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# Mythologies, Metros & Future Urban Transport



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INDIAN INSTITUTE OF TECHNOLOGY DELHI

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# Mythologies, Metros & Future Urban Transport

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# Mythologies, metros and future urban transport

*There is still no clear vision among planners, policy makers and transport experts about what cities in India need and what will make them better places to live in as far as mobility and access are concerned. The prevailing mythology is that construction of metro rail systems will somehow solve problems of the future and they remain the single one point agenda of almost all transport consultants in India. Review of urban mass transport systems over the past century shows that metro systems were the obvious choice when relatively inexpensive cars and two-wheelers were not available. With the introduction of efficient buses, computer and information technologies to manage large fleets, and the need to have flexible, medium capacity systems that go close to homes and destinations, bus rapid transit systems with dedicated lanes seem to be the only choice for providing affordable mass transport in our cities.*

DINESH MOHAN

## INTRODUCTION

Consider the following statements:

- “A comprehensive bus system - which would help remove thousands of cars from the streets - can be set up for the same cost as constructing a flyover, which often only serves to shift a traffic jam from one point to another... It is crucial to give due consideration to the magnitude of a project in order to avoid the risk of presenting 'show-case' solutions which are conceived for the media and only benefit a minority of the inhabitants” [Lerner 1996].<sup>1</sup>
- “Unfortunately sometimes rail systems are also chosen for the worst possible reasons... Rail system salesmen are legendary for the procedures they utilize for selling their expensive wares...bus systems are more flexible, an important asset in developing countries dynamic cities. As a city attraction center shifts, it is easier to adjust a bus system than a rail one” [Penalosa 2004].<sup>2</sup>
- “A sustainable city is one that wastes the least and conserves the maximum. Most importantly, it means making the existing system of people and resources work better--rather than throwing it away and trying to replace it with a single, capital-intensive project such as a subway or a rail-based system” [Rabinovitch 1995].
- “The demand for rail has continued to shrink because transit networks are unable to keep up with changing land use and travel patterns that have decentralized residences and employment.... Unfortunately, transit systems have been able to evolve because their supporters have sold them as an antidote to the social costs associated with automobile travel, in spite of strong evidence to the contrary. As long as rail transit continues to be erroneously viewed in this way by the public, it will continue to be an increasing drain on social welfare” [Winston and Maheshri 2007].

The above comments come from a wide spectrum of international experts, planners and politicians covering a period of more than a decade. Now examine the recent statements on need for metro rail projects for Indian cities from policy makers in India:

- A rail based Metro System is inescapable...World-over the practice is that when the population of a city reaches 1 million mark, the studies and investigations needed for a Metro System are taken up.” [Sreedharan 2004]
- “Punjab took a vital step towards the Mass Rapid Transit System (MRTS) era on Tuesday with the State Government inking a Memorandum of Understanding (MoU)... Similar rail systems would be set up at Amritsar and Mohali, steps for which are being taken on a priority basis... Speaking on the occasion, Chief Minister Parkash Singh Badal described it as a historic event which would completely revolutionise the development scenario in the State”.<sup>3</sup>
- “The Bangalore Metro comes with a package deal. Comfortable, quick, safer and economical, its energy requirement per passenger km. is only one-fifth of that of road based systems. Commuters can breathe easy, there will be no air pollution as the system runs on electric power. The economic rate of return is 22.3%”.<sup>4</sup>
- “The city is all set to have a metro rail of international standards to meet the increasing traffic congestion. The Andhra Pradesh Cabinet today approved the Rs 8,760 crore Hyderabad metro rail project covering 66 km and involving the construction of 63 stations”.<sup>5</sup>

Why are Indian policy makers out of sync with international expert opinion on choice of urban transport technologies and policies? Are Indian cities completely different from the rest of the world? Or, are the Indian experts oblivious of international developments in urban transport theory and practice? Is it possible that metro rail projects are in favour because they are extremely capital intensive and suit

most policy makers and contractors? Finally, even if all these explanations are partially valid, will urban metro rail projects help provide public transport at affordable prices, reduce congestion on roads, and reduce pollution and road traffic injuries and deaths?

In this article we trace the history of urban transport systems, successes and failures around the world, and the lessons thereof. We also describe the attributes of surface public transport systems (bus, light rail, tram) and grade separated systems (metro rail, skybus, monorail, light rail) and their suitability for 21<sup>st</sup> century cities. Finally, we comment on urban forms and other issues that affect accessibility and mobility in modern urban areas.

## HISTORY, TECHNOLOGY AND URBAN TRANSPORTATION

Urban transport can be roughly divided into the following periods:

*Pre 1850: Pre-mechanisation era.* Travel speeds (walking) about 5 km per hour. This limited city diameter to less than 5 km and influenced city form as the rich and the poor travelled at similar speeds.

*1850 – 1920: Steam engine / rail / tram / bicycle era.* Rail based transport is the first mechanised form to appear in mid nineteenth century, the bicycle in its present form at the end of the nineteenth century and the commercial motor car soon after. Before the perfection of the pneumatic tyre and improvements in road building technology large vehicles had to run on rails and so public transport was completely rail based. In the last two decades of this period the bicycle and the car appear as personal modes of transport for mainly the upper middle and rich classes. Average speeds go up to 10-15 km/h, city form decided by existence of rail tracks, and city size increases to about 10 km in diameter.

*1920-1950: Metro-bus-car era.* The diesel engine, good pneumatic tyres (making possible large buses) and mass produced cars become available in the first two decades of this period and change transport modes especially in the USA. Average urban speeds increase to about 30 km/h, buses start replacing rail based trams and metro goes mainly underground. Bicycles as personal mode starts reducing.

*Post 1950: Car era.* In this period cars become the dominant mode of travel in all rich country cities and for the upper-middle class everywhere. Underground metro systems also expand, but mainly in rich cities. Buses and para-transit remain the main modes for public transport in low income cities. Average car speeds on arterial roads go up to about 50 km/h, but door-to-door speed rarely exceeds 25 km/h. Cities can now be 20-30 km in diameter and form dictated by car travel.

Most large cities in high income countries (HIC) grew to their present size between 1850 and 1950. Technological developments were critical in changing the shape and form of the city. Before the invention of the steam engine everyone had to walk, ride horses or

horse carriages to get around. This meant speeds around 5 km/h for the rich and poor alike, and consequently city size was limited to about 5 km in diameter. Further, the city centre was very important as all important buildings and facilities had to be in the centre and that is where the rich preferred to live. City centres in Europe could be very grandiose as they represented the success of empires and the capital available from the colonies. These city centres developed as central business districts and remain so as the influential sections of society take pride in maintaining and improving these locations. Cities that have grown after 1950 do not have such characteristics and the elite of these cities do not have any particular emotional attachment to the old city centre.

Rail based transport starts in the second half of the 19<sup>th</sup> century. The first rail based metro line was completed in London in 1853, the first elevated railway in New York City in 1868, the first line of the Paris network in 1900, and in Mumbai the first suburban line, between Virar and a station in Bombay Backbay, in the year 1867. At the beginning of the twentieth century road surfaces were not very smooth and roads were paved with the same materials and technology used by the Romans: bricks laid on a well-prepared foundation of sand, gravel, and stone [Whitten 1994]. The use of asphalt and bitumen only gets perfected between 1910 and 1930. The pneumatic tyre for large vehicles takes shape after 1930 and so does the heavy duty diesel engine.

Therefore, mechanised transport could be comfortable only if vehicles moved on steel rails up to 1920 or so. This is why street trams became very popular as they were more flexible in operation and cheaper to build than underground rail systems. The golden age of the tramway system was the first quarter of the 20<sup>th</sup> century but starts declining in the 1920s. This was because systems resulting from the initial capital investment were reaching the end of their useful lives and the income from the system was not adequate enough for large investments necessary for renewal [Chant 2002]. This decline was aggravated by the appearance of the mass produced motor car and more efficient buses. The onset of the financial depression in 1929 in USA and Europe followed by the war in 1939 put the trams at great risk and they got replaced by buses (cheaper to introduce and run) in many cities helped along by the lobbying power of vehicle manufacturers.

But, underground or elevated rail and surface trains/trams remained the only mode of mechanised transport well into the 1920s for those who could afford it in all large cities of the world. This is when the largest cities expanded to around 10 km in diameter with populations around 1-2 million. If one lived away from the centre it was essential to live along the rail lines, and all factories and employment centres were built along these tracks. Rail technology decided the shape and form of these 19<sup>th</sup> century large cities in Europe and USA, also giving a great deal of importance to the central business district (CBD) as it could be fed by these trains.

