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ISSN (Print: 2537-0154, online: 2537-0162)

International Journal on:

The Academic Research Community Publication

DOI: 10.21625/resourceedings.v2i1.598

Integrated Urban Mobility

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Abstract

Habitually, urban mobility involves movement of inhabitants within or among urban areas. As cities continue to grow across the world, the resulting unregulated urban sprawl is associated with numerous adverse consequences. If these growing sub-urban areas and city cores are not adequately and efficiently interconnected by different modes of mass rapid transit systems (MRTS) from origin to destination for last mile connectivity, inhabitants continue to commute fittingly by private modes on consistent basis for their daily activities. This aspect thrusts high level of congestion and increases the commuting cost, collectively contributing to the degradation of urban environment and subsequently low quality of urban living often disengaging the city from its inhabitants. Additionally, with the surge in globalised socio-economic profile of urban areas coupled with ICT (Information and Communication Technology) enabled provision of urban services, the conventional notion of urban mobility is altering swiftly. The MRTS needs to develop inventive structure for the planning, designing as well as implementing mechanisms to offer widely accessible (spatially, socially, all age groups and gender types) choices for sustained urban mobility while gradually unfolding the city to its hurried inhabitants at all the possible levels and scales. In this context, this paper attempts to analyse and assess the current status of MRTS in the provision of last mile connectivity through the case study of Bangalore metropolitan city in India. The analysis intends to articulate the rational configurations for achieving efficient and inclusive urban mobility.

Keywords

Integrated urban mobility; Last mile connectivity; Socio-economic profile; Accessibility; Inclusivity; Quality of urban living

1. Introduction

With the increasing urban population and income, the demand for key services (housing, transportation, utility services, etc.) also increases manifold. Amongst these services, transportation is one of the most important service as it serves dual-purpose of mobility and access to diverse urban facilities while being a major factor in improving the quality of urban life. But it is one of the service which is more than often approached in a piecemeal manner. Several factors such as imbalance in the modal shift, lack of integration between various sectors, inadequate services for last mile connectivity (LMC), etc. have been encouraging urban dwellers to depend on personal mode of transport. Commute of people in the urban areas is predominately impacted by the urban form and the urban transportation system. The socio-economic and ecological development of a city is essentially driven by the efficient public transportation networks. Progression of a city is directly linked to its infrastructure development. But the

expanding transportation networks play a paradoxical role- they drive the development but meanwhile present a set of challenges. Hence, investing in the Mass Transportation System (MTS) is a critical mechanism for the holistic development of a city. MTS is designed to move large number of people in city core, suburbs and metropolitan areas in various types of vehicles. Unplanned and unmanaged urban sprawl is fueled by the significant and prime convenience offered especially in terms of LMC by the private transportation over public transportation. But whereas private transportation is highly unjustifiable in terms of resource consumption, depletion in the finite fossil fuels, movement of less number of people per hour on physical infrastructure which is built at high cost, increased vehicular traffic, congestion, increased commuting cost and time, degradation of urban environment, etc.

2. Indian Scenario -Urban PublicTransportation Infrastructure

The current scenario of urban transportation in India across all the metropolitan areas and cities is characterized by unplanned urban sprawl, declining share of public as well as non-motorized transport, increased overcrowding due to motorization leading to fatalities, sheer neglect of public transport users, pedestrians and cyclists. Forty decades ago, urban dwellers spent one tenth of their income on personal transportation. However, today urban dwellers are spending one fifth of their income on transportation, revealing a harsh economic reality. For ex: An average Indian family spends 15% of its income on transportation only. Regardless of the investments in developing and expanding Mass Rapid Transportation Systems(MRTS), the annual growth rate of motorized private vehicles has been around 15% leading to declining role of public MRTS modes. Although the country adopted a National Urban Transport Policy (NUTP) in April 2006 emphasizing on the incorporation of urban transportation and the intelligent transport systems as an important parameter of urban planning stage to encourage integrated land use and transport planning to minimize the travel distances and increased accessibility especially for the marginal segments of the urban population, the pace of motorization comprised of private vehicles (Refer Figure 1) has increased multi fold. The rapid growth of motor vehicles has its impact on the share of trips made by public transportation. While buses constituted about 9% in 1961, the share was drastically reduced to 1% in 2011 and it seems to have stabilized at this percentage thereafter. Although India accounts for only 2-4% of the world's total carbon emissions causing environmentally irreversible damage, it is important to address this issue as India is a rapidly urbanizing country with increasing demands for transportation.

