RESEARCH ARTICLE

Enhancing Bengaluru's public transport network: approaches and challenges

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Abstract: In recent decades, Bengaluru as a metropolis has witnessed explosive growth – both in terms of population, which has doubled since 2001, and growth in vehicles, which have more than quadrupled in the same period (RTO 2016). This has significantly stressed the city's road infrastructure, leading to congestion and increases in pollution. Economic losses due to congestion for two of the city's Information Technology corridors alone are estimated at INR227.7 billion annually (Bharadwaj 2015), without taking into account the health costs of increased emissions due to a surge in the number of vehicles plying in the city. 'Conventional' solutions addressing congestion within the city — such as road widening, creating one ways and building grade separators such as flyovers and underpasses — have failed to address the issue, and at the current rate of increasing vehicular volumes, the city's roads are forecast to be completely saturated by 2025.

This paper's premise is that public transport serves as the sole sustainable solution to Bengaluru's chronic congestion; only a large mode-shift towards public transport by 2025 can help reduce congestion on the city's roads. The paper advocates the Avoid-Shift-Improve strategy to achieve this, focusing on transport-specific improvements required to incentivise commuters to shift to public transport and identifies institutional and financial changes in the way of enhancing public transport in the city. The paper also forewarns against neglecting the city's conventional bus system in favour of other, capital-intensive modes of mass-transit, forecasting that buses will continue to meet over 75% of the city's public transport demand even after the completion of Phase I and II of the city's metro *and* the introduction of a functional commuter rail system.

Keywords: congestion, public transport, city development

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1. Introduction

India is urbanising rapidly. While 68.84% of India's population still lives in villages, the 2001–2011 decade marked the first occasion when India added a higher population to its cities than its villages[1]. With Indian cities as engines of growth and primary contributors to the country's GDP (60% currently; expected to reach 75%–80% by 2030[2]), economic migration to urban agglomerations will only increase. India is projected to add approximately 404 million citizens to its urban population by 2050 — the largest increase in the world[3]. Recent increases in population have also been accompanied by increases in incomes across India's middle and aspiring middle class[4]. Among other aspects, this increased income has been funnelled into the purchase of two and four-wheeler vehicles, the numbers of which have nearly quadrupled① since 2001 at a Compounded Annual Growth Rate of 10%[5].

City infrastructure — especially road infrastructure — has struggled to keep up with this increase in utilisation, leading to endemic traffic congestion across

① From 54.99 million to 2001 to 182.45 million in 2013 (MORTH 2013).

India's cities and poor road safety records. Vehicular growth has led to worrying increase in emission levels, which are estimated to cause close to 40,000 premature deaths in the country annually[6]. 'Conventional' solutions to alleviate road congestion — widening roads and building grade separators such as flyovers and underpasses — have failed to relieve gridlock. The current challenge, thus, calls for a far stronger and more inclusive approach to improve mobility in Indian cities.

This paper focuses on the city of Bengaluru, the fastest-growing metropolis in India[7], as a case study discussing the current transport scenario in the city. It then highlights how only a significant mode-shift to public transport can avert the city's road network from saturation within the next decade, while also focusing on institutional and financial challenges in the way of improving the city's public transport network. Our research advocates multiple approaches to enhance public transport in the city on a mode-wise basis over the span of the next decade, a holistic foundation upon which further improvements can be made.

1.1 Bengaluru – Brief Overview

Bengaluru, the capital of the state of Karnataka, is India's fifth most populated metropolis[8]. Founded in 1537, the city's strategic location and mild weather attracted the British who established a cantonment within the city in 1809, providing a fillip to trade and growth. The city's economic growth accelerated significantly after India's independence in 1947, with the establishment of numerous public heavy industries and educational institutions in the city[9]. More recently, Bengaluru has become a hub for Information Technology (IT) and biotechnology, attracting professionals from across the country. In this context, it is not especially surprising that Bengaluru's urban population growth rate of 46.68, between the 2001 and 2011 Censuses, was the highest for any district in the country[10].

Unfortunately, Bengaluru's spatial growth — to the tune of 264 square feet a minute between 2006 and 2012[11] — has been largely unplanned, and population and vehicular increases have severely overburdened the city's infrastructure. With a quadrupling of the number of registered vehicles plying in the city from 2001[12] to March 2016[13], most arterial roads in the city experience volumes of traffic in excess of double the installed capacity for smoother flow[14]. As per estimations by the Consortium of Traffic Engineers and Safety Trainers, average traffic speeds acoss 12 major arterial roads in the city have dropped from 35 km/h in 2005 to just 9.2 km/h in 2014[15]. The city was ranked sixth in IBM's Commuter Pain Index in 2011, a survey focusing on the emotional and economic toll of commuting[16]. The average citizen in Bengaluru spends more than 240 hours per annum stuck in traffic[17]. Significant increases in travel time to established industrial clusters have resulted in corporates such as Hewlett Packard altering their work timings. Others, such as Capgemini, have even decided to exit Bengaluru. It is estimated that the loss due to traffic snarls in Whitefield and Outer Ring Road is INR227 billion per annum[18].

Traffic congestion, thus, is an issue that needs to be tackled urgently in Bengaluru. The succeeding paragraphs focus on the existing transport scenario in Bengaluru, followed by transit scenarios for the future and their ramifications for the city.

2. Existing Transport Scenario in Bengaluru

Unlike other large Indian cities such as Delhi, Mumbai, Kolkata, and Chennai, Bengaluru does not currently possess substantial rail-based capacity for intracity passenger-trips, and thus still relies overwhelmingly on its road network for city transit. Multiple studies have attempted to understand modal split — the distribution of overall passenger-trips in a city by different modes of transport — patterns in Bengaluru. Three of the most recent analyses are listed in Table 1.

Table 1. Modal split in Bengaluru

Study	Private Transport		Non-Motorised Transport		Public Transport/Intermediate Public Transport	
	Two-Wheeler	Car	Walk	Cycle	Public Transport	IPT
Wilbur Smith Associates – Government of India (2008)①	17%	8%	26%	7%	35%	7%
Bangalore Mobility Indicators (2011)[19]	25%	6%	32%	3%	27%	7%
WRI India Household Survey (2013)②	28%	2%	30%	1%	35%	4%

① https://casi.sas.upenn.edu/sites/casi.sas.upenn.edu/files/iit/GOI%202008%20Traffic%20Study.pdf.
② Unpublished data; study done by WRI authors Srikanth Shastry and Sahana Goswami.

