Public transport (MRTS) and the need of choice mechanism: a case of the Indian public transport

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The Indian cities are growing and urbanizing rapidly, resulting in vast urban sprawls. Hence, the mobility of people is increasing, pushing the Government to develop a sustainable transport system in these cities. To achieve this goal, the Government is encouraging and developing mass rapid transit systems (MRTS) in cities. However, the goals and objectives set by the policies and Government guidelines are not met through the ongoing development process. The experiences of MRTS have raised some questions for transport experts and decision-makers in the country. These are regarding the justification for selection of technology of MRTS, the process of selection, coverage throughout the city, and affordability and acceptance by different city resident groups. According to the experts, there is a need for proper analysis and justification for the selection of any technology. This study with the objective to understand the gaps in the process of selection of technology for MRTS and associated controversies, reviews the policies, guidelines and proposals for suitable MRTS in India. The study concludes that the transport planners and decision-makers have failed to formulate a knowledge centre, as suggested in NUTP 2006 and 2014. This has been the main hurdle transfer the knowledge and experience from city to city. Additionally, the Indian policies and guidelines have failed to provide any explicit criteria to select technology of MRTS in the decision-making process. The study therefore recommends to formulate an expert mechanism/system to transfer expertise and experience from one city to another.

Keywords: Choice mechanism, expert mechanisms, knowledge centre, public transport.

Background

THE Indian cities are growing and urbanizing rapidly because of increasing industrialization, more economic activities and available job opportunities in the cities. This has resulted in vast urban sprawls in the cities with multiple land uses, but with lack of policy interventions[1]. With the decadal increase of around 32%, it is expected that India's urban population would grow to about 473 million in 2021 and 820 million by 2051 (ref. 2). According to the Census of India, the number of metropolitan cities with population of a million plus has also increased sharply from 35 in 2001 to 50 in 2011 (refs 2, 3). With growing urbanization, accessibility and mobility, the needs of the people have also increased resulting in increasing number of trips and trip length[1]. In response to this, people have selected personal modes of motorized transport over non-motorized and public transport. This has resulted in decreasing use of non-motorized and public transport. The probable reasons for this may be the concerns related to safety, delays, convenience, flexibility, easy availability and economic feasibility offered by the personalized mode, particularly two-wheelers, over public transport. Again, the local authorities might not be able to continue the pace of transport infrastructure development with growing transport needs of an urbanizing population. The authorities have failed to provide safe, effective, efficient and convenient public transport. The Government of India (GoI) decided to promote the use of public transport to reduce congestion and commuting time. As a result, it came up with a national-level policy in urban transport, i.e. the National Urban Transport Policy (NUTP) in 2006. Initiatives such as NUTP 2006 and the introduction of several urban transport projects under the Jawharlal Nehru National Urban Renewal Mission (JnNURM), have given a boost to the public transport system with the introduction of mass rapid transit systems (MRTS). However, with increasing urbanization, the idea to develop sustainable transport systems in these cities has not been achieved which is evident from most case studies. The goals and objectives set by the Government policies and guidelines are not met through the ongoing development. The experiences of these MRTS have raised some questions for transport experts in the country[4–10]. These are regarding the justification for selection of technology of MRTS, the process of selection, coverage throughout the city, and affordability and acceptance by different city resident groups[4–10]. The opinion of some experts highlights that there is a need for a proper analysis and justification for selection of any technology since there seems to be a confusion among transport planners regarding what type of technologies would be more suitable

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in Indian conditions[4–7]. In addition, operational experiences of some MRTS show that it is not necessary that a high-capacity system will always generate a high demand[7,8]. From the perspective of most of transport planners and decision makers in India, metro rail is viewed as the best solution for increasing the transport demand of urban areas, while for some light rails or bus rapid transit (BRT) are possible solutions. Again, there appear to be flaws in the selection process for a detailed project report (DPR) study of Pune Metro Rail with a lack of scientific base and public participation[11].

The main objective of the present study is to understand the gaps in selection of technology of MRTS. It reviews the policies, guidelines and the proposal studies of MRTS in India. The study recommends that it is necessary to have explicit criteria for selecting of technology for MRTS and a knowledge centre to transfer experience from one city to another. As suggested in Metro Rail Policy 2017, the study also recommends conducting an alternative analysis for selecting technology of MRTS for any city. Experts around the world have worked to develop expert systems/mechanisms suitable for selecting of effective and efficient technology for MRTS. Thus it is proposed to formulate an expert mechanism/system for assisting transport planners and decision-makers in selecting suitable technology for MRTS in the Indian scenario.

MRTS selection in the Indian scenario

This section presents the policies and guidelines regarding the selection process of technology for MRTS in Indian cities. The study analyses the proposals of metro rail and bus rapid transit systems in a few selected Indian cities, to understand the selection methodology and its rationale. It was not possible to consider any light rail transit (LRT) DPR in this study, as no such proposal studies or systems constructed in Indian cities in recent decades.

Policies and guidelines

Table 1 shows the policies, guidelines and recommendations published from time to time with regard to the selection of MRTS in Indian cities arranged in chronological order.

