Metro Rail and the City
Derailing Public Transport

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There is overwhelming evidence to show that capital-intensive metro rail systems serve only a small proportion of the total trips in cities in developing countries such as India. Public-private partnerships have not been very successful, and the Delhi Metro, which is considered to be the most successful project despite falling far short of its projected number of users, enjoys numerous tax benefits not offered to the bus system, which carries at least five times more trips. Metro projects around the country are planned and implemented in isolation without any concern for feeder trips and other modes of transport. In short, the current regime seems to be biased towards the magnitude of capital required for construction of a metro system, rather than the magnitude of its benefits.

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When evaluating mass transit options for Indian cities, metro rail systems are given preference over surface systems due to the belief that road-based bus systems cannot cater to the capacity requirement as much as metro systems. In addition, metro rails are perceived to have higher levels of comfort, speed, and efficiency than bus systems. Capital-intensive construction and the high operation cost of metro rail systems necessitate financial support from central and state governments, foreign loans, tax exemptions, and other subsidies. However, this has not deterred policymakers, elected representatives, and bureaucrats from promoting metro systems in almost all the million-plus cities in India.

Promoters of metro systems claim that they reduce congestion due to a shift of users from road-based motorised modes to metro systems. This mode shift is claimed to result in reduced air pollution and road accidents. However, the experience of metro rails in low- and middle-income countries around the world shows otherwise (Mohan 2008). The evidence suggests that available space on the road very quickly gets filled up with motorised vehicles due to induced demand and the modal shift to metros eventually does not result in reduced congestion or air pollution.

India has currently four operational metro rails, the Kolkata Metro in West Bengal, the Delhi Metro and the Delhi Airport Express Link in the national capital region (NCR) of Delhi, and the Bangalore Metro (Namma Metro) in Karnataka. Similar rail projects are being planned and/or are under construction in Ahmedabad in Gujarat, Bhopal and Indore in Madhya Pradesh, Chandigarh and Ludhiana in Punjab, Jaipur in Rajasthan, Kochi in Kerala, Pune and Mumbai in Maharashtra, and Hyderabad in Andhra Pradesh.

The Planning Commission proposal for urban transport in the Twelfth Five-Year Plan (2012-17) has recommended all Indian cities with a population in excess of two million should begin planning rail transit projects, and cities with a population in excess of three million should begin constructing them (Planning Commission 2011). The estimated investment for the development of metro rails in Indian cities is $26.1 billion (Planning Commission 2011). With this level of investment in metro rail systems, will we be able to adequately address the mobility needs of our urban population?

This paper addresses the following questions.

- What proportion of trips can be served by metro systems in Indian cities?

• Do financing metro systems have an adverse effect on financing other public transport systems?
• Can a metro project lead to overall improvement in a public transport system?

1 What Proportion of Trips Can Be Served by Metro Systems in Indian Cities?

As per Census 2011, 31% of the Indian population lives in urban areas. Fifty-three cities have a population of more than one million. Table 1 shows the travel patterns of people in cities of India of different sizes.

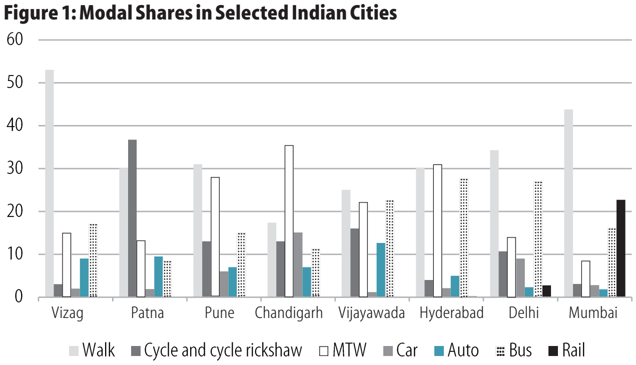
Table 1: Travel Mode Share (%) in Different City Sizes

City	Population	Walking	Cycling	Two-Wheelers	Public Transport	Cars	IPT
Category 1-a	< 5,00,000 with plain terrain	34	3	26	5	27	5
Category 1-b	< 5,00,000 with hilly terrain	57	1	6	8	28	0
Category 2	5,00,000-1 million	32	20	24	9	12	3
Category 3	1 million-2 million	24	19	24	13	12	8
Category 4	2 million-4 million	25	18	29	10	12	6
Category 5	4 million-8 million	25	11	26	21	10	7
Category 6	> 8 million	22	8	9	44	10	7
National		28	11	16	27	13	6

Source: Ministry of Urban Development (2008).

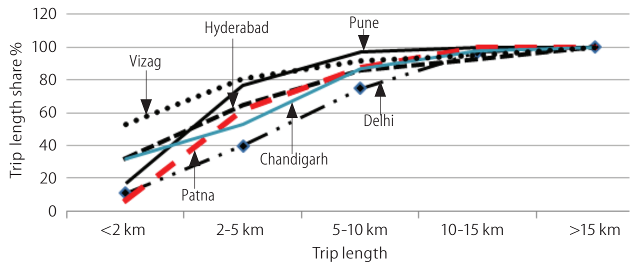
According to the Ministry of Urban Development's 2008 report, walking remains the dominant form of travel in cities. In cities with more than two million people, walking dominates other modes, except in megacities with more than eight million people. Recent surveys in selected cities (Figure 1) confirm this trend.[1] In megacities such as Mumbai and Delhi, the share of pedestrians is 45% and 33% respectively.

Figure 1: Modal Shares in Selected Indian Cities



Indian cities have a mixed land use structure with a substantial proportion of informal settlements (15% to 60% of the population living in slums). This has resulted in short trip lengths irrespective of city size. Figure 2 shows that even in big cities such as Mumbai and Hyderabad 80% of the trips are less than 10 kilometres (kms) in length and 70% of the trips are less than five km. In cities like Pune, 97% of the trips are less than 10 km and 80% are shorter than five km. The average trip length in medium- and small-size cities is less than five km.

Figure 2: Trip Length Distribution in Selected Cities



In cities such as Mumbai, Delhi, Hyderabad, and Pune, about 55%, 19%, 17%, and 19% of the population live in slums respectively (Census 2011). This income group of people cannot afford motorised public transport and are primarily dependent on non-motorised transport (NMT) even for longer distances. Only a small percentage of them use public transport for commuting (Tiwari 2002). Shorter trip lengths and a high percentage of low-income groups have resulted in a high modal share of NMT in these places.

As such, the modal share of NMT is about 30% in cities with more than one million people, which increases to nearly 60% in smaller cities (Table 1). Longer trips are dependent on bus systems, and in cities where organised bus services are not available, motorised two-wheelers (MTW), intermediate public transport (IPT), and cycle rickshaws dominate the modal share. The share of public transport (mostly organised bus systems) is more than 40% in cities with more than five million people.

