MODERN TRAMS

(LIGHT RAIL TRANSIT)

For Cities in India

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Foreword

In India, the subject of Urban Transport remained rather neglected till very recently. With the enunciation of National Urban Transport Policy in the year 2006, the issues related to urban transport have started coming to the fore. Indeed, the last 6-7 years have seen a lot of discussion, publications and many activities around the theme of urban transport. The Ministry of Urban Development, which is the nodal Ministry dealing with urban transport, has initiated a number of projects for public transport, from modern city buses to Metro rail, besides non-motorised transport and pedestrianisation, with the aim of completely transforming the urban transport scene in this country. However, so far, the mode choices have been limited to Buses, BRTS and Metro rail. Globally, there are other successful modes of medium capacity mass transport systems operating and there is a need to evaluate these too.

The Institute of Urban Transport (India), a body of professionals and registered as a Society, has been providing technical support to the Ministry of Urban Development. The Institute has undertaken several studies on different facets of urban transport. Many of the studies have been published for wider dissemination. The present white paper on possibilities and challenges of bringing in model tram systems into Indian cities is an effort in this direction.

I hope this publication gets widely circulated and suitably drives home the message to the policy makers and other stakeholders for adoption of this mode Light Rail Transit (LRT) systems also as a part of integrated multi-modal transport system in transforming the urban transport scene across India.

(Sudhir Krishna)

I N D E X

1. What is a Tramway (Light rail transit)

Tramways or light rail transit (LRT) is a medium capacity mode of mass rapid transport which straddles between the heavy capacity Metro rail and the low capacity bus services. It is a form of rail transit that utilizes equipment and infrastructure that is typically less massive than that used for heavy rail modes i.e. commuter/regional, and metro rail/subway. A few modes such as people movers and personal rapid transit could be considered as even "lighter". LRT may be at grade, partially grade-separated or completely elevated.

2. Historical background

The earliest form of LRT is the horse-drawn carriage. These were used in many cities around the World. Initially the carriages ran on the roads. In due course, the carriages had steel wheels running on steel rails to reduce friction.

The limitations of animal power were obvious. In the decade between 1880 and 1890, electrically-powered trams became technically feasible following the invention of a trolley system of collecting current. Trams became popular because roads were then poorly-surfaced. Before the end of the 19th century electric trams had appeared around the world, in cities such as Kyoto, Japan; Bangkok, Thailand; and Melbourne, Australia.

Melbourne

Early trolley car in Newton, Massachusetts

LRT traces its pedigree to trams that started operating more than 100 years ago. The advent of the car pushed out trams and many tram systems around the world had to be closed due to financial difficulties. The Energy crisis of the 1970s compelled cities to recall the tram in an upgraded version i.e. the LRT. The 'light rail transit' term was adopted in the 1970s in the United States, as a conscious break from the "obsolescent" image of trams; some cities however still prefer to call it tramway.

Electric tram

3. Worldwide usage

Worldwide data (2013) shows that LRT has been adoptedin 436 cities (includes 39 under construction and 30 under planning). Some of the countries are; Algeria, Argentina, Armenia, Australia, Brazil, China, Colombia, Denmark, Finland, France, India, Indonesia, Iran, Iraq, Israel, Italy, Japan, Korea South, Morocco, Netherlands, New Zealand, Norway, Panama, Romania, Russian Federation, Saudi Arabia, South Africa, Spain, Switzerland, Taiwan, Turkey, United Arab Emirates, United Kingdom, United States, Viet Nam. (Reference web page http://www.lrta.org).

International experience of 436 LRT systems worldwide confirms that LRT is the most successful medium capacity mode, with over 100 years of development behind it, yet incorporating the latest technology for the future.

4. Trams vs LRT

1. Trams is a mode as currently operating in Kolkata and possibly a few more cities around the World. However most tram systems operating around the World are the upgraded version of tram and designated asLRT. Salient differences between the old trams and the present LRT are as follows:

(i) In the traditional tram, the tracks and trains run along the streets and share space with road traffic. Stops tend to be very frequent and use roads as platform for the purpose. Because road space is shared, the tracks are usually visually unobtrusive and paved in the road surface.

(ii) In the case of LRT, the trains run along their own right-of-way and are often separated from road traffic. Stops are generally less frequent, and the vehicles are boarded from a platform.

(iii) Between tram and LRT there is a significant overlap of technology. Many LRT systems have a combination of the two, with both mixed and segregated right of way.

(iv) There is a significant difference in cost between tram and LRT. The traditional tram is often less expensive by a factor of two or more. Despite the increased cost, modern tramway or LRT is the current dominant form of urban rail transit development.

5. Features of LRT

LRT is a low cost, low axle load, eco-friendly, electrically propelled system with no local pollution and low noise and vibrations. Light rail vehicles (LRV) generally have a top speed of around 100 km/h though mostly operating at much lower speeds, more akin to road vehicles. LRT features include:

- Steel wheel vehicles operating on steel rails and are almost universally operated by electricity delivered through overhead lines. Electric power provides greater acceleration, making it suitable for operation with closely-spaced stations.
- Grooved steel rails laid flush with road surface or ballasted like normal railway track, making light rail the only system which can operate on both city roads and jointly with conventional rail services.
- Sharp road bends up to 25m radius, minimizing need for property acquisition and hence ideal for urban environment.
- Steeper inclines than heavy rail
- Shares its operational space with other road vehicles (e.g. automobiles) and often runs on, across or down the center of city roads.
- Grade separation only in exceptional circumstances.