The important milestones set up towards achieving sustainable urban transport in India specifically cater to human and public transport-oriented development, accomplished with the introduction of NUTP 2006. This is the first dedicated policy focusing particularly on urban transport in the country. With the objective to ensure safe, affordable, quick, comfortable, reliable and sustainable access for the growing number of city residents, the major focus of the Policy was on equitable road space allocation for commuters and not vehicles[2]. The Policy encouraged greater use of public transport and non-motorized modes by offering central financial assistance. Regarding selecting a particular technology for public transport in any city, NUTP mentions that, in India, various multiple proven technologies are available and that they must be selected based on the suitable city characteristics and technological parameters. NUTP clarifies that, ‘Given the wide range of possibilities, it is not possible to prescribe a particular technology in a generic policy and such a choice will have to be made as a part of city specific land use and transport plans.’[2] The NUTP recommends formulating a knowledge centre and system to assist selecting of technology for public transport in the Indian scenario[2]. However, to ease the selection of MRTS, NUTP described some advantages and disadvantages of various technologies. It suggests that the metro rail system can be used for very high-density corridors, where road space is limited. It is well suited for densely populated cities that have low sprawl and few spinal, long-haul corridors. LRT and BRT can be proposed for medium-density cities with limited sprawl. In case of medium-density corridors where space availability is adequate for supporting elevated structures or at grade tracks LRT is suggested, while for medium-density corridors where space availability is adequate for supporting the dedicated right of way BRT is suggested.

In 2008, the Ministry of Urban Development, GoI, in association with Asian Development Bank prepared the guidelines and toolkit for urban transport, focusing particularly on the medium-sized cities in India[12].

An important observation in this toolkit is regarding the proposal for urban transport projects submitted by urban local bodies (ULBs) under various schemes (such as JnNURM) including mass rail transit, BRT system, flyovers and other such urban transport projects. It mentions that the ULBs in Indian cities still lack the needed capacity and skill for urban transport planning. The proposals submitted provide inadequate information and incomplete analysis. Another issue is that most of the cities do not have long-term comprehensive urban transport strategy and thus the proposals are often not integrated with land-use patterns or other urban transport measures[12].

According to the JnNURM funding policy requirement, it is mandatory to submit a comprehensive mobility plan (CMP), which is considered as a key document providing the rationale for transport proposals[12]. In addition, it is also required/important to submit a separate study for alternative analysis in case of major projects costing more than or equal to Rs 5 billion in 2008 prices. The alternative analysis could be included in the CMP or DPR for projects costing less than Rs 5 billion[12]. The toolkit mentions the guidelines to assist decision-makers in selecting and narrowing down of the applicable options. These guidelines mostly cover the technical aspect, city-specific characters, and advantages and disadvantages of the system. Regarding the corridor and city density applicability,

Table 1. Technology choice criteria suggested in policies and guidelines for Indian cities

Criteria	Technology	Guidelines and toolkits for urban transport development	Twelfth Five-Year Plan	NTDPC	URDPFI-2017
PHPDT (in 2021)	BRT	7,500–15,000	≥4,000 and up to 20,000	≥4,000 and up to 20,000	Below 7,500 on one lane, 7,500–15,000
	LRT	15,000–45,000	≤10,000	≤10,000	15,000–45,000**
	Monorail		≤10,000	≤10,000	
	Metro rail	10,000–15,000* 40,000–75,000	≥15,000 for at least 5 km continuous length	≥15,000 for at least 5 km continuous length	10,000–15,000* 40,000–75,000**
Population according to 2011 census (millions)	BRT		>1	>1	
	LRT		>1	>1	
	Monorail		>2	>2	
	Metro rail		≥2	≥2	
Population density	BRT	Medium to high			Medium to high
	LRT	Medium to high			Medium to high
	Monorail				
	Metro rail				
Average trip length for motorized trips (km)	BRT		>5	>5	
	LRT		>7–8	>7–8	
	Monorail		About 5–6	About 5–6	
	Metro rail		>7–8	>7–8	
Road space requirement	BRT	Two lanes possibly 3–4 lanes at station			Two lanes, possibly 3–4 lanes at station
	LRT	Two lanes at grade			Two lanes at grade
	Monorail				
	Metro rail	None for elevated/ underground			None for elevated/ underground
City income	BRT				
	LRT				
	Mono rail				
	Metro rail	More than low, i.e. typically at least USD 1800			More than low, i.e. typically at least USD 1800

*Existing PHPDT with more than 15 km trip length. **Alignment is double-track railway. Source: Refs 2, 13–15.

the toolkit recommends similar suggestions as mentioned in NUTP 2006. Some of the important criteria suggested in the toolkit include capacity peak hour peak direction traffic (PHPDT) available on the corridor, city shape/ form (linear or circular), city specific per capita income, road space availability, environment sustainability, etc. (Table 1)[12].

Further in May 2011, a Working Group on Urban Transport for the 12th Five-Year Plan was constituted. The objective of the Working Group was to review the previous Five-Year plans, and prepare recommendations and proposals on urban transport for the 12th Plan[13]. In parallel, a National Transport Development Policy Committee (NTDPC) was also constituted in July 2011. The objective of this Committee was to develop a 20 years vision plan for urban transport in India[14]. Both the Working Group and NTDPC have suggested criteria on general choice of MRTS in Indian cities. These criteria are nearly identical, with only some additional comments in NTDPC. The choice criteria suggested in these two reports are then followed in NUTP 2014 as well. Table 1 presents the criteria suggested in these reports. The recommendations of the Working Group and NTDPC majorly propose to construct BRT and rail systems. However, while proposing a rail system, emphasis may be observed on metro rail than any other rail transit systems. The recommendations suggest a goal of providing suburban rail services in urban agglomerations with a population greater than 4 million[13,14]. While the recommendation of the Working Group and NTDPC discusses about the ideal choice of technology, it suggests that 'the choice of technology is a multi-determinant variant, including population, per capita disposable income, densification in city, availability and opportunity cost of land, morphology of the city and importantly, aspiration of people revealed through political demand, the comprehensive mobility plan with networked connectivity'[13,14] and further recommends with few criteria while selecting technology for MRTS. The criteria in these reports mainly emphasize on PHPDT, population and average trip length for a city and make a comparison among metro rail, LRT, monorail, BRT and city bus systems. In the case of 2 million-plus cities, these guidelines suggest conducting a detailed feasibility and DPR for metro rail and having at least 1 million ridership per day on organized public transport. In case of smaller cities with linear shape and a corridor projected with high demand, they propose metro rail with justified CMP and alternative analysis. Monorail is suggested to be suitable for narrow right of way with high-rise buildings on the sides as well as sharp curves, and BRT for higher PHPDT with overtaking lanes. The recommendation of the Working Group and NTDPC suggest to conduct feasibility and DPR study for cities with population more than 2 million for identifying MRTS proposals. Regarding at-grade and grade-separated construction, the reports accept that at-grade MRTS is the most convenient facility for commuters, while grade-separated system increases the trip time by 10–15 min. Thus, it is recommended that at-grade construction should be the default choice; however, the decision would depend on local conditions, including availability of land and road space[13,14]. Further in 2014, GoI introduced NUTP 2014, another refined policy on urban transport. The objective of this Policy was 'to plan for the people rather than vehicle by providing sustainable mobility and accessibility to all citizens'[15]. Public transport should provide a citywide, safe, seamless, user-friendly, reliable and good ambience with well-behaved drivers and conductors. It suggests that the Policy will encourage all types of technologies and does not support any specific technology. It is also not possible to prescribe a specific technology in the Policy[15]. The choice of MRTS should be decided with respect to the city specific land use and transport plans. NUTP 2014 nearly covered recommendations similar to those suggested by the Working Group and NTDPC while majorly following the NUTP 2006. This Policy also suggests that the at-grade technology should be selected, as the grade-separated systems increase trip time by 10–15 min to account for the need to go up and down[15].