Car ownership started increasing in the 1920s but most families did not own a car until the middle of the 20<sup>th</sup> century. By then the essential land use and transportation patterns of large cities in HICs except in the USA were well set with large CBDs. This encouraged building of high capacity grade separated metro systems, and in turn, the transport system encouraged densification of CBDs as large numbers of people could be transported to the centre of the city. The non-availability of the car to the middle class decided the widespread use of public transport and city form. However, this period when the bus and roads became comfortable (1920-1950), was also the period of great economic and social upheaval and little thought could be given to improving urban transport with innovations in management systems and technology. Car ownership increased much faster in the USA and so many cities did not have the political pressure to provide for public transport.

Most Indian cities have expanded after 1960 and all have planned for multiple business districts. In addition, in the second half of the 20<sup>th</sup> century most families did not own a personal vehicle and so all leisure activity revolved within short distances around the home. In the past two decades motor cycle ownership has increased substantially in Indian cities, as a result about 50% of Delhi's families own a car or a motor cycle at a very low per capita income level of about USD 1,400 per year. Such high levels of private vehicle ownership did not happen until incomes were much higher in HIC cities. Therefore, the high ownership of motorcycles, non-availability of funds to build expensive grade separated metro systems and official plans encouraging multi nodal business activity in a city has resulted in the absence of dense high population CBDs and city forms which encourage "sprawl" in the form of relatively dense cities within cities.

### **Changes in technology and declining demand for public transportation**

Most middle class families did not own air-conditioned cars with stereo systems in HICs before 1970. The cars were noisy and occupants were exposed to traffic fumes as windows had to be kept open. Under such conditions, the train was much more comfortable. This created the condition in which there would be a political demand for metro systems that came from the middle class and could not be ignored. On the other hand, brand new, quiet, stereo equipped, air-conditioned cars are being sold in India now at prices as low as USD 5,000-6,000, and used ones for quarter the price. This has made it possible for the middle class first time car owner to travel in cars with comfort levels Europeans had not experienced till the late 20<sup>th</sup> century. Air-conditioned, comfortable, safe and quiet travel in cars with music in hot and tropical climates cannot be matched by public transport. Owners of such vehicles would brave congestion rather than brave the climate on access trips and the jostling in public transport. If public transport has to be made more appealing, it has to come closer to home, reduce walking distances and be very predictable. These conditions would favour high density networks, lower capacity, surface transport systems (to reduce walking distances) with

predictable arrival and departure times aided by ITS information systems.

Wide ownership of MTWs has never been experienced by HIC cities. This is a new phenomenon, especially in Asia. The efficiency of MTWs – ease of parking, high manoeuvrability, ease of overtaking in congested traffic, same speeds as cars and low operating costs make them very popular in spite of MTW travel being very hazardous. Availability of MTWs has further reduced the middle class demand for public transport. In addition it has pegged the fare levels that can be charged by public transport operators. It appears that public transport cannot attract these road users who can afford an MTW unless the fare is less than the marginal cost of using MTW. At current prices this amounts to less than Rs 1 per km (US\$ 0.02). The only option available is to design very cost efficient public transport systems that come close to matching this price.

The above discussion shows that Indian cities in the 21<sup>st</sup> century are growing under very different conditions from those in HICs in the first half of the 20<sup>th</sup> century. The political and ideological forces combined with changes in technologies will make it difficult to provide efficient transport systems in the old manner. It will also be very difficult to move away from multi-nodal city structures with future job opportunities developing on the periphery.

Higher education and trade obviously have a reasonable amount to do with size of cities and form of urbanisation. The more "educated" we are, the larger the pool of resources we need both for work and human contact. Therefore, a large city becomes essential for a reasonable section of the population for finding "optimal" employment and friends. The Inverse of the same issue is that trade and industry need a large pool to select employees. This forces Indian cities to become larger than HIC cities. This is because for each rich person there is a larger number of poor people to serve her as compared to the proportion in HICs. So, the same number of professionals in an Indian city will coexist with a much larger number of poorer residents than that in a HIC. For the foreseeable future, this will make Indian cities much larger than the "mature" cities of Europe. The existence of large numbers of low income people pursuing informal trade and income generating activities places different political pressures on the rulers, and increases demand for low cost mobility and short distance access to jobs and trade.

This is offset by the middle and upper classes wanting to live away from the poor and form gated communities at the periphery of the city. These developments set up a powerful political demand, aided and abetted by contractors and consultants to provide infrastructure. The upper middle class of the post colonial nations mainly has the USA as a model for the good life. All Asian, African, South American cities are more influenced by the USA than any other society. For example, American town planners were sitting in Delhi helping us plan our cities in the 1950s [Breese 1963]. So all these cities have tried hard

zoning, with broad avenues and highways running through them. If this model has failed to become operational it is only due to inefficiency and shortage of finances! In the face of all these changes and constraints, the Indian upper class and policy makers still seem to think that just provision of rail based metro systems in our cities will solve all our problems.

**THE PROBLEM**

Pressures of global warming, rising pollution and road traffic injury rates, and difficulties of moving around in the city are putting pressures on the government to find solutions for “sustainable urban mobility”. In response to such pressures the Government of India announced a National Urban Transport Policy [Ministry of Urban Development 2005] and launched the Jawaharlal Nehru Urban Renewal Mission in 2006 for central assistance in overall development of cities with populations greater than one million [Ministry of Urban Development 2006]. The *Transport Policy* clearly states that its objectives would be achieved by:

- “Encouraging integrated land use and transport planning in all cities so that travel distances are minimized and access to livelihoods, education, and other social needs, especially for the marginal segments of the urban population is improved.”
- “Bringing about a more equitable allocation of road space with people, rather than vehicles, as its main focus.”
- “Enabling the establishment of quality focused multi-modal public transport systems that are well integrated, providing seamless travel across modes”
- “Encouraging greater use of public transport and non-motorized modes by offering Central financial assistance for this purpose.”

However, the *Policy* also indicates the confusion prevalent among policy makers and professionals regarding technologies needed for public transport by stating that “*Given the wide range of possibilities, it is not possible to prescribe a particular technology in a generic policy and such a choice will have to be made as a part of city specific land use and transport plans. It would also depend on the kind of city that would need to evolve at the particular location. The Central Government would, therefore, encourage all proven technologies and not promote any specific technology.*”

One would have thought that after the announcement of the above policies, transport planners in all cities would at least have focussed on the issue of bringing about a more equitable allocation of road space for people, rather than vehicles as its main focus. Not a single city in India has yet announced a policy of providing safe pedestrian or bicycle paths on all main roads in the near future. On the other hand all cities have sent in proposals for widening roads and building flyovers. About half a dozen cities have submitted proposals for introducing the Bus Rapid Transit System, but a larger number have dreams for building light rail, mono rail and metro rail systems.<sup>6</sup> The Delhi Metro Rail Corporation

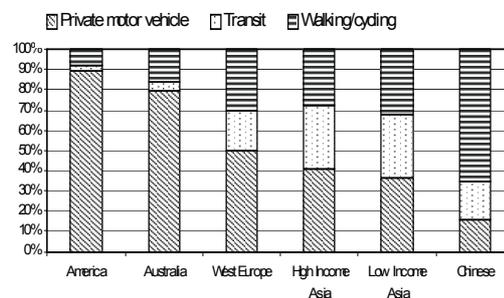
(DMRC) has completed building 65 km of metro rail in Delhi and has got approval for another 121 km, and the cities of Ahmadabad, Bangalore, Chennai, Hyderabad, Ludhiana, Mumbai and Pune are in various stages of planning /constructing one.<sup>7</sup>

There is still no clear vision among planners, policy makers and transport experts about what cities in India need and what will make them better places to live in as far as mobility and access are concerned. The prevailing mythology is that construction of metro rail systems will somehow solve problems of the future and this remains the single one point agenda of almost all transport consultants in India.