• In megacities, more of motorised trips or long-distance trips are dependent on public transportation.
• In category 2 cities, the modal share of bicycle trips are in the range of 10% to 15% and that of buses is in the range of 15% to 20%. The modal share is dominated by MTW trips. Hence, the potential for a marginal increase in bicycle trips

Table 2: Trip Profiles and Expected Speeds for Different Modes

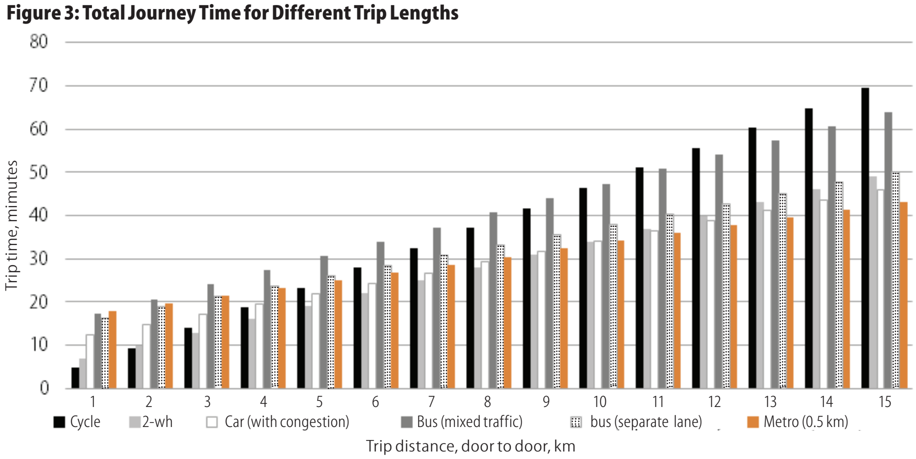
Mode	Access Time	Egress Time	Average Speed	Number of Modes Used in Making Trip
Two-wheelers	Time taking out vehicle from garage = two minutes	Time for parking vehicle and reaching destination = two minutes	25 km/hr	1; only two-wheelers used for total trip
Three-wheelers	Time walking from home to three-wheeler stand = five minutes (average distance of 350 metres)	Time getting off from three-wheeler and reaching destination = two minutes	20 km/hr	2; three-wheelers and walking
Cars	Time taking out vehicle from garage = five minutes	Time for parking vehicle and reaching destination = three minutes	40 km/hr	1; only cars used for total trip
Taxis	Time walking from home to bus stop = seven minutes (average distance of 500 m)	Time getting off from taxi and reaching destination = two minutes	40 km/hr	2; taxis and walking
Buses	Time walking from home to bus stop = seven minutes (average distance of 500 m)	Time walking to reach final destination from bus stop = seven minutes	18 km/hr	2; bus and walking
Metro	Total time walking from home to metro station (average distance of 500 m) and inside the station for buying ticket and reaching platform = eighth minutes	Time walking to reach final destination from metro station = eight minutes	35 km/hr	2; metro and walking

and a bus system integrated with an efficient IPT system has to be explored.

- In category 3 and 4 cities, trips are dominated by NMT and can attract inefficient IPT systems (like autorickshaws) and second-hand motorcycles if conditions for bicycles and walking are not improved.

Due to limited coverage of cities by rail-based systems (190 km of the Delhi Metro covers only around 12% of the total area within walking distance) as opposed to road-based bus systems, a metro commuter spends a significant amount of time on access (from origin to metro station) and egress (metro station to destination). Due to this additional time, even though the average main-haul (in-vehicle) speed in a metro is more than 30 km/hour, the average door-to-door travel speed falls for a short trip compared to a road-based system. Hence, metro systems have been found to be favourable in terms of saving time only if trips are 10 km or longer (Mohan et al 2005). Table 2 (p 66) explains trip profiles by different modes, while Figure 3 shows total journey time for different trip lengths by different modes.

Figure 3: Total Journey Time for Different Trip Lengths



Public transport provided by a metro rail or a bus system has a higher probability of usage if it is easily accessible by users. This includes accessible stations in terms of time, distance, safety, and convenience. In addition, minimum time loss at interchanges and reliable services are also important for the use of public transport. Since 500 metres (m) or less is the preferred walking distance, persons living along the metro line within walking distance have the highest accessibility to it. The area within 500 m from metro stations will be 18% of the total area of the national capital territory of Delhi after the four phases of the metro are completed (Advani 2010). Thus, even after the implementation of the four phases, 82% of the area of Delhi will be beyond walking distance of the metro. Expansion of the metro's influence zone beyond 0.5 km of walking distance depends on a feeder system. This is not easy because of inherent transfer costs and wait times at interchanges.

A transfer has a major impact on passenger journeys. Generally, a single long trip is preferred over short journeys involving transfers because each transfer implies added time, cost, inconvenience, and uncertainty. Transfers require good coordinated scheduling of feeder and main services, combined ticketing, and minimum waiting time. Whether a journey can be made without a transfer or needs one or more transfers always plays an important role in determining the modal choice.

Longer travel time or distance and higher cost imply lower accessibility and therefore a lower probability of using the system. Several researchers have found that an increase in distance to a transfer location reduces the propensity to use public transport (Keijer and Rietveld 2004; Loutzenheiser 1997; O'Sullivan and Morrall 1996). The time and distance disutility associated with the access and egress stages makes single-mode trips more attractive. The catchment area is thus not only a function of the absolute access and egress time, but also of the relative share of the total trip time. Access and egress times increase with increasing trip time, but the increase is not as strong as line-haul time, and the interconnectivity ratio (access and egress time as a proportion of total trip time) declines as the trip time increases. For most multimodal trips, the ratio falls within a modest range of 0.2-0.5. The results can be used, among others, in planning the catchment area of public transport and predicting the choice sets of realistic multimodal trips.

We can make an approximate estimation of the potential of trips by various modes based on trip length distribution, as shown in Tables 3 and 4. Since trip length is not the only criteria for selecting a mode, the percentage share shown in Table 4 is the maximum possible share of the mode indicated. In the case of Delhi, we know that after creating a 190-km-long metro network, its ridership is merely 5%. These approximate estimations indicate that regardless of city size, metros serve a small proportion of total trips. The share of bus trips will always remain higher than metros as they are more convenient for short trips. In a best-case scenario, if all the potential trips are converted to actual usage by different modes (which is unlikely), buses and a metro will together address the needs of about 50% of total trips, and the remaining 50% will require infrastructure for bicycles, rickshaws, and pedestrians.