6. Comparison with Metro rail

LRT differs from the Metro rail in that the train length is short, segregated right of way is not essential, may have road level crossings, coaches can go round sharp bends and no signalling and train control is essential. All these features limit the speed and the capacity of the LRT. When all these constraints are removed, the LRT becomes akin to Metro rail. Indeed LRT is a flexible mode that fits between the bus and the metro rail, and can behave like either of them. Additionally LRT, in comparison with a metro rail, is cheaper to build and operate. Ability to go round sharp road bends reduces the need to acquire roadside property and hence the project cost. Use of low axle load of 11 tonnes compared to 17 tonnes of Metro rail saves operating cost.

Delhi Metro rail

7. Comparison with Bus

1. LRT can generally provide a high quality ride, and when segregated, regularity in service. Bus systems though highly flexible perform less well in these respects. Additionally the buses have a limitation of capacity, comfort, convenience and reliability of service. Most importantly the 'image' of bus services as a rule is poor and hence to get the user of the car and two-wheeler to shift to the use of the bus is not easy.

OLD & NEW BUSES IN DELHI

2. LRT is capital intensive but cheaper than bus to operate for a given capacity at lower life-cycle cost, a higher commercial speed, reduced pollution. The preparatory time is relatively long and financing arrangements complex. Bus services, on the other hand, require much less funds and can be introduced quite quickly and plays a major role in city transport even when a popular rail transit mode operates in a city. While buses of various capacities may be used in a city, conservative approach is necessary when it comes to using rail transit technology.

8. Comparison with BRT (Bus-way)

1. LRT is similar to BRT in that it requires a share in the road space and will affect traffic flow on the road both during and after construction. BRT is of relatively recent origin born out of the need to discipline and to improve the performance of bus services and to provide mass rapid transport at low cost. It is reported to be operational in about 150 cities around the World and many more cities are in the process of planning. LRT however scores over BRT in terms of capacity and requirement of road space.

Boston LRT

Ahmedabad LRT

A tram of the Luas system in Dublin, Ireland

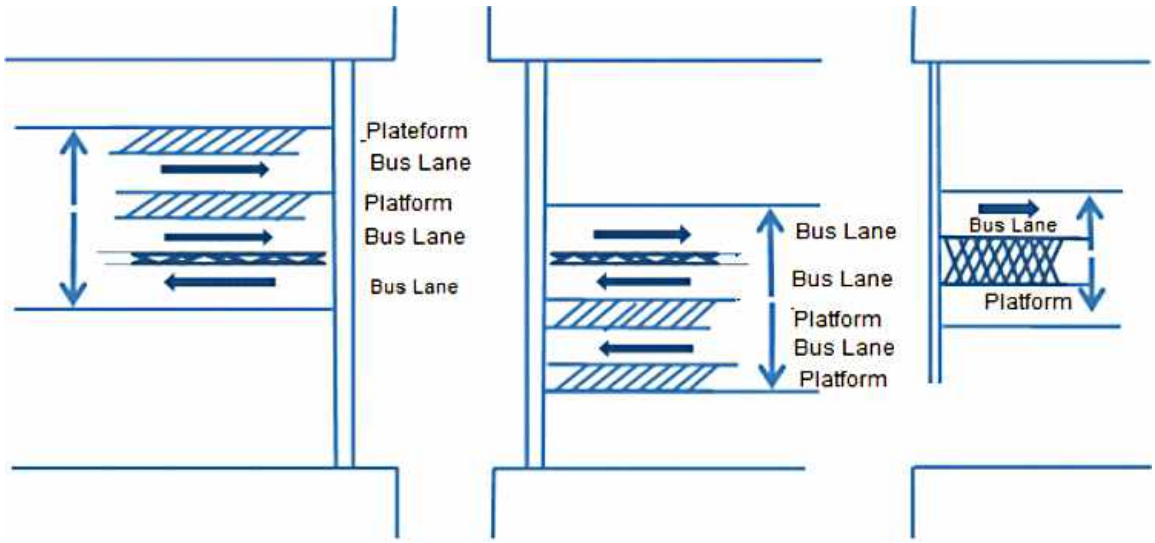
1. A World Bank study (Reference; World Bank Urban Transport Strategy Review –Mass Rapid Transit in Developing Countries Final Report, 2000 Halcrow Fox in association with Traffic and Transport Consultants (http://wbln0018.worldbank.org/transport/) has assessed that the Bus-way (BRT) output depends greatly on road network configuration, junction spacing and stop spacing. It typically has been demonstrated to be high at

   - About 10,000 peak hour peak direction trips (phpdt) at 20 kmph on arterial corridors and 15-17 kmph on urban corridors for a 1-lane each way bus-way.

- If provision for bus overtaking at stops is provided, passenger throughputs of 20,000 phpdt have been demonstrated and
- 2-lanes each way schemes are reported with even higher passenger flows.

2. Thus the carrying capacity of BRT appears to vary within a wide range depending on the design of BRT. In Indian cities very few roads will be able to provide space for overtaking facility and much less for an additional lane. Therefore the capacity of BRT is unlikely to exceed 10000 phpdt in most cases. This compares with the capacity of LRT which may go up to 30000 phpdt without requiring by pass facility or additional road lanes.

3. Secondly as per the WB study LRT requires less road space (2-3 lanes) than BRT (3-4 lanes) because overtaking facility is not needed and one island platform will suffice against two platforms for BRT, one in each direction.