The Urban and Regional Development Plans Formulation and Implementation (URDPFI) guidelines published in 2015 provide a framework for plan preparation and implementation process of MRTS[16]. They guidelines discuss the criteria and possible options for the cities. The Metro Rail Policy in 2017 confirmed the need to implement efficient and effective MRTS such as LRT, BRT and metro rail in several cities[17].

Its objective was to curb the growing personal motorization, air and noise pollution, congestion on roads, accidents, etc. by developing a sustainable public transport system. The Metro Rail Policy 2017 recommends the choice of MRTS depending on a variety of factors and not population alone[17]. Any city having 'high population may not have sufficient number of corridors with adequate density to justify investments in metro, while the cities with linear pattern may justify a metro even at lower population levels as they have fewer corridors and each would have high traffic density.'[17] The choice of MRTS in cities should be made such that it satisfies the social, economic and environmental perspectives in a sustainable manner. Due importance was given to each option of MRTS to evaluate it on equal weightages. The Metro Rail Policy 2017 recommends an alternative analysis of modes for transit-mode selection. It also recommends that the work which caters to the projected demand of commuters over the life cycle of the project with least cost of investment must be chosen[17]. The appraisal guidelines published for the Metro Rail Policy state that the Metro Rail Policy 2017 is an important step taken towards the unbiased planning and development of MRTS in cities in India and carrying out comparative analysis is a mandatory and one of the important and salient features of the Policy (ref. 18). According to the Policy, the ULBs must check on alternative options of public transport on economic, social and environmental aspects. However, the Policy holds true only if states need financial assistance from the Central Government, as urban transport development is constituted in the state list. It is necessary for the states to make it mandatory for cities to carry out unbiased alternative analysis of public transport technology while preparing MRTS. Another objective of alternative analysis is to take into account the opinion of stakeholders and to consider the locally preferred systems[17].

DPR and proposals analysis

This section presents a study of six DPRs of metro rail and BRT in Indian cities. It compares these DPRs based on the recommendations suggested by the policies and guidelines. Annexure 1 shows details of all the six proposed DPRs, including total cost and total length of the proposed corridor. This study considers DPR analysis under three major aspects. The first part discusses details of the proposed corridor (Annexure 1); the second part focuses on data and previous studies considered for proposal analysis, while the third part discusses the rationale considered for the proposal of the system. This section analyses these DPRs for alternative analysis and integration of proposals with CMP. The study in this section also verifies whether the willingness to shift and pay survey is conducted or not.

In 2011, Alwaye–Petta metro rail corridor in Kochi was sanctioned for a total length of 25.612 km (ref. 19). The vehicle ownership data collected in study report reveal that about 16% of the people owned two-wheelers and about 47% did not own any vehicle. The mode choice data in the study area suggested the dominant share of public transport, i.e. by bus to be consistently around 72%, followed by train and ferry at 1% and 8% respectively. The peak hour travel demand was 0.284 million for base year 2005. The mode share was calculated to be 81% for public transport, 8% for two-wheeler, 6% for cars and 5% for autos. The average trip length by public transport was 14 km; 9.4 km for two-wheelers, 12.5 km for cars and 7.8 km for autos. No study regarding mode shift and willingness to pay by the commuters has been reported in DPR. The study conducted by Rail India Technical and Economic Services (RITES) in 2001 for the preparation of a 'comprehensive study for transport system for Greater Cochin Area', recommended the provision of LRT system between Alwaye and Tripunithura[19].

The rationale for selecting metro rail mentioned that 'for city with population of 1.0 million, the share of public transport should be about 40–45%. The percentage share of public transport should progressively increase with further growth in the city population reaching a volume of about 75% when the population of the city touches the 5 million mark.'[19]

However, in Kochi, the share of public transport in the considered areas was 81% for a population of 1.8 million. Further, it is claimed that the bus system can optimally carry 8000 peak hour peak direction traffic (PHPDT). When traffic density on a corridor exceeds 8000 PHPDT, average speed of buses reduces, journey time increases, air pollution increases and commuters are put to increased level of inconvenience. Thus, when on-corridor traffic density during peak hours crosses this figure, provision of rail-based mass transport, i.e. metro system should be considered. For this case speed delay data may be studied, but DPR does not consider any such study nor does it discuss about volume count over congestion on the road. The road-based public transport system has been neglected with respect to the growing PHPDT, pollution and accident incidents and thus metro rail is necessary. Another justification for the metro rail is that the 'metro rail system may become inescapable if the traffic density on a corridor reaches 15,000 PHPDT. However, in a city like Kochi, where road widths are inadequate, this figure may not be more than 10,000 PHPDT.'[19]

Further it claimed that in Kochi 'with the growing economy and inadequate public transport services, the passengers shall shift to private modes, which is already evident from the high vehicle ownership trends in the region. This would not only aggravate the congestion on streets but also increase the pollution. Hence, it is essential to plan and provide for a light metro rail system in Cochin.'[19] However, the public transport share of Cochin is already very high with a low private motorized ownership.