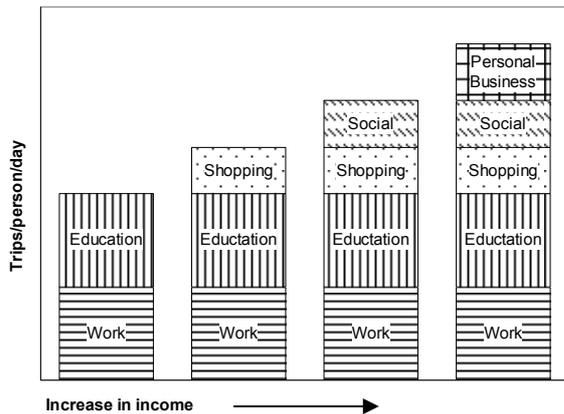
Unfortunately, the fact is that underground or elevated rail (or road) systems have not solved any of the problems of congestion, pollution or of access for a majority of city residents in any city in the world, especially new cities. In the next section we review the performance of “metro” systems around the world and use these data to understand the options available to us.

**ATTRIBUTES OF URBAN TRANSPORT SYSTEMS**

In this article we use the term “metro” to discuss all rail based urban transit systems that are largely underground or elevated. These systems would generally include metro rail transport systems (MRTS), monorail, elevated or underground light rail. Figure 1 shows the average share of urban public transit systems in different continents [Rodrigue 2005]. It is clear that on the whole North America and Australia have been reasonably unsuccessful in attracting people to use public transport in their cities. European cities have been somewhat more successful, but it is the Asian cities that have high use of both public transport and non-motorised modes. Besides factors of urban density and land use patterns that influence mobility patterns [Newman and Kenworthy 1999], one implication of these figures is that in general it is not easy to attract people to public transport modes when incomes are high.



**Figure 1.** Average modal shares in cities around the world - transit figure for low income Asian cities includes para-transit (adapted from Rodrigue 2005).



**Figure 2.** Effect of increasing income on trip demand per person.

**Trip demand**

Figure 2 is a conceptual representation of how transport demand increases with increasing incomes. The main point to be noted here is that only the work and education trips are compulsory in nature, and their numbers remain constant with increasing incomes. All the other trip types are flexible and smaller in number than work trips. Therefore, if we segregate work and education trips in time (which is being practised most Indian cities), then we need only to plan for the peak demand of work trips, as the optional trips would be undertaken at other times of the day. With appropriate neighbourhood school admission policies and provision of safe walking and bicycle facilities much of the demand for education trips can be converted to non-mechanised modes.

This is an important issue as all transportation and city development plans prepared by consultants in India have justified provision of wider roads and very high capacity transport systems on major corridors of a city based on linear projections of ever increasing total trips per capita.<sup>6</sup> Though the number of work trips does not increase with rising incomes or increasing population, the total number of trips per corridor can increase with increase in city size, but this can be moderated by transport demand management, change in modal shares and, therefore, it is not advisable to increase urban road widths beyond 40-45 m. Very wide roads inside a city disrupt social structures and community relationships, especially among children and the elderly [Dora 1999; Dora 2007].

**Door to door trip time**

Figure 3 shows door to door travel times for different trip distances. Bus travel times are for *Bus Rapid Transit* (BRT) systems where buses ply on dedicated lanes undisturbed by other traffic. The data presented in Figure 3 shows that:

- a. Travel by car or motorcycle will always give the least travel time compared to all other modes unless there is congestion on the road.
- b. Travel by any rail system (metro) that is underground or elevated has a minimum door-to-door trip time of about twenty minutes. Walking is faster

than using the metro for distances 1-2 km, and bicycling is faster for distances 3-4 km.

- c. BRT gives lower travel times than the metro for distances less than ~ 6 km.
- d. The metro only becomes efficient for trip distances greater than 12 km.
- e. If you introduce one change or one feeder trip for a metro trip, then travel by metro takes more time than by car or motorcycle for trips less than 12 km even if there is congestion on the road.

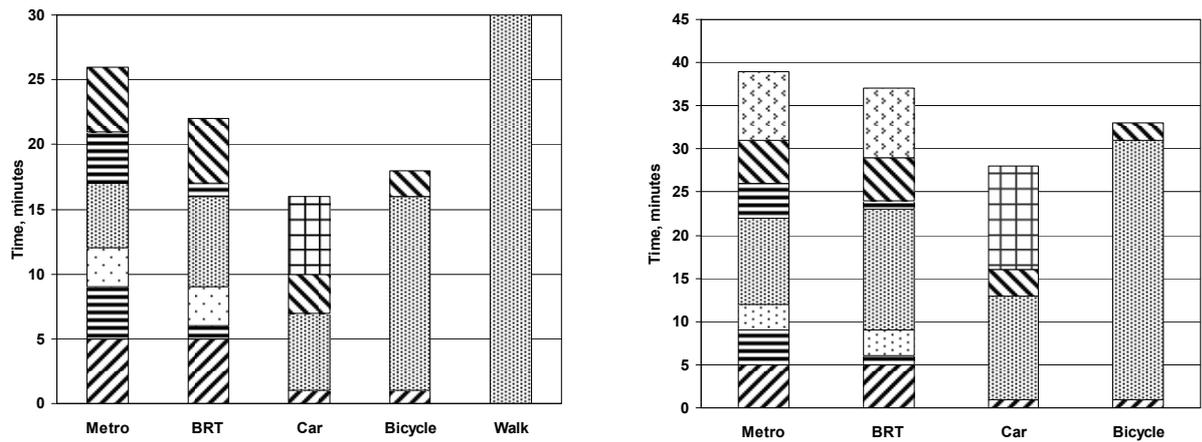
These numbers make it quite clear that elevated and underground public transport systems do not provide time saving compared to car or motorcycle use unless there is congestion on the road or the trip is very long. Because of the time lost on escalators and long walking distances inside underground or elevated metro and monorail stations, the use of BRT on dedicated lanes becomes more efficient for trips less than about 10-15 km.

**Modal share and trip length**

High income country experience

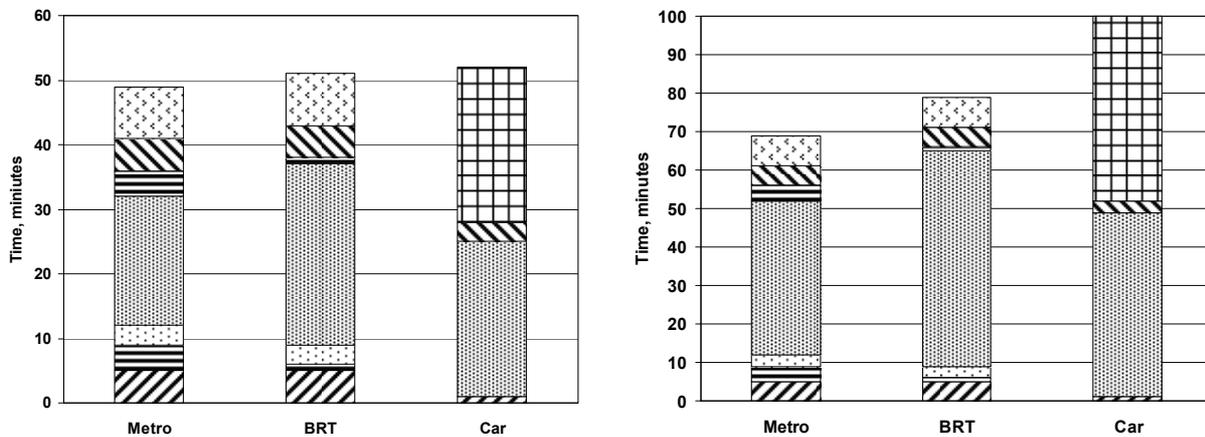
Figures 4 and 5 show the distribution of trips by different modes of transport in the metropolitan areas large cities in high income regions [Cerin, Macfarlane, Ko, and Chan 2007; Kawabata and Shen 2006; McGuckin and Srinivasan 2003; Morichi 2005; Statistics Singapore 2006; Transport Department 2007; Transport for London 2006; WBCSD 2004]. Table 1 shows the modal shares by different modes of transport in medium sized cities (population generally less than one million persons) in Europe [Commission for Integrated Transport UK 2001].

These data show the tremendous variation in car use and public transport use at similar levels of income. In most large cities in HICs car use remains high except in Hong Kong and Tokyo. Mobility needs and modes used are greatly influenced by urban form and infrastructure policies. Hong Kong and Tokyo, both have very dense and congested central business districts and restrictions on parking [Newman and Kenworthy 1999]. Tokyo is the only one among large urban conglomerations of the world where metro/rail transport captures more than 30% of daily trips. Generally this share remains around 20% even though some of these cities have extensive regional metro/rail networks: London – 1,140 km, New York – 550 km, Tokyo – 612 km, Singapore – 138 km, Hong Kong – 259 km, Paris – 798 km. Hong Kong is the only urban conglomeration where public transport accounts for a majority of the trips. This is probably because of the dense land use pattern of the city, relative unavailability of car parking space and the limits to expansion until recently. The Hong Kong experience is unlikely to be repeated in any other city. What is interesting is that walking plus bus use is high in all these cities, with the exception of greater New York.



