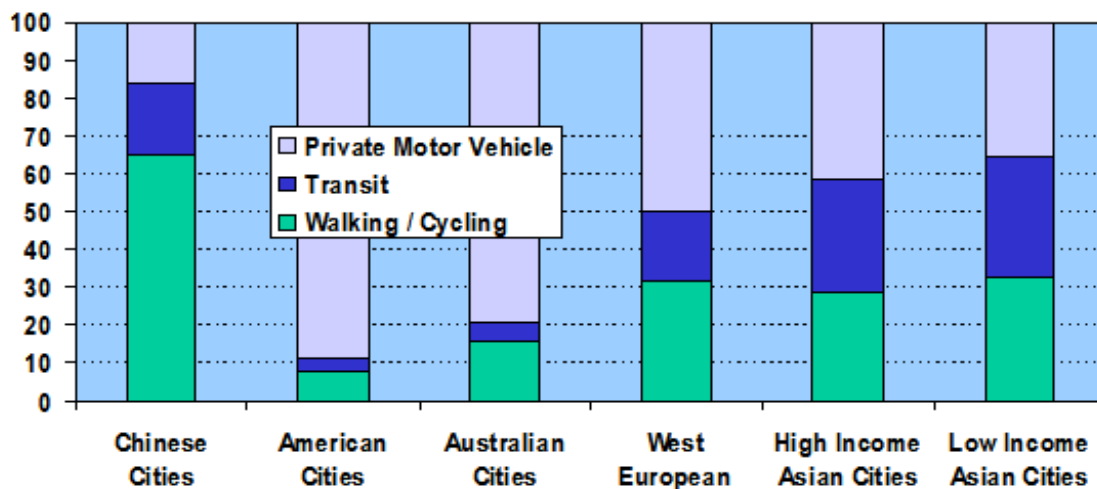


Figure 1. Modal shares in cities around the world (Transit figure for low income Asian cities includes para transit)

An international review of rail systems conducted for the concludes that "Central Business Districts have traditionally been the foci of transit systems and have the highest mode shares. At the broadest level, urban structure refers to the extent to which employment is concentrated in a single dominant centre (i.e., the CBD), in multiple centres polycentric urban form), or in numerous locations at very low densities (the dispersed pattern). A number of studies make clear that CBDs are most supportive of transit, while job decentralization, either in polycentric regions or in dispersed patterns, results in less use of transit for all trip purposes".¹² A study of 63 office relocations in London showed that decentralization resulted in 107 percent more automobile trips and 25 percent fewer bus trips than if the offices had not decentralized.¹³

It is clear that exceedingly large central business districts. For example, Tokyo, New York, Paris and London have central business districts with more than 750,000 jobs. Tokyo has one of the world's largest central business districts, with approximately 2.3 million jobs, with an employment density of approximately 150,000 per square mile, and almost all of central Hong Kong is a business district. This is why rail transit is so successful in these two cities. The massive central business district employment numbers and densities support a high degree of substitution by rail of automobile use that is not possible in smaller central business districts (because there is too little demand and it is too dispersed).¹⁴

When business districts are dispersed and incomes are relatively low compared to high income cities, the situation is even worse for rail based high capacity transit systems. Shanghai City has about 82 kilometres of metro and light-rail lines, but rail transport only accounts for 2 percent of the local traffic volume¹⁵. Mexico City (population 10 million) has 201 km of metro rail and it is the cheapest in the world, but it carries only 14% of trips (See figure below)¹⁶. The metro share has reduced as the share of buses has increased.

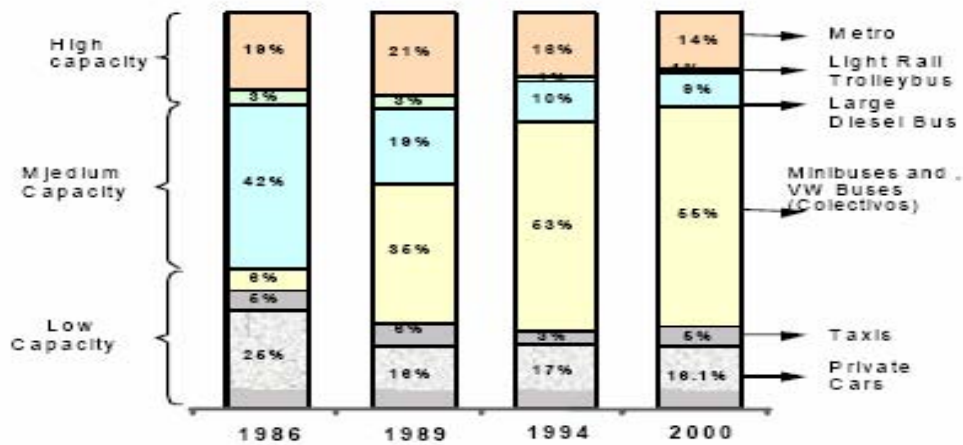


Figure 2. Modal shares in Mexico city

Experience from existing rail based transit systems indicates that they are only successful in utilization of their maximum capacities when implemented in cities which have the following characteristics:

- High density living with one major very high density central business district.
- Relatively high per capita income.

Cities with low per capita incomes and multiple and dispersed business districts are unable to attract high ridership shares and so rail based systems do not perform to capacity. Therefore, the size of a city should not be used as a sole criterion for deciding the type of technology to be used for transit systems.

¹² *Transit, Urban Form, and The Built Environment: A Summary of Knowledge (Volume 1, Part I)*. TCRP Report 16, Transportation Research Board, National Research Council, National Academy Press, Washington, D.C. 1996.

¹³ Daniels, P. W. Transport Changes Generated by Decentralized Offices. *Regional Studies*, 6: (1972) pp. 273–289.

¹⁴ Wendell Cox. *The Public Purpose, A National Journal*. <http://www.publicpurpose.com/>, 2004

¹⁵ Shanghai City Gives Priority to Rail, Bus Systems. <http://www.china.org.cn/english/travel/99055.htm>. 2005.01.14

¹⁶ Schipper, L. Sustainable Urban Transport: Progress in Mexico City and Potentials for China. International Mayors Forum on Sustainable Urban Energy Development, Kunming, P.R. China, 2004.