In March 2021, the Jaipur Metro Rail had sanctioned phase-I for the east–west corridor[20]. The important observation from DPR is that there is nominal increase in the daily passenger and PHPDT, with no change in the average trip length. The trip share details show that most of the trips are completed by walk, two-wheelers and public transport, i.e. 28%, 24% and 21% respectively. The free-flow speed considered in the four-stage model calculation is 36 kmph for two lanes and 40 kmph for four lanes[20].

DPR fails to discuss the growth pattern and opportunities in the region. Only the population employment ratio has been considered. Details and data in DPR suggest that no survey for commuters to understand willingness to pay and shift, or to consider the opinion of commuters to use metro was conducted. Even the data in DPR do not show shift from different modes to metro rail[20].

The comprehensive mobility plan already prepared for Jaipur suggests the possible option for public MRTS. The suggested MRTS options according to CMP are city buses, BRT, tramways and metro system (light or medium). However, CMP does not consider the option of LRT and straddled monorail. Even though DPR considers the CMP proposals, it does not discuss the development profile of the city, the direction of sprawl and the upcoming development activities and opportunities. It only mentions that 'with growing population and mega development plans coming up for the port city, the travel demand is expected to grow steeply'[20].

The proposal of Jaipur Metro Rail is justified based on population and the modal share. The DPR mentions that for the city with a population 1 million, the share of public transport should be 40–45% and when the population breaches the mark of 5 million, this share must progressively increase to 75%. Further, it is claimed that BRT and tramway are not suitable options, as the former can accommodate capacity up to PHPDT of only 10,000–12,000, while the latter can take PHPDT of 8,000–10,000. Another reason justifying metro rail includes the greater road space required for BRT and its failure in Delhi. While justifying the need of metro rail, it is suggested that the elevated metro rail requires less road space and no space if it is underground. Thus, based on the above facts and the capacity of the system, the metro system in Jaipur is justified. The demand level for the corridor in 2031 will be 27,750 PHPDT, which will not be handled by road-based systems, and thus the medium-capacity metro rail system should be constructed in Jaipur for this corridor, which can cater to the needs of 25,000–50,000 PHPDT[20].

In Nagpur, two metro rail corridors, north–south and east–west, were proposed in 2013. The total length of the north–south corridor is 19.658 km and the east–west corridor is 18.557 km (ref. 21). A study conducted by L&T Ramboll for Nagpur Municipal Council (NMC) in June 2007 recommended construction of medium rail transit system in phases. A total of 65 km of medium rail transit system and 20 km of commuter rail by 2031 has been proposed in this report along with additional medium rail transit or BRT corridor in the long term.

The DPR does not provide enough details about the mode share in Nagpur city[21]. The modal share is dominated by the external buses, i.e. either those buses leaving Nagpur city or entering the study area from other cities; it is more than 50% in the total share. Thereafter, the modal share is dominated by the private mode, i.e. two-wheelers, cars and autos. The share of local buses is about 12% (ref. 21).

Further excluding the external buses, the modal split for Nagpur city reveals that the modal share is dominated by two-wheelers and cars, i.e. 33.75% and 31.16% respectively. The major share is by autos (22.96%) and only 10% by local buses. The data show very low usage of public transport and greater dependency on private, motorized two-wheelers. DPR does not understand this point and also commuters are willing to shift from two-wheelers to metro rail. In the process of the four-stage model, it is assumed that the shift from other modes to metro rail will be from 10% to 50% (ref. 21).

The DPR, in response to justification in the selection of metro rail, mentions that it is a proven and worldwide accepted technology[21]. It portrays that the metro system is used in more than 160 cities worldwide. However, comparing it with LRT, the application of this system worldwide is in more than 400 cities[10]. A comparison of about eight car PHPDT with headway of 2.5 min shows that, LRT, monorail, urban maglev and metro rail can deal with the PHPDT demand of 24,480, 34,300, 23,100 and 50,000 respectively[21]. The road-based BRT has been neglected because it cannot cater to PHPDT above 8000, and the monorail because it is a costlier technology in construction and in operation and maintenance (O&M) than light metro. Metro rail is a more tested technology compared to monorail. However, there is no discussion regarding why LRT is neglected despite its less capital O&M cost and also it being the most tested technology worldwide[21].

The DPR for Ahmedabad Metro Rail was prepared in 2015. The Ahmedabad Metro Rail project consist of two routes, each having a total length 19.435 and 18.493 km respectively. The other details are given in Annexure 1. In the DPR, it is important to note that one of the studies by Delhi Metro Rail Corporation (DMRC) in 2005 mentioned the proposal of two corridors for suburban rail and two corridors for metro rail. In 2008, it was only proposed to prepare DPR for metro rail connectivity. The suburban rail proposal has not been mentioned thereafter, nor the option of monorail or LRT been discussed as a possible solution[22].