India is endeavoring to renew its urban public transportation infrastructure through the reforms in the political, financial and institutional domains under The Jawaharlal Nehru National Urban Renewal Mission (JnNURM). To be eligible for the financial and institutional support from JnNURM, the Ministry of Urban Development(MoUD) requires cities to develop Comprehensive Development and Mobility Plans along with detailed project reports highlighting the cost-sharing mechanism.

3. Re-thinking Urban Mobility – Mass Transist System

Urban mobility is no longer about just moving people within or among urban areas in motorized transportation. But, it should aim at offering widely accessible (spatially, socially, all age groups and gender types) choices to urban dwellers for conducting their daily chores. In this context, the conventional notion of urban mobility is altering swiftly with the surge in globalised socio-economic profile of urban areas coupled with ICT (Information and Communication Technology) enabled provision of urban services. A well planned and integrated MRTS hubs are key nodes providing socio-ecnomically and environmentally balanced commuting options at neighbourhood, city and regional levels. The concepts of environmentally and socio-economically viable MRTS choices for urban mobility can be potentially realised through the ICT enabled MRTS services assisting in reducing the volume of motorized traffic. The rapid development of innovative technology in the transport sector should be used creatively to evolve urban mobility planning framework focused on providing wider accessibility options to the cross-section of the urban society.

With increasing stress on natural resources, it has become pertinent that urban centres make a conscious effort to

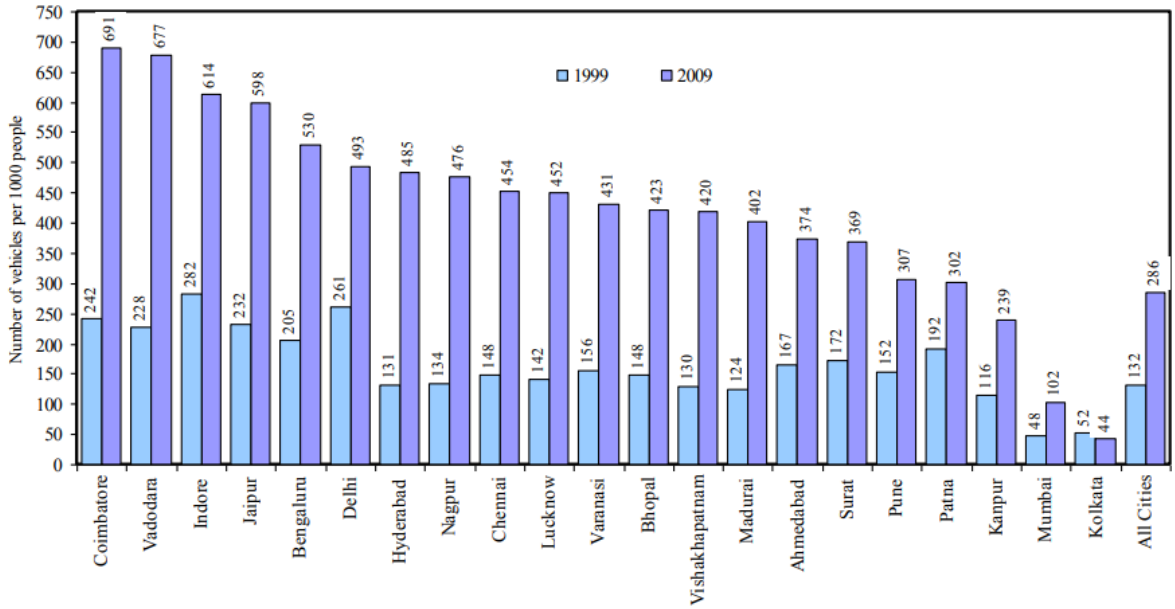

Figure 1. Vehicle ownership rate in selected metropolitian cities in India:1999-2009 Source : Transport Research Wing, Minisitry of Road Transport @Highways, Government of India, New Delhi

become sustainable. Increased use of public transport system is a well documented method for bringing down the carbon footprint of a city. Amongst the available modes, electric based mobility systems are currently the most preferred modes. Mass Transit Systems as the name suggests are designed for providing transporation to large number of people. These systems are usually deployed to connect various parts of a large city and its suburbs with each other. Since these systems provide mobility at a larger scale, they help bring down the footprint required for running transporataion services.

