EVALUATION OF PUBLIC TRANSPORT SYSTEMS: CASE STUDY OF DELHI METRO•

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ABSTRACT

Growing number of vehicular trips by cars and two wheelers which result in traffic congestion, air pollution and traffic accidents has become a major concern in urban areas. Investments in high capacity rail based mass transit systems are being promoted to arrest this trend. In the last two decades Kolkata, Chennai and Delhi have invested in MRTS/LRT systems. This paper analyses the methodology and arguments used to justify these systems. The paper presents evaluation of Delhi metro in terms of capacity, travel time and accessibility to the system and evaluation indices reflecting commuter's perspective.

KEYWORDS Delhi Metro, Public Transport, Buses

URBAN TRANSPORT

Transport situation in most Indian metropolitan cities is rapidly deteriorating because of the increasing travel demand and inadequate transportation system. Indian cities of all sizes are facing the crisis of urban transport. Despite investments in road infrastructure and plans for landuse and transport development, all face the problem of congestion traffic accidents and air pollution and the problems continue to grow. Large cities are facing an unprecedented growth of personal vehicles (two wheelers and cars) and in medium and small cities different forms of intermediate public transport provided by informal sector are struggling to meet the mobility demands of city resident.

In Delhi, number of two wheelers and cars continue to rise. Despite construction of flyovers and roads, the roads continue to face congestion at peak hours. In spite of the roads occupying 21 per cent of the total city area, this large number of motor vehicles causes extreme congestion on roads, ever slowing speed, fuel wastage, environmental pollution and an unacceptable level of road accidents. Delhi metro has been planned to reduce congestion on Delhi roads and augment the current public transport, which is primarily buses.

Delhi metro

RITES recommended a rail-based system, comprising a network of underground, elevated and surface corridors, aggregating to 198.5 kms, to meet the traffic demand up to the year 2021. The whole project, estimated to cost Rs. 15000 Crore at 1996 price level was expected to handle 12.6 million commuter trips. First phase of metro has been completed. DMRC web site indicates a number of benefits to metro. These are: Time saving for commuters, Reliable and safe journey, Reduction in atmospheric pollution, Reduction in accident, Reduced fuel consumption, Reduced vehicle operating costs, Increase in the average speed of road vehicles, etc. This paper presents an analyses of the benefits attributed to Delhi metro. Similar benefits were expected from Kolkata and Chennai metro also. However, performance of metro in both cities has not met the expectations.

Chennai metro

S.Vydhianathan (2003) discusses India's first elevated rail transit system in Chennai. This system has escalators to platforms, lifts for the aged and the handicapped, and modern stations. Chennai MRTS

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should be the most attractive travel option in a metro that has about 20 lakh vehicles on the road, endless hold-ups, rising pollution and a bad safety record. Yet, there are very few commuters in a three-car train and the stations are deserted – the city virtually denies its existence. Despite the huge investment of Rs.269 crores, there are no returns. Commuter patronage refuses to pick up, though the city buses are over crowded. The time has come to review the entire approach to urban transport and come up with an integrated approach to rail and road systems. Many reasons are attributed for the Chennai MRTS remaining a non-starter. Two key reasons seem to the higher fare structure and the absence of inter modal transport facility at the stations in the first phase.

Kolkatta metro

The Kolkatta metro railway is the first and only underground railway project implemented in India. The average weekday transit trips estimated in 1971 were 4.6 million, which were projected to increase to 5.3, 6.7 and 8.3 million in 1976, 1983 and 1990 respectively according to the report on Calcutta Mass Transit Study, prepared in 1971. Singh (2002) presents year-wise total working expenses and total traffic earning of the metro railway. The expected traffic in 1978 after opening of the first phase was anticipated to be 469 million passengers and in 1990, 612.5 million passengers. The annual passenger volume was estimated to be 623.7 million by 2000. The number of originating passengers on the metro railway during 1999-2000 was only 55.8 million, which is much below, approximately one-eleventh of the estimated traffic ten years ago in 1990. Low traffic is one of the main reasons of the metro railway being unviable. The system originally estimated to be constructed at a cost of Rs. 140 crores was completed at a cost of Rs. 1600 crores.