The data collected in DPR consist of household survey data and existing land-use details from the draft development plan 2021 for mapping land use along the corridor. Other details include existing proposed road network, public transport service, classified volume count data, space survey, employment data, willingness to pay and shift survey, etc. The volume count and PHPDT study conducted at major locations along the proposed metro corridor shows the dominant share of private vehicles at almost 65%. The travel speed along most of the corridors is more than 25 kmph in study area. The city bus service covers almost 88% of the developed Ahmedabad Municipal Corporation area and carries 0.9 million passengers per day, catering to roughly 11% of the trips in the city. The BRT has road network of 63 km and attracts 0.117 million passengers daily with the peak hour speed of 25 kmph. The modal share both in Ahmedabad and Gandhinagar is dominated by walk and bicycles, i.e. 46% and 42% respectively. The private vehicles cater to almost 30–35% of the trips in the study region. The trip length frequency distribution for the study area shows that the majority have trip length less than 8 km and average trip length for the study area is 6.6 km. The average value for public transport and four-wheelers is slightly higher, i.e. 9.57 and 9.66 km respectively. A willingness to pay and shift survey conducted for public transport and non-public transport (private vehicle and intermediate public transport) users suggests that 54% of the users are willing to shift to the new public transport mode. The major shift in this share is seen by the two-wheeler commuters and auto passengers[22].

The rationales discussed for justifying the metro rail mainly include the recommendations of the Working Group on urban transport for the 12th Five-Year Plan as a base for selection. However, of the given criteria the metro rail system is justified only on criterion of population and not on the criteria of PHPDT and average trip length. The issue of Right of Way (RoW) availability along corridors has also been mentioned as an important rationale for selection of metro. Further, the light capacity metro rail in this case has been justified as better amongst other systems on the criteria of PHPDT and as one of the tested and reliable technology. The reasons for discarding Monorail technology include higher O&M cost than the metro rail and less experience and reliability of monorail technology in India. The final choice of mode to be adopted was based on techno-economic considerations in this case. The light capacity metro system is adopted in Ahmedabad because it is a stable, tested and reliable technology, having the capacity to cater PHPDT from 15,000 to 25,000 (ref. 22).

The DPR for Surat BRT was prepared in February 2008 along with CMP of the city. The population of Surat city according to the 2001 census was 2,433,785, comprising a total area of 112.27 km^2. The population density of the city according to the 2001 Census was 21,677 persons/km^2, i.e. 216.77 persons/ha. Considering the urban agglomeration, the population according to the 2001 census was 2,811,464. With growing development, the area of Surat Municipal Corporation (SMC) has been increased up to 312 km^2 in 2007. Also, migration in Surat is high and male-dominant. Around 55.85% of the total population consists of migrants who have migrated for employment. The physical expansion of the city over previous decades shows a radial development pattern with rapid growth in all directions. Surat is classified as a compact city with very high density, the developed area density exceeding 215 person/ha (ref. 23).

'The city is compact and has been outwardly expanding along the transport corridors. The growth trends indicate sprawl tendency towards south and north east.'[23] The total length of road network in Surat according to the approved developed plan, excluding the National Highway and State Highway is 1150 km. According to the land-use proposed, the total cover of road network was 9.2% of the total Surat Urban Development Authority area, which is relatively less. The street network in Surat is classified as ring radial form and grid iron pattern. RoW is majorly found to be exceeding 30 and 18 m. The trip rate in Surat city has increased from 1.02 in 1988 to 1.31 in 2004, considering all modes of travel. When the trip rate for only motorized vehicles is considered, it was 0.55 in 1988 and around 0.8 in 2004, indicating the significance of motorized trips. The data collected for trips by mode suggest that most of the share is by non-motorized mode, i.e. walk; almost 42% of the trips is completed by this mode. This is followed by two-wheelers (28.39% of the total trip share) and bicycles (13.44%). The average trip length is about 5.3 km, which is unsuitable for rail-based transit. This trip length is excluding the walk trips. If the walk trips are considered, the average trip length for Surat is around 4.1 km (ref. 23).

The data suggest that with the provision of better transit facilities, many commuters are willing to shift to public transport. Almost 59% and 74% of the respondents have indicated their willingness to shift to an improved public transport system for work and education purposes respectively. Factors like safety, comfort and reliability have been ranked as important for the choice of public transport.

A total of ten corridors was proposed to be constructed in Surat in two phases with a total network length of 87.7 km (29.7 km in phase 1 and 58 km in phase 2) and 2010 was considered as the base year. The ridership calculation was projected for 21 years, i.e. till 2031 for phase-1 only, that is, for corridors 1 and 2. A total of 158,000 passenger trips per day was expected for the base year and projected to be 1.58 million passenger trips per day by 2031 for both corridors. The major shift of commuters was seen from bicycles, two-wheelers and autos for trips of length more than 4 km. However, the results in Table 1 calculated by the model show a total ridership of 158,009 for the base year 2010 and projected to be 965,049 by 2031. The data claimed in DPR show disparity. The data in one section do not match with the same in the other sections. The average operational speed is expected to be 25–30 kmph with a headway of 1 min on corridor 1 and 4 min on corridor 2. The PHPDT data are not shown in the DPR, which shows insufficient data compared to metro DPR.

The DPR for Hubli–Dharwad BRT was finalized in March 2013 (ref. 24). The study proposed a BRT in the Hubli and Dharwad twin cities, connecting their city centres that are separated by approximately 22 km. The total road network in Hubli–Dharwad is 700 km and the road density is approximately 3.29 km/km^2. The per capita road length is 0.8 km and average road width is 9.5 m. The road covers 22.69 km^2 of total area, accounting for 22% of the total developed area. According to the proposed comprehensive developed plan 2021, the total area proposed for the road network is 30.05 km^2 which constitutes 21.87% of the total developable area[24].