Currently the various forms of MTS include suburban rail network, busways, light rail transit systems and metros. Of these, metros are being widely adopted across metropolitan cities in India as means of sustainable urban mobility (Refer Figure 2).

The major advantages of Metro systems:

- Requires 1/5th energy per passenger km compared to road-based system.
- Causes no air pollution in the city and lesser noise levels
- Occupies no road space if underground and only about 2 meters width of the road if elevated.
- Carries same amount of traffic as 5 lanes of bus traffic or 12 lanes of private motor cars (either way), if it is a light capacity system.
- Is more reliable, comfortable and safer than road based system
- Reduces journey time by anything between 50% and 75% depending on road conditions

3.1. Last Mile Connectivity (LMC)

While MRTS is being provided as a sustainable urban mobility tool, adoption of the same by citizens is based on a number of factors including comfort, accessibility, suitability and security. While the infrastructure that constitute

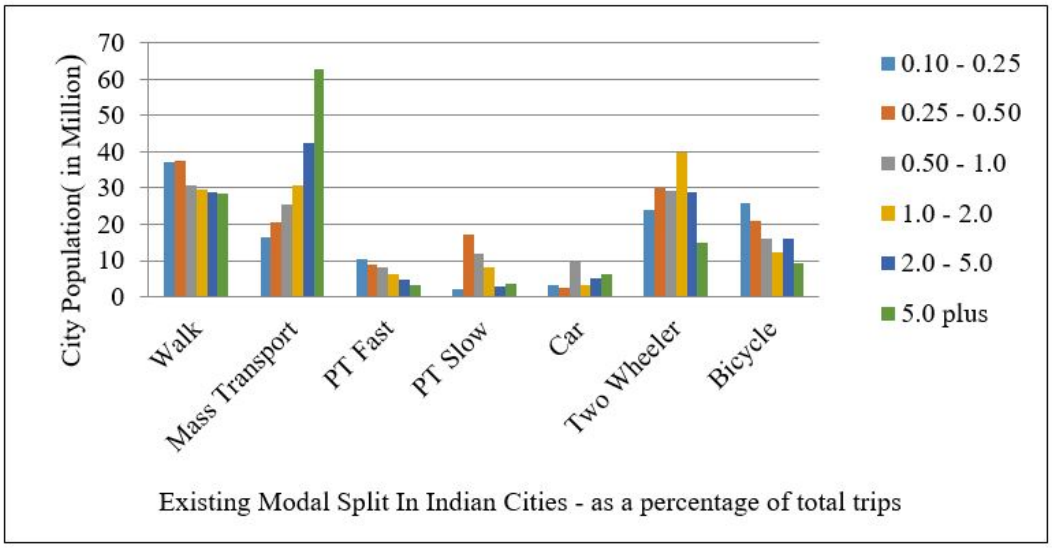

Figure 2. ExistingModal Split In Indian Cities - as a percentage of total trips

Last Mile Connectivity (LMC) are usually not controlled by the MRTS, it forms a vital part of the system. LMC refers to the first and last portion of a user's trip – besides the part covered by MRTS – that one needs to cover on their own either by walking, cycling, riding an auto rickshaw, etc. A person can opt for various modes to undertake a trip including buses, metro, train, walk and cycle (75% of the people rely on non-motorized transport), etc. or a combination of these. While MRTS forms the core of the trip, LMC refers to the first and last portion not covered by MRTS during the trip (Refer figure 3).