Table 3: Trip Length Distribution (Cumulative %) in Selected Cities

	Mumbai	Delhi	Hyderabad	Pune	Patna	Chandigarh	Vizag
< 2 km	42	11	32	17	6	32	53
2-5 km	69	40	65	77	62	53	81
5-10 km	81	75	86	97	88	87	92
10-15 km	90	97	93	100	100	98	95
> 15 km	100	100	100	100	100	100	100

Table 4: Potential Trips (%) for Different Modes in Selected Cities

	Mumbai	Delhi	Hyderabad	Pune	Patna	Chandigarh	Vizag
Metro (>10 km)	19	25	14	3	12	13	8
Bus (5-10 km)	12	35	21	20	26	34	11
NMV (2-5 km)	27	29	33	60	55	21	28
Ped (>2 km)	42	11	32	17	6	32	52

Potential trips are estimated based on the percentage of trips with trip length in the range indicated within brackets, as shown in Mohan et al (1996) and Advani (2010).

Table 4 shows the maximum possible shares of metro, buses, bicycles, and pedestrians, not including cars and two-wheelers, and other factors such as cost, convenience, and so on that influence mode choice. Also, the metro is assumed to be present on all arterial roads, thus being within walking distance for most of the population. Cars and motorised two-wheelers will be at least 50% of the potential bus and metro trips. Table 5 shows cities with more than two million people and the potential share of metro trips, based on data in Table 4 for similar size cities. The most likely share of metro trips is estimated to be 50% to 75% of potential trips.

Table 5: Estimated Share of Potential and Most Likely Metro Trips in Cities with Population Greater than Two Million

S No	City	Population	Potential Metro Trips (% Share)	Most Likely Metro Trips (% Share)
1	Kozhikode	20,30,519	8-12	4-5
2	Patna	20,46,652	12	6
3	Kochi	21,17,990	8-12	4-6
4	Coimbatore	21,51,466	8-12	4-6
5	Indore	21,67,447	8-12	4-6
6	Ghaziabad	23,58,525	8-12	4-6
7	Nagpur	24,97,777	5-8	2-3
8	Lucknow	29,01,474	5-8	2-3
9	Kanpur	29,20,067	5-8	2-3
10	Jaipur	30,73,350	10-14	6-8
11	Surat	45,85,367	10-14	6-8
12	Pune	50,49,968	5	2-3
13	Ahmedabad	63,52,254	10-14	6-8
14	Hyderabad	77,49,334	14	6-8
15	Bangalore	84,99,399	12-16	6-8
16	Chennai	86,96,010	12-16	6-8
17	Kolkata	1,41,12,536	12-16	6-8
18	Delhi	1,63,14,838	22	10-15
19	Greater Mumbai	1,84,14,288	19	10-15

It can be concluded that if a city decides to invest in a metro system regardless of city size, it is for a small proportion of total trips. Usually in cities with a population of two to three million, the proportion of trips that are potentially metro trips will be less than 5%. In future, with population growth, these cities may have a population around five million, but the proportion of potential metro trips will not be more than 8%.

Forecast and Actual Ridership of Delhi Metro

Delhi Metro's average daily ridership increased from 82,179 in December 2002 to almost 1.4 million passengers in March 2011 (DMRC 2011). The ridership of Delhi Metro has been much lower than its estimated numbers. Table 6 shows the actual as well as projected ridership of Delhi Metro for four years of operation. It can be seen that the actual ridership has remained at about one-fourth of the projected figures.

Table 6: Projected and Actual Ridership of Delhi Metro in Phase I Corridors

Year	Passengers Per Day*		Actual as %
	Actual	Projected	of Projected
2006	5,00,000	25,00,000	20
2007	6,20,000	28,00,000	23
2008	7,70,000	30,00,000	25
2009	9,00,000	34,00,000	26

* Rounded-off numbers.
Source: UNFCCC (2011).

Given the trend of low ridership, Delhi Metro has revised its projected ridership many times after the completion of Phase I. The original feasibility study for developing a metro system for Delhi projected a daily ridership of 3.1 million passengers by 2005, which was later reduced to a projected demand of 2.18 million passengers per day on the first three corridors (65.8 km). This figure was further reduced to 1.5 million in 2005 (Mohan 2008). The latest revision came in 2011 (DMRC 2011), according to which the target was achieving an average ridership of two million passengers per day by the end of the year on a 190-km long network. It should be noted that the revised ridership of the 190-km network is less than the projected ridership of the 65-km of network in 2006. The inaccuracy in the estimation of projected figures for ridership has been accepted by the Delhi Metro Rail Corporation (DMRC), as seen in the following statement from the audit report of Phase I by the Comptroller and Auditor General (CAG) of India, "The fact that transport modelling for ridership was not carried out accurately by RITES [Rail India Technical and Economic Service], was accepted by the company (DMRC) as well as the Ministry of Urban Development (MoUD) before the Empowered Group of Secretaries in 2005" (2008).

To estimate the use of Delhi Metro per unit length of the network, Table 7 shows the number of passengers per km of the metro network based on actual ridership. It gives an average of ~10,500 passengers per km. Also, the revised projection of a ridership of two million passengers per day for the 190-km network gives 10,500 passengers per km. It is clear that ridership of the metro system stabilises around 10,500 passengers per km. Using this, an estimate of the ridership for the future network can also be made.

Table 7: Delhi Metro Ridership, Passengers Per Kilometre Per Day

Year	Network Length (Km)	Passengers Per Km Per Day
2007	65	9,550
2008	68	11,300
2009	76	11,600
2010	156	9,900
2013	~190	~10,000
Average		~10,500

The forecast of ridership for metro systems (or any transportation project) has a very critical role to play in evaluating their success or even the need to have such a system. These data show that the original estimate of 45,000 passengers per day per km for Phase I was exaggerated by more than 400%.

Metro projects in India (Delhi, Kolkata, Bangalore, and Jaipur) have been undertaken as stand-alone projects without any integration with bus systems, autorickshaws, cycle rickshaws, bicycles, or pedestrians, which are their important feeder systems. Therefore, the beneficiaries of the systems are much less than their non-users. Very small investment has gone into improving facilities for bicyclists, pedestrians, and bus systems, and cities continue to invest in preparing feasibility studies and detailed project reports for metro and monorail systems, as discussed in the next section.

2 Do Financing Metro Systems Have an Adverse Impact on Financing Other Public Transport Systems?

Most metro systems in India have been financed through debt-equity mechanisms. While equity is shared equally among state and union governments, debt is raised through loans from agencies such as the Japan International Cooperation Agency (JICA), formerly known as the Japan Bank for International

Cooperation (JBIC). In some cases, state or union governments also share debt in the form of subordinate loans. This method of financing has been used by the metro systems in Delhi, Kolkata (East-West Corridor), Bangalore, and Chennai. The other mechanism, known as a public-private partnership (PPP), has been used by metro systems in the Delhi Airport Express link, Mumbai, Hyderabad, and Gurgaon. In this, private entities contribute to some or most of the finance (Table 8).