BRT – LANE REQUIREMENT AT BUS STOPSLRT- LANE REQUIERMENT AT STATIONS

4. No doubt BRT is low in initial cost compared to LRT, but the cost differential disappears when

   I. the cost of buses and bus depots is included

   II. the life cycle cost is calculated taking into account the higher capacity and longer life of light rail vehicles compared to buses,

   III. the fact that LRT needs less road space than a bus-way, is taken into account,

   IV. the external benefits of fuel, land and energy conservation, low pollution and safety are counted

V. the cost of dedicated infrastructure for LRT is not counted (Buses do not have to pay for use of roads).

5. Recent reviews of BRT, however, show its inadequacy in terms of pollution and capacity as per reports from the two most successful BRT systems i.e. in Bogota and Curitiba. It appears pollution caused by BRT buses has become unbearable in Bogota. In Curitiba congestion on the system has become a cause of concern. Plans to upgrade some BRT corridors to LRT have reportedly been mooted.

9. Issues in LRT

1. Opposition to LRT has been mainly on 3 counts: first, that modern spatial arrangement (urban sprawl) is unsuited for fixed-line transit systems such as LRT; second, that LRT is too slow to compete with personal vehicles; car and 2-wheeler; and three, that LRT does not generate sufficient return on capital investment.

2. All three issues will become a thing of the past with the emerging new thinking. The issue of Urban sprawl as an urban growth policy is being reviewed and initiatives are being taken to move towards compact cities. Secondly it will no longer be slower than personal vehicles once LRT is segregated from road traffic, particularly when passing though congested areas. These two features will help improve the viability of LRT.

10. A case for LRT

1. A modal choice survey by UITP in 1997 showed that an average 11% car drivers had transferred to using LRT in 93% of the cities since the opening of the LRT. Another survey by UITP showed that in 100% of the cities responding, customers rated LRT as being more accessible than buses, 73% rated LRT as more reliable than buses. Specific figures for a few cities are given hereunder.

2. In Nantes (France), where the first of the LRT was built (opened 1985, extended 1989 - 14.2 km with 30 stops), the use of public transport has accelerated, the increase in use of private motor vehicles has moderated and the decrease in cycling has stopped. Between 1984 (before the tram) and 1995 the rider-ship of LRT + bus increased by 65.1%. 43% of the total

public transport journeys are now made on the LRT (33m journeys per year). 16% of LRT users had never used the bus network before the LRT was built and 39% of LRT users had a private vehicle which they could have used - they prefer the LRT to the car for certain journeys. The main reasons for choosing the tram are its rapidity and accessibility to go to work or to go shopping. (Source: UITP Light Rail Commission and Town Planning Agency of Nantes area, 1998).

3. In Strasbourg (Germany) total publictransport rider-ship increased by 45% (1990 to 1997) since the opening of the LRT, car use in the city center reduced by 17%. The evidence is that LRT not only attracts passengers to itself but also, where there is good integration between modes, increases rider-ship of the public transport system as a whole.

4. In Zurich, a city of around 300,000 population - a similar size to Coventry in UK - only 29% of journeys are made by private car, whereas in Coventry the figure is more than 75%. Car ownership rates are actually higher in Zurich than in Coventry, but people do not use them for many of their urban journeys. Zurich has an integrated public transport system that utilizes buses, trolley-buses, trams, light rail, commuter trains, funiculars and passenger ferries in a dense and highly utilized network. Coventry has buses and one lightly used commuter railway line with just two suburban stations and the city's main railway station within the city boundaries. To all intents and purposes buses are the only mode of public transport within the city boundaries.

11. A case for LRT

18. When a bus is an integrated part of a transit network, its contribution is far more significant than when operating as a solo service. Ottawa, with its wide use of BRT, has in the five years from 1991 to 1996 shown a ridership decline of 18% as against a population increase during this same period of 8%. Calgary on the other hand, with a mixed tram and bus transport system, has increased its patronage by 30% and identically increased its population by 8%. It has integrated its system in such a way as to cultivate transfers and capture new riders. Transfers are a crucial element of expanding transit under the present pattern of dispersed trip destinations.

Zurich

Essen, Germany.

Brentwood station, Calgary, Canada

Essen, Germany.

12. Relevance of LRT for India

The foregoing analysis shows that modern LRT even though not yet used in India (old trams operate in Kolkata) deserves serious consideration for use as a mode of medium capacity mass rapid transport. Before going further, it will be useful to review the Kolkata tram with regard to its performance and usefulness.

13. Kolkata tram

Tram was in use in India in several cities such as Kolkata, Mumbai, Delhi, Patna, Kanpur, Chennai and Nasik. The only surviving tram operates in Kolkata which is neither cared for nor is being abandoned.

14. Growth of Kolkata tram

1. Kolkata Tram System was inaugurated in 1880 with Metre-gauge track, horse-drawn from Sealdah to Armenian Ghat via Bowbazar Street, Dalhousie Square and Strand Road. However, steam engines were gradually introduced and by the end of the nineteenth century, the company owned 166 tram cars, 1000 horses, seven steam locomotives and 19 miles of tram tracks.

Horse-drawn tram

2. Between 1900 and 1905, the electrification of the tram system and conversion to the standard gauge was completed. The system continued to expand. In 1943 the Calcutta tram was connected with Howrah station through the new Howrah Bridge. The total track length was around 70 Km.