(a) 3 km trip

(b) 6 km trip



(c) 12 km trip

(d) 24 km trip

- Walking to station/veh**
 **Walking in station**
 **Waiting at station**
- Journey in vehicle**
 **Walking to destination**
 **Congestion (car)**
- One change**

**Notes:**

Metro: A generic term used for all underground or elevated mass transport systems including MRTS, light rail, monorail and skybus.

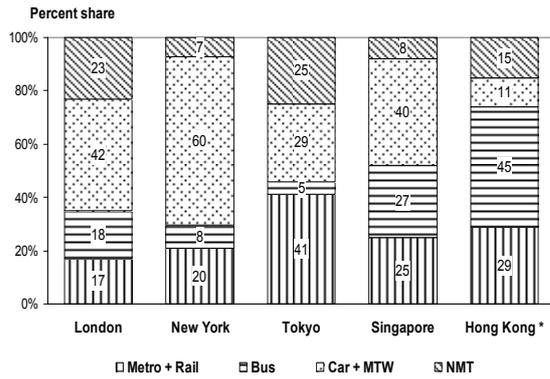
BRT: Bus Rapid transit, bus system running on surface dedicated bus lanes.

Car: Term includes motorcycles.

**Assumptions:**

- Walking speed: 6 km/h; Bicycle speed: 12 km/h; Average Metro speed: 35 km/h; Average BRT speed: 25 km/h; Average Car speed: 30 km/h without congestion, 15 km/h with congestion.
- Average time taken from origin to BRT/Metro station and to destination: 5 minutes (500 m)
- Average time spent walking inside metro stations: 4 minutes
- Average time spent waiting for train/bus: 3 minutes
- Congestion: Extra time spent in car if there is congestion
- One change: Extra time taken for changing routes once on BRT/Metro or taking one feeder bus to metro: 8 minutes (shown only for trips > 3km)

**Figure 3.** Door-to-door trip times by various modes of transport for different travel distances.



Notes:  
 All figures are for city metropolitan areas.  
 MTW: Motorized two-wheelers, NMT: Non-motorised transport – walking and bicycling.

\* Figures for Hong Kong adapted by including 15% share for NMT.

**Figure 4.** Distribution of trips by different modes of transport in large cities in high income regions (Source: Adapted from Cerin, Macfarlane, Ko, and Chan 2007; Kawabata and Shen 2006; McGuckin and Srinivasan 2003; Morichi 2005; Statistics Singapore 2006; Transport Department 2007; Transport for London 2006).

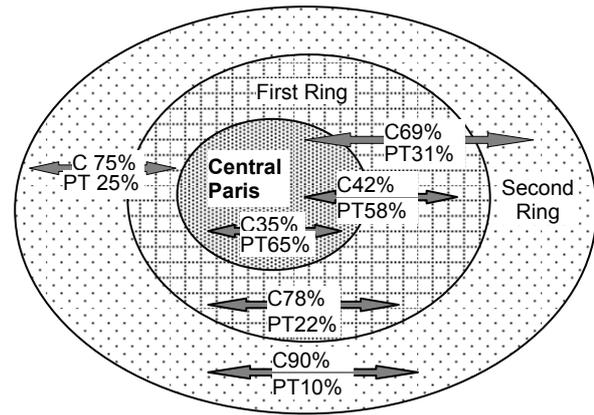
Figure 5 shows that public transport use is more than 60% only in Central Paris and less than 20% for travel within areas outside. Public transport is preferred only when travelling to the central part of Paris which has severe congestion on roads and limitations on parking space. All other cities record similar data. It is only in central Tokyo, New York, and Singapore, that public transport use exceeds 60%.

All medium sized cities of Europe have public transport use less than 30% except Leeds which manages 36% (Table 1). But, Leeds has a very high car and MTW use of 61%. These data show that car use can remain high even with provision of public transport (eg Edinburgh and Leeds). However, car

City	Modal share, percent		
	Car + MTW	PT	W&C
Bristol, UK	65	12	23
Leeds, UK	61	36	3
Nantes, France	58	14	28
Helsinki, Finland	54	20	26
Marseille, France	53	12	35
Edinburgh, UK	52	29	19
Newcastle, UK	48	19	33
Brussels, Belgium	44	18	38
Frankfurt, Germany	42	21	37
Stuttgart, Germany	36	25	39
Amsterdam, Neth's	32	16	52

MTW- motorized two-wheeler, PT – Public transport  
 W&C – Walking and cycling

**Table 1.** Modal share of trips by different modes of transport in medium sized cities in Europe (Source: adapted from Commission for Integrated Transport UK 2001)



Notes: C – Car and MTW, PT – Public Transport

**Figure 5.** Trips by mode in the Paris region (Source: Adapted from WBCSD 2004).

use is low in Amsterdam and Stuttgart where walking and cycling share is higher than public transport.

The experience of cities in HICs shows that just the provision of metro systems is not a sufficient condition for controlling car use. The empirical data from both large and medium cities suggests that car use does not seem to reduce when walking, bicycling and bus use is low. This points to the importance of urban design and land use patterns which make it easier for people to walk/bicycle safely and have easily accessible public transport stations.

Low and middle income country (LMIC) experience

Table 2 shows the modal shares of large cities in LMIC. It is not easy to obtain data that are strictly comparable as many studies do not account for walk and bicycle trips accurately. Sometimes train and bus statistically are not available separately. The data in Table 2 have been put together from different sources which have not used exactly the same definitions [Baker, Basu, Cropper, Lall, and Takeuchi 2005; de la Torre 2003; de Villa and Westfall 2001; Hidalgo 2004; Roth 2000; Tiwari 2002b; Urban Age 2007; World Business Council for Sustainable Development 2001]. However, they are good enough for detecting broad trends and patterns

These data from LMIC show car use is low in all cities. Use of private modes of transport is relatively high only in those cities where motorcycle use is higher than car use. Hanoi is a special case as bus and para-transit services are almost non-existent and motorcycles are relatively inexpensive [JBIC 1999]. When walking and bicycling trips are measured they constitute about a third or more of the trips in most cities. A study from Bangkok (noted for its traffic jams) also shows that about 30% people use non-motorised modes for getting to work [Ross, Pongsomlee, Punpuing, and Archavanitkul 2000]. No city has significant use of rail based transport except in the case of Mumbai. Manila, Delhi, Shanghai and Mexico City have metro networks of about 48, 60, 148 and 201 kilometres respectively, but account for only 2, 2, 4 and 14 percent of the local commuter trips. The case of Mexico City which has the largest metro

City	Modal Share, percent				
	Walk + bicycle	Car + MTW	Bus	Paratransit+taxi	Metro / Rail
Bangalore, India	18	35*	41	6	-
Bogota, Colombia	13	11	73	3	-
Delhi, India	37	18*	40	3	2
Hanoi, V'nam	32	60*	8		-
Johannesburg, S.Africa	33	33	5	24	5
Lahore, Pakistan	37	35*	14	14	0
Manila, Philippines@	-	21	24	53	2
Mexico City, Mexico@	-	20	61	5	14
Mumbai, India	47	11	16	3	23
Shanghai, China	54	14	28	-	4

MTW- motorized two-wheeler \* Majority MTW  
@ Walk and bicycle not included

**Table 2.** Modal share of trips by different modes of transport in cities in low and middle income countries (Baker, Basu, Cropper, Lall, and Takeuchi 2005; de la Torre 2003; de Villa and Westfall 2001; Hidalgo 2004; Roth 2000; Tiwari 2002; Urban Age 2007; World Business Council for Sustainable Development 2001)

network of 201 km is interesting. Though the fare charged in Mexico city is one of the lowest in the world, it carries only 14% of trips and the share has reduced over time as the share of mini-buses and *colectivos* has increased. Among low and middle income cities the case of Mumbai seems to be a unique one where rail trips account for 23% of commuter share. This is probably because the rail system in Mumbai is over a century old and the older part of the city developed along these rail lines when personal modes of transport were not affordable. This experience is not likely to be repeated in any modern large city.