Transit systems, catchment areas and feeder trips

Research studies show that proximity was perhaps the strongest determinant of a resident's likelihood of riding rail transit. Distance had even a stronger effect on the likelihood of rail commuting at the worksite-end of a trip.¹⁷ U.S. research allows for some generalized conclusions about pedestrian access to transit. Between a distance of 0.8 and 2.4 km, the proportion of transit riders who walk to or from transit steadily decreases and rail's mode share falls about 1.1 percentage point for every 100 ft increase in walking distance to stations up to a distance of 1.6 km.¹² Data from Netherlands suggests that the ridership starts declining from a distance of 150m and 500m should be considered a reasonable catchment radius for a walking trip to the station.¹⁸ For the bus, tram and metro, mean access and egress times have been found to be 5.9 min for walking, which translates to an average distance of 393 m to the rail or bus station.¹⁹

These findings illustrate why rail based systems are more successful in high rise cities. Figure 3 below shows the differences in walking distances between access to high rise and low rise buildings. A large number of passengers exiting from a metro station can be accommodated in a high rise building. A person going to the 30th floor has to walk the same distance as one going to the 1st floor. Moreover, the access trip to the 30th floor is in a lift which is free, safe, protected from the weather and non-energy demanding. On the other hand, a person employed in low rise buildings (3-6 floors) may have to walk 1-2 km to reach the 5-10 building (equivalent of the 30th floor). In the latter case it is possible the this person may not opt to use metro rail. If a bus is used for the feeder trip, then the passenger has to spend extra time and money to make the trip. This is also a disincentive.



Figure 3. Effect of low rise and high rise buildings on access trips to public transit.

It is quite clear that for high capacity rails systems to capture enough riders to justify their high capacities, they must operate on dense residential areas also where a significant number of people live in high rise buildings. This is only possible at relatively high incomes when cities can be planned to accommodate middle class families in high rise buildings. This situation is not likely to be common in Indian cities in the foreseeable future.

Financial viability

Motorcycles, scooters and mopeds comprise 60-80 percent of motor vehicle fleets in Indian cities. In a city like Delhi approximately 60-70 percent of families own a motor vehicle (at least one car, motorcycle, scooter or moped). This means that motorised two-wheeler ownership has become possible for the main wage earner of lower middle class households and college students belonging to middle class families. A family earning about Rs. 10,000-15,000 per month (US\$ 200-300) can own a motorised two-wheeler. This is a new development in urban living. When European and North American countries and Japan had similar levels of income vehicle ownerships were very low and people were forced to use public transport. With such high levels of vehicle ownership it will be every difficult to attract people to public transport unless the latter is made very convenient and inexpensive.

The marginal cost of running a motorcycle or scooter is about Rs.0.50-0.70 per km. It is unlikely that two-wheeler owners will use public transport unless the fare is about the same or less than the Rs.0.50-0.70 per km. Use of a two-wheeler also gives freedom in mobility, it is easy to park at home and close to place of work, and it can get to the from of the line at traffic lights.

¹⁷ Cervero, R. Ridership Impacts of Transit Focused Development in California. Berkeley: University of California, 1993.
¹⁸ Pettinga, A. Design Criteria and Model Split in Dutch Residential Areas. De Bilt, The Netherlands, Grontmij Consulting Engineers, 1992.
¹⁹ Krygsmana, S., Dijsta, M. and Arentzeb, T. Multimodal public transport: an analysis of travel time elements and the interconnectivity ratio. *Transport Policy*, 11, 265-275, 2004.

Public transport fares in Indian cities cannot be higher than about Rs. 0.50 per km (2005 prices). At present, most city bus fares are around this range. Any system which has operating costs above this amount will have to arrange for subsidies which are not regressive in nature. In addition, research results show that public transport demand is relatively sensitive to fare changes, so that policy measures aimed at fare reduction (subsidisation) can play a substantial role in encouraging the use of public transport, thus reducing the use of private cars.²⁰ This rules out most rail based high cost systems.

Public transport and access

Public transport stations must go close to origin and destination of commuters. Preferably within 500 m of both home and work place.²¹ Only road based systems can do this. Rail based systems, on an average usually add another 200-300m of walking within stations including staircases. This reduces the acceptance of rail based systems compared to surface bus systems especially for children, the elderly, health impaired (heart disease, arthritis, etc.) and the physically disabled. The latter group may account for 20-30% of the population on any given day.

Metros, congestion and the environment

Reviews of the metro systems around the world conclude that rail based systems do not reduce congestion or improve the environment:

- “None of the systems (rail based) appear to have reduced the problems caused by the car... None of them caused a decline in overall bus usage...None of the systems caused reduction in car usage, congestion relief, or improve air quality”.⁹
- “Public officials tend to exaggerate the consequences of (widely unpopular) metropolitan traffic congestion for political gain...Public transit investments are unlikely to meaningfully reduce congestion...Public officials can cynically use congestion as a rationale for funding for high-profile, politically-popular transportation (and, increasingly, public transit) projects. Put simply, public transit expenditures in the name of congestion reduction are growing because they are broadly popular, and not because most people believe that they are effective ways to reduce traffic congestion”.²²
- “There is evidence from the literature that expenditure on new rail-based schemes can divert resources away from bus routes used by low-income people with no alternative mechanized mode of travel. There are now some signs of a shift from light rail to bus-based systems, following on from the earlier shift from metro to light rail To sum up, it seems that the impacts of many of the new urban public transport systems are much smaller than those anticipated by those promoting them. The expectations of the systems developed more recently seem to be more modest, but overall the expectations do not seem to be being met”.²⁴
- Figure 4 shows that availability of metro systems in Tokyo and US cities has not increased city road speeds. The average increase has been 2.5 percent (Table 2). The largest increase was in Washington (7.0 percent), where by far the most extensive and expensive new rail transit system was built.