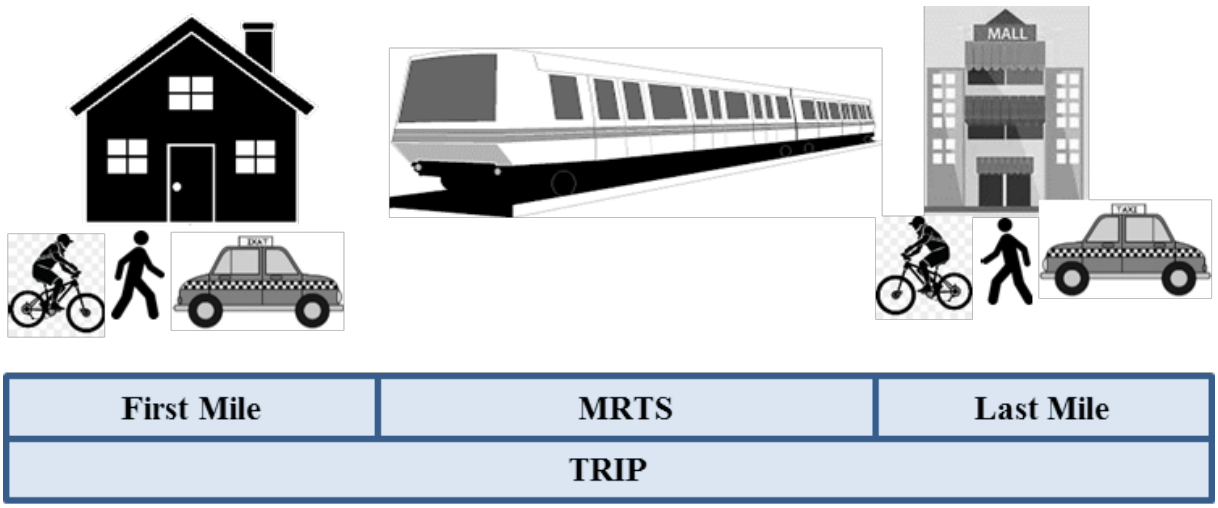

Figure 3. Concept- First and last mile connectivity

LMC is important since they help the commuter complete the trip by plugging the gaps between origin/destination and MTS. Lack or inadequate LMC encourages commuters towards private mode of transportation which provides several advantages such as comfort, ready availability, convenience, etc. Unfortunately, providing last mile connectivity is grossly neglected in the current scenario in Indian cities. Most MTS focus on improving the cost, convenience, comfort and safety of the transit system only and not of the entire trip. The most common strategies to improve LMC are integrating various modes of transport (esp. intermediate public transport) and providing feeder services to various catchment areas. There is an emerging acceptance towards adopting more area centric strategies instead of just station centric. This comes from the realization that LMC will undoubtedly require some amount of walking/cycling. A lot of research has been done to establish the link between ridership and immediate built-up surrounding of the transit system.

4. Bangalore Metropolitan City – Contextual setting

Over the past seventy years, Bangalore, the capital city of Karnataka state in India famously referred as Silicon Valley of India has transformed from being a nondescript small town into metropolis. Bangalore. It is ranked as the most dynamic city in the world and adds about 500 families and 80,000SqM of built up area per day owing to the socio-economic reforms that are accelerating the pace of urbanization. In the past decade, with the 91% of people in urban district, the built up area in Bangalore has increased by 590% (Refer Figure 4).