Figure 1 highlights the current composition of vehicles in Bengaluru. As is evident, two-wheelers form the bulk of vehicles on Bengaluru's roads at 69%, with private cars the second highest demographic. Buses form a miniscule proportion of total vehicles at less than 1%.

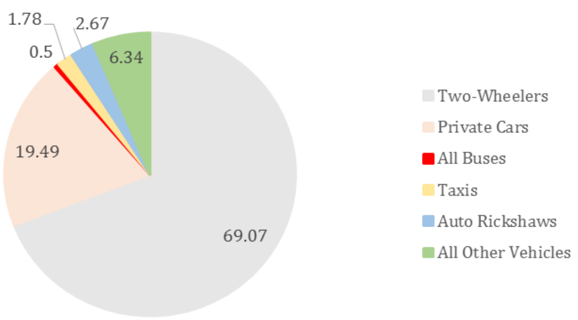

Figure 1. Vehicular composition percentage in Bengaluru①, March 2016.

As seen in Table 1, while different surveys differ on the exact composition of modal split in Bengaluru, private vehicles are, in general, assumed to comprise approximately 30% of the total modal share in Bengaluru. Non-motorized transport accounts for approximately a third of total trips in the city, with public and intermediate public transport making up the remainder.

Given the composition of vehicles in the city, it is not surprising that the majority of trips completed using private vehicles are by two-wheelers. While the share of public transport in overall passenger-trips in Bengaluru is hardly abysmal, it is notable that comparisons with earlier studies suggest that the mode-share of public transport in Bengaluru's passenger-trips has stagnated — an unhealthy sign when considering the city's increasing emissions and congestion. The city's mode-share of public transport also compares unfavourably to India's other metros such as Delhi having 43%, Mumbai with 45% and Kolkata with 54%[20]. In this context, it is instructive to briefly examine the existing public transport setup in Bengaluru.

2.1 Bus Services

As Bengaluru depends on its road network for transit, its bus system plays a critical role in public transport. Public bus services in the city are operated by the Bangalore Metropolitan Transport Corporation (BMTC). BMTC is the sole provider of bus-based public transport services in the city, and its operations extend to urban, peri-urban and rural areas within the Bengaluru Metropolitan Region. With an effective fleet of 6,218 buses serving a metropolitan area of 5,130 square kilometres[19], the Corporation caters to 5.02 million passenger-trips on a daily basis[21], making it one of the largest city bus operator in the country. The Corporation, along with several private fleet operators, also provides chartered services to major industrial and technology parks as employee shuttles. While not 'public' transport in the strictest sense, these services serve to reduce the volume of vehicles entering and exiting significant white-collar business clusters during peak hours.

BMTC is among the most innovative city bus operators in the country and has proactively utilised funds under the erstwhile JnNURM scheme to augment its fleet, while also enhancing services by inducting over 700 A/C buses into its fleet. It was the first city bus corporation in India to introduce an Intelligent Transport System (ITS), allowing passengers real-time information on upcoming bus arrivals, apart from providing the control room immediate information about bus operations. In another first in the Indian context, BMTC is scheduled to roll out a smart-card to enable cashless transactions on its services. The Corporation has, however, been criticised for low and erratic frequencies on many bus routes and for charging relatively high fares vis-à-vis other city bus operators in the country.

2.2 Metro Services

In 2007, Bengaluru began construction of a metro rail system operated by the Bengaluru Metro Rail Corporation Limited (BMRCL)②. Phase I of this metro — a north-south 'green' line and an east-west 'purple' line intersecting at Majestic, one of the city's transport hubs — spans a total of 42.3 km. Initially scheduled to be completed in 2011, the project has been plagued by delays; as of May 2016, the east-west line and the northern portion of the north-south line — 27 kilometres in total[22] — are operational, with a daily ridership of approximately 140,000[23]. Phase I is now ex-

① Data from http://rto.kar.nic.in > Vehicle Statistics > Bengaluru Metropolitan City as on March 2016. Accessed 10 May 2016. All figures in percentages.

② The Bangalore Metro project is being implemented by a Special Purpose Vehicle (SPV) called Bangalore Metro Rail Corporation Limited (BMRCL) which is jointly owned by the Government of India and the Government of Karnataka.

pected to be completed by the beginning of 2017 and the cost has escalated from INR81.5 billion to INR 138.5 billion[23].

Phase II of the metro — including extensions to the two existing lines, apart from two new metro lines — spans a total of 72 kilometres at an estimated cost of INR264 billion[24]. While this is scheduled for completion in 2019, the fact that this phase is still at the stage of land acquisition suggests that operations are likely to commence well past 2020. Figure 2 highlights the service coverage of Phase I and II of the metro (indicated in red and orange, respectively) as well as BMTC's routes (indicated in blue).

2.3 Rail Services

Unlike most metropolitan cities in India, Bengaluru lacks significant suburban rail services. While the existing railway network links the city's Majestic transit hub with multiple surrounding townships — not to mention several IT and industrial clusters on the city's