Table 3 shows the distribution of length of trips in Mumbai and Delhi [Baker, Basu, Cropper, Lall, and Takeuchi 2005; RITES 1998]. These data show that in spite of the greater metropolitan areas of these mega cities having populations in excess of 15 million and city diameters over 15 km, a majority of the trip lengths remain below 5 km, and only about 20% of them are greater than 10 km if walk trips are taken into account. An analysis of trip times for Delhi shows that 26% of the trips by bus take less than 30 minutes and another 23% take 30-45 minutes [RITES 2005b]. The former trips are likely to be less than 3 km and the latter 3-6 km in length. The same study shows that 60% of the car trips took less than 30 minutes.<sup>9</sup> These data clearly show that even in very large cities in India a vast majority of trips remain less than 10 km in spite of large city size. This is likely to be true for many of the other cities mentioned in Table 3 also as all of them have significant proportion of non-motorised and bus trips. These data point to the fact that large cities in LMIC may have different travel patterns in terms of trip lengths than those in HICs as a majority of the people do not own cars. This is

Trip length, km	Percent of trips	
	Mumbai	Delhi
0 - 3	57	} 40
3 - 5	12	
5 - 10	12	35
10 - 15	8	} 25
> 15	11	

**Table 3.** Trip length percentages in Mumbai and Delhi (Adapted from Baker, Basu, Cropper, Lall, and Takeuchi 2005; RITES 1998)

supported by studies from Europe which show that trip length increases significantly only when people are able to own cars and travel at high speeds or use long distance commuter trains as time budgets remain relatively constant [Knoflacher 2007a].

It seems that a majority of people in LMIC cities chose to live closer to work as they do not have the option to travel at high speeds. This would mean that these large cities function as cities within cities and the effect of sprawl is different in character from the sprawl of HIC cities and we should be careful when evaluating transportation policy literature from HIC cities. If Indian large cities have high density living in spite of the sprawl, as compared to western cities [Urban Age 2007] and trip lengths are relatively short, then it becomes an ideal case to plan for walking and bicycling facilities for the healthy and efficient bus transport systems.<sup>10</sup>

The data presented above show us that contrary to the widespread perception of most urban policy makers and planners, rail based metro transportation systems play a limited role in most large cities of the world except Tokyo. The cities where metro systems have a wide network and are successful in attracting a significant proportion of commuter trips are those where the system was initiated in the first half of the 20<sup>th</sup> century, cities which have very dense and large central business districts [Cox 2004; TCRP 1996]. This is probably because the only form of mechanised transport the middle class commuters could afford had to be public transport. Technological choices were limited before the 1940s and the only system available had to be rail based. Therefore, work places and homes had to be along these lines which fed city centres, and the large cities of the early 20<sup>th</sup> century had little choice but to take these forms.

Another characteristic common to most large and mid-sized cities is that use of personal modes is low only in those cities where the combined share of walking, bicycling and public transport trips is high. Provision of public transport facilities alone is not sufficient to ensure low use of personal modes. Provision of efficient and widespread bus transport systems seems to be essential for significant transport use, even for the use of metro systems. For example, in Singapore 25% of the commuters use the metro systems but 60% of them combine it with a bus trip [Statistics Singapore 2006].

Cities in LMIC that have grown after the 1950s seem to be different in character with multiple business districts, mixed land use (largely by default, illegally), relatively short trip distances and a large share of walking and public transport, even if the latter is not provided by the city authorities.<sup>11</sup> Car share remains below 20% even at per capita incomes of incomes of US\$ 6,000-8,000 (Bogota, Mexico City). This is an important point to note as Indian incomes are not likely to reach these levels in the next twenty years. It is also clear that no city in a LMIC has been able to build a metro system that attracts a majority of public transport passengers. This is partly because no city that has grown after 1950 has a large and dense central business district. All large Indian cities are growing around the periphery and will not have dense centres in the future.

In the next section we review the performance of rail based grade separated (elevated or underground) metro systems to understand why their presence in growing low and middle income cities has not been as successful as in the large cities of some HICs.

## METRO RAIL PERFORMANCE

Metro systems in India have been justified on the basis of the following criteria [Sreedharan 2004]:

- Need to be in place when city size exceeds 3 million population
- Very high carrying capacity of 40,000 – 60,000 persons per hour per direction (pphpd).
- Reduction in time of travel, personal transport use, traffic congestion, pollution, road traffic crashes, and buses on the road.
- Increase in social welfare.

### City size, income and metro performance

One of the main justifications for introduction of Metro systems is that all large cities need a grade separated metro system as there is enough demand for transporting more than 40,000 passengers in one hour per direction during peak time. The website of the Delhi Metro Rail Corporation states: "It has been observed that in developed countries, planning for mass transit system starts when city population size exceeds 1 million; the system is in position by the time the city population is 2 to 3 million and once the population exceeds 4 million or so, planned extensions to the Mass Rapid Transit Systems is vigorously taken up... The city of Delhi with a population of round 16.2 million should have had an MRTS network of at least 300 KM by this time".<sup>12</sup>

The original feasibility study for developing a metro system for Delhi justified the economic feasibility of the system projecting a daily ridership of 3.1 million passengers by 2005 [RITES 1995]. This was later reduced to a projected demand of 2.18 million passengers to be transported per day on the first three corridors (65.8 km) when completed in December 2005 [Sreedharan 2003], and then in 2005 further reduced to 1.5 million a day.<sup>13</sup> The system is actually operating at around 0.6 million passengers

per day at the end of 2007, less than twenty percent of projected capacity. Similarly, the Kolkata metro is operating at about ten percent projected capacity [Singh 2002].

The first few metro corridors are always selected to be on the most heavily travelled stretches in a city, and so it should be surprising that the Indian metros are operating at such low levels. There are very few cities in LMICs that have metro systems. Table 4 summarizes the experience of metro (and light rail) and bus rapid transit use in LMIC cities [Cox 2001; The Bus Rapid Transit Policy Center 2007; The World Bank 2006; UrbanRail.Net 2007]. Most LMIC cities have small systems and the largest systems are much smaller than those in the cities included in Figure 4. Metro systems in LMIC cities are operating between 10 to 20 thousand passengers per day per route km (tpdpk) with Mexico City and Beijing having the highest rates (around 20,000 tppdpk). Mexico City has the oldest (30 years), the most extensive (202 km) and the cheapest system. Table 4 also shows the experience of cities with light rail systems (monorail included) and all of them have very low rates.

In Figure 6 (a-f) we examine the influence of city population, per-capita income and total transit length on the systems' productivity in terms of tppdpk. Figure 6 a shows that even in large cities (> 8 million) there is large scatter and no strong relationship with size of the population (Figure 6a). The rail systems are operating with an average productivity of 11.5 tppdpk. This should be examined in light of the fact that the projection for Phase I of the Delhi Metro for 2005 was 33.5 tppdpk and the projection for 2011 at the end of phase II is 16.1 tppdpk. Large city size does not ensure high productivity as Shanghai has half the productivity level as Mexico city at similar large populations (18 m). Similarly, per capita income does not have any strong relationship with metro productivity levels (Figure 6c) and some low income cities have higher rates than high income cities and vice versa. It is often argued that as the system length increases ridership levels will improve. Figure 6e gives no evidence for this. Shanghai (228 km) has less than half the tppdpk than both Mexico City with a large system (202 km) and Beijing with a small system (96 km). It is also likely that tppdpk productivity decreases as the system expands because it starts covering less dense corridors. In Figure 6 (b,d,f) we also examine BRT tppdpk productivity levels. For the cities examined BRT systems seem to compete well with Metro systems with levels of productivity similar to the best rail systems. Population size, per capita income, and length of the BRT system seem to have little effect on productivity. This means that BRT systems are more likely to have success than rail systems on any heavily travelled route in any city.