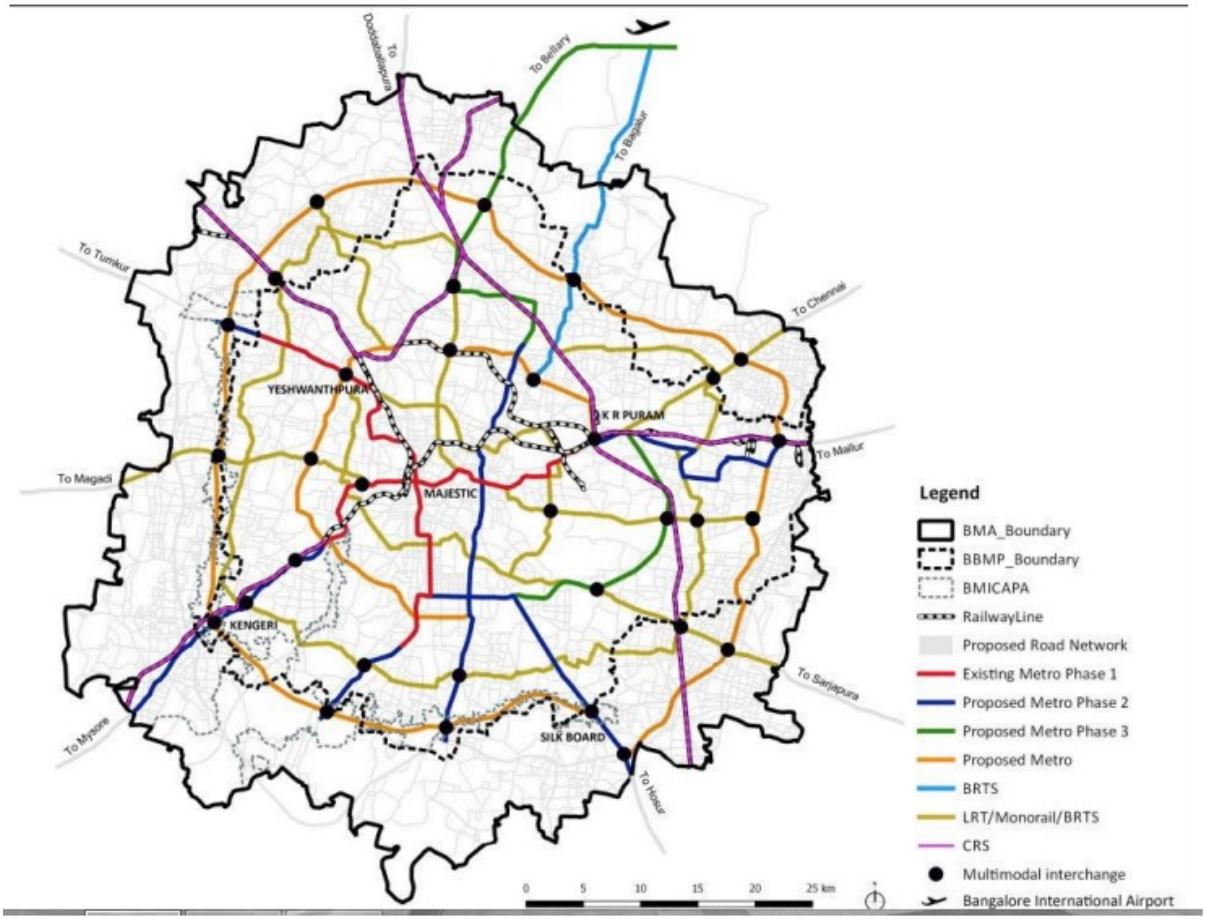

Figure 4. Bangalore metropolitan area showing the extent of public transportnetwork to cater to the expanding urbanization

4.1. Mapping the mobility of Bangalore Metropolitan Area

The transformation of the city has been exceptionally marked by several phases of investments/developments in various socio-economic sectors (public and private), remarkable demographic growth as well as flourishing informal economy. These aspects are accompanied by increasing private vehicle ownership, exceptionally accumulative share of private modes of travel on urban streets, traffic congestion, rising pollution levels, decreasing quality of urban life, etc. At present Bangalore metropolitan area is served by three major modes of transportation which operate exclusive of each other resulting in non-coordinated and non-integrated service pattern of public transport system often leading to poor performance and irrational consumption of public resources (Refer Table 1).

Table 1. Three major modes of Public Transport serving Bangalore metropolitanarea

Sl. No.	Mode of transport	Remarks
1	Bus Transit System	- Provided by Bangalore Metropolitan Transport Corporation (BMTC). 40,000 buses carry 4 million commuters running over 1 million kilometres per day.
2	Rapid Transit System (Metro rail system)	- Provided by Bangalore Metro Rail Corporation Limited (BMRCL) - The carrying capacity of a single metro line is 40,000 for a three coach with a frequency of 1.5 minutes assuming the standing density of 8 people per SqM.
3	Para Transit (public feeder bus services, auto rickshaws and taxis)	- Provided by both BMTC (feeder bus services limited to certain areas) and private owners (dedicated private company bus services, auto rickshaws and taxis) not having any fixed schedule or routes.