Kolkata Tram in 1920s

Kolkata Tram in 1950s

3. In 1951, Government of West Bengal enacted Calcutta Tramways Act of 1951 and in 1967, took over the Company and assumed management. The 1970s and 1980s marked the shrinking of the tram system, with the closure of Howrah section and some other routes. Total track length was now reduced to 61.2 km in the 1970s. The trend continued in early 1980s as well. However, due to absence of alternative modes, the utilisation of the tram system continued.

Kolkata Trams in 1980s

Trams rolling out of a Calcutta Tramways Company depot in Kolkata

Kolkata Tram

4. Gradually, most of the profitable routes in and near the city centre were discontinued due to construction of Kolkata metro. However, the trend was reversed albeit temporarily in 1985-87 when tram was extended connecting city centre to the core (BehalaJoka). Increasingly, the tram was considered too slow for the city's streets and hence, the cause of traffic disruption. This led to the suspension of trams during the peak seasons like Durga Puja, when demand for transport would be high, denying the opportunity for ridership capture and increase in revenues. Also single way operations were implemented in one-way streets, further reducing ridership.

15. Kolkata tram after 1992

In 1992, CTC undertook a new venture by introducing bus services. The trend of shrinkage of Tram network resumed in 2000's with more lines being closed for construction of Metro, rail, Flyovers, and other development projects in the city. These routes have continued to be suspended, even after construction works were completed. For many of the routes, the original terminals which were the major traffic generating points were also cut off. In the period between 2005 and 2011, the abandoned tram tracks were concretised. This step has increased the road space for the private motorised vehicles by converting the dedicated Tram Right-of-Way into the carriage way. This also led to the removal of barrier between the Tracks and road, which acted as the trams stops. As a result, the tram users have been forced to board and alight from the trams in the middle of moving traffic.

Before concretization
Boarding/alighting stop for tram users

After Concretization
Tram users have to board/alight after crossing traffic

16. Learning from Kolkata tram

1. Kolkata tram service has deteriorated over the years both in quality and financially on account of the misplaced view that it is a hindrance to the movement of road vehicles. No wonder, Currently, CTC (agency which operates the Tram System in Kolkata) is facing financial challenges. The operational efficiency of CTC (revenue from operations as a percentage of total expenditure), is about 20%. Around 40% of the expenditure is met through Government subsidy and the balance 40% is shown as deficit (Annual reports 2008-09 and 2009-10).

2. A reconnaissance survey by IUT team to study the tram operation and meetings with various stakeholders, including Government officials, industry, professionals, NGOs and the tram users showed that there is a widespread view that Kolkata Tram operations should not only be continued but also upgraded. It was felt that the trams have the potential to play an important role in the urban transport system of Kolkata. Also a view was expressed that trams have a heritage value and is integral to the socio-cultural fabric and identity of the city; most of the interviewees have fond memories of the tram system with which they have grown. The review suggests that there is a future for upgraded trams in India.

17. Present mass rapid transit services in India

1. Mass rapid transit in cities in India in the past has been limited to suburban services and buses. Indian Railway suburban rail services started in 1928 in Mumbai. This was followed by a similar rail system in Chennai in 1931 and in Kolkata in 1957 and a few other cities. There has not been much investment in the upgrade of these services. Recently, however, considerable progress has been made in the upgrade of the Mumbai suburban rail services.

Mumbai suburban rail

2. The first underground Metro rail of length 18 km started operating in Calcutta in 1984 and later an 11 km elevated rapid transport system was commissioned in Chennai, as an extension to its existing suburban rail system. Extensions to both systems are now under construction.

3. Work on the third Metro rail project started in Delhi in 1998. First phase of 65 km was completed in 2007. The second phase of the project of length about 125 km was completed in 2010. Construction of 3rd phase is in progress. A small length of Metro rail in Bangaluru started operating in 2012. Construction of Metro rail systems has started in 6 more cities i.e. Kolkata, Chennai, Bangalaru, Kochi, Jaipur, Gurgaon and Mumbai. Many other cities such as Lucknow, Nagpur, Pune, Ludhiana, Ahmedabad Metro, Bhopal Metro, Indore Metro and Chandigarh are planning rail transit.

4. Standard bus services which are low capacity MRT modes (Up to 5000 phpdt) till recently were limited to about 15 cities. After 2009 the number of cities operating bus services has increased to 65 JNNURM cities when nearly 16000 buses were sanctioned. The enormous gap between demand and supply of mass rapid transit is presently met by para-transit in the form of three wheeler motorized tempo and manually driven cycle rickshaw which have much lower capacity.

18. Need for a medium capacity mass rapid transit mode in India

1. Metro rail can serve corridors with demand level more than 30000 phpdt and buses are good for corridors with demand level upto 5000 phpdt. For demand below the range of 30000 phpdt, it would be uneconomic to introduce Metro rail. Metro rail requires flat curves (necessitating property acquisition) and long ramps taking up much road space. Demand level between 5000 to 30000 phpdt needs medium capacity modes. Three modes of MRT are in use around the world in this category; BRT, LRT and Monorail. LRTand Bus rapid transitare essentially at-grade modes. Monorail is an elevated mode suited in congested areas with limited ROW and where at grade service cannot be introduced.

2. These three medium capacity modes i.e. BRT, LRT and Monorail however, have their own application to specific situations and limitations in terms of capacity, but all three modes can be a part of a citywide multimodal integrated system of MRT. This can be seen from the case study of Delhi where a multimodal integrated MRT network has been planned with all four modes, Metro rail, BRT, LRT and Monorail as shown in the table below. This excludes the Metro rail corridors as planned by DMRC (Metro rail network however has undergone changes since).