EVALUATION CRITERIA

As discussed in the previous section both Kolkata and Chennai metros have not performed as per expectations. This makes it imperative to analyze evaluation criteria critically. Following section presents analyses of Delhi metro system.

a) Influence zone

Public transport service has to meet the needs of commuters. This includes accessible stations, minimum affordable time loss at interchanges, safer and reliable services. Since 500 m. is an ideal walking distance, population residing along the metro within walking distance has the highest accessibility to metro. the area within 500 m from the metro corridor is 31% (198.5 sq.km. out of the 640 sq.km. of total urban area) of Delhi thus, after the implementation of the complete system 69% area of Delhi will remain beyond walking distance of metro. Expansion of metro influence zone beyond 31% will have to rely on feeder system. This is not easy because of the inherent transfer costs and wait times at interchanges.

Limit of access to metro is based on the assumption of most comfortable walking distance as 0.5 km. When this distance increases passengers have to use feeder system, which requires a transfer. A transfer has major impact on passenger journey. Generally simple long trip is preferred over short journeys involving transfers because each transfer implies added impedance in terms of time, cost, inconvenience and uncertainty. Transfer requires a good coordinated scheduling of feeder and main service, combined ticketing and waiting time. A journey made without any transfer and a journey with one or more transfers always plays an important role in modal choice. To compare bus and metro as a transit service, both are considered without any transfers and in that case influence zone is the area within the distance of 0.5 km (walking distance) is taken. Shukla (2004) has estimated that population residing within a distance of 0.5 km, 1 km and 2.5 km from the metro station and trips originating from these regions for phase 1, Shahadara – Barwala metro line of length 23.8 km. Population residing within 0.5 km can reach metro by walking but people residing at more than this distance have to use rickshaw or feeder bus. Population residing within the area of walking distance is 346560 for the corridor length of 23.8 km. Total length of metro line is 198.5 km, applying the same methodology for accessible population as line 1, total population residing within the distance of 0.5 km is 2890426. This is approximately 2.2 % of the total population of Delhi. Figure 2 shows total number of trips originating in the region for different catchments radius.

Trips originating in the region of 0.5 km distance i.e. walking distance is approximately 374939 for metro length of 23.8 km. Applying same weight to the total length of 198.5 km, number of trips

originating in the region of 0.5 km distance is 3127117. This shows that only 3127117 trips can be shifted to metro if all the persons have destination along the metro corridor. This may not be true.

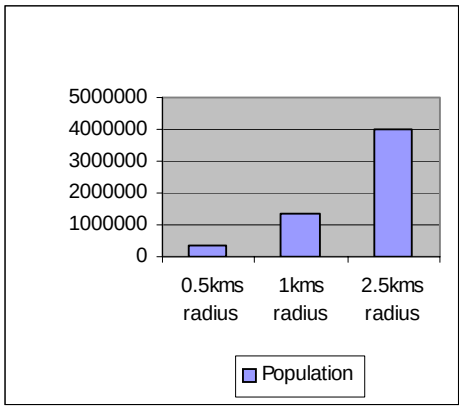


Figure 1: Total base population along the trunk line residing in the region for different catchments radii.

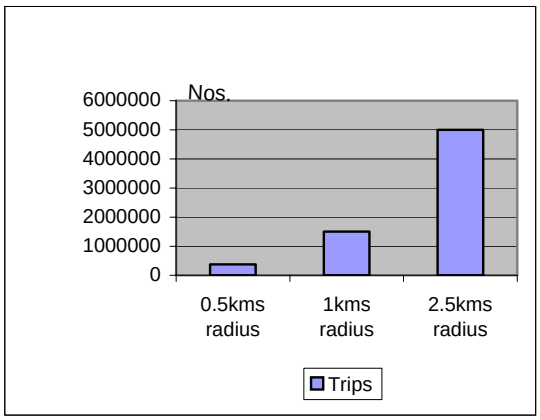


Figure 2: Total number of trips originating in the region for different catchments radii

b) Feeder service and an integrated ticket

If a very good, coordinated, well-organized feeder system is provided to the Metro, accessibility of metro will increase. DMRC is planning for an integrated ticket. If the integration works out, the same ticket will be valid in metro trains as well as buses. However, this will translate to higher rider-ship only if commuters are willing to accept the added transfer time and transfer costs.

c) Luggage

One of the Metro stop is Sahadra railway station, it is at walking distance from Sahadra railway station and Sahadra bus terminal but people traveling through this may not take benefit of metro due to restrictions on carrying luggage in metro trains. Many passengers coming and going through railway station and bus terminal have a luggage with them as it is connected to long distance travel. Metro is not available to them.

d) Parking

Parking place outside the Metro station has been provided but non-metro user can also use it. To encourage people to use Metro there should be a separate parking place for the monthly pass holders.