Figure 7 shows all the productivity (tpdpk) of metro systems in all cities with MRT in Table 4 and also New York and London. This again shows a wide scatter and just high density is not enough to project metro use with certainty. What is of note is that even in the very large HIC cities the metro share of

City	Population Million	Country per capita income US\$ per year	Type	Pass/day Million	Length km	Pass per km per day Thousand
Mexico City, Mexico	18	6,760	MRT	3.90	202	19.31
Shanghai, China	18	1,500	MRT	1.80	228	7.89
Kolkata	16	620	MRT	0.16	17	9.41
Delhi	15	620	MRT	0.60	65	9.23
Istanbul, Turkey	12	3,750	MRT	0.42	28	15.00
Beijing, China	12	1,500	MRT	2.10	96	21.88
Rio de Janeiro, Brazil	11	3,000	MRT	0.50	45	11.11
Manila, Phillipines	10	1,170	MRT	0.40	29	13.79
Bangkok	9	2,490	MRT	0.58	44	13.18
Santiago, Chile	6	5,220	MRT	0.57	60	9.50
Kuala Lumpur, Malaysia	5	4,520	LRT	0.17	55	3.09
Medellin, Columbia	4	2,020	LRT	0.29	29	10.00
Guadalajara	4	6,760	LRT	0.13	24	5.42
Tunis, Tunisia	2	2,650	LRT	0.40	32	12.50
Mexico City, Mexico	18	6,760	BRT	0.28	20	14.21
Sao Paulo, Brazil	16	3,000	BRT	0.80	78	10.26
Bogota, Colombia	8	2,020	BRT	0.79	42	18.81
Curitiba, Brazil	3	3,000	BRT	2.43	122	19.92
Quito, Ecuador	2	2,210	BRT	0.38	36	10.50

**Table 4.** Performance details for Metro (MRT), Light Rail (LRT) and Bus Rapid Transit systems (BRT) in low and middle income cities (Data sources: Cox 2001;The Bus Rapid Transit Policy Center 2007;The World Bank 2006;UrbanRail.Net 2007; official websites of metro systems; official websites of BRT systems).

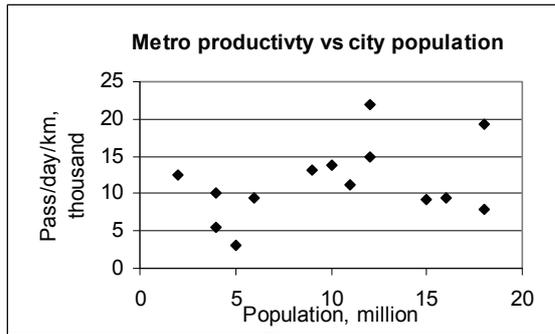
commuters is less than thirty percent except in Tokyo. In any case Tokyo and Hong Kong are exceptions, where urban rail productivity (passengers carried per km of rail) is around 27 thousand passengers per day per km [Cox 2001]. In almost all other cities in LMIC this number is less than forty percent of that in Tokyo. For example London, Paris and New York metros operate at less than half the productivity of Tokyo, and all other cities at even lower factors. Light rail productivity factors are generally less than one-tenth that of Tokyo in almost all cities.

Table 1 also shows that medium sized HIC cities have very low public transport use (which includes bus use). In the largest metro networks of around 200 km in Mexico City and Shanghai, the metro system accounts for less than 15 % of motorised trips, and if walk and bicycle trips are included it could be less than 10%. It appears that metro systems in LMIC mega cities are not likely to be very successful in attracting even a significant proportion of the total number of commuter trips and the possibility of the same is even lower.

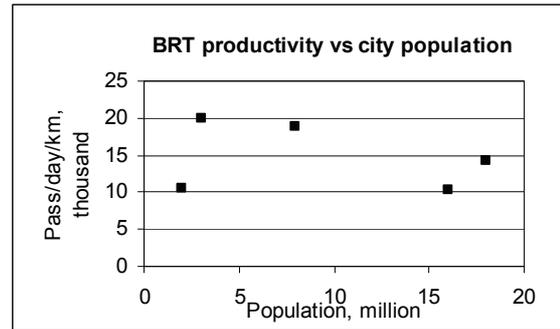
Therefore, it is not surprising that the projected ridership of 34 thousand passengers per day per km of Metro in Delhi did not come true as there is no empirical evidence for such high ridership values anywhere in the world. The Delhi metro system is

expected to complete 186 km of rail lines in 2011 and have projected a ridership of 3 million passengers per day. If we take the most successful example of Mexico City then this likely to come true, but at present Delhi rates (which also reflect the average experience of cities around the world) then the ridership is likely to be less than half that projected. This means that at the end of Phase II of the Delhi Metro project it is likely to account for much less than 10% of all trips.

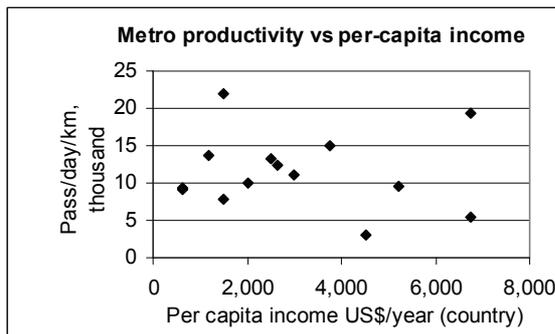
Many other studies of rail systems in LMIC cities come to similar conclusions. A study of rail systems in HIC cities concludes that "There are now some signs of a shift from light rail to bus-based systems... There is evidence from the literature that expenditure on new rail-based schemes can divert 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" [Mackett and Edwards 1998]. Another study of LMIC cities states "It is difficult to justify the use of rail-based mass transit for most cities in the developing world... Conversely, the bus-way system offers unrivalled performance and value for money. The fact that recent experience has seen a strong and growing demand for metros and LRT suggests that the



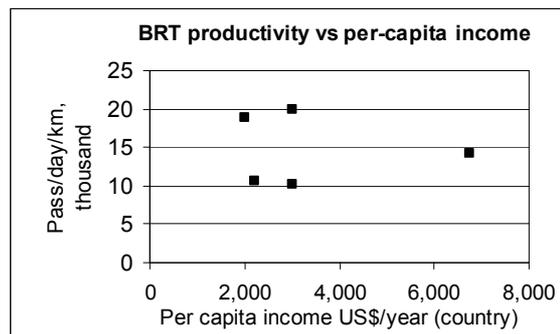
(a)



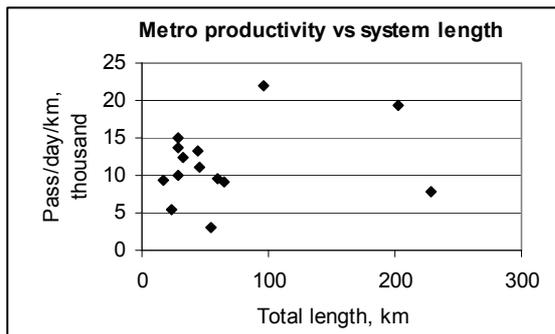
(b)



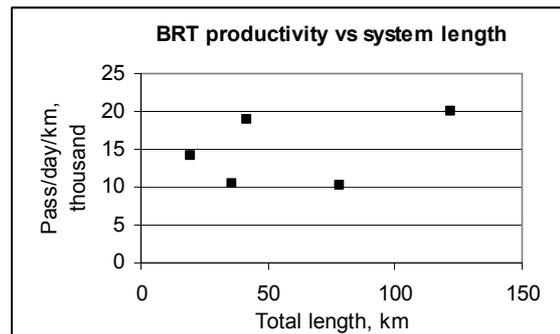
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(d)

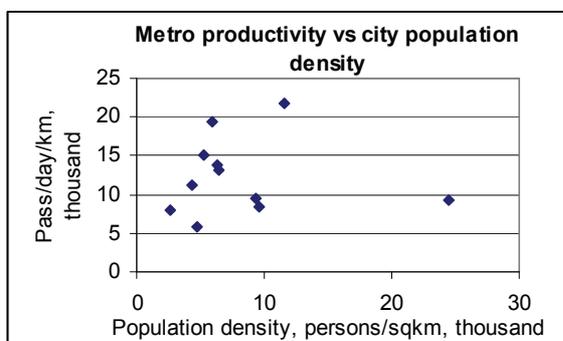


(e)



(f)

**Figure 6.** Productivity (passengers carried per day per km of system) of metro (including light rail) and bus rapid (BRT) systems in low and middle income cities (Data sources: Cox 2001;The Bus Rapid Transit Policy Center 2007;The World Bank 2006;UrbanRail.Net 2007; official websites of metro systems; official websites of BRT systems.)



**Figure 7.** Productivity (passengers carried per day per km of system) of metro systems in low and middle income cities with different population densities.

influence of intangible factors is as strong, if not more so, than the technical evidence” [Fouracre, Dunkerley, and Gardner 2003]. Another study done for the World Bank found that typical at-grade LRT throughputs were about 4,000-6,000 passengers per hour compared to busway average of 15,000 and there were no known LRT’s operating at-grade which approach the passenger carrying capacity of the existing Curitiba, Quito or Bogota busways

Various studies suggest that rail based systems are no longer suitable for cities which do not have very dense and large central business districts. Cox in his review of rail based systems around the world summarizes that “Exceedingly large central business districts are necessary to serve metro rail systems. For example, Tokyo, New York, Paris and London

have central business districts with more than 750,000 jobs. Virtually no other urbanized area in the developed world has a central business district with more than 400,000 jobs” [Cox 2004]. An international review of rail systems conducted for the US government also concludes that “Central Business Districts have traditionally been the foci of transit systems and have the highest mode shares...While job decentralization, either in polycentric regions or in dispersed patterns, results in less use of transit for all trip purposes” [Daniels 1972;Daniels 1981].