Modes	Corridors	Length
Metro rail	6	115 km*
At-grade BRT	26	294 km
LRT	6	47 km
Monorail	3	48 km

** Phase III is also in progress. For phase IV DPR preparation is in progress, after implementation of phase IV, the total metro length will be more than 400 km.*

3. Delhi and Ahmedabad are presently operating BRT services, 9 cities are at the construction stage and 2 cities at the planning stage. LRT though planned for Delhi has not yet been introduced. Monorail has been introduced in Mumbai planned for Kozhikode and Delhi and under consideration in Bangaluru, Chennai and Trivandrum.

Monorail in Kaualalumpur

19. Planning and design of LRT

1. A city has several corridors with demand ranging from a few hundred trips to several thousand trips per hour that need to be served by MRT. Similarly, starting with a mini bus to midi and maxi bus and finally guided and rail transit modes, the capacity of each mode increases. Each MRT mode has a role and limitations. All corridors in a city do not need a high cost, high capacity Metro rail. Similarly, a bus may not necessarily be able to meet the demand on all corridors. This is illustrated by the table below taken from the actual planning of the MRT network for Delhi.

Mode	Length km	Road width m	Max. phpdt	Design phpdt
BRT	118	35-45	9289	4500-9000
LRT	41	30-45	26408	13000-20000
Monorail	48	15-30	20780	3000-20000
Metro rail	170	>30 m	66135	48000

2. For an economic transport network, it is necessary that capacity of the chosen mode matches the future projected demand level in a corridor. Over-provision in a corridor will be uneconomic. Thus, alternative modes of mass rapid transit may be needed as appropriate to each corridor. The number of modes for acity, however has to be rationalized to achieve critical mass for each mode and to achieve economy of scale. Such a multi-modal system will be least cost with best possible financial viability and hence affordability and sustainability. This is important to ensure environmental sustainability and social sustainability as well as for MRT to continue to grow with growth in demand.

3. The choice between the three medium capacity modes; LRT, Monorail and Bus rapid transit depends on several factors.From consideration of commuter convenience at grade modes should be preferred as climbing up and down, particularly for short trips is eliminated. At-grade modes offer the best aesthetics as they do not interfere with the skyline or the privacy of roadside premises. Thus at-grade BRT and LRT is the first choice for Commuter Convenience, low initial cost, low operating cost and hence financial sustainability.

4. Between LRT and BRT, the choice depends on demand level and availability of road right of way on a corridor. As stated earlier, the capacity of BRT is unlikely to exceed 10000 phpdt as a rule. This compares with the capacity of LRT which may go up to 30000 phpdt without

requiring additional road lanes. Secondly as stated earlier LRT requires less road space (2-3 lanes) than BRT (3-4 lanes) because overtaking facility is not needed and one island platform will suffice against two platforms for BRT, one in each direction.

5. In selecting from amongst the 4 more commonly used medium capacity modes i.e. LRT, Monorail, Electric Trolley Bus (Similar to bus in capacity) and BRT, four factors have to be kept in mind; safety, environment, energy and land conservation. LRT and Monorail help in all four features and offer the best safety, minimum pollution, conservation of fossil fuel and minimum land requirement; ETB helps with two features i.e. pollution and energy saving; bus is the least favoured in respect of these four elements;

Mode	Pollutioncontrol	Fuelsaving	Safety	Land Conservation
LRT	yes	yes	yes	yes
Monorail	yes	yes	yes	yes
ETB	yes	yes	-	-
BRT (Bus)	-	-	-	-

6. At-grade modes may affect the safety of other road users. Buses (or ETB) operating in mixed traffic conditions, as at present, can meander, being unguided, thereby creating a safety hazard for other road users. At grade LRT is a guided mode of transport and cannot meander. It therefore provides much better safety than the non-guided bus or ETB. The safety of Bus operating in segregated lanes will perhaps lie somewhere in-between depending on the design of the dedicated lanes. Grade separated modes do not affect the safety of other road users.

20. Aesthetics and Technology

At-grade modes offer the best aesthetics as they do not interfere with the skyline or the privacy of roadside premises. Elevated modes affect the skyline. Monorail however, scores over elevated rail transit in aesthetics due to the slim guide beam needed overhead. Monorail however is a totally new technology, not yet available in the country. LRT technology is akin to railway technology and is easily absorbable by the Industry in the country.

21. Capex, Opex and Life cycle cost of alternative modes of MRT

1. LRT has not yet been introduced in India, but it has been planned for Delhi; a mixture of at-grade and elevated construction of length 47 km. The cost estimate is as follows;

Delhi LRT Capital Estimates

Description	Cost (INR in Crore at 2007-08 price levels)	% of Total Cost
Preparatory Expenses	10	0.25
Land Government	628	16.65
Land Private	28	0.76
Fixed Infrastructure Civil	442	11.72
Fixed Infrastructure Electrical Systems	300	7.94
Fixed Infrastructure - Depot & OCC	483	12.78
Rolling Stock	1456	28.55
Signaling, Telecom & AFC	84	2.23
Taxes & Duties	345	9.12
Total	3776	100

2. For the sake of comparison, the tables below show the capex and opex of alternative modes of MRT. These costs are based on a life cycle cost study undertaken by IUT and which is available on IUT web site.