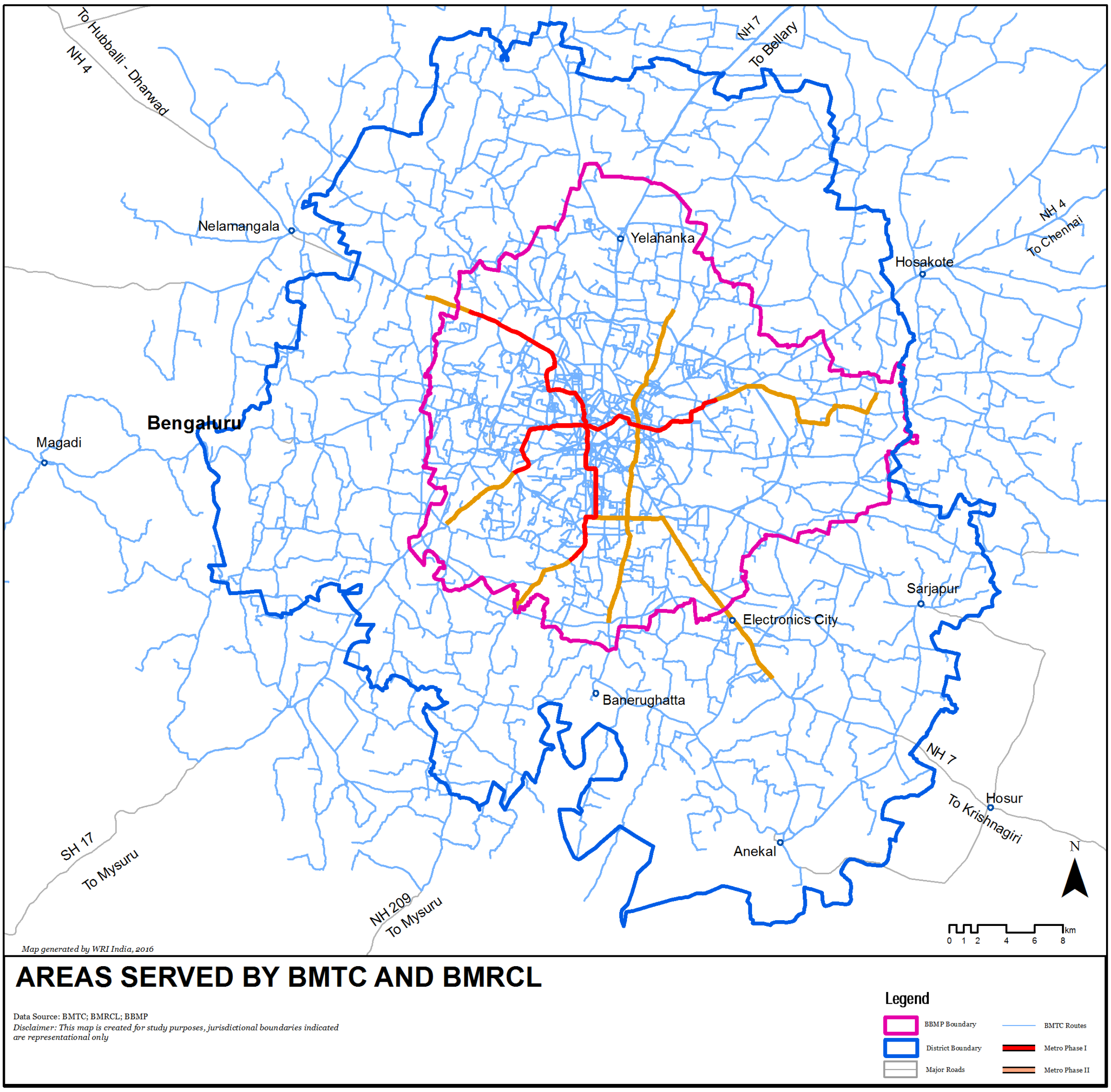

Figure 2. BMRCL and BMTC service coverage①.

① Map created by the WRI team (Raj Bhagat and Abhishek Sobbana) using data collected from BMTC and BMRCL.

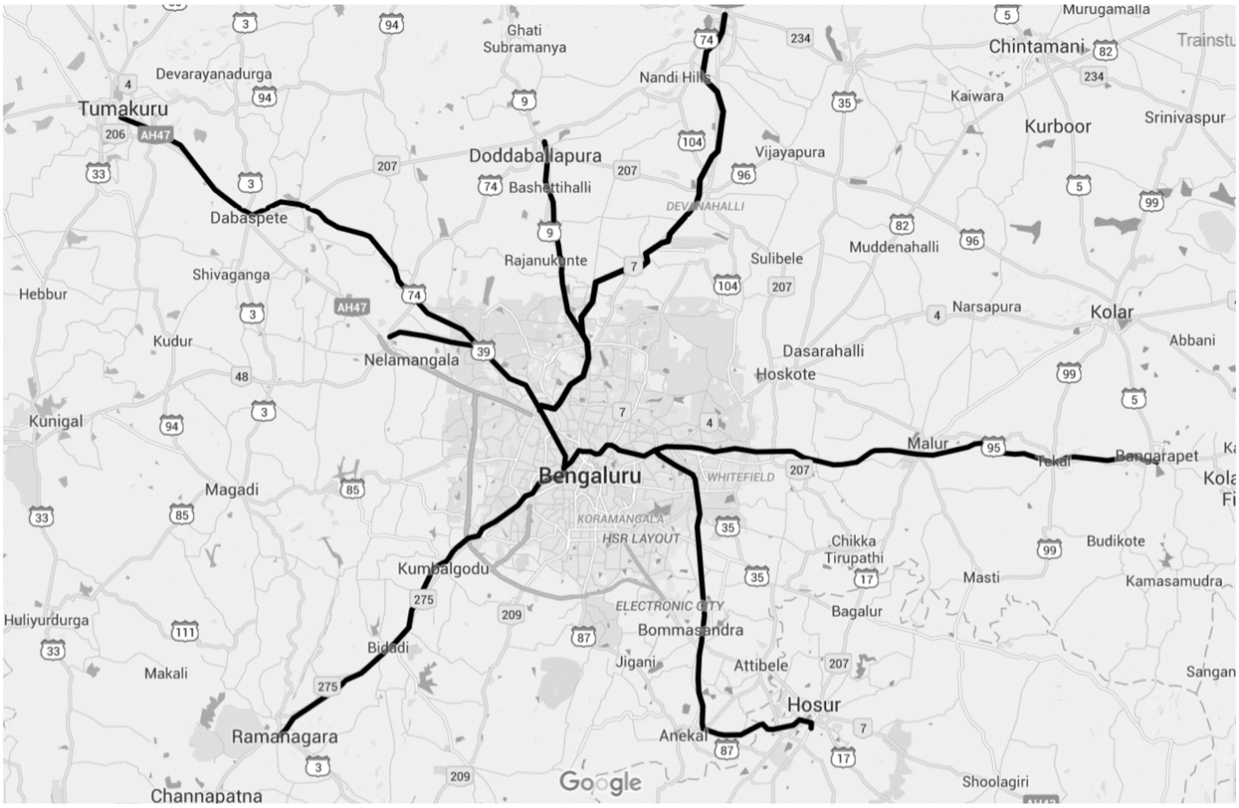

Figure 3. Proposed commuter rail network in Bengaluru, Phases I and II.

periphery① — rail services for short-distance commuters are infrequent. As such, the idea of a Commuter Rail System for Bengaluru — using the existing rail network to provide frequent suburban and peri-urban rail services for the city — has gained traction over the last five years[25]. However, progress on developing the network for a Commuter Rail (Figure 3) has been negligible since the proposal was mooted.