INITIAL AND MAINTENANCE COST OF METRO

American Dream Coalition fact sheet presents that a myth is 'pay no attention to the high construction cost, because once rail lines are built they will last forever' and the reality is
'Rail lines must be rebuilt and equipment replaced every 20 to 30 years. Reconstruction often costs much as the original construction.'

The Washington, DC, metro rail system was built at a cost of $12.5 billion. Today, its managers say that over next ten years they will need to spend another $12.5 billion renovating roadbed, replacing cars, and refurbishing stations. (americanderamcoalition.org). The federal transit administration calls these "capital costs" but really they are maintenance costs, and as such they make rail much costlier to maintain than buses. Total length of 198.5 km of metro rail will cost Rs.10751/- Crores (excluding taxes and duties) and metro has not mentioned anything about the maintenance cost. As mentioned above, maintenance cost of metro rail is as much as the original cost. It should have been considered in the cost evaluation, as it needs a large amount. Already 100% cost overrun is estimated for first phase of the metro (Rs. 12000 crores instead of Rs. 6000 crores estimated for first phase in 1996.)

Table 1 evaluates DMRC statements, which are published in different newspapers articles. DMRC officials have often used these statements for justifying and highlighting the benefits of metro system. Therefore it is important to analyze these statements. The analysis questions the basis of benefit assessment methodology for metro.

Table 1: Evaluation of DMRC statements:

<table>
<tr><td>1.</td><td colspan="3">Metro will carry the same amount of traffic as nine lanes of buses.</td></tr>
<tr><td></td><td>1 bus carries 80 passengers, 9 buses carries 9*80 = 720passengers</td><td>1 metro has 8 bogey, each bogey carries approximately 100 passengers = 800</td><td>This is static capacity comparison. This does not provide any useful information for comparing the corridor capacity, which is most crucial for public transport system.</td></tr>
<tr><td>2.</td><td colspan="3">It reduces journey time by 50 to 75%.
It is not clear that time is reduced by 50 to 75% is the journey time of buses or journey time of passengers shifted from buses to metro.</td></tr>
<tr><td>a)</td><td>Journey time of buses</td><td colspan="2">As buses have to stop at every 500 m after a certain limit it is not possible to increase its speed.</td></tr>
<tr><td>b)</td><td>Journey time of passengers shifted from buses to Metro</td><td colspan="2">It needs a total trip profile comparison. If metro stops are given every 500 m, average speed of metro will remain between 15-20 km/h.</td></tr>
<tr><td colspan="4">Bus passengers will use feeder bus to reach Metro and if they don't that means they are living close to Metro station. Therefore very few passengers will shift from bus to Metro. Two wheeler users can shift to Metro, if two wheeler owners are living near metro corridor. However, if they are living away (at distance more than 500 m) then question is why they were not using bus earlier. What will attract them to use metro?</td></tr>
<tr><td>3.</td><td colspan="3">Average Speed of buses will increase from 10.5 km/h to 14 km/h</td></tr>
<tr><td></td><td>Journey speed of bus is dependent on frequency and distance between bus stops and junctions. Speed improvement can come from rationalization of bus stops and junctions.</td><td colspan="2">If the bus has to stop many times, average speed will go down.
Speed may not get affected due to the number of passengers on the bus stop. If only a single person is boarding/alighting speed of bus has to decelerate.

New system can be implemented to increase the speed by introducing separate lane for buses and by stopping buses at alternate bus stops only.
1 2 3 4 5

This will increase the distance between two bus stops and therefore will increase the speed.
Route 620A: 1…3…5
Route 620B: 2…4…6</td></tr>
<tr><td>4.</td><td colspan="3">2400 less buses on the roads…!!</td></tr>
<tr><td></td><td colspan="3">Bose (1998) shows that Vehicle projection and composition (%) for Delhi for 2011 is,
2-wh 3-wh car/jeep taxi bus total
56.21 3.46 38.47 0.51 1.35 2786016
Forecasted no. of buses in 2011 is 37611.
2400 buses of that mean only 6.38%.
This indicates that even 2400 less buses on the roads makes only marginal difference.</td></tr>
<tr><td>5.</td><td colspan="3">Less bus will be on the roads so less congested roads will be.</td></tr>
</table>

Wendell (1998) presents that Roadway Congestion Index (RCI) i.e. Ratio of number of vehicles per lane and capacity of lane) doesn't get affected much more by the metro implementation.