CAPEX AND O&M COST OF MRT MODES

S no.	Mode Rscrores per Route km (2011-12)	Capex Crore per Route km per annum	O&M Rs.	SOURCE
1	Metro rail (elevated)	182.05	8.8 (2016-17)	**CAPEX** DMRC, Hyderabad and Kochi **O&M** time series of DMRC.
2	Monorail (elevated)	214.27	7.2 (2016-17)	**CAPEX** Kozhikode, Delhi and Mumbai **O&M** first year of Kozhikode

S no.	Mode Rscrores per Route km (2011-12)	Capex Crore per Route km per annum	O&M Rs.	SOURCE
3	Light rail (elevated)	159.25	6.05 (2016-17)	**CAPEX** Delhi LRT escalated to 2012-13 **O&M** based on Elevated Monorail
4	Light rail (At grade)	107.36	6.5 (2016-17)	**CAPEX** Delhi LRT escalated to 2012-13 O&M based on Monorail
5	BRT (At grade)	27.38 (Incl. bus)	14.9 (2014-15)	**CAPEX** Ahmedabad, Rajkot **O&M** DTC, BEST, BMTC, MTC + OCC, Security
6	BUS (At grade)	17.67 (Incl. bus)	16.3 (2014-15)	**CAPEX** as per WGUT for 12th Five Year Plan. **O&M** Cost Data for DTC, BEST, BMTC, MTC

It will be seen that while capex in Monorail is the highest, Capexis lowest for BRT and bus service. Between Metro rail and LRT, the latter is less expensive both in capex and opex (Of course offers less capacity as well). The combined effect of capex and opex i.e. the life cycle cost is shown in the table below.

Life cycle cost of modes of MRT

The LCC of various modes has been calculated at different PHPDT levels i.e. demand or usage levels. The result is summarized in the table below. It has been assumed that the capacity of the modes is not a limitation.

PHPDT	Metro Rail	Monorail	LRTS (Elevated)	LRTS (At-Grade)	BRTS	Buses
3000	80.80	69.45	73.10	39.42	41.27	**17.75**
5000	56.94	49.24	49.32	27.59	31.81	**17.78**
7000	45.03	39.32	38.34	22.83	27.81	**17.51**
10000	36.12	32.77	28.92	18.26	24.59	**17.36**
12000	31.88	29.47	25.74	**16.63**	23.40	17.29
15000	27.98	26.93	21.86	**14.91**	22.17	17.30
20000	23.14	24.05	18.85	**13.31**	21.01	17.22

PHPDT	Metro Rail	Monorail	LRTS (Elevated)	LRTS (At-Grade)	BRTS	Buses
25000	19.97	22.33	16.76	**12.30**	20.21	17.24
30000	18.39	21.14	15.37	**11.64**	19.75	17.19
35000	16.89	20.34	14.33	**11.20**	19.37	17.19
40000	16.05	19.74	13.60	**10.88**	19.14	17.16
45000	15.39	19.29	13.04	**10.62**	18.92	17.18
50000	14.67	18.91	12.59	**10.39**	18.77	17.19

As evident from the above table, LRTS (At grade) remains the cheapest mode at various levels of demand. In all cases, LCC reduces substantially as the PHPDT i.e. demand increases except in the case of the buses. Furthermore, in terms of life cycle cost, elevated LRTS also becomes cheaper than BRTS above 15,000 PHPDT.

The table further illustrates that elevated LRTS is cheaper than Metro rail at all PHPDT levels i.e. demand levels. Between Metro rail and Monorail, the table shows that monorail is cheaper than Metro rail up to 15000 PHPDT. However Metro rail is cheaper than Monorail above 15000 PHPDT. A comparison between Metro rail and Monorail is irrelevant because monorail is a medium capacity mode and also as Monorail is recommended for special locations where the road right of way is limited and elevated Metro rail or elevated LRTS will be unsuitable for environmental reasons.

22. Kolkata tram after 1992

1. LRT model in the developed countries has evolved over the years. This has been led by the realization that public transport must become the mode of choice for commuters from considerations of energy conservation and protection of environment. This will be so if the service is convenient for the commuter. Hence priority to public transport is considered essential. To achieve this if necessary all other traffic on a street is stopped if the street is

Low floor LRV

narrow. Accordingly LRT as a rule operates at-grade. This was easy since road right of way in developed countries is mostly high since the roads were designed with car use in mind.

2. Originally trams operated mixed with road traffic. This limited the speed of the tram to that of road traffic. With a view to improve the speed and to make the LRT more attractive it was made to operate in dedicated lanes with preferential signaling at road intersections. The other main feature in this direction is the extra low floor (200mm) vehicles. The commuter has just one step to take to board and de-board. In some case even low platforms have been provided for level board and de-board.

23. LRT model for India

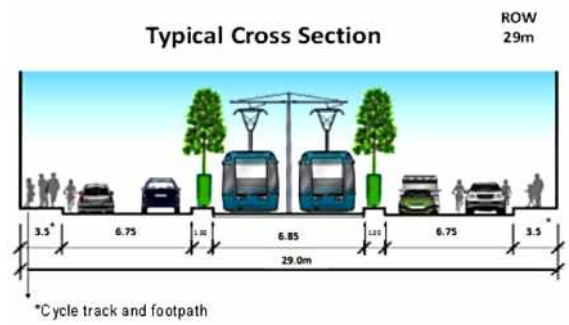
1. Conditions in India are very different. Some of the differences are;