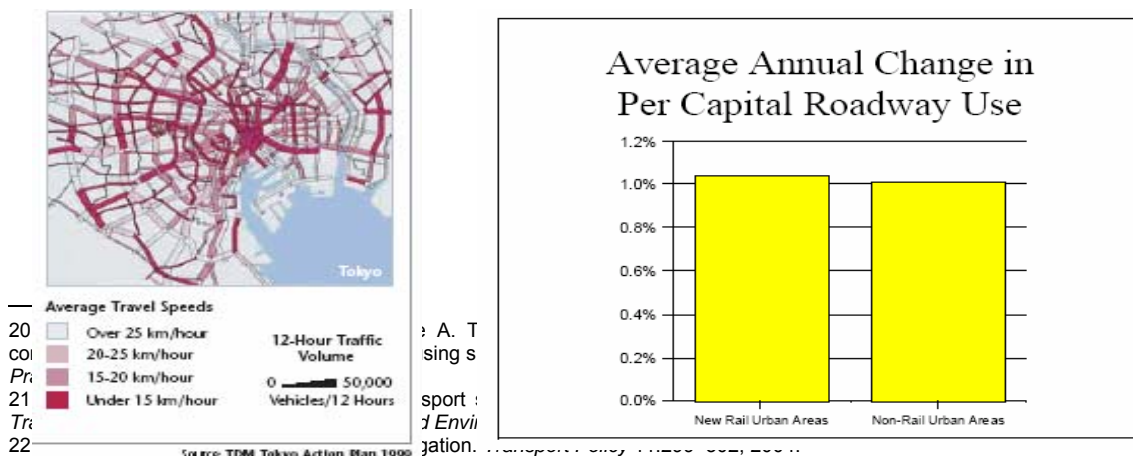


Figure 4. Congestion levels on Tokyo roads (above left) and road way use in US cities with and without new rail projects.

Cities, public transport and Bus Rapid Transit Systems (BRT)

"In many urban areas in both developed and developing countries the SMP believes that there are important opportunities for increased utilization of bus and "bus-like" systems (including paratransit) to take advantage of the flexibility inherent in road-based systems. Advantage should also be taken of opportunities to incorporate new vehicle technologies (including propulsion systems) and new information technologies into these "bus-like" systems".²³

International evidence suggests that with modern communication systems, smart card ticketing, GPS, intelligent transport technologies and computer optimisation techniques it has become possible to serve urban transport needs with modern rapid bus transit (or high capacity bus systems) very adequately. These bus systems have the following advantages:

- i) BRT systems can serve the needs of medium sized cities all the way up to mega cities.
- ii) BRT systems can easily reach capacities of 20,000 passengers per direction per hour. These capacities are very adequate for cities which have multiple business districts and medium rise buildings. In such cities higher capacity systems will never run at peak capacity. However, experience from cities like Bogota and Sao Paulo demonstrates conclusively that capacities up to 40,000 persons per hour per direction are feasible when catering to high density central business districts.
- iii) BRT can be implemented at a fraction of the costs involved in building MRTS and LRTS systems. BRT systems use existing right-of-way on urban corridors and so the modifications involved do not disrupt the city significantly.
- iv) A major advantage of BRT is its flexibility in meeting changes in the city development and in changes in demand in quality and quantity. Expanded or new services can be introduced whenever needed. The BRT does not fix the city structure for ever like fixed track systems.
- v) Rail systems can only serve a very limited area of a city. Not one developing country city subway system serves more than 10% of population. BRT'S can achieve very high coverage at low investment costs. As they are road based they can go very near homes and destinations and cover most of the city as planned for 80% of Bogota residents. This would not be possible technically or financially with rail systems
- vi) When road systems are modified for BRT, it results in complete urban renewal as a part of the BRT project. This does happen in case of rail systems.

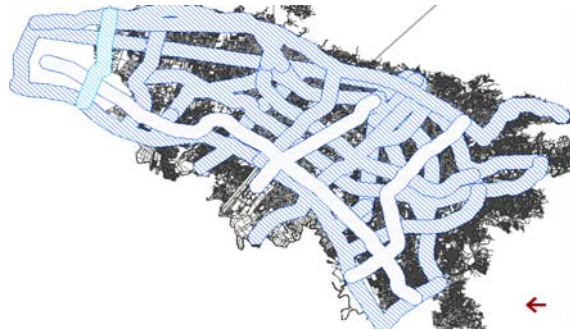


Figure 5. Planned BRT coverage in Bogota, Columbia

Some important questions about public transport systems:

Question 1 Can road-based systems like buses/ trams/ electric trolley buses can optimally cater to traffic loads more than 10,000 -12,000 peak hour peak direction passenger trips (phpd)?

Modern bus rapid transit systems in many cities are carrying far higher numbers

Evidence

Bogota, Columbia: Maximum of 45,000 passengers per hour, per direction

São Paolo, Brazil: Maximum of 21,600 passengers per hour, per direction

Porto Alegre, Brazil: Maximum of 25,600 passengers per hour, per direction

Question 2. Can rail based transport system cause air pollution?

Answer:

Rail based transportation systems does not cause pollution from emissions of the vehicle but do from all the services provided at stations, especially if they are underground (e.g. air-conditioning systems, etc.). Similarly, if electric trolley buses are used on the surface they also would not have local emissions. Therefore, this is not the preserve of rail based systems. The statement also does not account for emissions from power plants which provide energy to the rail based system.

Question3. Can metro carry the same amount of traffic as 9 lanes of buses..”

Answer: Modern bus rapid transit systems operate on 1 or 2 lanes in each direction. Single lane capacities can reach 20,000 and 2 lane capacities 45,000 pphpd.

4. Is a rail based Metro System inescapable for cities over 1 million population?

Answer: There is no such agreement among transportation planners. There is no evidence that the type of transit system is determined by population size alone. Land use patterns and income levels are far more important irrespective of the population.