Figure 3 indicates that RCI is not reduced in most cities of the world, except a marginal reduction at Washington D.C. after introduction of metros.

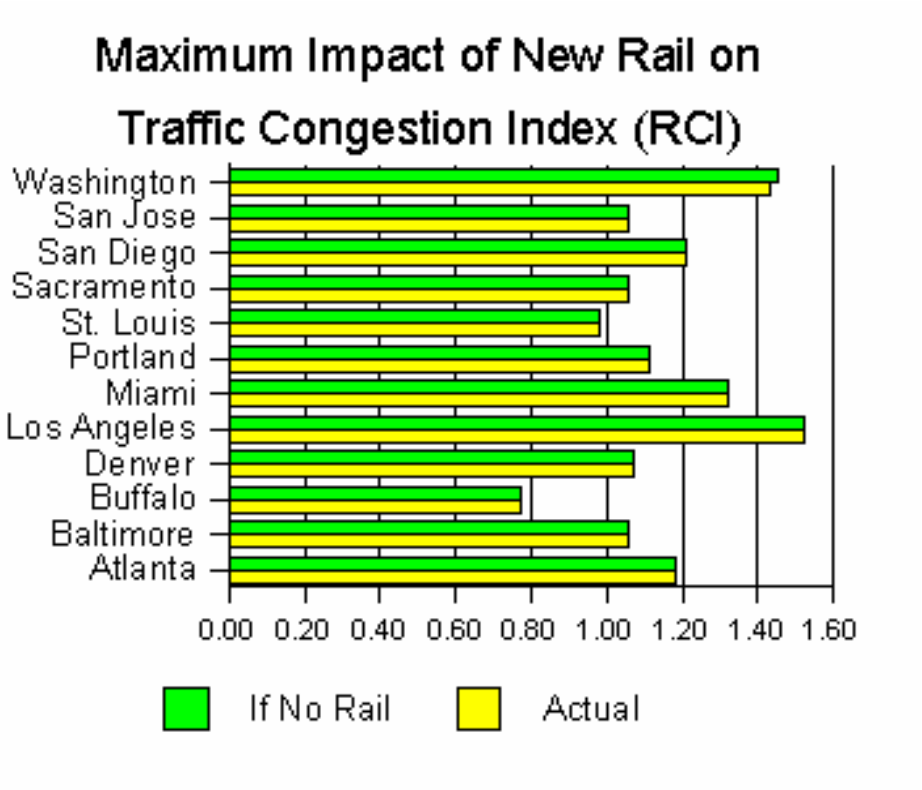


Figure 3 Roadway Congestion Index

There are other important issues, which should be considered while evaluating and comparing services provided by metros and buses.

1. Flexibility

In any case if demand of route pattern changes it is very difficult to change the Metro route accordingly. But in case of bus, it is very easy to change the route in a short time and at low cost.

2. Convenience to reach stop/station

Generally people living within walking distance of metro stations or bus stops can reach the system conveniently. This requires high-density residential areas near the metro stations. When 198.5 km corridor of metro is completed, 31% area of total urban area of Delhi will be within walking distance of the metro corridor, however only 2.2% of the total population will reside in this area. Since bus stops are on all arterial roads, which are about 1000 km long. Therefore bus stops will serve higher accessibility compared to metro stations.

3. Speed

Metro has stops at average distance of 1.0 km and average distance between bus stops is 500 m. Because of more stops, buses run at lower speed. If distance between bus stops is increased and a separate lane is provided to run the buses, speed of buses also can go up.
If metro has to stop at every 500 m, average speed of metro will go down.

WHO WILL USE THE METRO?

When DMRC expects that in 2021, 12.6 million commuter trips will be handled by metro, it means some passengers traveling by other modes at present will be shifted to metro. Who are these people? Are they car users? Or bus users? Or two-wheeler users or others?

Table 2: Percentage of trips by mode and length wise.