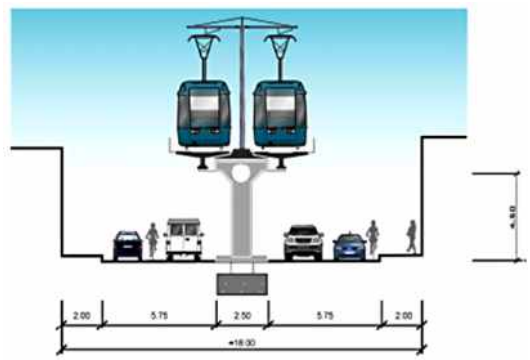
   - Demand level in Indian cities is far greater than in the developed countries.
   - Congested roads; mixed traffic, slow and fast, largely indisciplined
   - ROW of roads in general in India is rather limited
   - Jay walking to cross the road is quite common

2. The western LRT model has to be suitably modified to suit Indian conditions. There is a realization in India that public transport needs to be promoted, but when it comes to giving it priority, the planners feel shy. There is a resistance to give public transport dedicated lanes and preferential signaling at road intersections to make the service fast.The European model of at-grade LRT is unlikely to succeed in India considering that road users in developed countries are too few and much more disciplined. It is however important that PT remains attractive and in that context speed of travel is important. Therefore if physically segregated lanes cannot be provided for LRT, it should be elevated where necessary, if not all the way. It will add to road space.

3. Hence the first modification that may be necessary if demand level is high and road is narrow is that LRT is elevated. Once this modification to western model of LRT is accepted, the need for the expensive low floor LRVs is eliminated.Elevated, LRVs can be with normal floor level and platforms can be provided at the normal height for commuters to board and de-board at level. Elevated LRT will not require fencing which otherwise is found essential in Indian conditions to control 'jay waking'.

4. When LRT is at-grade i.e. at road level within a dedicated corridor width of 3.3m on each side of the median of the road requiring a total ROW for LRT of about 8.2m of the road between stations. Additional road space is required at stations. Stations are provided with access control through turnstiles. Stations may be located as near to the road junctions as feasible so that the entry and exit of passengers from the stations is through the existing zebra crossings. However, some stations may have to be provided at mid-sections with new signalled Zebra crossings.





24. Learning from Kolkata tram

Practice Worldwide is, LRT gets preferential signaling at road intersections. Three levels of priority are adopted depending on pattern of traffic; immediate priority, priority once the minimum green time of the current active phase is reached; priority once the current stage active is finished. The time for which the priority signaling will be 'ON', will be the time required for the train to cross the junction i.e. few seconds. For example in the case of Delhi LRT project out of 38 signalized intersections, 5 have been accorded priority 1, 25, priority 2 and balance 8, priority 3. Grade separation has been proposed at three intersections.

25. System design

The system design will include definition of: arrangement of Power Supply, Overhead traction equipment, Automatic Fare Collection system, preferential signalling for LRT, Articulated Rolling Stock for negotiation of sharp curves (each about 40m long), Depot & Workshop requirements

and Track structure. One centralized maintenance and overhaul Depot for Rolling Stock, Signalling, Communication & other equipment is required. Operation Control Centre (OCC), training facilities are also part of Depot. Approximately 30 hectare of land is required for the Depot.

26. Financing

1. The financing strategy has to be based on all possible sources of funding and methods to capitalize on them. The main source of revenue is user charges. The level of affordability of a large section of society and political considerations do not permit full cost recovery through user charges. The other key funding sources are Government Budgetary Support, tax concessions and dedicated levies, land monetization, recovery from non-user beneficiaries, debt and private investments. Support from Government is linked with the Nation's budget, hence unpredictable and mostly inadequate. The paradigm of financing has to clearly move towards non-users beneficiaries and the polluters pay principle.

2. It appears that Central and State taxes constitute up to 15% of the cost in rail transit projects and up to 19 % in the case of buses. Thus tax concessions will off-set a substantial part of the project cost. Dedicated levies can be levied on non-user beneficiaries mainly property and users of private modes. The value created in the proximity zones can be recovered through land monetization; i.e. a 'Betterment Levy' or 'Land Value Tax' or enhanced property tax or grant of development rights. Transit Oriented Development (TOD) will help make MRT viable and attractive. With increasing limitations on Government funding, private sector is being involved. Both the Government and the private partner contribute equity and raise debt for the balance amount. Bilateral soft loans can be tapped and funding from multi-lateral agencies should not be ruled out.

27. Project Development Process

1. Three main project development stages are involved;Pre-feasibility stage, Techno-economic feasibility stage, and Detailed project report.

2. The Pre-feasibility stage is required to establish a prima facie case for a project. If the project is found to be necessary and feasible, a Techno-economic feasibility study is done to define the project outline for administrative approval to proceed further with the preparation of the

DPR. The Detailed project report defines the project fully and provides a detailed cost estimate along with its financial profile and a financing plan for project sanction. The precise alignment and station locations etc. are fixed during this stage. All three stages involve similar investigations. The difference is in the depth of the study. As the project development progresses the accuracy level is improved.

3. The content of the DPR depends on the project implementation strategy. Three strategies can be considered i.e. PPP, Government through SPV and Government cum BOT. If the project is to be funded by the Government, then the DPR has to fully define the project before inviting bids for construction.

28. Implementation via PPP or 'Government cum BOT'

1. LRT Project development involves four major steps;
   - Transaction structuring and selection of the PPP partner,
   - Final location survey and general arrangement/layout drawings,
   - Choice of mode, choice of technology in that mode and system design, and
   - Design of civil engineering structures.