Table 8: Financing Pattern of Metro Projects in India

	Union Government (%)	State Government (%)	JICA (%)	Others* (%)	Total ($ billion)
Metro project					
Delhi Metro Phases I and II	18	18	53	10	5.9
Kolkata	100	0	0	0	0.4
Kolkata East-West Corridor	24	30	46	0	0.9
Bangalore	15	15	45	25	1.6
Chennai	20	20	59	0	2.96
Public-private partnerships					
Delhi Airport Express Link	19	19	0	62	0.8
Mumbai Phase 1	9	22	28	41	5.1
Hyderabad	9	0	0	91	3.3
Gurgaon	0	0	0	100	0.22

Metro systems that have been initiated as PPPs have faced major impediments. The Delhi Airport Express Link has been transferred to the DMRC after Reliance Infrastructure opted out. A number of issues are under discussion regarding the funding and approval of this line, as seen in recent media reports.

According to an official of the urban development ministry,

> The role of banks in funding about Rs 2,200 crore to the Delhi airport metro line is under the scanner. In the case of Airport Metro Express project, which was bagged by Reliance Infra, lenders led by Axis Bank had extended a loan of Rs 2,220 crore against government-approved debt of Rs 1,247 crore. The funding pattern mentioned what would be the debt component, equity and contribution of DMRC, Delhi and central governments. While DMRC has taken approval for higher spending, we have nothing on record showing the private player getting clearance for higher debt.

Due to this increase, the DMRC has to now pay almost double the termination fee that was envisaged. Responding to this, a Reliance Infra spokesperson said the project was awarded under competitive bidding to the highest bidder and the estimated cost of the DMRC was therefore not relevant in the present case. "Moreover, estimated cost of concessionaire was advised to DMRC at the initial stage itself and it has not escalated further. It does not require any formal approval from government or DMRC", he added (*The Times of India*, 2 October 2013). A few days later, a report said,

> The showpiece Airport Metro faces the threat of becoming a non-performing asset (NPA) since the lenders have not been getting the instalment for over two months. While the lead lender Axis Bank had asked the DMRC to terminate the contract and pay 80% of debt, DMRC has turned down the proposal saying this is not compulsory on its part... News agencies reported that the consortium of lenders led by Axis Bank may send notice to Delhi Airport Metro Express Pvt Ltd (DAMEPL) for non-payment of dues for over two months quoting an official of IIFC [India Infrastructure Finance Corporation] (UK). Even the proposal of the union urban development ministry to the group of ministers (GoM) to direct DMRC to pay 80% of debt has been returned by the cabinet secretariat. The ministry has been asked to hold inter-ministerial consultation involving finance ministry, Planning Commission and even Delhi government before referring the matter to GoM. The UD ministry has sought comments from these agencies in 15 days (*The Times of India*, 12 October 2013).

The rapid rail metro in Gurgaon is the first fully privately financed metro system in India. The line was originally tendered by the Haryana Urban Development Authority (HUDA) in 2007 as a point-to-point 3.2 km link between Sikanderpur and National Highway 8, but real estate company DLF wanted to expand it to provide connectivity to its Cyber City. A new tender was issued in July 2008, and the only bidder was a DLF-Infrastructure Leasing and Financial Services (IL&FS) consortium. The project is being implemented in the PPP mode. Its entire cost will be borne by the private party and the Haryana government will provide right of way on a leasehold basis. Under this model, the private party will also maintain and operate the metro at its own cost. While the HUDA initially objected to a private company making a profit from public transport, an agreement was eventually reached for the consortium to pay it Rs 7.65 billion ($117.0 million) over 35 years in "connectivity charges" as well as 5% to 10% of advertising and property development revenue.

The contract for the Rs 9 billion ($137.7 million) project was awarded in July 2009, with completion scheduled in 30 months time. The line is to be built and operated by Rapid MetroRail Gurgaon Limited (RMGL), the consortium of DLF and IL&FS. DLF owns many properties near the stations, while IL&FS is the majority stake holder in the joint venture with 74% equity. The project cost was Rs 10.88 billion ($166.5 million) as on October 2012. A year later, a news report said, "Four days after the deadline for the launch, there is no sign of Rapid Metro rail services in Gurgaon. Rapid Metro has already missed two deadlines earlier – in January and March" (*Indian Express*, 7 October 2013).

The construction of Mumbai metro lines 1 (11.4 km) and 2 (31.8 km) involve Reliance Infrastructure. The progress has been very slow and Reliance has blamed the Mumbai Metropolitan Region Development Authority (MMRDA) for not being able to get the necessary clearances on time. A recent report stated that Reliance is most likely to exit from line 2 and has asked for higher fares on line 1 even before it has become operational (*Business Line*, 27 September 2013). The Hyderabad Metro is being constructed with Larsen and Toubro's involvement. The line is to be completed by 2014. From all this, it seems participation of the private sector in financing metros in India has not been very successful.

2.1 Tax Exemptions

In addition to debt and equity, state and central governments provide financial support to metro projects in the form of tax and other exemptions. The exemptions are provided in various forms during different stages of financing, infrastructure development, and operations. The following are the different exemptions granted to Delhi Metro (CAG 2008).

(1) Interest-free subordinate loans from the Government of India (GoI), the government of the national capital territory of Delhi (GNCTD), the HUDA, and the New Okhla Industrial

Development Authority (NOIDA) for the cost of land required for the project.
(2) The long-term debt required for the project was raised by the GoI through a loan agreement with the JICA at a concessional rate of interest and transferred to the company.
(3) Exchange rate fluctuation risk for the period of repayment of the foreign loan is to be equally shared by the GoI and the GNCTD.
(4) Exemption from property tax and electricity tax.
(5) Exemption from import duty, excise duty, sales tax, and works contract tax.
(6) No dividend to be paid on government equity till the JICA loan is fully repaid.

Subsidies for rail-based infrastructure and similar capital-intensive projects are often justified as a support system for financing such projects. Without subsidies and other support systems from governments, it is not feasible to construct and operate such projects. In terms of operation, subsidies are required to keep fares low. The high cost of operation cannot wholly be recovered from passengers as high ticket prices will deter people from using it, defeating the very purpose of a public transport system.

The DMRC has been provided with many tax exemptions.

Table 9 lists the number of taxes paid by the capital's bus transportation agency, the Delhi Transport Corporation (DTC), and the DMRC. It can be seen that while the DTC pays a number of taxes imposed by the centre and state governments and the municipal corporation, the DMRC is exempt from most of these.

