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TRANSPORTATION RESEARCH AND INJURY PREVENTION CENTRE

A FRAMEWORK FOR SELECTING AN APPROPRIATE

URBAN PUBLIC TRANSPORT SYSTEM

IN INDIAN CITIES

Geetam Tiwari
Deepty Jain

Prepared by:

Geetam Tiwari
Professor
E-mail: geetamt@gmail.com

Deepty Jain
Assistant Professor,
E-mail: djain@tripp.iitd.ac.in

Research Support: Pratik Jha, Ph.D Scholar, TRIP Center, IIT Delhi

Transportation Research and Injury Prevention Centre
Indian Institute of Technology, Delhi

For More Information Contact

E 2261, Palam Vihar, Gurugram 122017 Haryana, Delhi NCR, India

Tel: +91 9717702286

Email: info@theinfravisionfoundation.org

Website: www.theinfravisionfoundation.org

Summary

The need for a good public transport (PT) has been accepted by most policymakers, experts, and citizens in India. While there is a consensus in justifying investment in an excellent public transport system, there seem to be divergent views on accepting different strategies to improve the quality of public transport systems. In the last two decades metro systems have been introduced in many Indian cities, however, creating public transport priority on roads for public buses -- exclusive right of way, junction designs to prioritise buses and bus stop locations to ease bus commuters' movement -- has been opposed in many cities because it leads to increased congestion in car lane. With growing incomes and increase in vehicle ownership public transport share continues to decrease in most cities despite making heavy investments in constructing and operating metro systems. All metro systems operating in Indian cities have 25-35% of the projected ridership. Since all benefits and revenue generation is dependent on the actual ridership, none of the systems have achieved the benefits estimated at the time of approval of the project. If a quality public transport system has to be provided to all citizens, an integrated public transport system is required which can serve the differentiated travel demand in different city size, land use patterns.

This document presents a framework to understand the differentiated travel demand in Indian cities and suitability of various public transport system options to meet the demand. Travel pattern data available from Census 2011 and other published reports and results of research papers have been used in this report to understand the travel patterns and suitability of various travel modes. Majority of the trips in any city are less than 10kms in length regardless of densities and incomes. While road based bus systems are suitable for trips shorter than 5 kms, high performance systems like metro are attractive for long trips-longer than 10 kms. For mega cities(> 8 million population) a well-integrated system- 300-400km of metro and 1000 km of bus system provides an attractive public transport option for most citizens. Smaller cities (1million population), bus system running on all arterial and sub arterial roads with few sections of exclusive lane can meet the travel demand. Intermediate public transport vehicles (three wheelers, e rickshas) are suitable for very small cities and also provide very good feeder system to bus and metro system in larger cities. It is important to understand the complementarity of different public transport system and provide an integrated system at all levels -policy, planning, design and operations. The financial feasibility of various public transport options has not been discussed in the report, because public transport should be viewed as an essential service for the citizens and suitable options of financing the options that can serve the mobility needs of all citizens. Decision makers may select a mix of public transport systems requiring optimal financial support.

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Abbreviations

BRT Bus Rapid Transit

HA Hectare

INR Indian National Rupee (₹)

IPT Intermediate Public Transport

LRT Light Rail Transit

MRT Mass Rapid Transit

MTW Motorised Two-Wheeler

NCP National Commission on Population

PT Public Transport

ROW Right of Way

SDG Sustainable Development Goal

UN United Nations

1. INTRODUCTION

1.1 Background

The need for good public transport (PT) has been accepted by most policymakers, experts, and citizens in India. Often this is justified to help reduce vehicular pollution, congestion, and traffic accidents in cities. In recent years, the availability of quality PT systems has become important owing to the United Nations Sustainable Development Goals (UN SDG) adopted by most countries.