Since all cities in India have weak central business districts, are expanding in a radial mode and all new businesses and residential developments are being located on the periphery, this has very important implications for us. Taken together with all the other evidence discussed above, it is clear that none of the new grade separated rail systems (metro, light rail or mono rail) will contribute to transporting a significant number of commuters in Indian cities in the future.

**METRO RAIL, CONGESTION AND SOCIAL WELFARE**

**Congestion**

Congestion reduction is one of the most often used justification for underground or elevated rail systems. However, most other studies also support the findings of Winston and Maheshri. Mackett and Edwards [1998] conducted a worldwide survey to investigate the decision-making process involving the selection of the most appropriate technology for an urban transport system and found that the benefits of new urban public transport systems are much smaller than those anticipated by those promoting them. In most systems some or most of the funding comes from the central government and this causes a problem because the local government does not have to bear the risk of when the benefits do not occur in reality to the extent assumed. Even worse, 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. This has been found true even for light rail projects, “The justification for such high quality systems 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...Hence there is a need to consider lower cost alternatives, for example, bus-based systems” [Edwards and Mackett 1996].

**Pollution**

It stands to reason that if congestion is not relieved by metro systems then, neither would pollution be. Because, if road space and the number of vehicles remain the same, then pollution cannot decrease. This has been supported by many studies and the general conclusion is that there is no significant reduction in city pollution with the introduction of metro systems and they have not done anything significant in terms of addressing the problems caused by the car [Mackett and Babalik Sutcliffe 2003]. This is because existing road space is

Mode	CO2 g/pass-km
Car	
Petrol	186
Diesel	141
Hybrid	125
Bus	56
Metro	107

**Table 5.** CO2 emissions by mode – grammes/passenger – km of travel (Source: Bannister 2005).

always filled by vehicles over time and congestion does not reduce either by increasing road space or with introduction of metro systems [Mogridge 1997; Stopher 2004] but public officials cynically use congestion as a rationale for funding for high-profile public transit projects [Taylor 2004]. The latest report from the Texas Transportation Institute shows that in the past 25 years congestion has increased in every single urban area in the USA in spite of all investments in transit and road construction [Schrank and Lomax 2007].

The main reason for the failure of metro systems in reducing congestion or pollution is that they increase transport supply to their area of operation (in addition to the road system) by being underground or elevated. If there is a temporary decongestion of the road that is quickly filled up by latent and induced demand [Cervero 2002; Noland 2001]. The only example of reducing congestion in the central area of a large city comes from London where congestion pricing has been introduced [Santos and Shaffer 2004]. It stands to reason that if road traffic does not ultimately get affected by metro systems neither would road traffic crash rates.

**Greenhouse gases**

Ever since the emergence of a scientific consensus on global warming issues, concern about carbon dioxide (CO<sub>2</sub>) and other greenhouse gases has taken centre stage [IPCC 2007]. Transportation is a major source of greenhouse gas emissions, and the most rapidly growing anthropogenic source, and it needs to be controlled. Table 5 gives estimates of CO<sub>2</sub> emissions per passenger km by mode of travel [Bannister 2005]. Figure 8 shows estimates of CO<sub>2</sub>

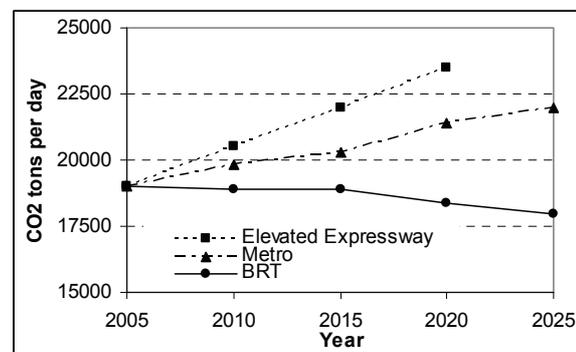


Figure 8. Estimates of CO2 production per day for Taipei (Taiwan) for different transport options (Source Chang 2007).

emissions for Taipei (Taiwan) for different urban transportation options and is also shows much better performance of BRT compared to BRT systems [Chang 2007]. Metro CO<sub>2</sub> emissions turn out to be almost double (for coal, diesel or gas power plants) than for bus because of extra efficiency loss at the power plant and transmission losses [Kågeson 2001]. This is why BRT systems are being favoured over metro and personal transport in urban areas [Christopher Zegras 2007; Vincent and Jerram 2006].

### Social welfare

One of the most detailed analyses of welfare benefits from metro rail systems has come from the Brookings Institute in Washington DC [Winston and Maheshri 2007]. The authors have used rail transit demand and cost models to estimate users' benefits and agencies' budget deficits and also account for rail's effect on the cost of roadway congestion, safety, real estate prices etc. They conclude that metro rail systems in the USA have failed to provide overall welfare benefits and, "Because no policy option exists that would enhance the social desirability of most urban rail transit systems, policymakers only can be advised to limit the social costs of rail systems by curtailing their expansion". Their analysis does not detect economic benefits in terms of reducing congestion, air pollution or accidents. They also find that energy costs of building a metro system are so high (128 million litres of petrol for one line in Portland, Oregon) that it "would take a minimum of 15 years to even begin to achieve energy savings". In regard to commercial development, "case studies have yet to show that after their construction transit systems have had a significant effect on employment or land use close to stations and that such benefits greatly exceed the benefits from commercial development that would have occurred elsewhere in the absence of rail construction". Other studies indicate that elevated metro systems can have negative effects on residential housing prices due to noise and other benefits tend to less in high income housing areas [Brons, Nijkamp, Pels, and Rietveld 2003; Debrezion, Pels, and Rietveld 2004; Nelson 1992]. The literature on the effects of railway stations on property value is mixed, ranging from a negative to an insignificant or a positive impact and commercial properties enjoy a higher positive impact compared to residential properties.

### The Delhi Metro

The experience of the Delhi Metro substantiates all of the above observations in terms of low ridership rates, and no positive welfare in terms of *actual* reductions in pollution, road traffic crashes or congestion. However, studies claiming welfare benefits are based on notional time and energy savings [Murty, Dhavala, Ghosh, and Singh 2006; RITES 2005a]. These studies calculate environmental benefits based on the theoretical reduction of motor vehicles and not the actual experience. They also do not take into account any increase in motor vehicles or trips due to induced and latent demand.<sup>14</sup> Time savings are calculated on the basis of only the train trip and not door to door time. There are generally no door-to-door time savings by metro unless the trips are greater than 12 km as shown in Figure 4. This is

mainly because access and egress times for underground or elevated systems average can average more than 20 minutes [Krygsman, Dijst, and Arentze 2004].

Actually, pollution in Delhi has increased over the past three years [CSE 2007] especially NO<sub>x</sub> and respiratory particle matter. The number of vehicles and road traffic crashes also increased by about 20 percent [Delhi Traffic Police 2007]. Traffic monitoring on the metro corridors shows that the number of motor vehicles increased and the number of buses remained constant after over the past three years [Tiwari 2007]. Metro authorities projected a decrease in buses but there has been none, and now extra feeder buses are being added to the fleet by them to bring passengers to the metro stations.

Exaggerating benefits and underestimating costs is not confined to the Indian experience. A study of more than 210 transportation infrastructure structure projects worldwide demonstrates that cost underestimation and exaggeration of benefits (both by an average factor of two) is common, especially for rail projects [Flyvbjerg, Holm, and Buhl 2002; Flyvbjerg, Holm, and Buhl 2005]. The authors conclude that "Underestimation cannot be explained by error and is best explained by strategic misrepresentation, that is, lying". They also show that forecasts have not become more accurate over the 30-year period studied, despite claims to the contrary by forecasters. Decision makers should not trust cost estimates and cost-benefit analyses produced by metro project promoters and their analysts. In the case of the Delhi metro the cost of capital alone accounts for subsidy of Rs. 35,000 per passenger passengers per year.<sup>15</sup> This is more than the per capita income (Rs 28,000 per year) of India and more than 60% of the estimated per capita income of Delhi (Rs. 56,000 per year). This is obviously not sustainable. At this cost we could send over a million children to a good private school every year. The policy implications are clear, if the risks generated from misleading forecasts are ignored or downplayed it will be to the detriment of social and economic welfare.