Table 9: Comparison of Tax Liabilities of DTC and DMRC

Delhi Transport Corporation	Delhi Metro Rail Corporation
1 Taxes on acquisition of immovable property	1 Wealth tax
	2 Fringe benefit tax
a Tax on acquisition of land (state)	DMRC is exempt from the following taxes
b Property tax (municipal body)	1 Property tax
2 Taxes on acquisition of buses	2 Sales tax
a VAT (state)	3 Works' contract tax
b Central excise (centre)	4 Income tax
c Customs duty in case of imports (centre)	5 Capital gains tax
	6 Customs
d Octroi (municipal body)	7 Excise
e Entry tax (state)	
3 Taxes related to operations	
a Excise duty on consumables (centre)	
b VAT on consumables (state)	
c Excise and VAT on spare parts	
4 Tax on use of vehicles for transporting passengers	
a Motor vehicle tax (state)	
5 Advertisement tax (municipal body)	

Source: Tiwari and Kharola (2008) for DTC data; DMRC (2011) and *The Times of India* for DMRC data.

Tiwari and Kharola (2008) show that approximately 9% to the capital cost of a bus, and 19% of the cost of operating a bus service can be attributed to various taxes and duties, though its externalities are considerably lower than private motorised transport. If bus transport corporations are offered similar tax benefits as metros, most transport corporations will become profit-making entities. There has been no serious discussion of this at the central or state government levels, while the Ministry of Urban Development has issued a detailed note on "Innovative Financing for Metro Projects" (MoUD 2012). The note highlights the importance of metro projects.

> As you are aware MRTS projects (rail based as well as bus based) are highly capital-intensive. Yet they ought to be taken up in almost all million plus cities on an emergent basis not only to catch up with the backlog of urban transit infrastructure but also to plan for the future. Without these projects, movements in the cities have become a huge challenge. Poor mobility can become a major dampener to the economic growth. The growth of India has to happen through urbanisation and urbanisation is to be driven by efficient, effective, affordable, quick, comfortable, reliable and sustainable transportation, with the MRTS projects providing the main backbone.

It is accepted that metros are capital-intensive projects, and PPPs may not be the best option. "In 113 cities having metro rails, 88% have been developed and are being operated in public sector mode. Whereas in only 12% cities some form of Public Private Partnership exists." It is suggested in the note that since metro projects result in increase in property values in the catchment area of MRTS corridors, the increased value should be captured to fund MRTS projects. It states,

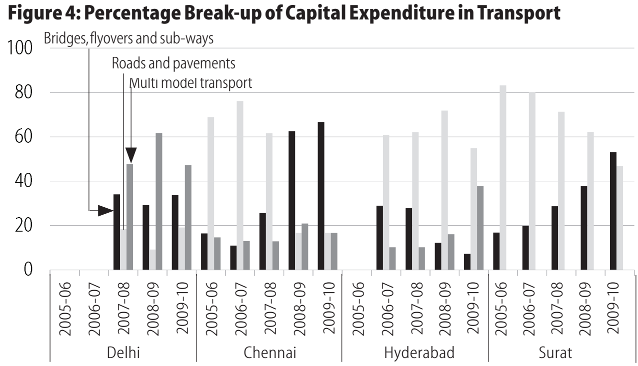
> As such there is a strong case for the government to encash the increased property value (sale/rental) in the catchment area of MRTS corridor as well as the increased FAR [floor area ratio] along the MRTS corridor which can be used to not only part fund the project cost but also for providing interest subsidy to make available the loans to the SPV [special purpose vehicle] implementing the project on a very concessional rate so as to maintain its debt service coverage ratio (DSCR) of more than 1.15 each year.

Clearly, the government is very keen to implement MRTS projects, which will never carry the majority of trips in a city. However, there is no commitment to improving bus systems or infrastructure for bicycles other than offering grants to buy buses in a few cities, as discussed in the next section.

Transport Expenditure in Selected Cities

Though transport is a state subject, the responsibility of local road improvement and implementation of projects related to road infrastructure development lie with cities or urban local bodies (ULBs). The major focus of ULBs has been relieving congestion by increasing road widths, building flyovers, and enabling an uninterrupted flow of motorised vehicles on roads. Figure 4 shows

Figure 4: Percentage Break-up of Capital Expenditure in Transport



Source: CoC (2005, 2006, 2007, 2008, 2009); GHMC (2006, 2007, 2008, 2009); Government of NCT of Delhi (2007, 2008, 2009); SMC (2009).

the expenditure pattern of ULBs in the transport sector in Delhi, Chennai, Hyderabad, and Surat, four cities of different population sizes.

Figure 4 shows that in both Chennai and Surat, the focus is on constructing bridges, flyovers, and subways. Hyderabad and Delhi have invested in multimodal transport, which primarily means metro rail systems. The improvement of the infrastructure for NMT is not accounted for separately in city budgets.

The Jawaharlal Nehru National Urban Renewal Mission (JNNURM) scheme of the central government has identified 63 cities in its first phase for urban renewal and reforms, and it will assist ULBs to upgrade and provide adequate infrastructure services. Among the basic civic amenities are access to clean water, sewage disposal, and transport infrastructure (MoUD 2005). Providing transport infrastructure and upgrading it includes the procurement of new buses, planning and optimisation of bus routes, planning other supportive public transport systems, road widening, and so on.

Table 10 shows the type of projects taken up under the scheme. Table shows that BRTS corridors have been planned and approved in nine cities, bus procurement has been sanctioned for 53 cities, and other projects related to infrastructure expansion have been approved for 21 cities. Only Nanded and Bangalore have been exclusively taken up for improvement of the infrastructure for NMT users.

3 Have Metro Projects Led to Overall Improvement in Public Transport Systems?

Since Delhi Metro is the largest metro system in India, and is also considered one of the most successful public transport projects, we present a brief overview of its process of development and its impact to draw lessons for other cities interested in investing in metro systems.