2.4 Intermediate Public Transport

Bengaluru also boasts of a robust Intermediate Public Transport (IPT) system. This consists primarily of auto-rickshaws and call taxi services. Auto-rickshaws account for the majority of IPT services in Bengaluru. As of March 2016, there were over 160,000 registered auto-rickshaws in Bengaluru[13]. Although they are a vital component of the transport system in Bengaluru, quality of service is generally low due to factors such as poor safety, haggling for fares, and high rates of refusals to ply.

Call taxis operated by companies such as Meru and Mega serve the higher-end of the IPT market. More recently, the aggregator-based taxi model has begun to represent a significant and growing share of transport services in Bengaluru. Aggregators such as Ola and Uber, by virtue of relatively low fares, easy availability, and the convenience of a door-step pickup have managed to gain an estimated 0.5%② of total motorised passenger-trips in 2016, primarily passengers previously using auto-rickshaws and regular taxis. In addition to auto-rickshaws and call-taxis, minivan-based IPT services operate in the peri-urban areas of the Bengaluru Metropolitan Region.

3. Transport Scenarios

The evaluation of future transport scenarios for Ben-

① Major IT and Industrial Clusters with Convenient Railheads:

Area	Closest Railway Station(s)
Whitefield (IT cluster)	Whitefield, Hoodi
Electronic City (IT cluster)	Heelalige
Chandapura and Attibele (Industrial cluster)	Heelalige
Anekal and Jigani (Industrial clusters)	Anekal Road
Kempegowda International Airport	Doddajala
Kumbalgodu (Industrial cluster)	Hejjala

② Assuming 40,000 of the city's 65,000 registered taxis are with aggregators, each completing a set of ten trips on a daily basis. The estimated daily motorised passenger demand for 2016 is 8.82 million trips.

galuru requires an estimation of the city's daily travel demand. Table 2 projects Bengaluru's travel demand – within the boundaries of the city's municipal corporation, the Bruhat Bengaluru Mahanagara Palike (BBMP) — for 2025; this projection is derived from the baseline year of 2011.

Table 2. Projected travel demand for Bengaluru in 2025

Year	Population	Per Capita Trip Rate (Daily)	Total Daily Passenger Trips	Daily Passenger Trips (Motorised)①
2011	8.03 million	1.31[19]	10.52	7.36
2025	11.07 million②	1.40③	15.50	10.85

While the majority of city trips fall within BBMP limits (800 square kilometres), it is also pertinent to note the growth of population in the Bengaluru Metropolitan Area outside BBMP limits, encompassing eight major industrial clusters④ and townships that generate significant economic and employment travel demand to Bengaluru city.

With the population of the Bengaluru Metropolitan Area outside BBMP limits projected to touch 4.64 million by 2025, even assuming a conservative Per Capita Trip Rate of 1 in this area and that only 50% of trips originating from these areas involve travel into the BBMP limits, the projected daily tally of motorised passenger trips in Bengaluru for 2025 increases to 13.17 million. Our estimate is marginally higher than modelling based on the Comprehensive Traffic and Transportation Plan (CTTP) of 2011, which assumes a daily demand of 12.72 million motorised passenger-trips for 2025.

Modelling based on the CTTP also indicate that a Business as Usual (BAU) approach to transport in Bengaluru will lead to total saturation of the city's roads by 2025, given the endemic congestion already prevailing on Bengaluru's roads. As the existing Right of Way (RoW) along the majority of the city's roads is insufficient for significant road widening, apart from the fact that roadway capacity expansion rarely serves as a long-term solution to traffic congestion, these estimates recommend that at least 75%–79% of total motorised passenger-trips should be made by public transport and IPT in 2025 to ensure a sustainable flow of traffic on the city's roads. This requires a significant augmentation of public transport capacity; however, solely augmenting capacity in itself is no guarantee of increased ridership, especially in the absence of service quality improvements that incentivise mode-shifts towards public transport.

4. Approach

Given the current mode-share of public transport in overall passenger-trips in Bengaluru, it is evident that only a proactive approach can enable a scenario where close to 80% of passenger-trips in the city are by public or Intermediate Public Transport in 2025. Our approach consists of three components which are articulated very briefly below:

Sustainable capacity augmentation: Proactive rather than reactive expansion of public transport capacity at a higher rate than anticipated increases in transport demand. This requires a careful evaluation of costs, capacity, transit speeds and the gestation period of different modes of transit capacity augmentation across the city. At present, BMTC buses and the Purple Line of the metro run to its capacity during peak hours, incentivising users to switch to private modes of transport.

Improving operational efficiency: The reliability of public transport is a major component of commuter decisions to switch to, and continue using, mass transit. While frequency increases provided by fleet augmentation are a means to improving transport reliability, increased operational efficiency through rationalised routing systems, better maintenance, and safety policies help further improve transport reliability through increased efficiency.

Improving service quality: Service quality also plays an important role in incentivising public transport utilisation. Above all, public transport must afford a convenient and pleasant commute — convenience in terms of a fast, seamless journey and pleasance in terms of fleet comfort and interaction with staff. This requires a high level of integration across transit modes.

The following section focuses on two macro-level challenges to enhancing public transport facilities in Bengaluru. This is succeeded by an application of our approach to existing and upcoming mass-transit mo-

① Assuming 70% of overall passenger-trips to be motorised, in line with prevailing estimates.
② Projections based on the Revised Structure Plan for Bengaluru 2031, p. 93.
③ Per capita trip rates are observed to increase with increases in city populations. The figure of 1.4 is in line with estimates from WSA (2008) and CSTEP (2011) for a city of 11 million residents.
④ These clusters include notable townships and industrial clusters such as (a) Ramanagaram and Channapatna (b) Harohalli, (c) Nelamanagala, (d) Thyamagondlu, (e) Dodballapur, (f) Devanahalli, (g) Hosakote and (h) Hebbagodi and Bommasandra.

des in the city, apart from the network as a whole.