The United Nations (UN) Sustainable Development Goal (SDG) Number 11 aims to promote inclusiveness and sustainable urbanisation, such that cities can act as productive and accessible places for attracting talent, encouraging innovation, and creating economic growth. There are ten specific targets and 15 indicators (UNDP, 2020) for achieving SDG Goal 11. SDG Target 11.2 specifically mentions urban transport. According to this target, "By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons". To measure the progress towards achieving SDG Target 11.2, cities are to measure the proportion of the population within 500 m (walking time = 5 min) of a PT system. Localising SDG Target 11.2 involves city governments ensuring a PT system with at least two important dimensions of accessibility: physical and economic. This translates to ensuring barrier-free physical access to the PT system, as well as affordable fares for using the PT system.

India is expected to double its urban population over the next two decades. At present, nearly 30% of the urban population in India lives in small cities (populations less than 5 lakhs) (Ministry of Housing and Urban Affairs (MoHUA), 2019). Given the expected urbanisation rates in India and the envisaged future share of urban dwellers in the total population, SDG 11 and the question of sustainable urbanisation are of the utmost importance for Indian cities.

While there is a consensus in justifying investment in an excellent public transport system, there seem to be divergent views on accepting different strategies to improve the quality of public transport systems. For instance, investment in metro rail systems is justified and widely accepted. However, creating public transport priority on roads -- exclusive right of way, junction designs to prioritise buses and bus stop locations to ease bus commuters' movement -- has been opposed in many cities because it leads to increased congestion in car lane. All metro systems operating in Indian cities have 25-35% of the projected ridership. Since all benefits and revenue generation is dependent on the actual ridership, none of the systems have achieved the estimated benefits at the time of approval of the project. Up gradation of bus systems have generally been linked to bus technology and promotion of electric buses. Very little effort has gone into performance improvement of buses. The public transport ridership continues to reduce in most cities and use of motorised two wheelers and cars continue to increase. A large proportion of the population continue to depend on walking and bicycling on roads which have high traffic risk and conflicts with motorised traffic because they cannot afford to use another mode of travel. The city, state and national governments have to have a considered policy and strategy to ensure access to quality public transport system to all citizens.

2. COMMUTER PREFERENCE

The current travel patterns, i.e., choice of travel modes and distances travelled, reflect commuters' preference as well as the impact of availability and quality of various travel mode options. Specifically, travel distance is influenced by current vehicle ownership, availability of the public transport (PT)system, financial ability of the commuters and land use patterns. Census 2011 gives the distribution of work trips by distance and modes at the district level (urban and rural). This provides a good source to understand the variation in modal share and trip distances in cities by the population size, population density, per capita income and the spatial distribution of various activities in the city.

The rising income levels and the increasing affordability of motorised personal vehicles have resulted in the increasing use of motorised two-wheelers (MTW) and cars for daily mobility needs. MTW ownership has been increasing much faster than car ownership in both urban and rural areas. Personal vehicles hold an advantage over mass transit systems as they offer users a convenient door-to-door service. In addition, the availability and convenience of a certain mode of travel is also decided by the design of the infrastructure. The current road designs in Indian cities are extremely hostile to pedestrians and bicyclists. All PT systems have access and egress trips largely as walk trips. Poor quality of pedestrian infrastructure affects the use of the PT system.