The data collected from 8800 household surveys revealed the per capita trip rate for these twin cities to be 1.48 with an average trip length of 5.1 km, including walk trips. The share of walk trips in these cities was comparatively high due to the compactness of the cities. However, the average trip length of motorized trips was high at 8.6 km, which is expected in linear cities. The data suggest that 35.5% of the total trips is by bus and 30.7% by two-wheelers without considering walk trips, indicating high reliance on buses and two-wheelers. The average journey speed for Hubli–Dharwad cities is about 28 kmph. The existing bus services on the proposed corridor carry about 70–80% of the people on the corridor. Buses within the cities make about 0.25 million trips daily[24].

The number of public transport buses in these cities is adequate, but these buses are old. Therefore, new buses must be procured, justifying the proposal of the BRT system in Hubli–Dharwad. The proposed BRT projected daily passenger volume flow of around 170,000 persons for the base year 2011. By 2031, this was expected to be about 0.4 million passengers. The estimated capacity in terms of PHPDT for the corridor was around 6,000 in 2011 and 10,000 by 2031 (ref. 24).

Results and discussion

Urban transport is an important aspect for the development of any city. It is necessary to develop an efficient and effective urban public transport system for sustainable development along with inclusive growth of a city. GoI has continuously introduced and amended national-level urban public transport policies and guidelines. The government is encouraging urban local bodies to implement and construct MRTS in their cities. However, the proposed and implemented MRTS in many cities have been questioned by transport planners and policy-makers, leading to controversies about suitability of these systems. This study deals with the concerns related to these controversies by examining the respective policies, guidelines and proposal reports of MRTS in Indian cities. Some of the important observations include the alternative analysis of MRTS and knowledge centre to support the decision-making. This study also analyses gaps in the detailed study reports of the proposed systems, biased decision-making, lack of integration among CMPs and the proposals.

Knowledge centres and expert mechanisms

Mackett and Edwards[25] mention that in order to make a city sustainable, it is important to provide attractive public transport and to achieve this goal cities may require a new public transport system or MRTS. At present, a variety of options like monorail, metro rail, LRT, curb-guided buses, etc. are available. Mackett and Edwards[25] have worked on the formulation of an expert system, to transfer knowledge and expertise from one city to another, for selecting an appropriate public transport technology for any city. NUTP 2006 has clearly highlighted that there are various proven technologies[2], and thus it is not appropriate to prescribe any particular technology in a general policy. The choice of the system is driven by the criteria majorly dependent on the city and the needs of its residents. However, it is difficult to make decisions regarding the same and thus proposes to formulate a knowledge-based centre and system to support the choice of MRTS technology in India. A review of policies, guidelines and proposals in the present study does not observe any such related discussion about knowledge centre or expert system in the Indian scenario. Thus, it is recommended to formulate a knowledge centre and expert mechanism to transfer knowledge from one city to another, which would assist transport planners and decision-makers in selecting MRTS technology.

Biased decision and missing explicit criteria

The recommendations and guidelines proposed in the Working Group and NTDPC report majorly focus on parameters like population, PHPDT (capacity) and average trip length, to compare among BRT, LRT, monorail and metro rail. Whereas parameters like population density, road space and city income are rarely considered. The considered criteria are mainly from the perspective of city and technology aspects. The resident/commuter-specific criteria such as average journey time, city income, willingness to shift, convenience, etc. which play a major role in effective operation of MRTS, have not been addressed in these guidelines. The average journey time, convenience and income are major contributing factors for selecting the mode of transport by a commuter. However, the guidelines have instead focused on population as the major factor, which has been used as the rationale for selection of MRTS technology in many cities. It is critically important to discuss whether only population would be able to generate such high demands for MRTS and become a rationale for selection of an appropriate system. The Metro Rail Policy 2017 mentions that the choice of MRTS depends on a variety of factors, irrespective of the population. While comparing between DPRs of metro rail and BRT, the metro rail DPR highlights the data and rationale considered in the proposal. It also discusses the four-stage modelling and demand level in detail, while the DPR for BRT does not discuss the same. Again, only Ahmedabad metro rail and Surat BRT have been keen to conduct willingness to shift and pay survey, while the other DPRs for metro rail as well BRT do not consider these important details. The Working Group and NTDPC have advised that understanding the aspirations of the residents is important. However, without inclusion of their perspectives in the survey or any other relevant commuter survey data, it is difficult to understand or predict their willingness to shift and pay, or any specific requirement to be incorporated in the proposals.

The guidelines as well as DPRs for selection of appropriate MRTS technology majorly highlighted BRT and metro rail technology only. Thus, the present study only reviews DPRs for BRT and metro rail systems. In the Indian cities only BRT and metro rail systems are proposed and constructed. Monorail and LRT systems are either rejected or not considered. In most cases of DPRs for metro rail, the population is proposed as an important rationale. In the case of Ahmedabad metro rail, the rationale for selection of metro rail mainly includes the recommendations of the Working Group on urban transport and NTDPC. However, these recommendations were justified on the criterion of population only, and not the other two, i.e. PHPDT and average trip length criteria. The road-based BRT has been neglected because it cannot cater to PHPDT above 8000, and the monorail because it is a costly technology to construct and incurs higher O&M than metro rail. Also, other rationales put forward for metro rail suggest that it is a tested, proven, reliable and worldwide accepted technology than other rail-based systems. There is no rationale regarding why LRT is neglected while having less capital O&M cost and being the most tested technology worldwide. LRT has been successfully operated in more than 400 cities worldwide[10]. While the other systems like LRT, straddle type monorail and urban maglev may play a better role on parameters like urban landscape, effect on ambient surrounding and technological factors, they are neglected in the selection process. The justification for metro rail in Kochi reads: 'metro rail system may become inescapable if the traffic density on a corridor reaches 15,000 PHPDT. However, in a city like Kochi, where road widths are inadequate, this figure may not be more than 10,000 PHPDT.'[19] This raises the question that, if only the rail-based system must be proposed as a solution with PHPDT of 10,000, then why has only metro rail been proposed and no other technologies like LRT, monorail or suburban rail? Most of the metro rail DPRs have considered previous transport proposals for technical data inputs. In many of these DPRs, it is proposed to use suburban rail, LRT or BRT. However, the DPRs do not address these proposals in detail and discard them without further discussion. In most cases, the metro rail corridor has been proposed to the previously proposed LRT or suburban rail corridor.