5. Challenges

Two major challenges exist to improving public transport as a whole in Bengaluru: lopsided financial investments in public transport and the currently fragmented institutional setup that hinders co-operation and progress across transit agencies within the city.

5.1 Lopsided Financial Investments in Public Transport

As mentioned earlier in this paper, the bulk of public transport demand in Bengaluru is currently met by its expansive bus system operated by the BMTC. Even with newer modes of mass transit — such as the metro — under progress, BMTC is likely to remain the central mode of public transport in the city. As of 2016, BMTC catered to 5.02 million passenger-trips on a daily basis[21], close to double that of the city metro's projected ridership even for 2031. Endemic delays in constructing and opening new metro lines have also resulted in ridership on the metro falling significantly short of projections made in its Detailed Project Report, as seen in Table 3.

Table 3. Metro rail projections and actual ridership

Year	Population①	DPR Projections – Daily Metro Ridership②	Actual Daily Ridership
2011	8.03 million	1.02 million	0.04 million
2016	8.99 million	1.48 million	0.14 million③
2021	10.06 million (projected)	2.20 million	–
2031	12.60 million (projected)	2.80 million	–

However, in comparison to the upcoming metro project and roadway reengineering works, BMTC receives minimal financial support from the state government. Unlike most city bus operators in the country, it receives no operating subsidy from the government, barring payments towards its heavily-subsidised student passes and a few other categories of discounted passes. BMTC has received a total of INR5.6 billion since 2007 as assistance from agencies of the state government towards fleet enhancement[26]. However, the state has invested INR85 billion in roadway construction and improvement work over the last two years alone[27,28] and will invest INR264 billion in Phase II of the Bengaluru Metro[24].

BMTC will not lose relevance even after newer mass-transit modes start operating in the city. There is substantial evidence to show that, both internationally and in India, city bus operators cater to a larger number of passenger-trips even in the presence of an extensive metro rail network. Transport modelling from Delhi, for example, estimates that 64% of public transport trips are made by bus even with a 256 kilometre metro network in place[29]. In the context of Bengaluru, BMTC is the only mass-transit mode that can change routes in real time based on passenger demand and serve as a critical last-mile service linking metro, BRT, and rail stations with surrounding residential and commercial areas. Even in a scenario with multiple other modes of mass transit operating, BMTC's service coverage remains unmatched, as Table 4 indicates. In addition, as most upcoming mass-transit projects entail long gestation periods and are unlikely to be fully operationalised within the next five years, Bengaluru's bus system has an especially significant role to play in the interim period — as the only method of rapidly expanding public transport capacity during this period if the government supports it.

Table 4. Transit modes and service coverage

Transit Mode	Service Coverage
Bus (BMTC)	5,130 square kilometres (1,321 road kilometres utilised)[19]
Metro (BMRCL)	114 kilometres (Phase I + Phase II)
Commuter Rail (IR)	161 kilometres (as initially proposed)[25]
BRT	280 kilometres (proposed)[17]

As any enhancement of the city's public transport network depends significantly on BMTC, the lack of meaningful investment in the mainstay of the city's public transport system poses a challenge to overall systemic improvements.

5.2 The Institutional Framework for Public Transport in Bengaluru

Bengaluru's institutional framework for public transport is highly fragmented — different government

① Population figures are from the Revised Structure Plan for Bengaluru 2031 (page 93), and are only for areas of Bengaluru within the boundaries of the Bruhat Bengaluru Mahanagara Palike (BBMP). These totals will thus be lower than population estimates for the Bengaluru Urban Agglomeration as a whole.
② Data from the report 'Need for Government Support for Public Bus Transport' by CSTEP, p. 18.
③ Daily ridership since the opening of the underground section of the east-west metro corridor on 30 April 2016. (Times of India 2016)

agencies manage individual aspects of urban transport and seldom co-ordinate among themselves. All urban transport and planning agencies① in Bengaluru report to the Urban Development Department (UDD), which is the apex body responsible to approve funding for almost all transportation projects. However, there is little transparency about decisions pertaining to urban transportation projects and their status of funding[30].

The lack of a Unified Metropolitan Transport Authority hampers transport enhancement in multiple ways. In the current setup, different transport agencies often work at cross-purposes and do not frequently apprise each other of major developments under their aegis. There are two major ramifications to this: first, the development of a common mobility ticket or card is usually hindered in the absence of an overseeing authority. This is because agencies are unable to resolve disputes around payment settlement mechanisms or 'telescopic' fares, where an integrated fare is charged for a multimodal journey. Second, as there is no overseeing authority to plan for upcoming transit changes, other transport agencies take time to service any disruption or modification in existing transport services (such as the opening of a new metro line requiring feeder bus services), resulting in reactive rather than proactive transport planning within the city.

To simplify the institutional framework and establish a comprehensive decision-making process, the government of Karnataka created two Unified Metropolitan Transport Authorities② in 2007. The Directorate of Urban Land Transport (DULT) oversees different land transport authorities in Karnataka, while the Bangalore Metropolitan Land Transport Authority (BMLTA) is responsible for Bengaluru. Though these institutions were designed to direct and co-ordinate between different land transport agencies, they lack the necessary legal backing and independent control of funds to mobilise projects. As such, transit agencies are not mandated to coordinate with the Unified Metropolitan Transport Authority. This is unfortunate, as a strong Unified Metropolitan Transport Authority is a prerequisite for the smooth implementation of a truly seamless, multimodal public transport in a city. The current convoluted institutional framework is a major challenge in the way of enhancing public transport in the city as each operator functions independently and there is no integration in the approach.

The most successful example of functioning of a Unified Metropolitan Transport Authority is Transport for London (TfL), which co-ordinates between multiple transit agencies operating different modes of transit③. Besides London, a number of other cities have begun the transition towards achieving multimodal integration, among which Paris, Singapore, Hong Kong, and New York have also been able to integrate public transport with intermediate public transport. This would not be possible in the absence of a Unified Metropolitan Transport Authority[31].

The following sections of this paper discuss transit-specific approaches to enhance public transport in Bengaluru over the next decade by building capacity as well as augmenting service quality.

6. Transit-Specific Approaches

As mentioned earlier in this paper, our approach to enhancing public transport in Bengaluru consists of three major components: sustainable capacity augmentation, improving operational efficiency, and improving service quality. These aspects are discussed in the forthcoming sections.