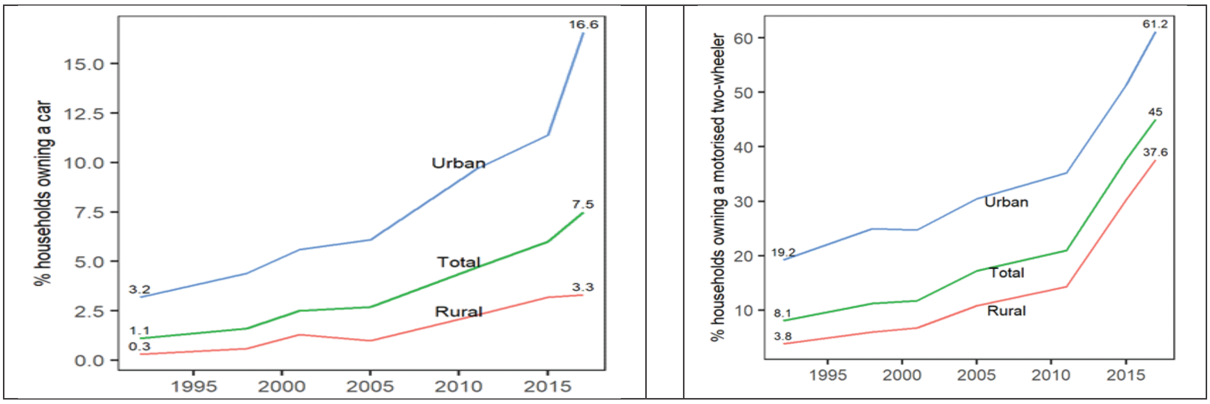

Figure 1: Car and Motorised two wheeler ownership in India

(Source: National Family Health Surveys (NFHS) for 1993, 1998, 2005, and 2015 (IIPS, 2021), those reported by Census in 2001 and 2011 (Chandramouli, 2012) and Longitudinal Ageing Study of India (LASI) for 2017 (IIPS et al., 2020)

The most important aspect of commuter preference for choice of mode is convenience and reliability. The convenience, adaptability and flexibility offered by personal vehicles especially motorised two wheelers results in a large proportion of commuters choosing MTW for daily commute. As these vehicles are under the control of the user, they can be made to take any route and as many detours as possible. In direct contrast, the buses or the metros have a fixed route, and if the destination of the user does not fall along this route, then he/she has to make transfers, which might be complicated and time consuming. Thus, the trip from work to home, although comprised of several trips, remains a single trip in the mind of the user of a private vehicle. In other words, the number of transfers involved while using a private vehicle is zero. This is especially important as the total number of transfers needed to reach a destination influences the choice of public transport mode and route. The flexibility of personal vehicles makes it a preferred mode of transport compared to buses and metros.

An efficient PT system must compete with the convenience and comfort offered by a personal vehicle. The choice of the public transport system and its operations needs to be identified based in the context of travel demand pattern as well as the inherent characteristics (capacity, reliability, network connectivity, operating cost, capital cost) of the PT system.

The selection of the appropriate PT system depends on understanding the commuter's preferences, city land use patterns, and expected changes in factors that affect commuter's preferences as well as the performance characteristics of different PT systems.

3. PUBLIC TRANSPORT SYSTEM TYPOLOGIES

Various types of mass rapid transit (MRT) or public transport system can be proposed for a city. This can range from the formal and closed form of systems like metro rail transit, light rail transit (LRT), suburban rail, and bus rapid transit (BRT) to small-size buses and shared auto rickshaws operated informally by private operators. In this section, we discuss the characteristics of the various types of public transport systems that can be deployed in cities. In addition to the conventionally identified public transit systems, we also include the definition of paratransit or intermediate public transport (IPT) system, as these systems also serve a significant proportion of the travel demand in Indian cities.

PT systems can be classified based on the right of way (ROW-shared, partially shared or exclusive) and ownership (private or public or hybrid). The design, operations, and performance of the system is influenced by these factors.

Road-based bus systems and intermediate PT systems have shared right of way where buses or three wheeled autorickshaws move in mixed traffic conditions. The performance of the system is affected by the presence of other traffic.

Bus systems can be assigned exclusive lanes along the complete route of partial route length. This is an at-grade system that mixes with other traffic at junctions, and also, buses may travel in mixed traffic conditions partially. Bus system performance improves while moving in exclusive lanes in terms of reliability and speed. Since the same bus moves on lower category roads in shared ROW, most commuters are not required to change routes and benefit from short access distance to bus stops and fewer transfers. Many tram systems and trolley bus systems also run at-grade, mostly in the median lane partially sharing the right of way with other traffic.

Fully exclusive right of way is designed for high-speed systems like metro, LRT, or regional rail. Due to exclusive ROW, the system has a high level of reliability. However, the network coverage is limited as compared to at-grade systems resulting in longer access distance. Therefore, these systems are suitable for trips generally longer than 10 km. Bus systems can be assigned exclusive right of way as in closed Bus Rapid Transit systems. The system performance improves however the dependence on feeder system increases and access distance increases for the commuters like metro systems.