As on January 2018, the vehicular population is 7.5 million with 2000 vehicles registering every day. The public sector is attempting to address the multifaceted problems of increasing vehicular volume by capacity building (for ex: widening roads, imposing one-way traffic on certain roads, construction of grade separators, construction of elevated corridors, flyovers, underpasses, etc.) and this is further fueling the use of private mode of transport ultimately impacting the quality of urban life. The loss of lives due to road accidents, the man hours and economic loss due to congestion are of grave concerns and hence demand for an effective multi-modal MRTS for efficient (in terms of planning, management, LMC, economic, accessibility, environmentally conscious) urban mobility.

4.2. Commuting in the Bangalore city

It is crucial to understand how people commute for different purposes in the city to analyze the modes of commute (Refer Table 2).

Table 2. Comparision of the mode of commute (percentage) in three major metropolitan areas of India

Metropolitan area	By walk	By cycle	By metro / train	By bus	By private vehicle
Delhi	25%	10%	33%	25%	7%
Mumbai	33%	6%	33%	22%	6%
Bangalore	35%	7%	20%	33%	5%

The comparative analysis of the commuting in the three major metropolitan areas reveals certain aspects about the commuting. Although commuting by private vehicles is a mere percentage, our city roads are always clogged and congestion is increasing at a rapid rate. On account of this, commuters are spending on an average 15 to 20 minutes more to reach their destinations. Relative analysis of the future projections suggest that the majority of the people commuting to work by car is an unlikely scenario. But yet paradoxically, majority of metropolitan areas are being proposed and planned for private modes of commuting rather than those modes which are primarily used for first and last mile of the commuting. As is the case majority of metropolitan areas, in Bangalore city, short-sighted solutions especially imposing one-way streets are increasing the total distance traveled to on an average by 35% . This trait is closely linked to toxic carbon emissions and increasing temperatures (Refer Figure 5).

These commuting modes have social implications as well. The study of three street scenarios informs that people who live abutting the areas having wide streets with heavy vehicular traffic, streets with moderate traffic and narrow streets with very light traffic found to have one friend and two acquaintances, two friends and three acquaintances

and , four friends and six acquaintances respectively. Thus, the commuting and the networks impact inhabitant's socialization process.

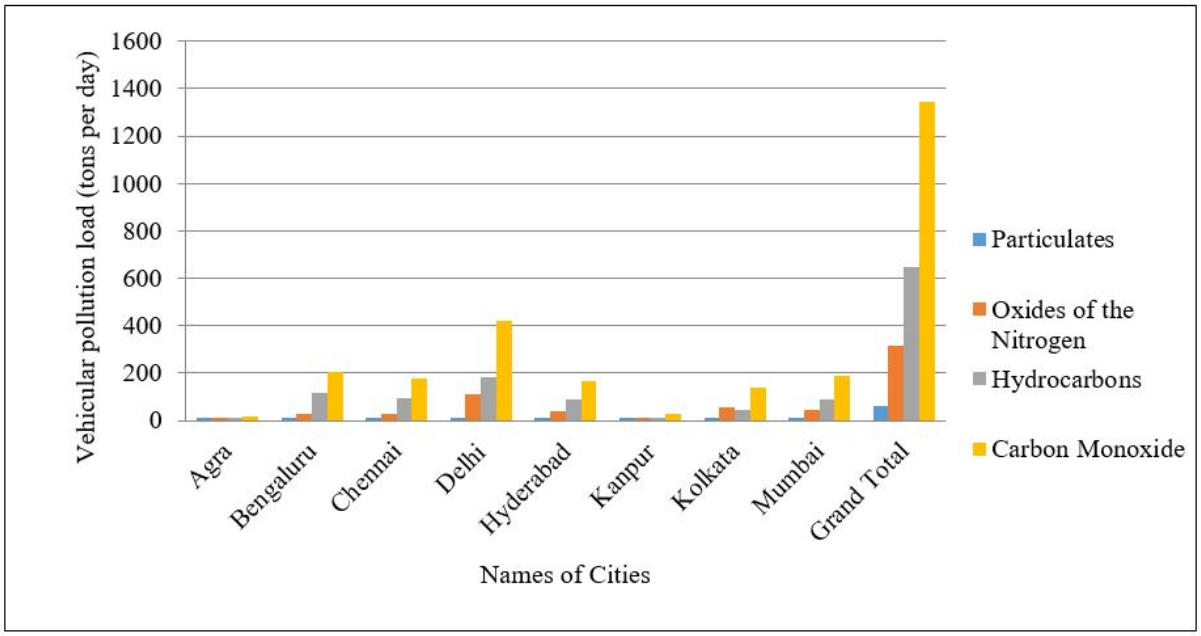

Figure 5. Status of the vehicular pollution control programme inIndia Source: (March, 2010), CPCB, MOEF, GOI