Evidence:

There is extensive debate on this issue over the past decade and the general agreement is that high cost rail based systems are not only unviable but do not solve city problems as projected. This why international agencies like the World Bank have stopped funding rail based metro projects – “Where they are politically acceptable, busways should often be the first step in mass MRT (rapid transit system) development, and for many cities they will remain the MRT system for the foreseeable future” (See Appendix 2). There are no rail base MRTS systems being built in South America or Africa. All rail based projects have been cancelled in Columbia. On the other hand most large cities in S. America (Lima, Santiago, Cali) and a few in Africa (Daar-es-Saalam, Nairobi, Cape Town) are planning new bus based systems.

The Sustainable Mobility Working Group of the World Business Council for Sustainable Development in their report states “Compared to its investment in urban roads and railways, the private sector expresses little interest in busways, yet they are among the most cost-effective means of improving urban mobility. The great benefit of dedicated busways is their ability to move large numbers of passengers — typically up to 25,000 passengers per hour per direction — at relatively low cost, typically \$1 to \$3 million per kilometer, 50 to 100 times cheaper than subways”.

Statements from other experts:

i) "There are now some signs of a shift from light rail to bus-based systems, following on from the earlier shift from metro to light rail. There is evidence from the literature that expenditure on new rail-based schemes can divert resources away from bus routes used by low-income people with no alternative mechanized mode of travel... To sum up, it seems that the impacts of many of the new urban public transport systems (rail based) are much smaller than those anticipated by those promoting them. The expectations of the systems developed more recently seem to be more modest, but overall the expectations do not seem to be being met."²⁴

ii) "The justification for such high quality systems (rail based) is usually in terms of their positive image and their role in reducing road congestion and stimulating development. Neither of these effects have been substantiated. Such systems are very expensive and are unlikely to be used to capacity. Hence there is a need to consider lower cost alternatives, for example, bus-based systems... In fact, according to the junior Minister of Transport the UK government does now appear to recognise that light rail is very expensive and that considerable improvements in cities could be obtained using guided busways and lighter rapid transit"²⁵

iii) "Virtually any public benefit that has been achieved through urban rail could have been achieved for considerably less by other strategies. Virtually no traffic congestion reduction has occurred as a result of building new urban rail systems. Yet, virtually without exception, urban rail systems have been promoted to public office holders and voters as a means of reducing traffic congestion in highly automobile oriented urban areas".²⁶

Question5 Is China planning only metro systems?

Answer:_No. China is planning BRT systems in many cities.

Evidence

i) Rapid transit beats Shenyang metro

Shenyang, the capital city of Northeast China's Liaoning Province is planning to turn to a bus-rapid-transit (BRT) system after a costly proposed subway project has remained stalled for 10 years, leading government officials say. "There are many successful examples of BRT for us to follow. This is also the first step for Shenyang to become a modern international metropolis, "Shenyang's Mayor Chen Zhenggao said at a rapid transit forum held last Tuesday.²⁷

ii) China Sustainable Energy Program has funded BRT projects in 3 cities:²⁸

- Beijing Transportation Development & Research Center: To develop strategies for bus rapid transit (BRT) system promotion and segment demonstration.
- Chang An University: To support the Xi'an municipal government to develop strategies for bus rapid transit (BRT) system promotion and segment demonstration.
- Chengdu Institute of Urban Planning & Design: To support the Chengdu municipal government to develop a Transit-Oriented Development (TOD) plan and Bus Rapid transit (BRT) system.

iii) A growing number of cities in China are taking part in the BRT programme. Shanghai has begun a sustainable transport partnership created by World Resources Institute (WRI)... Yangzhou and Changzhou have followed the ecocity planning and management programme set up by municipal government and the Deutsche Gesellschaft fuer Technische Zusammenarbeit(GTZ). Xian, Chengdu, Tianjin, Wuhan, Xiamen, Shengyang, Suzhou and other cities are investigating the feasibility of integrating BRT into their road systems. It is only natural therefore that BRT, an economical and low cost choice, is being implemented in these cities.²⁹

24 Mackett, R. L. and Edwards M. The Impact Of New Urban Public Transport Systems: Will The Expectations Be Met? *Transpn Res.-A*, Vol. 32, No. 4, Pp. 231-245, 1998.

25 Edwards, M. and Mackett, R. L. Developing New Urban Public Transport Systems - An Irrational Decision-Making Process. *Transport Policy*, Vol. 3. No. 4, pp. 225--239, 1996.

26 Wendell Cox. *The Public Purpose, A National Journal*, <http://www.publicpurpose.com/>, 2004.

27 China Daily, 2004-07-27, http://www.chinadaily.com.cn/english/doc/2004-07/27/content_351834.htm

28 <http://www.efchina.org/programs.transport.list.cfm>, Jan 05.

29 Fengwu, W. and Wang, J. BRT in China. *Public Transport International*, 4:38-40, 2004.

- iv) See Appendix 1, Sections 8 & 9 for BRT plans in Beijing and Chongqing.

Question 6 Which Indian cities need metro systems?

a. It is often argued that Delhi, Kolkata and Mumbai need high capacity rail based metro systems other cities will need medium or light capacity bus systems. The argument is based solely on the population levels of Indian cities that cities with more than 5 million population become candidates for high capacity rail systems and those with less population medium or light rail.

Fact:

The size of a city does not necessarily dictate what kind of a system it will need. High capacity metros have only been successful in high rise dense cities with a large and dense central business district. The Kolkata metro is attracting only 10% of its projected capacity though it was constructed on a very highly travelled route. Bus rapid transit systems are successful in large cities: Sao Paulo, Bogota, Taipei, Jakarta, etc. Light rail systems are not necessary as in most situations a modern BRT can carry as many passengers at a fraction of the cost.