Mode	% of trips made by mode	Average trip length of mode
Two wheeler	17.59	10.03
Three wheeler	2.80	6.14
Car	6.94	11.28
Taxi	0.06	11.47
Bus	62.0	10.66
Others	10.61	----

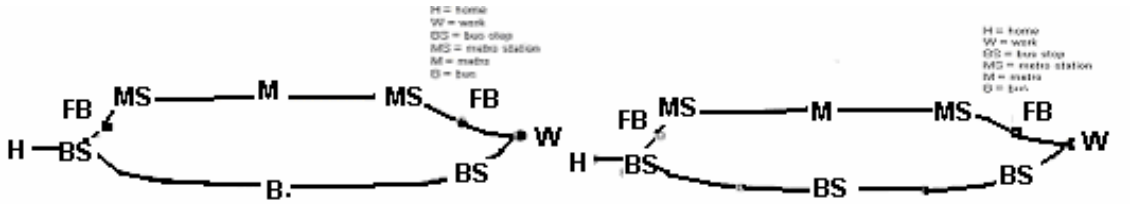
As per 1994 ORG survey (table 2), 62% trips are by buses with an average trip length of 10 km (table 2). About 18% trips are by two wheelers, which have similar average trip length. Remaining 20% trips are by other modes like cars, taxi and three wheelers. Since cars provide door-to-door service, car users are not likely to shift to metros. Therefore in the following section we analyze trip profile of bus and two wheeler users to understand the probability of these trips changing to metro.

Bus users

A home to work trip is considered as presented by figure 4(a). If direct bus is available one has to walk up to bus stop, which generally lies at less than 500 m and takes bus to reach the bus stop near the work place and again walks for less than 500 m and reaches work. In case of metro, person living within the 500 m distance from metro walks up to metro station and takes ride in metro and again walks little to reach work. However, for person who lives away from the metro station trip by cycle rickshaw or auto-rickshaw or by a feeder bus is required to reach the metro station.

Each type of transfer has its own characteristics and impact on the person. Possibility of person to shift the mode includes all these transfer impacts. Figure 4(b) presents a trip from home to work which needs a transfer in-between.

A person has to change a bus to reach his destination area if it is not covered by any direct route. In that case the waiting time at transfer bus stop and the distance and convenience from bus stop where one has alighted to the bus stop from which one can get the next connecting bus is important. In the case of metro, time at transfer points and convenience of changing trains is an important factor which will influence modal shift. Thus, instead of just comparing available travel options by total time, fare, distance, etc. one should consider this influence of transfer activity (waiting time at transfer point, convinces at of changing trains) for the total trip comparison.



Effect of each transfer should be considered in comparision of different paths

Figure 4(a) and (b)

Two – wheeler users

If two-wheeler users want to use the public transport then the question is why they have not used buses when metro was not started and what will attract them to shift to the metro?
Table 3 presents different issues affecting two wheeler users for mode shifting.

Table 3: Issues affecting two wheeler users for mode shifting

Issue	Bus	Metro	Remarks
Door to door service	One has to walk up to bus stop (maximum 500 m)	One can reach to the metro station by walk or by cycle rickshaw, auto rickshaw or by feeder bus.	Probability of shifting the mode is very low.
Transfer inconvenience	If destination does not lie in any bus route one has to shift in-between	If direct route is not available one has to get transferred in-between	Transfer type can be different for metro and bus.
No need to follow timings	One has to follow the schedule of buses	One has to follow the metro schedules	If more frequencies are provided then it can help to shift the two wheeler users to bus or metro
Work/shopping place is very near	In any case one will use two wheeler only	In any case one will use two wheeler only	As distance is short probability of shifting from two wheeler to bus or metro is negligible.
Travel timings	If only in-vehicle time is considered it takes more time than metro	If only in-vehicle time is compared, Metro takes less time.	User will compare a total profile, i.e. total access time of trip it includes transfer-waiting time, availability of connecting bus/rail, convenience to reach at stop/station. As metro has less stoppage in comparison to bus and it has separate track and doesn't mix with other traffic, its speed is more than bus system.

CONCLUSION

Metro systems have been planned to reduce congestion on the roads. However systems planned in India shows that cost overrunning and under utilization of capacity. Methodology and arguments used to justify these systems needs careful analysis. High capacity system does not necessarily generate high demand. Estimation of passenger demand for transit services should consider complete journey of commuters including access time.

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