4.3. Last Mile Connectivity in Bangalore Metropolitan Area

In a highly socio-economic disaggregated city, for a larger mass walking and cycling are the most viable solutions for negotiating the final leg of the MTS (Refer Table 3). If the policymakers do not adopt and integrate long term and holistically sustainable solutions for the urban mobility, Bangalore might become unlivable by 2030. Although Bangalore has received huge investments for initiating and expanding the mass rapid transit system (MRTS) networks, the much required provision of convenient and economical LMC has not gained the required attention which is also a vital factor for the successful and efficient usage of MRTS.

Table 3. LMC percentages for the origin and destinations

Sl. No.	LMC from origin to MRT station	LMC from destination to MRT station
1	Feeder bus- 5%	Feeder bus -5%
2	Rickshaw - 20%	Rickshaw- 15%
3	Two wheeler - 20%	Two wheeler 20%
4	Walking / Cycling - 55%	Walking / Cycling 60%

5. Integrated Urban Transportation for Efficient Urban Mobility

The most obvious intention of public transportation is to provide better quality mode of commuting. Whereas integrated urban mobility system aims at persuading commuters to use public transport over personal modes by providing LMC, demand mobility choices, wider accessibility, comfort and convenience to a larger extent.It is important to increase the competitiveness of public MRTS by integrating both the modes of commuting- private and public within the urban areas. The integration should aim at increased socio-economic benefits through the organizational process in which the various planning aspects across institutions, sectors, operators and modes of transportation are brought together (Refer Table 4).

Table 4. Types of transportation integration and theirobjectives

Sl. No.	Type	Objectives
1	Integration between transport measures and land use planning	To improve the quality of urban environment Efficiency in the use of resources Improving accessibility (spatially and socio-economically) Increasing the safety factor for all age groups and gender types.
2	Integration with other fields such as urban environemnt, public health, urban economics, etc.	
3	Integration between different transporation modes, provision of infrastructure, operation, management, ticketing information as well as service integration, etc.	

5.1. Measures for integrated Urban Transit Hub for Efficient Urban Mobility

The design of the most robust configuration of transportation solutions (qualitative and quantitative indicators) for integrated urban mobility can be supported by different approaches, methodologies and tools at different scales and levels.

Key elements in the process of developing integrated urban mobility:

- Development of framework for the proovision of viable MTS with emphasis on modal shift.
- Including aspects of policy reforms, economic objectives, planning structures and frameworks for citizen involvement.
- Development of performance measures.
- Application of performance measure.

5.2. Role of LMC in promoting experiential qualities of urban built environment

Living and working preferences have seen a major shift, as approximately 60% of urban populace are identifying active transport as a high priority. Efficiently planned and managed LMC often involves active transport and human powered transportation such as walking, cycling and variants such as cycle rickshaws, skateboards, push scooters, hand carts, etc. provide both transportation as well as recreation and are especially important for short trips that form the largest share of trips in urban areas while enhancing urban dwellers' quality of life.

Active transport allows in forming a place- based connection with the background, context and community of the neighborhood and city. Furthermore, engaging in active transport facilitates social interaction strengthening a sense of place and belongingness (Refer Figure 6).

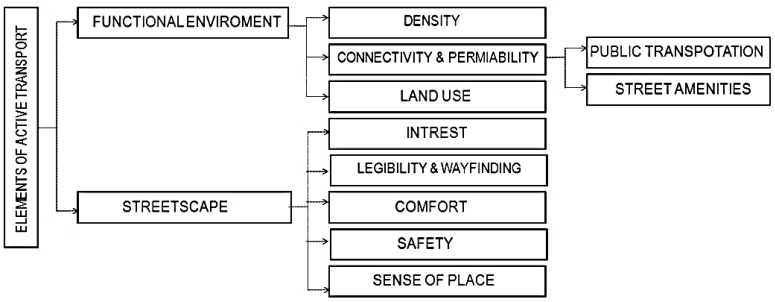

Figure 6. Conceptual framework - Correlated elements ofpublic transportation, built environment and active transportation