Missing provision of alternative analysis

Alternative analysis is an important stage while proposing any transport plan. Vuchic[26] has meticulously described the process for selection of a transit system. In the process of transit plan development, evaluation and selection, he suggests the design of alternative plans as the basic material and starting a process with this stage[26]. Vuchic[26] mentions that, 'since there is no exact methodology for development of an optimal transit network, in most cases planning consists of development and evaluation of several alternative plans. The purpose of developing alternative plans is to examine a range of possible solutions and compare them to find the most advantageous one.' However, the guidelines and DPRs have not discussed regarding alternate plans or alternative analysis, except the Metro Rail Policy 2017 (ref. 17). This Policy confirms implementation of effective and efficient MRTS in Indian cities. The Policy and its appraisal guidelines confirm the requirement of alternative analysis[17,18]. However, the guidelines hold true only when the states or ULBs seek financial assistance from the Central Government. If any ULB does not seek financial assistance from the Central Government, it may execute the plans without following these guidelines. The DPRs do not provide an alternative analysis, which is necessary for unbiased decision-making. This study has considered six DPRs and none addresses alternative analysis in its report.

Lacunae in DPR and integration with CMP

The review of six DPRs suggests lacunae in them for approval of MRTS projects, where there is no appropriate integration of the proposed MRTS with CMP. The DPRs submitted for MRTS projects provide inadequate information. In some DPRs, it is found that the focus of selection of MRTS is mostly emphasis on technological demand level with manipulations. Thus the proposals submitted for MRTS may not have been properly analysed and provide insufficient information. This is evident from the demand level and trip length projected in metro rail DPRs, in case of Jaipur and Nagpur metro rail, where it can be observed that the passenger per day demand level and trip length show less significant projections over the projected period.

The integration of proposals with CMP suggests that it has been considered in case of BRT proposal only, whereas the Ahmedabad metro rail proposal considers the development plan. The DPRs for metro rail fail to discuss about future growth and development trends in these cities, whereas the DPRs for BRT discuss city growth and development plans along with the existing road statistics and details of the city. In case of DPR for metro rail, only Ahmedabad metro rail has considered specific and relevant data for the study, while other DPRs fail to discuss and provide basic data for the proposal. In case of BRT, only the DPR for Hubli–Dharwad BRT discusses the rationale for selection, while the DPR for Surat BRT does not discuss these factors. The justification for BRT selection mentions that even though the number of public transport buses is sufficient, these buses are old. Thus, we need to procure new buses.

At grade and grade-separated systems (elevated/underground systems)

An important suggestion put forth while proposing any MRTS by the Working Group[13], NTDPC[14] report and NUTP 2014 (ref. 15) is the emphasis on at-grade system compared to grade-separated systems. The policies and guidelines recommend having an at-grade system, as it saves 10–15 min compared to a grade-separated system. This can play an important role for effective and efficient operation of MRTS in Indian cities, as the trip length in these cities are shorter. Studies have revealed that the Indian cities generally have an average trip length of approximately 5–6 km and they form multi-nuclei settlements[6,7,27]. However, the DPRs suggest that the trip length for both metro and BRT is approximately in the range 6–8 km. The average scheduled speed calculated for the respective corridors in DPRs varies from 30 to 35 kmph. The average speed of existing traffic on roads and the proposed systems was found to be almost the same, or the average speed of the existing traffic was even better than the proposed MRTS in some cases. Considering this fact, a motorized two-wheeler with an average speed of 30 kmph for door-to-door trip length of 8 km will need 16 min to complete the trip. While comparing this with grade-separated metro rail, average commute time with average scheduled speed of 30 kmph, as needs time for access and egress, will exceed 16 min. It can be observed in the case of Indian cities that the modal share is majorly dominated by private motorized vehicles, especially by two-wheelers, except for Kochi. From 1991 onwards, two-wheelers have shown a steep growth in registration[28]. The growth of two-wheelers between 1991 and 2001 was four times faster compared to population growth[3,28]. The probable reasons for this may be convenience, flexibility, comfort, affordability and fuel-efficient options provided by this segment. It suggests that commuters prefer more convenient and time-saving options of motorized two-wheelers. Thus, it is advisable to save time in access and egress trips which can provide a more flexible, accessible and convenient system to the commuters. The difference of average journey time of at-grade and grade-separated systems, even at an average difference of 10 min, can affect transport mode choice to a great extent.

Conclusion

In Indian cities, the Government is encouraging development of sustainable transport systems. However, MRTS is associated with controversies among transport planners

Annexure 1. Comparison of Metro and BRT DPRs

Criteria	Kochi Metro Rail Project (2011) 2015	2020	2025	2030	Jaipur Metro Rail (March 2012) 2014	2021	2031	2041
Total length (km)	24.912				12.067			
Total estimated cost (crores)	3733.00	Without taxes @ average August 2011 price index			2677	With central taxes @ April 2011 price index		
Cost per km (crores/km)	149.85				221.84			
Study area (sq. km)	730.00							
Population (in million)	1.81 for greater Kochin area @ 2001				4.199			
Population density (persons/Ha)	24.79							
Peak demand (PHPDT)	13,681	17,663	21,065	23,621	11,264	16,376	27,750	29,169
Daily ridership (in million)	0.382	0.468	0.539	0.601	0.210	0.293	0.422	0.443
Trip length (km)	7.33	8.46	9.55	10.02	5.1	5.3	5.5	5.5
Headway (min)	5	4	3		6	4	2.5	
Designed speed (kmph) Scheduled speed (kmph)					80 32			
Number of stations	23				11			
Station average spacing	0.923				0.912			
FIRR (%) EIRR (%)	3.04 14.02				8.24 18.60			
Comprehensive mobility plan considered (Yes/No)	No				No			
Alternative/comparative analysis (Yes/No)	No				No			
Willingness to pay and Shift	No				No			