City with bus rapid transit	Population million	National per capita income US\$
Jakarta, Indonesia	9	680
Kunming, China	4.6	890
Quito Ecuador	1.8	1,240
Bogotá, Colombia	7	1,910
São Paulo, Brazil	10	3,060
Curitiba, Brazil	2.7	3,060
Porto Alegre, Brazil	3.7	3,060
Los Angeles, USA	12.3	34,870
Nagoya, Japan	2.2	35,990

Evidence:

i) High Capacity metro rail systems are only successful in cities like Hong Kong, New York, Tokyo etc. According to Wendel Cox "Exceedingly large central business districts are necessary to serve metro rail systems. For example, Tokyo, New York, Paris and London Each of the examples have central business districts with more than 750,000 jobs. Tokyo has one of the world's largest central business districts, with approximately 2.3 million jobs, with an employment density of approximately 150,000 per square mile. Virtually no other urbanized area in the developed world has a central business district with more than 400,000 jobs, and most are in the range of 50,000 to 200,000. The massive central business district employment numbers and densities support a high degree of substitution by rail of automobile use that is not possible in smaller central business districts".²⁶ No Indian city has a central business district that supports such a large number of middle class jobs.

ii) In low and middle income countries, it is not necessary that a rail metro system gets used by a large proportion of the commuters. For example, Mexico City (population 10 million) has 201 km of metro rail and it is the cheapest in the world, but it carries only 14% of trips.^{30,31}

Question 7 Should we compare the cost of different systems?

Answer:

Comparison of costs between alternate systems is essential for any public expenditure:

i) The average cost projected by DMRC for 274.6 km of metro for all projects proposed is Rs. 130 per km.

ii) The total cost of Bus Rapid Transit Systems (including complete refurbishing of roads involved, signaling systems, disabled friendly road surfaces and facilities, bus stations, road side furniture including lights, and low floor modern buses) is Rs. 10-15 crores per km including buses depending on the corridor.

30 Ciudad De México, <http://www.urbanrail.net/am/mexi/mexico.htm>, 2005-01-07.

31 Schipper, L. Sustainable Urban Transport: Progress in Mexico City and Potentials for China. International Mayors Forum on Sustainable Urban Energy Development, Kunming, P.R. China, 2004.

iii) Bus Rapid Transit Systems are at least 10 times less expensive as metro systems. This means that for the same cost BRT systems can reach more than 10 times the number of people in a city than metro systems.

Question 8: Should we look at alternate options for funding public transport systems ?

Answer Property development for raising resources cannot be justified only for metros. If this is justified for metros, then the same should facility should be available to bus operators who have large properties available at depots, or even universities and schools who have been given large tracts of land by the government.

†

Rs. 35,692 are requested for 274.6 km of metro in Indian cities.

For the same amount of money more than 2,500 km of modern bus rapid transit corridors can be built in Indian cities including purchase of 12,500 modern low floor buses. Such a development would alter the look and shape of our cities and would be the most extensive urban renewal project ever as street furniture, street lights, drainage systems, all get a tremendous facelift as a part of the BRT project.

High capacity MRTS systems are justified on the logic that they can carry up to 60,000 passengers per hour per direction. Therefore, a line should carry a total of about 12 lakh passengers per day (on the basis of 10 times peak capacity) in both directions. According to news paper reports, the Delhi metro is transporting about 1 to 1.2 lakh passengers per day – this amounts to about 10% of projected capacity.

Therefore, there is no reliable evidence that the Delhi metro project can be justified on economic criteria.

SUMMARY OF SELECTED BUS RAPID TRANSIT SYSTEMS

1. City: Bogotá Country: Colombia Population: 7 million
Description

TransMilenio opened in 2000, with Phase 1 completed in 28 months. By May 2003 the system was comprised of 41 km of exclusive busways, 61 stations, 470 articulated buses and 235 feeder buses providing service to up to 792,000 passengers daily. Currently under expansion, 40 additional kilometers and 60 stations will be added to the line. The bus fleet will also increase by 335 additional articulated buses and 170 feeder buses. These additions are being gradually introduced between 2003 and 2005. In 2002, 207 million passengers were transported by TransMilenio. By July 2003 the system was transporting 744,000 weekday passengers at a rate of up to 45,000 passengers per hour, per direction. Each bus moves an average of 1,596 passengers per day. Eleven percent of riders own cars. Future plans: The overall expansion will continue until 2016, when the system will be 388 km in length. When complete, more than 80% of Bogota's citizens will live less than 500 meters from a TransMilenio line.

2. City: São Paolo Country: Brazil Population: 10 million
Description

The busway system consists of 28 km of median busways and 137 km of dedicated bus lanes that are separated from traffic by heavy studs. Passing lanes are employed on some of the busways. Peak bus flow is 300 buses per hour. Daily ridership among busway lines ranges between 38,000 and 230,000 passengers a day (up to 21,600 peak hour passengers per direction). Operating speeds range from 16 to 22 km/hr. The Jabaquara Busway operates in the Sao Mateus-Jabaquara corridor, serving an industrial area. The line has a ridership of 230,000 passengers per day and transports 21,600 peak hour peak direction passengers. Speeds 22 km/h.

3. City: Curitiba Country: Brazil Population: 2.7 million
Description

Five bus transit corridors were planned and by 1982 the transit corridors were complete. The entire system is comprised of 54 km of exclusive bus lanes. About 70% of commuters use the transit system daily, despite one of highest automobile ownership rates in Brazil. Along each of the five arteries there is a trinary road system, comprised of middle

express bus lanes with vehicle lanes on each side for local auto traffic and parking. ITS features along the running way include signal priority. Currently, 75% of all weekday commuters now travel by bus. Curitiba's bus lines serve more than 1.9 million passengers per day, over fifty times more riders than in the 1970's. The average operating speed of biarticulated buses (all-stop) is 20 km/hour and direct bus speeds are 30 km/hour. Sul Busway line carries 156,231 passengers per day and 13,014 peak hour passengers per direction. Future Plans: Future plans to extend the rapid bus network will reduce the need for conventional bus services.