3.1 Lessons from Delhi Metro

The Delhi Metro story began in 1969 when the plan for a metro rail system was proposed in a study of traffic and travel characteristics in Delhi. In 1996, serious discussion was initiated on this and plans for a mass rapid transit system (MRTS) took shape. The MRTS, it was claimed, would alleviate the congestion problems of Delhi and reduce pollution dramatically. A report titled "Delhi on the Move 2005: Future Traffic Management Scenarios" (Mohan et al 1996) studied the travel patterns in Delhi and put forward three main ideas – (a) the non-viability of metro systems in many locations and evidence that such systems do not reduce vehicular traffic on the surface, and hence do not result in pollution reduction either; (b) the success of high-capacity bus systems initiated in

Table 10: Cities Approved for Different Transport Projects Funding under JNNURM

Types of Projects	Category of Cities					
	1	2	3	4	5	6
Comprehensive mobility plan (CMP)	Ajmer-Pushkar	Thiruvananthapuram	Coimbatore Kochi Madurai Jabalpur Amritsar	Pune Surat		Kolkata
Non-motorised transport (NMT)	Nanded				Bangalore	
Bus rapid transit systems (BRTS)			Indore Bhopal Visakhapatnam Vijayawada Rajkot	Pune Surat Jaipur	Ahmedabad	
Bus procurement	Nanded Ujjain Ajmer-Pushkar Mathura Imphal Aizawl Haridwar Agartala Puri Shimla Panaji Nainital Bodh Gaya Itanagar	Trivananthapuram Ranchi Guwahati Chandigarh Mysore Raipur Bhubaneswar Dehradun	Patna Indore Coimbatore Bhopal Ludhiana Kochi Visakhapatnam Agra Madurai Varanasi Meerut Jabalpur Allahabad Asansol Dhanbad Faridabad Vijayawada Amritsar	Pune Surat Kanpur Jaipur Lucknow Nagpur	Chennai Hyderabad Bangalore Ahmedabad	Mumbai Kolkata Delhi
Other projects (roads, flyovers, railway overbridges, and so on)	Nanded Haridwar Shimla Kohima Itanagar	Mysore Dehradun	Indore Baroda Kochi Vijayawada Amritsar Rajkot	Surat Nagpur	Chennai Hyderabad Bangalore Ahmedabad	Mumbai Kolkata

Source: Compiled from LEA Associates South Asia (2009); JNNURM (2009a); and JNNURM (2009b).

Curitiba (Brazil) and the reasons why such systems would be ideal for Delhi; and (c) the need to establish dedicated bicycle lanes on all arterial roads in Delhi as a precondition for efficient traffic flow.

For implementation and operation of the metro project, the DMRC was registered in May 1995 as a joint venture between the Ministry of Urban Affairs and the GNCTD. It started operating in December 2002 with an eight-km line (CAG 2008). With the completion of Phases I and II of Delhi Metro, there is now an operational network of 190 km consisting of elevated, at-grade, and underground lines. The group of ministers approved Phase III of the Delhi MRTS project in August 2011. The approved Phase III network has four corridors covering a route length of 103 km and 67 stations. The approved cost of the project is $7 billion. In addition, the extension of the Delhi Metro to Faridabad, covering a route length of 13.9 km with nine stations, has also been approved and will be funded by the Government of Haryana and central government (DMRC 2011). Phase IV of the project over a network of 108.5 km has been proposed by Delhi Metro, but is yet to be approved.

While the metro corridor has continued to expand, the proposal of exclusive lanes for buses and bicycles has met with a very different fate. Construction of the first phase of the BRT corridor with detailed designs for bicycle lanes and pedestrian-friendly raised crossings and tactile markings on the road was undertaken between 2006 and 2008. Design details had to be revised several times to accommodate the constraints posed by other services and stakeholders. Several rounds of meetings were held with public works department engineers explaining why the existing road guidelines and standards had to be modified as per international guidelines to construct the BRT corridor.

After two fatal accidents on the corridor under construction, media reports focused on how exclusive bus and bicycle lanes were going to take space away from car traffic. A number of reports repeatedly stressed that such designs had no place in a city like Delhi, which has been experiencing an increase in car and motorcycle traffic (Thynell et al 2010). The media reports were selective in highlighting accidents and slow traffic at the time of construction. The actual design details and facts about the expected benefits to the majority of commuters pointed out by experts did not make any difference to the media's reporting style. The first 6 km of the corridor opened in April 2008 and media reports labelled the project variously as "Big Road Trauma" and "Corridor of Chaos". In the first week of operation, there were instances of hardware and software failure in signal operations, bus drivers not stopping at designated stops, and car drivers using the bus corridor to avoid traffic delays in the car lanes.

By the second week, operation improved and traffic survey reports showed 200 buses moving in the exclusive corridor carrying 15,000 persons per hour at an average speed of 20 km/h at peak hours. The average speed of buses and ambulances had improved to 20 km/h compared to 10 km/h on other arterial roads in Delhi. Surveys of bus commuters and bicycle users showed that the majority of them (~80%) were satisfied with the design of the new corridor and would like it to be extended (CSE 2009). However, the government announced that it would evaluate the designs carefully for their impact on car traffic and slow down the expansion of the corridor. A public interest litigation (PIL) was filed against the BRT corridor in March 2012, the petitioner pleading among other things that the time of car users was more valuable than that of bus commuters, and that the exclusive corridor for buses be therefore removed. A survey of bus commuters and bicycle users was again conducted in 2012. This time too it was found that bus commuters and bicyclists benefited from the BRT corridor.

The Delhi High Court's final judgment on 24 September 2012 noted the following.

> The writ petition itself has highlighted that number of people using personal vehicles for transporting themselves has proportionately risen far more than those who use public transport, i e, buses. In fact, this data has been used by learned counsel for the writ petitioner to urge scrapping of BRT on the ground that scarce public space, i e, roads is being wasted by creating dedicated corridor for buses, which corridor remains empty most of the time, and against that cars and two-wheelers jostled for space.
>
> The respondent would agree with the figures provided and do concede that if the current trend continues, by the year 2021 car ridership would increase by 106% and bus ridership would increased by only 28%, but would use this very data to urge that keeping in view the fact that road space cannot be augmented, there is no option other than to put into place a good public transport system, with BRT being an integral part thereof; for only then would the citizen of Delhi shift to public transport.

However, after this judgment, there has been no progress in the implementation of the BRT in Delhi, while work on Phase III of the metro has continued.

3.2 Impact of Delhi Metro

Compared to road-based systems, metro systems have a high requirement of space for their station area. For property development around stations, the area requirement far exceeds the station area. Since metro line alignments as well as its stations are most often underground or elevated, the magnitude of energy required for the construction of such systems is much more than that of road-based systems. In addition, metro stations as well as passenger coaches are air-conditioned. Due to these reasons, construction and operation of metro systems have many implications on urban populations, energy requirements, and emission produced.