Criteria	Nagpur Metro Rail (November 2013) 2016	2021	2031	2041	2016	2021	2031	2041
Total length (km)	19.658				18.557			
Total estimated cost (crores)								
Cost per km (crores/km)								
Study area (sq. km)	217.00							
Population (in million)	2.41 as per 2011 census							
Population density (persons/Ha)	110.85							
Peak demand (PHPDT)	10,089	10,936	12,934	15,729	7,746	8,460	9,906	11,882
Daily ridership (in million)	0.168	0.186	0.224	0.278	0.184	0.198	0.235	0.286
Trip length (km)	6.419	6.453	6.533	6.522				
Headway (min)								
Designed speed (kmph) Scheduled speed (kmph)	95 32–34				95 30			
Number of stations	17				19			
Station average spacing	0.865				1.024			
FIRR (%) EIRR (%)	10.35 17.70				10.35 17.70			
Comprehensive mobility plan considered (Yes/No)	No							
Alternative/comparative analysis (Yes/No)	No							
Willingness to pay and Shift	No							

Criteria	Ahmedabad Metro Rail (Mar 2015) 2018	2021	2031	2043	2018	2021	2031	2043	Surat BRTS (2008) 2010	2031	Hubli–Dharwad BRTS (2013) 2001	2011	2031
Total length (km)	19.435				18.493				87.7		22		
Total estimated cost (crores)	5815	Inclusive taxes @ March 2014 prices			4020	Inclusive taxes @ March 2014 prices							
Cost per km (crores/km)	299.20				217.38								
Study area (sq. km)									312		202		
Population (in million)	6.3								2.4	2.8	0.78	1	1.5
Population density (persons/Ha)									216.00			47	76
Peak demand (PHPDT)	8,121	10,463	17,245	25,425	11,290	13,902	21,994	30,092				6,000	10,000
Daily ridership (in million)	0.496	0.670	1.123	1.601					0.158	1.579		0.17	0.4
Trip length (km)	6.99	6.99	6.97	7.29									
Headway (min)													
Designed speed (kmph) Scheduled speed (kmph)	80 33				80 32								
Number of stations	17				15								
Station average spacing	0.875				0.811								
FIRR (%) EIRR (%)	10.45 19.94				10.45 19.94								
Comprehensive mobility plan considered (Yes/No)	DP discussed									Yes			Yes
Alternative/comparative analysis (Yes/No)	No									No			No
Willingness to pay and Shift	Yes									Yes			No

and decision-makers in the Indian scenario. This study identifies gaps in the proposals, policies and guidelines for selecting appropriate technology for MRTS during the decision-making process. The study concludes that the transport planners and decision-makers in India have failed to formulate a knowledge centre, as suggested in NUTP 2006 and 2014. This has been the main hurdle to transfer knowledge and experience from one city to another. In addition, in the Indian scenario the policies and guidelines have failed to provide any explicit criteria to select appropriate technology for MRTS during the decision-making process. The development of MRTS is capital-intensive and requires high traffic demand to be operated efficiently. It varies according to the technology of MRTS. The development cost of metro rail is high compared to BRT, whereas the development cost of LRT is lower than the metro rail but higher than BRT. However, the proposals suggest that metro rail and BRT have found major focus in developing MRTS. Other technologies like LRT, monorail, etc. have not been considered in the decision-making process. Thus, in Indian cities, it is critically important to discuss whether they would be able to generate this high traffic demand for such a capital-intensive system. It is necessary to discuss whether such heavy investment is required for speed and comfort, or a less capital-intensive system with more city-wide coverage is sufficient. Also, commuter participation, city landscapes, heritage monuments, etc. have been neglected in this process. It is important to note that in Jaipur which houses many ancient monuments of cultural heritage and historical importance, it was proposed to construct an elevated metro across the city. The proposal lacked integration with CMP, the growth pattern and development vision of the city. Such proposals do not justify the reasons for not considering previous proposals for further considerations. The proposal studies reveal that the demand projections and data considered are manipulated. Thus, the present study strongly recommends preparing DPRs integrated with CMP and alternative analysis for an unbiased decision-making process. It is recommended to conduct alternative analysis among available options over a specific period of the life cycle. This study proposes to formulate expert system/mechanism for selecting technology for MRTS in the decision-making process. Such a mechanism will help identify the most effective MRTS technology in any city considering city, technology and commuter-based criteria. This expert system/mechanism may be formulated by combining explicit criteria and alternative analysis suitable for the Indian scenario. It is advisable for the Indian cities to design an at-grade system for its effective and efficient use.

Future work

This study proposes the formulation of expert system/mechanism by combining explicit criteria and alternative analysis for selecting technology of public transport in Indian cities for future work. These criteria can be formulated by identifying the parameters and benchmarking of dataset among various technologies of MRTS. Further, it involves the study of several alternative methods. The probable method identified for alternative analysis is the multiple criteria decision making technique. This method is proposed because it can incorporate quantitative as well as qualitative aspects of any proposed system. The Cost–Benefit Analysis/Cost and Revenue Analysis majorly focuses on the monetary aspects of a project. The future scope includes identifying criteria for comparing the various technologies for MRTS in the Indian scenario.

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