4. City: Porto Alegre Country: Brazil Population: 3.7 million

Description

Porto Alegre's rapid transit system, which first opened in 1978, consists of seven busways (see separate entries for descriptions of individual busways). The public transport agency EPTC manages the busways, with bus service provided by 14 private companies and one public company. The most recent busway opened in 2004. Farrapos Busway is one of seven busways operating in Porto Alegre - 25,600 passengers per hour, per direction in the mornings and 21,100 passengers per hour, per direction in the evenings

5. City: Quito Country: Ecuador Population: 1.8 million

Description

There are currently two busways operating in Quito. The first, El Trole, began service in 1996. Electric trolley buses are employed on the line and were chosen over diesel buses due to air pollution concerns (diesel engine emissions were not fully controlled in the 1990's). An extension of the El Trole line was completed in 2000. Construction began in early 2002 on a second busway, Ecovia, which is now operational. Diesel buses that meet strict emissions requirements were chosen for this busway. There is a combined ridership of 240,000 daily riders on the El Trole and Ecovia busways. Future Plans: A third busway, the North Central runner, is under construction and should be operational in 2005. The fourth busway, Eastern South runner, is in the planning stages.

www.quito.gov.ec/DMT/dmt_inicio.htm

6. City: Kunming Country: China Population: 4.6 million

Line: Bus Lanes

Description

Kunming is the first city in China to develop bus lanes. The initial section of busway opened for service in April 1999, improving downtown traffic flow. By January 2004, 20 km of bus lanes were operational in three corridors. When complete, 40 km of bus lanes will be in service. Ridership - The passenger capacity of buses using the corridors has increased by nearly 50%, to 8,000 hourly passengers/lane. Overall bus capacity of the city has increased nearly 50%, from 500,000 riders a day prior to bus lanes (1999) to a million a day in 2004. The bus transit mode share has increased from 8% to 14%; a large portion of this shift was due to increased ridership by former bicyclists. However, since the bus lanes have opened car volume has nonetheless decreased by 20%. Future Plans: An additional 41 km of rapid bus service is planned.

7. City: Los Angeles Country: USA Population: 12.3 million

Description

Metro Rapid design began in the summer of 1999 and service was implemented less than a year later, in June 2000. The initial two lines, Ventura and Wilshire-Whittier, are part of the Federal Transit Administration's BRT Demonstration Program (Los Angeles is a consortium member). Planners chose the Wilshire-Whittier and Ventura corridors for the demonstration because of high passenger demand. Service was designed to complement, not replace, local bus service. Twenty-four additional Metro Rapid lines have been planned and seven are currently in service. Ridership increased by 25 to 30% in the two demonstration corridors (Wilshire-Whittier and Ventura). The remaining seventeen lines are being constructed at a rate of four per year, with the final lines scheduled to open in 2008. Currently, a total of nine Metro Rapid lines (two demonstration lines and seven extension lines) serve over 140 miles in Los Angeles County. When all lines are constructed, Metro Rapid will operate over 450 miles of roadway in the Los Angeles area. Future Plans: Seventeen additional corridors are being developed, adding roughly four new lines per year.

8. City: Beijing Country: China Population: 14 million

Description

Beijing is the most congested city in China, with 14 million people. Over 21 million trips are made daily, and 80% increase from 1986. Currently there are over 2 million cars

(and 12 million non-motorized vehicles). Beijing is implementing a transportation improvement program that includes construction of a rapid bus transit system, to be completed before the 2008 Olympics. The pilot corridor should be fully operational in 2005. When fully complete, the new bus system will measure 187.5 miles (300 km) in length and will provide links to the metro system and the 2008 Olympic Game facilities. Capacity is anticipated to be 210,000 passengers/day. Buses are anticipated to reach an average speed of 20-25 km/hr for local bus service, 25-30 km/hr for limited stop service and 35 km/hr for express service. This will be 20-50% faster than conventional buses. Future plans: Initial plans include construction of ten BRT lines over 200 km.

9. City: Chongqing

Country: China

Population: 4 million

Description

Chongqing's new bus service will be developed in two phases. The first is a 12 km, 6-lane exclusive busway, the second a 3 km busway along a mixed-traffic road. The total bus system will be 15 km in length and will serve the Central Business District, the Hi-tech Development Zone and the University area. The current bus system will be converted to express and feeder buses. Passenger capacity is anticipated to be 102,600 per day. Trip speeds are anticipated to increase from 17.05 km/hr to 25 km/hr. The estimated speed from a bus test run was 23-24 km/hr.

10. City: Lima

Country: Perú

Population: 8 million

Description

Lima is implementing a new government-run bus system to replace the current privately operated system of public transport. 42,000 buses are now in Lima's private fleet with minibuses comprising nearly 90% of this number. The new plan will implement a rapid transit system with feeder routes in order to improve efficiency, 28.6 miles of busways will be built along a north-south axis, from Independencia in the north to Chorrillos in the south. Feeder routes will serve the end terminals from the low income areas at edge of Limaen commute, lessen congestion and reduce the accident rate.

Selected extracts from international reviews

World Bank Urban Transport Strategy Review -Mass
Rapid Transit in Developing Countries
Final Report
July 2000

Halcrow Fox in association with Traffic and Transport Consultants
<http://wbln0018.worldbank.org/transport/>

Capacity. Busways, depending on specification, have a practical capacity of 10 -20,000 passengers per hour per direction (pphpd), or occasionally higher. There are no examples of LRT carrying flows in excess of 10,000 pphpd, and there is reason to doubt whether they can achieve much higher flows. Metros by comparison carry very large passenger volumes – 60,000 pphpd or higher; and high-specification suburban rail can typically carry 30,000 pphpd.

Ability to segment the market. Bus systems have this ability, by running basic and air-conditioned / guaranteed seated/express buses. Rail systems exceptionally provide women-only carriages, but otherwise do not segment the market.

S1.2.11 While implementation is quite demanding (in terms of institutional co-ordination and traffic engineering/control skills), the evidence is that thereafter the operational performance is robust. Cost is relatively low – the infrastructure is typically US\$ 1- 1.5mn/km and the all-in cost including buses at the top end of the range is US\$5mn/km. A major advantage of busways is their flexibility in implementation and operation. While continuous, segregated busways are desirable, short discontinuities (where the road cross-section does not allow implementation) can be overcome using traffic management techniques. Busways can be implemented incrementally as funds allow, and their performance can be upgraded over time.