2. The first part is essential to follow the PPP approach. The second part is equally essential because of the complexity and time consuming nature of the activity and the involvement of nearly all city agencies. This cannot be left to be resolved after the concession agreement has been signed to avoid the resulting time and cost overruns during construction.

3. Choice of mode affects the city image and the city should have a say in this. Choice of technology affects the ongoing maintenance needs and cost and hence is a matter of concern for the city. It is therefore essential that the mode and technology are specified by the city.

4. If however these two aspects are left open and the PPP bidders are given the freedom to offer their own mode and technology, it will amount to leaving the choice for these two features for the city, for all times to come, to the winner of the first round of bidding. For economies of scale the future corridors in the city will have to adopt the same mode and technology. City should not allow the choice of these two important features to the chance winner of the first bid process.

5. The three implementation strategies are compared in the following table in respect of;
   - Equity contribution and debt liability
   - Sharing of revenue risk
   - Management and
   - Time needed to start ground activity

Comparison of Implementation Strategies

ITEM	PPP	Govt./SPV	Govt. & BOT
Equity	Shared	100%	Govt. funds infrastructure Rolling Stock and O&M is offered on BOT
Debt liability	Shared	Govt. Only	NIL
Revenue Risk	Shared	Govt. Only	NIL
Management	Private	Govt.	Government : Construction and Project Management; Bot Operator: Rolling Stock, Systems integration and O&M
Time to start of Ground Activity	24 Months	18 Months	11 Months

29. Construction Planning

1. LRT is similar to BRT in that it requires a share in the road space and just like BRT will affect traffic flow on the road both during and after construction. Some of the problems/criticism faced by the BRT corridor under construction/operation are related to:

   (i) Traffic management during construction including temporary signage

   (ii) Utility diversions particularly Underground utilities

   (iii) Cutting of trees

   (iv) Facilities for Pedestrian crossing

   (v) Traffic signal planning, installation and phasing

   (vi) Planning and providing additional alternative routes for MV traffic

   (vii) Planning for parking of vehicles of residents along the corridor

(viii) Delays to the movement of motor vehicle traffic, after construction particularly at the road junctions

(ix) Public awareness, Lack of lane discipline and education.

(x) Supply of Rolling Stock is on critical path.

2. It is therefore important that all these problems are designed out before taking up construction of LRT. Problems on account of Item (v) in the case of LRT should be minimal as unlike buses there is no need for LRT to turn left or right. Secondly, LRT trains will come at 3-5 minute intervals, get preferential signalling and cross the road junction in 20 seconds without much impact on other traffic. Items (vi)–(ix) have not been detailed during project planning and hence need attention. Items (i)–(iv) however cannot be planned in detail until the precise alignment and location of stations has been fixed.

30. Potential for application of LRT in India

1. LRT has become a common fixture in many cities around the World over the past several decades. Cities with well-established rail transit systems have significantly higher per capita transit rider-ship, lower average per capita vehicle ownership and mileage, less traffic congestion, lower traffic death rates and lower consumer transportation expenditures than otherwise comparable cities.

2. Proponents of LRT argue that rail transit increases community well-being by creating jobs, boosting economic development and property values, and reducing pollution and traffic congestion--all while providing drivers with an economical alternative to the personal vehicle. Opponents counter that LRT provides little of these benefits to citizens and that, even if some benefits are realized, the costs still outweigh any potential benefits to society. Even though opponents continue to oppose, urban rail systems are being opened and expanded at a rapid pace.

3. Most Indian cities are low rise urban sprawls and require medium capacity modes only. As per the recommendations of the working group on urban transport for the 12th FYP, LRT should be provided in all cities with a population of million plus. There are 53 cities in this category as per the 2011 census. Thus all these cities are candidates for introduction of LRT. In large cities, LRT will be a part of the citywide multimodal MRT network. In other cities, LRT may be the main mode of MRT.

4. In the existing city corridors, if necessary, LRT can be elevated. In new townships and urban extensions however, space should be left in the middle of the road for introduction of at-grade LRT at appropriate stage. LRT has use at special locations such as the TajMahal in Agra and Victoria Memorial in Kolkata to protect them against pollution and to promote tourism.

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Our Vision

To be the thought leader for industry, its voice for policy change and its guardian for effective implementation.

Our Mission

To carry forward our initiatives in support of rapid, inclusive and sustainable growth that encompass health, education, livelihood, governance and skill development.

To enhance efficiency and global competitiveness of Indian industry and to expand business opportunities both in domestic and foreign markets through a range of specialised services and global linkages.

About Institute of Urban Transport (India)

The Institute

The Institute of Urban Transport India (IUT) was established in May, 1997 as a professional body under the purview of the Ministry of Urban Development Government of India (MOUD) as a premier professional non-profit making organization and registered under the Societies Registration Act. The aim and objective of the Institute is to promote, encourage and coordinate the state of the art of urban transport including planning, development, operation, education, research and management.

The membership of the Institute comprises Academicians, Architects, Economists, Engineers, Transport Planners, Town Planners and professionals from various disciplines The Institute has more than 60 institutional members, 1300 individual members and 70 Associate Members. It has association with foreign organizations such LTA Singapore, GIZ, UITP etc. IUT also has interaction with foreign cities. It hosted a delegation from Shanghai and recently from Taiwan.

The Secretary, Ministry of Urban Development, Government of India, is the ex-officio President of the Institute. Its Governing Council has members from various premier organizations connected with Urban Transport and State Governments. The Institute has Chapters at Bangalore, Chennai, Hyderabad, Mumbai, and Roorkee.

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