Electricity Consumption and Emissions

Delhi Metro consumes electricity for traction (running of trains) as well as for non-traction purposes (air-conditioning of underground stations, lighting of stations, lifts, and escalators, and so on). An analysis of the cost stream of Delhi Metro shows that electricity contributes 25% to 30% of the total operating cost. To evaluate such a system, it becomes essential to estimate the emissions attributed to its operation. According to a 2007 estimate, electricity generation in India contributes ~38% of CO_2 equivalent emissions (MoEF 2010). This is because production of electricity in India (up to ~70%) is mainly by coal-based thermal power plants. Since coal in India has a high fly-ash content (30%-40%), fly-ash residue and pollutants settle on soil, contaminating areas and becoming harmful to agricultural activities. In addition, the combustion of coal releases emissions of sulfur dioxide (SO_2), nitrogen oxides (NO_x), particulate matter (PM), carbon monoxide (CO), volatile organic compounds (VOCs), and various trace metals such as mercury into the air through stacks that disperse the pollution over large areas. Therefore, electricity-based metro systems may have less direct emissions in a city but contribute to carbon emissions at power plants during the generation of electricity used for its operations.

A recent master's thesis (Kumar 2012) at the civil engineering department, IIT Delhi, carried out a life cycle assessment of compressed natural gas (CNG) buses and the metro in Delhi. It reveals that only considering the operational aspect of transportation systems gives an incomplete picture of the overall cost. For instance, life cycle energy consumption per passenger km travelled is 90% to 120% higher for the Delhi Metro than vehicle operation. Life cycle greenhouse gas (GHG) emissions per passenger km travelled are 93% to 123% higher than vehicle operation. The energy and GHG increases are primarily due to infrastructure construction, infrastructure operation and maintenance, vehicle manufacturing, and vehicle maintenance. The GHG emissions of Delhi Metro are 1.5 times higher than the CNG-run bus system in Delhi.

Displacement of Low-Income Households

According to the environment impact assessment report of Phase I of the Delhi Metro, the project needed 348.45 hectares of land and had to relocate ~2,500 *jhuggies* (Hazards Centre 2006). Several households from different slum settlements were relocated to a designated resettlement colony called Holambikalan, located at the north-west periphery of Delhi. A scholar at the civil engineering department, IIT Delhi, investigated the impact of dislocation of households on their travel needs (Anand 2007). A survey of 2,000 households in the resettlement colony was carried out in 2004 and it found the following effects on the socio-economic profile and accessibility of relocated households.

- Bus route availability and frequency of buses declined after relocation. For 66% of the households, income fell after relocation. On an average, household income decreased from Rs 3,145 ($78.6) to Rs 2,514 ($62.85).
- Almost 99% of the households did not need use of para-transit modes for access before the relocation, but all households had to use these modes to travel after relocation.
- The daily travel distance after relocation increased from an average of 4.4 km to 15.4 km, resulting in an increase in travel time as well as cost.

Fatalities during Construction

From information obtained using the Right to Information (RTI) Act, 2005 in December 2007, there were 60 fatal accidents during the construction of the Delhi Metro from 2000 to 2007. There were also 26 major non-fatal accidents during the same period. According to another source (Civil Society 2009), which obtained information on accidents during the metro construction from police records (using the RTI Act), the total deaths were 261 and the total number of people injured was 481 by 2009.

Real Estate

Income from real estate development has a significant share in the operational revenue of metro systems. The Delhi Metro project generated as much as half of its total operational revenue from the sale and development of real estate during its initial years of operation. The implementation of the metro project led to an increase in real estate prices in areas adjacent to the metro line. According to studies done in 2007-08 (Swamy 2008), for residential areas, on an average, land value within 500 m of the metro line increased by 11%, and for commercial areas, on an average, land value within 500 m of metro line increased by 18%. Also, land value changes have been consistent and higher after the operation of metro compared to the construction and planning stage and it increases by 2% to 4% every year.

The experience with the first two phases of the Delhi Metro shows that even with ~190 km, ridership reached only a quarter of the forecast. Consequently, its modal share is less than 5%. Since the cost of metro projects runs into billions of dollars and they hardly seem to reach a double digit in the modal share of cities, it raises the important question of their cost-effectiveness. This is not counting the subsidy per passenger per year in the case of the Delhi Metro. It is important to evaluate the cost effectiveness of metro systems vis-à-vis other road-based public transportation options. Bus-based rapid-transit systems have been implemented successfully in many cities around the world and they have been shown to be competitive with metro systems. These are the least capital-intensive mass transit options available in the world. In Delhi as well as most metropolitan cities in India, buses have the major share of public transportation. With no support of the sort given to metro systems by the government, the quality of their infrastructure and operations has been affected. Thus the current regime of subsidy seems to be biased towards the magnitude of capital required for construction of a system, rather than the magnitude of its benefits.

3.3 Access/Egress Trip Characteristics of Delhi Metro Users

An on-board survey of ~1,100 metro commuters was carried out in 2011 (TRIPP 2011). The following were the major findings of the survey.

(1) More than half the respondents used non-motorised modes (walking 44%, cycling 1% and cycle-rickshaw 9.6%) for access and egress. Para-transit modes (cycle-rickshaws and autorickshaws) had a combined share of almost one-third (31%) of the access-egress trips; almost three times that of buses (11%). Usage of private motorised modes – motorised two-wheelers (MTWs) and cars – for access-egress also differed significantly. While MTWs were used for less than 4% of the access-egress trips, cars were used for 9.4%.

(2) Forty-five per cent of respondents mentioned owning no vehicles. MTWs and cars were owned by almost an equal number of respondents (~25% each) and less than 5% owned both MTWs and cars.
(3) The average trip length was 20.3 ± 0.5 km. More than 80% of the respondents had trip lengths longer than 10 km.
(4) As an indicator of mode-shift, survey respondents were asked to mention the alternative mode for their current trip. Less than 2% of the respondents mentioned non-motorised modes (walking, cycling and cycle-rickshaw) while more than half (52.5%) mentioned buses. One-eighth mentioned auto-rickshaws and 15% and 25% mentioned MTWs and cars, respectively.
(5) Up to 18% of the respondents mentioned that they would not make their current trip if the metro was not available. This indicated that up to 18% of the metro trips could have been induced trips. Any transportation system that reduces the travel time for a long-distance trip compared to other modes is bound to attract induced trips. This is also called the "rebound effect". Metro systems with an exclusive right of way have much higher in-vehicle speeds than any road-based system. For short trips (less than 10 km), the gain in overall average trip speed is not significant, but it is for long trips. While induced trips contribute to ridership of metro systems, they contribute little towards the benefit provided by a public transportation system. They are simply more trips produced, and not previous trips by other motorised modes shifting to public transportation.

A study by Advani (2010) developed a travel demand model for public and private transport modes in Delhi, including the metro network. It highlighted the following issues.

Role of Cycle-Rickshaws: The study found that nearly 27% of metro trips are dependent on rickshaws. If the present policy of the Delhi government restricting rickshaws in several parts of the city continues, metro ridership will be adversely affected.