S1.3.6 Busways are clearly beneficial to the poor. Many of the poor use buses and busways create major accessibility benefits for them, particularly when they live in the outer city areas,

and particularly with ‘ open’ systems, or ‘ trunk-and-feeder’ when there is through-ticketing. If ‘ greener’ busways were developed, then the poor in particular would benefit from this through better health (they often spend long hours living, working or travelling in the street environment), but maybe at the expense of higher tariffs.

S1.4.17 Incorporating Attitudes to MRT – there often appears to be a gulf between the results of apparently rational technical analysis and what is actually implemented, and this often points to a weak project development process. This particularly concerns the support for rail systems compared with bus systems by politicians, when analysis shows bus systems to be more affordable and more readily implemented.

S1.4.21 Forecasting Requirements – we have reported on the poor record of forecasting costs, ridership and revenues, and have analysed the probable causes. This has created a heavy burden of expectation, and then produced problems when they have failed to materialise. To some extent forecasts will always be uncertain, but much can be done to avoid them being misleading.

S1.5.2 Busways – where they are politically acceptable, busways should often be the first step in MRT system development, and for many cities they will remain the MRT system for the foreseeable future. We have seen that they can – in the right environment, effect major improvements in accessibility, benefiting most of the city’ s population, and particularly the poor. And they can achieve this quickly and incrementally as conditions and funding allow.

Characteristic	BUSWAY	LRT	METRO	SUBURBAN RAIL
Current Applications	Widespread in Latin America for 20+ years	Widespread in Europe Few in dev’ g cities, none with ‘high’ ridership	Widespread, skewed to Europe and North America	Widespread, skewed to Europe and North America
Segregation	At-grade	At-grade	Mostly elevated/u’ gd	At-grade
Space req’ t	2-4 lanes from existing road	2-3 lanes from existing road	Elevated or u’ gd, little impact on existing road	-
Flexibility	Flexible in both imp’ n and op’ s, robust operationally	Limited flexibility, risky in financial terms	Inflexible and risky in financial terms	Inflexible
Impact on Traffic	Depends on policy/design	Depends on policy/design	Reduces congestion somewhat	May increase congestion when frequencies high
PT Integration	Straightforward with bus operations. Problematic with paratransit	Often difficult	Often difficult	Usually existing
Initial Cost US\$m/km	1-5	10-30	15-30 at-grade 30-75 elevated 60-180 u’ gd	-
Practical Capacity Pass/hr/direction	10-20,000	10-12,000? (no examples)	60,000+	30,000
Operating Speed Kph	17-20	20? (no examples)	30-40	40-50+

Selected extracts from

Mobility 2001: World Mobility at the End of Twentieth Century and its Sustainability

Prepared for the Sustainable Mobility Working Group of the World Business Council for Sustainable Development by the Massachusetts Institute of Technology and Charles River Associated Incorporated

www.wbcsgmobility.org

What future for the busway and urban rail?

Busways are among the most cost-effective means of improving urban mobility. The great benefit of dedicated busways is their ability to move large numbers of passengers — typically up to 25,000 passengers per hour per direction — at relatively low cost, typically \$1 to \$3 million per kilometer, 50 to 100 times cheaper than subways.

Latin America is a pioneer in dedicated busway deployment, led by Brazil and the storied example of Curitiba . Today, busways exist in Quito (Ecuador), Bogotá , Lima, Santiago, and the Brazilian cities of Recife, Porto Alegre, Goiania, São Paulo, and Belo Horizonte. Beyond being relatively cheap, busways can be deployed quickly, which makes them popular in cities enduring difficult political and financial conditions.

Bogotá: It is Never Too Late to Start Improvements

Bogotá's "Transmilenio," which started operation in December 2000, was built upon the concept of "Troncales" (busways) drawn from Curitiba. Bogotá's first "troncal" was actually built in the 1980s on Caracas Avenue. Although never operated as originally designed, this two-lane-per-direction busway was used by nearly 500 buses and carried, under difficult conditions, an estimated 35,000 passengers per hour per direction — astounding levels for a busway, surpassing the practical ridership levels often obtained by metros. The Transmilenio project modified the infrastructure and operational standards of Caracas Avenue and implemented busways on two other main arteries. Current costs of busway development are estimated at \$5 million per kilometer, with financing coming from a 20% increase in the gasoline tax as well as from national government transfers. Currently, 20 additional corridors for busway development are being considered to expand the system. The stated goal of the city government is eventually to have 85% of the city population within 500 meters of a bus stop.

Bogotá has also taken important steps toward building a "car-free" culture. For example, "Pico y Placa" restricts the use of 40% of the private autos during weekday peak hours. To date, Bogotá has avoided many of the negative consequences that plague a similar program in Mexico City. In addition, the city implemented two car-free days (in February 2000 and 2001), aimed at educating the population about alternative ways to move in the city. Building on the relative success of these initiatives, the city government put its policies to the test in a public referendum, which the voters approved. The referendum includes the "celebration" of a "Car-Free Day" the first Thursday of every February, and the restriction of all private autos during weekday peak hours starting in 2015. The government has also embarked on an aggressive program to link the entire city by nearly 200 kilometers of bike lanes.