6.1 Sustainable Capacity Augmentation

Different areas of a city require different public transit interventions. While choosing a mode of mass transit, it is important to understand its effectiveness in resolving transport issues in the context of the amount of time required to make it operational, its long term implications on the city's changing fabric, and economic feasibility in implementation.

Given Bengaluru's population and projected growth

① Some major agencies are:

Agency	Responsibility
Bruhat Bengaluru Mahanagara Palike (BBMP)	Upkeep, maintenance and development of local roads
Bangalore Development Authority (BDA)	Planning and execution of city-based development projects
Bengaluru Metropolitan Transport Corporation (BMTC)	Operation of bus services within the Bengaluru Metropolitan Area
Bengaluru Metro Rail Corporation Limited (BMRCL)	Operation and planning of the metro rail project in Bengaluru
Bangalore Metropolitan Regional Development Authority (BMRDA)	Planning and execution of development projects in the 8000 sq km Greater Bengaluru region
Indian Railways (IR)	Railway operations

② Unified Metropolitan Transport Authorities were a requirement for cities to receive funds under the erstwhile JnNURM scheme.

③ Surface Transport (buses, cycle, taxis and private hire, river services, streets); Rail and Underground (Tube, TfL rail, trams, Emirates Air Line, Dockyard Light Rail, Overground); Crossrail (a joint venture between Transport for London and the Department of Transport to build a new railway line).

in motorised passenger-trips over the following decade to 13.17 million motorised daily passenger-trips, the city, quite evidently, merits a wide range of mass-transit modes for seamless, speedy, and economical public transit. This paper focuses on city buses, BRT, and metro rail, and also briefly touches upon the proposed Commuter Rail System for the city. Given the need to create capacity to cater to 79% of total motorised passenger-trips in the city by 2025, we discuss a Business as Usual (BAU) scenario and an ideal, though not infeasible, scenario.

The Business as Usual scenario looks at BMTC fleet expansion over the previous five years as well as the present speed of construction of the Metro Rail. BMTC's effective fleet augmentation since 2011 is depicted in Figure 4, with an increase of just 369 buses in five years despite assistance from the JnNURM scheme.

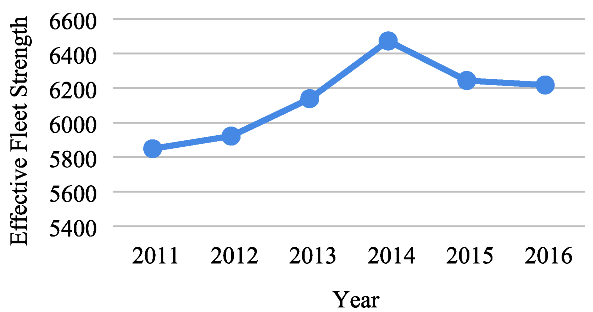

Figure 4. BMTC effective fleet augmentation 2011–2016.

Assuming a similar rate of fleet expansion and taking into account an effective augmentation of 1,000 buses across 2016–2017[32]. BMTC's fleet size is expected to expand by 1,500 buses by 2025, increasing total bus capacity to 8.3 million①. At the present rate of construction of the Bengaluru Metro, the metro network will touch 75 kilometres in 2025, with an estimated daily capacity of 1.5 million. With no current push for Bus Rapid Corridors or a Commuter Rail System, public transport capacity will be at the total of 9.8 million — marginally insufficient to cater to the expected demand even at full capacity. More importantly, however, the current piecemeal development of public transport in the city hardly incentivises significant mode-shifts towards public transport, and public transport utilisation is unlikely to increase beyond present levels. Ridership figures from Delhi indicate a daily ridership of around 0.8 million for a metro network of 75 kilometres in length, and assuming BMTC's existing load factor of 74.5%② to continue for its augmented fleet, overall bus ridership will increase to approximately 6.2 million, summing up to just 7 million in daily overall public transport ridership.

In terms of capacity augmentation, a desirable scenario would see the existing bus network considerably increasing capacity, the completion of Phase II of the Metro, the operationalisation of feasible Bus Rapid Transit Corridors, and the initiation of a Commuter Rail System in a manner that avoids disturbing the schedules of long-distance trains.

The introduction of rail-based mass-transit systems in the form of an expanded metro network and a functioning Commuter Rail System are good examples of sustainable capacity augmentation. It is, however, important to remember that while investing in capital-intensive rail-based modes of mass transit is inevitable and necessary at the present stage, the city bus system — the mainstay of public transport in Bengaluru — should not remain neglected.

6.1.1 City Bus Capacity

Previous sections in this paper have focused on BMTC's service coverage and the centrality of buses to public transportation in large cities to make the case for increased investment in augmenting city bus services. Added to these points is the fact that significant latent commuter demand exists in the city, demand that the Corporation has been unable to tap due to a lack of buses. BMTC's fleet is dwarfed by the number of company buses operating in the city, many of which transport regular passengers illegally after dropping their employees[33]. In addition to this, over 44,000 maxi-cabs and vans are registered in the city[13], several acting as a parallel public transport system on routes and times underserved by BMTC. The existence of a flourishing, unregulated, and unsafe quasi-public transport system in the city clearly indicates deficiencies in the supply of 'legal' public transport across multiple locations in the city. Inadequate bus frequencies on many routes — especially during peak hours when buses run late due to traffic — add to commuter dissatisfaction, hardly incentivising continued use of bus transport.

There is thus a strong case for BMTC to expand its fleet — to provide safer, more reliable public transport to a large segment of the city's commuting populace

① The calculation is based on assumption of: Number of buses * 8 trips per bus * load factor (number of seats and standees)

② Data from "State-wise Physical Performance of State Road Transport Undertakings 2015 – Part IV" published by the Ministry of Road Transport and Highways, accessible at http://bit.ly/29vgjAG (Requires a login and password) as well as to decongest the roads. The Corporation has forecast a need for the city's bus fleet to touch 8,500 by 2018①. In an ideal scenario, BMTC's fleet should reach at least 10,000 buses by 2020, thus creating an effective capacity of 10.82 million passenger-trips on a daily basis. Unfortunately, the Corporation's plans of fleet augmentation over the past few years have been hampered by delays and non-delivery of buses from the suppliers. BMTC, however, can augment its fleet more rapidly by tapping underutilised private buses in the city through a gross-cost contractual model, wherein private operators supply and operate buses on routes defined by BMTC, with BMTC collecting fares and providing compensation on a per-kilometre basis to the operators in question.