Transport Policies: The study gives insights into the impact of policies that may lead to an increase in speeds of cars and two-wheelers. Public transport trips fall when the speeds of cars and two-wheelers increase. Also, the fall in metro trips is much more compared to bus trips. However, when the speeds of cars and two-wheelers decline by 10%, metro trips increase by more than 100%. These results highlight that rail-based systems will be more attractive when roads are congested.

Importance of Bus System: The study highlighted the importance of the bus transport system. Even after completing 256 km of the metro network, at least 64% of public transport trips in Delhi will be by bus. In addition to this, 31% of metro trips are dependent on bus feeder systems. Despite an extensive metro network, the bus system has to be made more efficient if public transport is to be promoted in a city. From this finding, it can also be argued that bus routes parallel to the metro system should not be discontinued because buses can act as a feeder mode for parallel metro stations.

Access Environment around Metro Stations

Access to metro stations contributes to a significant proportion of disutility (or inconvenience) for a trip by metro. First, the access and egress parts of a public transportation trip involve the physical effort of walking to and from stations, for transfers, and so on. Second, unlike the bus network, which has much higher coverage and smaller catchment areas for each bus stop, metro stations have much larger catchment areas. Due to this, there is a large fraction of the city's population for which access and egress distances are longer than a comfortable walking distance of 500-700 m. Third, as the access and egress trips become longer, individuals have to interact with more elements of road infrastructure, such as footpaths and pedestrian crossings. Pedestrian infrastructure has an important implication for the safety of public transport users and thus determines, to some extent, the willingness of individuals to use public transportation. Therefore, the disutility of a metro trip increases even more if the pedestrian infrastructure is inconvenient or absent,

To measure the accessibility of Delhi metro stations, accessibility audits were carried out at a sample of three major stations – Hauz Khas, Kashmere Gate, and New Delhi Railway. All the three stations lie on the yellow line, which runs north-south, and the three stations are located in three different parts of the city. Hauz Khas is located in the southern part, Kashmere Gate in the northern part, and New Delhi in the central part.

The Hauz Khas metro station caters mostly for residences and educational institutions in Hauz Khas, Kalu Sarai, Swami Nagar, Panchsheel Park, Katwaria Sarai, and Munirka. Kashmere Gate is the largest metro station and is located near an interstate bus terminal, which makes it a major interchange station between buses and the metro. In addition to interstate buses, there is a terminal for intra-city buses. Due to this, the area around this metro station is a major pedestrian hub. In addition, it is a transfer station between two metro lines – yellow and red. New Delhi is also a major multimodal hub since it is located at New Delhi Railway Station, which is one of the busiest railway stations in India. The audits were carried out at these metro stations to evaluate the accessibility of metro stations by pedestrians. In the audit, assessments were done of footpaths and pedestrian crossings. The following were the major parameters that were objectively assessed and rated.
(1) Pavement quality
(2) Geometry of pavements – width and height
(3) Lighting quality (especially for pedestrians)
(4) Barrier-free design standards (ramps and other facilities).

Major Findings from the Accessibility Survey

(1) Footpaths are present physically but they are rendered useless because of frequent discontinuity and inconvenient height. The discontinuity occurs due to driveways in front of residences, cross-streets, street furniture, trees, construction

material, potholes, manholes, and encroachment by parked vehicles. This encourages pedestrians to walk on the road, where they are exposed to risk from fast-moving traffic.
(2) There is a lack of pedestrian infrastructure along the roads providing access to metro stations.
(3) Adequate pedestrian infrastructure is available outside metro station entry gates, but it does not have barrier-free standards, and ramps were missing in all the metro sections that were audited. This makes it difficult for people with disabilities or the elderly to access stations.
(4) Where the entry of metro stations is at mid-block locations, dedicated pedestrian signals or zebra crossings are absent. The only time this is eliminated is when entry is on both sides of a road.
(5) There is an absence of lighting on footpaths. Most often, the lighting provided for the road meant for vehicular traffic is obstructed by trees or other street furniture, leading to darkness on footpaths.

4 Conclusions

(1) Metro systems will benefit a very small share of city residents who travel longer than 8 km to 10 km. Usually in cities with a population of three million, this share is less than 10%.
(2) Due to the high capital requirement of metro projects, government support is required in the form of equity shares, grants, and various tax exemptions. With an increasing number of million-plus cities in India, it needs to be evaluated whether state governments can sustain such a financial burden.
(3) A major part of revenue of metro systems comes from sources other than fare-box revenue. This has a significant implication on the self-sustainability of metro systems. It leads to the dependence of metro systems on real estate development, which often occurs at the cost of displacing poor households.
(4) Emissions and electricity consumption based on a life-cycle assessment of the Delhi Metro is higher than the CNG-run bus system.
(5) Travel demand models used in the planning and ridership forecasts of metro systems need to account for the access-egress stages of a metro trip. An underestimation of inconvenience during those stages may lead to highly overestimated ridership of metro systems.
(6) The use of motorised modes to access metro stations to increase their coverage is not very effective. Delhi shows that passengers are likely to use the metro only for long trips. However, most trips in Indian cities are short (less than 10 km) in length. Thus increasing the coverage of a metro using feeder buses cater only for a very small proportion of trips. Motorised modes to access metro stations also add to out-of-pocket expenses as well as travel time, thus discouraging their use. In addition, use of these modes to access metro stations adds to vehicular emissions.
(7) The key to improving the coverage of metro systems is to have a safe infrastructure for non-motorised modes – walking and cycling. While these modes have zero emissions, their use also adds no out-of-pocket expenses.
(8) Due to the design and limited coverage of metro systems, their use is most likely to occur for long-distance trips. This leaves a major (up to ~80%) proportion of the trips in cities to be catered for by road-based systems. Thus metro systems have a minimal effect on the ridership of, or demand for, bus systems.
(9) Metro stations lead to an intense flow of pedestrians and other access modes around station areas. The design of a metro system should include redesigning the nearby road network, thus providing for the safe dispersal of metro commuters.

The Delhi Metro has been planned and implemented as an independent project with very little integration with bus or other modes of transport. It has become more of a construction project than an integrated transport system that meets the mobility needs of the majority of commuters. Metro projects that are under construction in other cities follow the same pattern. Budget analyses of selected cities shows a lack of investment in infrastructure required by pedestrians, bicyclists, and buses.

It is clear from the above analysis that metro systems will serve only a small proportion of the total trips in a city. PPPs have not been very successful, and the most successful project enjoys a number of tax benefits not offered to the bus system, which carries at least five times more trips. Metro projects have been planned and implemented in isolation without any concern for feeder trips and other modes of transport. The current pattern of planning them and investing in them in India has not benefited any citywide public transport system.

NOTE

1 Latest survey data are available in comprehensive mobility plan (CMP) documents of various cities on the MoUD website.

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