Annexure 4. Accessibility of different modes

INDICATOR OF ACCESSIBILITY:

Accessibility is a very important factor when we consider transportation. For example even if we have a trunk line with high capacity made on a high origin destination points, even then if the trunk line is not easily accessible then the construction and high speed of the trunk line may get overshadowed by the inaccessibility of the line (Or the station). Thus there is a need for a quantitative tool that can give us an indication of accessibility. An attempt was made at deriving an indicator that would give realistic values of accessibility and at the same time is simple to calculate. For this purpose the following indicator of accessibility is developed.

$$[T1/(T1+T2)] + [A*(n-1)]$$

The smaller the value of this accessibility ratio is the better accessible the mode of public transport it is. And a larger value indicates difficulty in accessing the route. Here T1 is the time taken by a user to access the trunk line i.e. The time taken by him to start from his residence and reach the Mass rapid transport vehicle after walking (or using a feeder system if available depending on his trip profile) and time taken to reach at final destination from egress point. T2 is the time taken by the user to travel a fixed standard distance on the trunk line. n is the number of different modes taken by the user. It is at least two as the person even if he doesn't take a feeder trip starts from his residence and walks up to the station and then boards the MRT. A is the factor which takes into account the perception of discomfort by the user at transfers. This factor shall be unique for a given community and depends upon its socio-economic behavior. This factor can in reality only be calculated by a survey of the given population residing in the area, which is the potential user of the system. (In this paper value of A is taken as 0.1)

Accessibility of different modes is compared on the basis of total trip profile.

Mode	Access time	Egress time	Average speed at line haul	n
2-wh	Time of taking out vehicle from garage = 2 minutes	Time spent for parking vehicle and reaching to the destination = 2 minutes	25 km/hr	1; only two wheeler is used for total trip
3-wh	Time spent in walking from home to 3-wh stand = 5 minutes (average distance of 350 m)	Time spent in getting off from 3-wh and to reach at destination = 2 minutes	20 km/hr	2; 3-wh and walk
Car	Time of taking out vehicle from garage = 5 minutes	Time spent for parking vehicle and reaching to the destination = 3 minutes	40 km/hr	1; only car is used for total trip
Taxi	Time spent in walking from home to bus stop = 7 minutes (average distance of 500 m)	Time spent in getting off from taxi and to reach at destination = 2 minutes	40 km/hr	2; Taxi and walk
Bus	Time spent in walking from home to bus stop = 7 minutes (average distance of 500 m)	Time spent in walking to reach at final destination from bus stop = 7 minutes	18 km/hr	2; bus and walk
Metro	Total time spent in walking from home to metro station (avg. distance of 500 m) and time spend inside the metro station for getting ticket and to reach at platform= 8 minutes	Time spent in walking to reach at final destination from metro station = 8 minutes	35 km/hr	2; Metro and walk

Mode	Access trip				Line haul										A	n	[T1/(T1-T2)]-[A*(N-1)]									
	avg. speed	t1	t1'	T1	T2																					
					1	2	3	4	5	10	15	20	25	1			2	3	4	5	10	15	20	25		
2-wh	25	2	2	4	2.4	4.8	7.2	9.6	12	24	36	48	60	0.1	1	0.63	0.45	0.36	0.29	0.25	0.14	0.1	0.08	0.06		
3-wh	20	5	2	7	3	6	9	12	15	30	45	60	75	0.1	2	0.8	0.64	0.54	0.47	0.42	0.29	0.23	0.2	0.19		
Car	40	5	3	8	1.5	3	4.5	6	7.5	15	22.5	30	37.5	0.1	1	0.84	0.73	0.64	0.57	0.52	0.35	0.26	0.21	0.18		
Taxi	40	5	2	7	1.5	3	4.5	6	7.5	15	22.5	30	37.5	0.1	2	0.92	0.8	0.71	0.64	0.58	0.42	0.34	0.29	0.26		
Bus	18	7	7	14	3.3	6.7	10	13.3	16.67	33.33	50	66.7	83.3	0.1	2	0.91	0.78	0.68	0.61	0.56	0.4	0.32	0.27	0.24		
Metro (0.5km)	35	8	8	16	1.7	3.4	5.1	6.86	8.571	17.14	25.7	34.3	42.9	0.1	2	1	0.92	0.86	0.8	0.75	0.58	0.48	0.42	0.37		

Assumptions:

Maximum trip length of the trips made inside city is 25 km.

Average walking speed is 1.2 m/sec

Factor A is taken same for all modes and is 0.1.

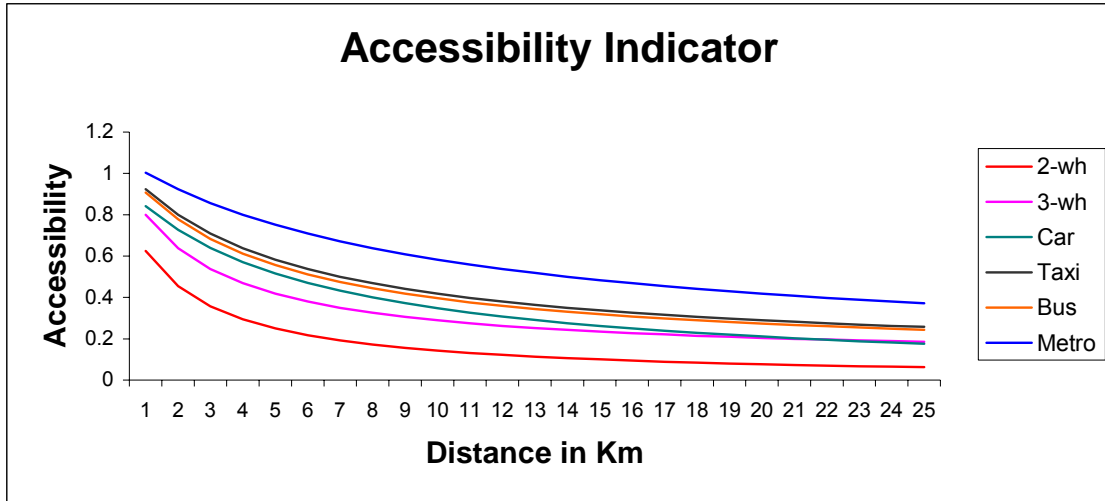


Table and graph shows that, how accessibility of different mode changes as distance of travel changes. It indicates that always two-wheeler has more accessibility than any other mode for trip made inside the city and very less accessibility of metro occurs when all other options are available.

Table shows optimum distance for each mode

Mode	Optimal distance (km)
2-wh	1.8
3-wh	2.5
Car	4.8
Taxi	7
Bus	6.5
Metro	14

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