## CONCLUSIONS

International empirical evidence and the Delhi experience indicates that metro rail systems (elevated or underground) have not delivered the goods in terms of passengers carried or social welfare and are unlikely to in cities that do not have a very dense and large central business district. All Indian cities are developing on the periphery, have multiple business districts, and are not suited to fixed line very high capacity rail systems. The demand will never come up to the theoretical capacity of these systems partly because metro rail is not time saving as a vast majority of trips in Indian cities are less than 10 km in large cities. The presence of motorised two-wheelers makes it even more difficult as the marginal cost of travel amounts to less than Rs. 1 per km. Public transport cannot charge more than this amount without losing ridership. Therefore, we have to promote an efficient and economical public transport

system that has a dense network, is flexible, on the surface and of medium capacity (15,000 – 30,000 passengers per hour per direction). The BRT with dedicated bus lanes seems to be the only option left as it can be built at five percent of the cost of metro systems [Allport and Thomson 1990; Ben-Akiva and Morikawa 2002; Fouracre, Dunkerley, and Gardner 2003; Fulton, Hardy, Schipper, and Golub 2007; GAO 2003; Halcrow Fox 2000; Levinson, Zimmerman, Clinger, Rutherford, Smith, Cracknell, and Soberman 2003; Penalosa 2004; Ridley 1995; The Bus Rapid Transit Policy Center 2007; Tiwari 2002a; Tiwari 2002c; Winston and Maheshri 2007; World Business Council for Sustainable Development 2001].<sup>16</sup>

The cost of building elevated rail systems (including monorail and light rail) is around Rs. 1,500 million per km and for underground systems Rs 2,000-2,500. On the other hand, BRT systems cost about Rs. 50-10 million per km. About 20-30 km of BRT can be built for each km of the metro. This cost of the BRT system includes shifting of water and electric services, providing better footpaths and bicycle lanes and installing modern lighting and other road furniture. This happens because when the road layout is altered you get an opportunity to redevelop the corridor. So a BRT project ends up being an urban rejuvenation project. Since the metros are underground or elevated they do not have this effect on the ground

There are strong reasons why surface BRT is preferable in modern LMIC large cities [Knoflach 2007b]:

**Economic:** Public transport on the ground in the form of buses and street cars is cheaper to build, maintain and to operate.

**Efficiency:** Public transport is one of the most efficient modes with respect to energy consumption, use of space and safety. Therefore, there is no reason to remove it from the road surface.

**Accessibility:** Elevated or underground public transport loses half or even two-thirds of potential customers compared to street level public transport modes. Further, if public transport is separated from the street level, it becomes necessary to build and operate escalators, lifts, etc. This enhances the costs for construction, maintenance and operation.

**Security:** The entire transport system on the street level is under public social control and is, therefore, much safer.

**Urban economy:** Street level public transport is good for urban economy. The experience of European cities show that replacing street level public transport by underground systems has a negative effect on local shops. Underground or grade separated public transport systems increase both disparities and the need for longer travel.

**Structural:** Public transport on street levels keep people moving without fundamental changes of urban structures and the system provides flexibility as land use changes.

**Urban vision:** It is crucial to integrate public transport also in the mental map of people and visitors. Public transport on the streets tells the people that it is a socially balanced city.

**Environmental:** Public transport on the street level serves as an indicator for an environment friendly transport policy of the city. To integrate public transport in the human society it is necessary to keep it on the road surface instead of the sky or underground.

It is clear that urban metro systems appeared at the end of the 19<sup>th</sup> and early 20<sup>th</sup> century when there were no choices except rail available for the middle class commuters for mechanised travel. They got a further boost during the cold war when deep tunnels were justified as air raid and nuclear shelters and cost was no criterion. The evidence seems to be clear that elevated and underground rails systems are far too expensive and not very successful in 21<sup>st</sup> century LMIC large cities. Surface light rail systems may have a role in connecting megacities with surrounding towns on existing rail alignments. With the challenges of global warming staring us in the face, the only choice we have is to plan our cities for safe walking and bicycling facilities on all roads, bus rapid transit systems on all major roads, supplemented by low energy consuming economical taxi systems.

## NOTES

<sup>1</sup> Mr. Jaime Lerner was the Mayor and chief architect of the Curitiba (Brazil) Master Plan. During his 12 years in office, Lerner devised many of Curitiba's innovative and inexpensive solutions to city problems and is credited for introducing the first version of the bus rapid transit system in his city.

<sup>2</sup> Mr. Enrique Penalosa was Mayor of Bogota, Columbia, and chose to implement a bus rapid transit system instead of a metro system. He is in demand world wide to share his views on city planning and development.

<sup>3</sup> *Ludhiana to have its Metro rail service*, The Hindu, Wednesday, Oct 10, 2007, Online edition, <http://www.thehindu.com/2007/10/10/stories/2007101053990500.htm>.

<sup>4</sup> Bangalore Mass Rapid Transit Limited (BMRTL), Benefits of Namma Metro, <http://www.bmrc.co.in/benefits.html>, accessed 2007-10-15.

<sup>5</sup> Hyderabad to have metro rail, The Tribune, online edition, Sunday, January 21, 2007, Chandigarh, <http://www.tribuneindia.com/2007/20070121/nation.htm#4>, accessed 2007-10-16.

<sup>6</sup> See the website of the Ministry of Urban Development to get an insight into this confusion (<http://urbanindia.nic.in/moud/programme/ud/main.htm>). The Ministry has to repeatedly write to the states and cities to clarify matters. e.g. "...This Ministry is receiving proposals for flyovers road widening, Metros etc. under JNNURM Viability Gap Funding budgetary support from Government of India... while proposing any option, all other options should also be evaluated specially when high cost options are being proposed" (D.O. No. K-14011/07/2007-UT, dated: 22nd May, 2007, from Secretary Urban Development to Chief Secretaries of all states).

<sup>7</sup> The Managing Director of DMRC, Mr. E. Sreedharan, is today convinced that all cities above 3 million population should have a metro system and is in the process of preparing detailed project reports for implanting such systems (see *Project Monitor* 20 October 2007: <http://www.projectsmonitor.com/detailnews.asp?newsid=7734>).

<sup>8</sup> The Ministry of Urban Development website <http://jnnurm.nic.in/missioncities.htm> includes all the city development plans submitted under the JNNURM. Almost all of them use this argument of increase in demand for widening roads.

<sup>9</sup> At average urban speeds of 20 km/h in Delhi, this would mean that even 60% of the car trips are less than 10 km.

<sup>10</sup> The average density in persons per square km for metropolitan regions of low and middle income cities are: Mumbai - 4,080, Delhi - 1,227, Kolkata - 7,978, Bangalore - 1,050, Shanghai - 2,619, Mexico City - 3,796. Similar statistics for some HIC cities: London - 679, Berlin - 818, New York - 783.

<sup>11</sup> When public transport is not provided officially, informal systems using mini-buses, three-wheelers and vans operate semi-legally or illegally and provide a majority of the motorized trips. No low or middle income city is without such systems.

<sup>12</sup> Delhi Metro Rail Corporation website [http://www.delhimetrorail.com/corporates/needfor\\_mrts.html](http://www.delhimetrorail.com/corporates/needfor_mrts.html) accessed on 2007-11-03.

<sup>13</sup> Delhi Metro Rail Corporation website [http://www.delhimetrorail.com/corporates/projectupdate/expected\\_ridership.html](http://www.delhimetrorail.com/corporates/projectupdate/expected_ridership.html), accessed on 2005-12-02.

<sup>14</sup> Newspapers reported the results of study done by CRRI ('Metro brings down pollution levels', Times of India, 5 Jun 2007) claiming a benefit of Rs. 20,725 million by the end of 2007 based on savings in petrol, diesel and CNG, passenger time due to faster mode, reduction in environmental pollutants and the like.

<sup>15</sup> Based on a capital expenditure of Rs. 105,710 million for Phase I, 600,000 passengers day (300,000 roundtrips), depreciation and interest rate at 5% each.

<sup>16</sup> Details of and studies regarding bus rapid transit system are available at [www.go.brt.org](http://www.go.brt.org). In India, the cost of a BRT system is Rs. 50-100 million and metro system 1,500-2,500 crore per km.

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