6.1.2 Bus Rapid Transit Capacity

While augmenting the city's bus fleet is urgently required to enhance Bengaluru's public transport, indefinite augmentation of conventional bus fleets is likely to yield declining returns beyond a certain level. The largest② disincentive to switching to conventional buses for users of private vehicles is speed; buses — which move slower than general traffic as they need more room to manoeuvre the city's roads and stop frequently — do not provide a time-efficient solution to commuting within the city. In this context, the CTTP recommended close to 280 kilometres of Bus Rapid Transit (BRT) Corridors for the city; high-frequency services utilising segregated bus ways on high-demand, high-quality roads; bus ways backed with quality stations that enable level boarding; and prepayment of fares. The advantage of BRTs over conventional buses are numerous; they enable average bus speeds to increase to over 30 kmph, and well-branded BRTs with comfortable bus stations offering real-time information on arrivals have proven far more successful in persuading non-bus users to shift to mass transit than conventional bus systems. They are also significantly less capital-intensive than constructing a metro and can be constructed in far shorter lengths of time.

Of the 12 corridors identified by the CTTP for BRT implementation, the pilot is expected to be trialled on the 31.7 km stretch from Silk Board to Hebbal, creating capacity of 0.5 million passenger-trips on a daily basis by conservative estimate[34].

① Unpublished; based on communication by the chief traffic manager to Aloke Mukherjee.

② Survey responses from the Detailed Project Report on the proposed BRT corridor from Silk Board to Hebbal prepared by EMBARQ India.

6.1.3 Commuter Rail Capacity

The initial feasibility study on the Commuter Rail System recommended four corridors of such a system; with a distance of 161 kilometres, these corridors are not touching Bengaluru's centrally-located City Station. This was later expanded to a 440-kilometre network criss-crossing the city centre. Given the high levels of rail congestion surrounding City Station, large-scale requirements are needed to re-engineer City Station to handle increased local services, not to mention operational changes required on the eastbound line from City Station to enhance rail capacity in the extended scenario. Considering this in the context of low levels of enthusiasm from both the railways as well as the State Government, it is unlikely that a 440-kilometre Commuter Rail Network is likely to materialise by 2025. As such, the initial 161-kilometre network has been envisaged in our 2025 scenario. As per calculations by RITES — running trainsets of 15 coaches each at a peak frequency of 10 minutes — the total capacity created by a Commuter Rail Network of 161 kilometres is 0.8 million passenger-trips on a daily basis[25].

While the total capacity of public transport (including the metro) will total 14.6 million — higher than the capacity necessary for 2025 — under this scenario, ridership trends are estimated in Table 5.

6.2 Improving Operational Efficiency

Capacity augmentation, though critical in enhancing public transport in a city, needs to be accompanied by improvements in the operational efficiency of public transport to further improve reliability, especially during peak hours. In the context of Bengaluru, the existing bus network provides plenty of scope for increased operational efficiency over two aspects visible to commuters: routing and operational safety.

Table 5. Break-up of estimated ideal ridership by 2025

Mode of Transport	Estimated Ridership
79% of total daily motorised pas senger-trips	At least 10.4 million
IPT	1 million③
Metro	1 million④
Bus + BRT	8.2 million⑤
Commuter Rail System	0.6 million⑥

③ Assuming a marginal increase from the baseline scenario.

④ Based on Delhi Metro ridership for a similar metro length.

⑤ Assuming an effective increase of BMTC's fleet to 10,000 buses and operationalization of BRT corridors at a load factor of 70%.

⑥ Assuming an average daily load factor of 70%.

6.2.1 Routing

BMTC's method of routing buses, while suitable for the city when the Corporation first came into existence, is currently outdated for a city as large as Bengaluru. The Corporation follows a destination-based routing system, where the aim is to connect the city's major hubs (in this case, Kempegowda Bus Station, K.R. Market, and Shivajinagar Bus Station) with most major — and many minor — localities through direct services, apart from attempting to connect major localities in the city with each other, again through direct buses.

While this system of routing works well in small cities with a few major localities, as a city grows — with new important localities forming — the number of direct routes required to service this growth increases exponentially. In Bengaluru's case, this becomes evident when comparing the number of routes in the city (over 2,300) with cities of comparable size and bus fleet strength: London (approximately 700)①, Shanghai (approximately 1,000)②, and Seoul (approximately 360)③. This results in multiple problems. First, numerous bus routes are closely duplicated by other routes for a majority of the journey, requiring commuters to remember several different route numbers for the same commute. This results in an overcomplicated, intimidating system especially for new users. Second, this renders providing passenger information and designing route maps a highly complicated task due to the multiplicity of routes. Third, the high route-to-bus ratio results in several less-popular routes being served by a single bus, resulting in low bus frequencies on many routes.

Based on an analysis of the existing system and its deficiencies, our research recommends that BMTC move towards a direction-based routing model instead. Rather than aiming to connect each major locality to each other through a direct and often infrequent route, a direction-based model envisages a 'connective grid' of high-frequency buses running throughout the city. In Bengaluru, this has taken the form of the Bengaluru Intra-city Grid (BIG) Bus Network with five different categories of routes④. While the number of transits a user makes during an average trip might increase, the higher frequency of buses results in a faster trip on the whole. Besides the 'Trunk', the feeders also need to be strengthened such that the transfer is smooth and the buses do not loose patronage. As bus routes are shorter on average under a direction-based system, it is possible to increase bus frequencies without significant fleet augmentation. BMTC is currently rolling out the new system in phases; when completed, it is expected to make the bus network in Bengaluru vastly more efficient.

6.2.2 Safety and BMTC

While a mode-shift to public transport is likely to improve road safety by reducing the number of vehicles on Bengaluru's roads, BMTC buses can also be made safer. Buses belonging to the Corporation were involved in 306 fatal accidents from 2012 to 2015, resulting in 327 fatalities, approximately 10.9% of the total fatal accidents and fatalities in the city⑤. 17% of the fatalities were passengers (boarding, alighting, and while commuting), almost all of which occurred in non A/C buses. These fatalities were primarily due to passengers falling off while boarding and alighting a moving bus, attributable to driver negligence in not keeping the doors closed while the bus is in motion. Based on this analysis, WRI's research has recommended that an automatic door-closing system be fitted in all buses, preventing the bus from moving when the doors are open.