Increasing the modal share of active transport is possible in any urban area. However, the effectiveness depends on several urban area specific factors, including topography, climate, culture, political commitment, public awareness, governing policies, long term goals and attractiveness of the alternatives. One of the key parameters for active

transport is urban density: Most cities in developing countries have high-density and therefore highly suitable for active transport-oriented development and policies. Active transportation should be emphasized as a sustainable form of mobility in urban planning / urban design and in public health as an opportunity for increasing recommended levels of physical activity for better public health. In this context, a combination of urban planning, urban design, land use patterns and multi-modal MRTS that promotes active transport would promote active, healthier and more livable communities providing balanced urban mobility.

5.3. Indicators for developing LMC integrated urban mobility

Various factors concerned with LMC can be well integrated to provide efficient urban mobility. The following table explains the various indicators concerned with LMC and the recommendations for evolving better mobility solutions (Refer Table 5).

Table 5. Indicators and recommendations for developing LMC integrated urban mobility

Indicator	**Recommendations**
Physical integration of diverse modes of trnsportation	The best way to gauge return on investment on any transport infrastructure is the number of people it moves for every unit of investment of public money. Hence the physically integrated MRTS is the most feasible option as it can move 831 people per hour per direction for every Rs. 1 billion invested which means nearly 38 times return on investments as compared to moving 22 people per hour per direction on a stand alone road infrastructure. MRTS should be integrated with suburban rail system supported with the feeder bus system along with the non-motorised transportation infrastucture and park-ride facilites which will result in the over 250 kilometers of efficient LMC. Dedicated bus lane - Dedicated bus lanes should be provided to encourage commuters to take public transport. This ensures that the bus gets priority on road despite the heavy traffic conditions helping commutters reach their destinations on time and thus avoid depending on private mode for LMC.
Urban mobility	Mobility solutions such as utilization of shared transportation infrastructure by different modes,transit nodes, park and ride, Park and go, bike / parking lots, web and mobile based commuter travel planning application, etc. should integrated in the MRTS.
Finacial and Institutional Integration	All the MRT projects should be multi-modal to include feeder buses and facilities for non-motorised transport. The cost of these facilities should be included in the DRPs of the MRT projects to resolve the funding issues. Seamless partnership and master contorl facility if multiple transport operators are involved.
Sevice- Ticket fare -Travel Information Integration	This inegration enables passengers to plan their commute in the most efficient and economical ways for an uninterrupted commutting.
Charging congested stretches	Through the interface of intelligent transport systems (For ex: ERP System - Electronic Road Pricing System), charges should be levied to help moderate and spread out vehicluar traffic for the optimal usage of the road network while suggesting alternative routes.

Continued on next page

Table 5 continued

Vehicle Quota System	This system helps in determining the number of vehicles on road as urban dwellers have to apply for a permit to own a vehicle. This permit should be heavily priced and the permission period should be short term. This measure helps in controlling the number of private vehicles on road inturn reducing the congestion. MRTS should be integrated with suburban rail system supported with the feeder bus system along with the non-motorised transportation infrastucture and park-ride facilites which will result in the over 250 kilometers of efficient LMC.
Mode shares, disaggregated by gender	Specific allocations in the state and city transport budget for women's safety in public transport. Percentage of walking/cycling, MRTS, intermediate public transport, two & four wheeler trips by women.

6. Conclusion

Majority of commuters can be persuaded to use mass rapid transit commuters if para-transit and non-motorized modes for first and last mile connectivity are easily accessible. Therefore, efficiently planned and implemented first -last mile connectivity through all the possible modes has a major influence on the usage, promotion and accessibility of the mass rapid transit systems. Better planned, designed and organized LMC could yield tangible and intangible positive benefits and could be steadily realized during the continued operations of the MRTS. Inventive concepts such as collaboration between transit operators, funding agencies, planning authorities, public sector units, local businesses, citizen involvement along with the interface of technical advancements are vital for evolving well coordinated and comprehensive first and last mile connectivity to promote integrated and sustained urban mobility.

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