Over 75% buses involved in fatal accidents were fitted with small non-standard side-view mirrors replacing the original mirrors. The replacements were primarily due to high breakage rate of standard mirrors caused by inappropriate assembly and handling while cleaning and maintenance of the bus. WRI's blind-spot analysis ascertained that drivers were unable to see anything at a height of 1.3 to 3.5 m from the bus front, resulting in frequent collisions with two-wheelers attempting to overtake the bus. Based on this analysis, our recommendation is to replace non-standard small mirrors with Automotive Industry Standard (AIS) mirrors. Emphasis on safe and defensive driving training was also recommended for all BMTC drivers based on the assessment of the present training module.

6.3 Improving Service Quality

While capacity is a prerequisite for ridership for any

① London: http://data.london.gov.uk/dataset/tfl-bus-stop-locations-and-routes.

② https://www.travelchinaguide.com/cityguides/shanghai/transportation/ town-bus.htm.

③ http://citynet-ap.org/wp-content/uploads/2014/06/Seoul-Public-Transportation-English.pdf.

④ These include 'Trunk' routes on arterial roads, 'City' routes replicating traditional city routes, 'Feeder' routes linking trunk routes with adjoining areas, 'Connect' routes enabling transit between adjacent arterial roads without entering the city centre, and 'Circle' routes operating on the Outer Ring Road.

⑤ Unpublished; BMTC accident data was procured from BMTC by Roshan Toshniwal; City data available at http://www.bangaloretrafficpolice.gov.in/index.php?option=com_content&view=article&id=55&btp=55.

mode of mass-transit, service quality is crucial to attract a larger range of users to the system than just those without access to private transport. In this context, Bengaluru's transport system requires multi-modal integration — both physical and fare integration — to enable seamless commuting and improved last-mile connectivity options. Focusing on buses, BMTC's commitment to provide real-time bus running information and scrap ageing buses is commendable; however, its fare policy requires a relook.

6.3.1 Multimodal Integration

Current progress to integrate BMTC and the Bengaluru Metro — either through physical or fare integration — has not been promising. In June 2016, it was not possible to perform a multi-modal journey on a single ticket, and a common metro-bus pass introduced earlier was abruptly withdrawn[35]. If a single mobility card for the city cannot be introduced, BMRCL and BMTC should honour each other's smartcards once the latter rolls out its cashless ticketing system. Telescopic ticketing① across modes will incentivise commuters to use the most efficient multimodal route to their destinations, optimising ridership across modes.

To ensure the highest levels of utilisation of the metro and proposed Commuter Rail System, it is necessary to ensure sufficient integration of the metro with other modes of transit. This is especially important in the context of last-mile connectivity methods such as feeder buses and Intermediate Public Transport. Feeder routes from metro and rail stations should be designed carefully through a demand assessment study through the collection of mobility data, a review of existing bus routes around the two metro termini, and an evaluation of environmental factors② around these two metro stations. While BMTC had earlier introduced 'Metro Feeder' buses, routes introduced were not based on an analysis of last-mile demand from metro stations, with these routes closely replicating existing bus routes. Rather unsurprisingly, these routes failed to gain ridership.

6.3.2 Bus Fares

BMTC's fares are among the most expensive of any bus operator in the country, as Figure 5 comparing five major city bus operators illustrates:

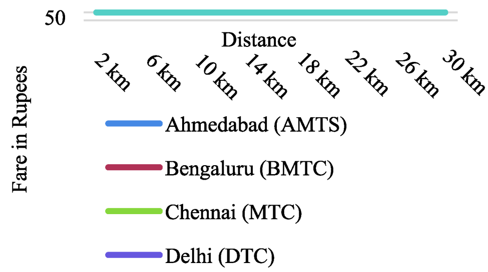

Figure 5. Bus fare comparisons.

Apart from irrational fare jumps, the current fare structure is problematic in that it avoids round fares for the most part, resulting in frequent change hassles for commuters. Among complaints received by the BMTC, those about conductors not returning change rank among the most frequent, often souring interaction between commuters and the bus system. Equally problematic is the current fare structure that heavily penalises passengers changing buses during a trip — multi-bus journeys can cost up to 65% more than a single-bus journey of equivalent length.

At the outset, BMTC should look at fixing fares in multiples of five rupees to reduce change hassles among commuters, apart from reducing — if not abolishing — transfer penalties with the introduction of their cashless smartcard system. Unfortunately, in the absence of significant financial support from the government, it is unlikely that BMTC will be able to reduce their fares meaningfully in the near future to make them attractive to owners of two-wheelers. This is compounded by relatively high rates of taxation on State Transport Undertakings (STUs) in Karnataka. Data from the Ministry of Road Transport and Highways, 2014, reveals that of 45 STUs surveyed, taxes form a higher proportion of BMTC's cost than 25 other STUs③. As the state government does not provide operating subsidies to BMTC, it can consider reducing the rates of motor vehicle taxes paid by the undertaking, allowing it to pass on these benefits to commuters, making public transport fares more competitive to using a two-wheeler.

7. Conclusion

Bengaluru, currently the fastest-growing metropolis in India, is at a decisive point in its history. With most road infrastructure heavily overloaded, city planners

① This allows passengers to travel across modes of transit on a single, integrated fare.

② These include congestion levels, roadway characteristics, road layouts and capacity to plan optimal feeder routes from these stations.

③ Data from 'State-wise Financial Performance of State Road Transport Undertakings 2015' published by the Ministry of Road Transport and Highways, accessible at http://bit.ly/29kfnAs (Requires a login and password).

can opt for conventional solutions in wider roads and elevated corridors, further incentivising people to use private transport. Alternatively, they can decide to use road capacity more efficiently by encouraging multiple forms of mass transit — a critically necessary approach in the case of Bengaluru. In the context of mass transit in India, the current trend in India is to prioritise capital-intensive rail-based system such as metros. Our research, however, indicates that Bengaluru will remain heavily dependent on bus transit even after the introduction of rail-based mass transit, with 80% of public transit trips still by bus.

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No conflict of interest is reported by the authors.

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