The operational speed of any PT system is dependent on the length of the shared/exclusive ROW and spacing of stops. PT systems like metro, LRT and closed BRT station spacing is 1-1.5 km. Therefore the operational speed is about 30-35Km/h. Underground or elevated stations require much larger investment as compared to PT stops at grade. Therefore spacing is at least 1 km. At grade stops can be at a shorter spacing (500m-700m). This ensures shorter access distance to commuters however operational speed reduces to 20-25Km/h. For short commuting distance

(2-6 kms), door to door journey time is shorter in at grade systems as compared to exclusive underground or elevated systems. These details are explained in Annexure 1.

The rail-based systems have government ownership, whereas bus-based systems can range from complete government ownership to systems partially regulated by the government and fully managed by private operators. All these systems can be classified as formal systems governed by state or central legislation. These systems are defined as:

1. Metro rail transit, or metros, refers to that mode of transport that utilises fully segregated and grade-separated tracks, which may be elevated or subterranean, passing through the core sections of a city. They employ cutting-edge control technologies that enable high-frequency operations. These are the most expensive system among all types of mass rapid transit; however, they can deliver high levels of service in terms of speed and frequency.
2. Light rail transit (LRT), as the name suggests, are light trains equivalent to current tram cars in size. This system uses a fully segregated and typically grade-separated right of way with complex control systems. Short segments can run at grade. The cost of the system largely depends upon whether it is underground, elevated or at grade. In terms of cost of travel and capacity, they are considered as an intermediate between bus and metro systems.
3. Suburban rail is usually part of a larger rail network and is frequently at grade (with a mix of bridges and level crossings), thus, segregated from road traffic. These systems operate within the context of broader network needs and are distinguished by large headways and longer station spacings (as compared with both metros and LRT).
4. Tram vehicles run on fixed rails at grade in shared right of way. Vehicles are usually lighter and shorter than main line and rapid transit trains. Today, most trams use electrical power, usually fed by a pantograph sliding on an overhead line; older systems may use a trolley pole or a bow collector.
5. Trolley Bus is an electric bus that draws its electricity from overhead wires, which are generally suspended from roadside posts, using spring loaded trolley poles. The trolleybus is also known as **trolley coach** or **trackless trolley** or **trackless tram**. The trolleybus is a **pneumatic tyre vehicle**.
6. Bus rapid transit (BRT) runs on designated right of way, which might be busways (physical separation of the track) or bus lanes (painted lines demarcate the right of way). BRTs are characterised by well-designed bus stops, structured operations, an efficient ticketing system, and clearly defined corridors with a central hub for bus parking. These systems typically deliver a high-quality service at a reasonable cost. BRT system can be designed as a closed system where no other bus shares the ROW created for BRT buses to open system where buses run on mixed traffic in part of the route and move in exclusive corridor in the remaining route. Exclusive corridors in congested sections provide advantage to commuters.
7. Bus system runs on the existing carriageway with minimal priority. A network of bus routes can be created where different size buses can run to meet the varying commuter demand at different times. Generally, bus lanes are marked on the left lane and bus stops are located on the left along the pedestrian path. Bus stop locations are important to ensure better accessibility and safe crossing facility to commuters. Depending on the demand and road right of way, size of bus can vary.
8. Paratransit or intermediate public transport (IPT) may be defined as the intermediate mode between privately owned automobiles and conventional transit with fixed routes and schedules. Run by private operators, generally under free market conditions, paratransit/IPT modes manoeuvre into areas bus cannot serve, provide frequent door-to-door service, and act as a feeder system to the metro or suburban rail system. Paratransit/IPT modes

are generally characterised by fleets of motorised three-wheeled (autorickshaws, electric rickshaws etc.) and four-wheelers (minibuses, shared vans, passenger taxis etc.) and offer a wide range of services in terms of seating capacity, speed, geographic coverage, levels of comfort, and route fare. A major advantage of these modes is that they take less time to load and unload, stop less frequently, run on shorter headways, and provide services at low price.

9. Areal Ropeway Transportation(ART) system is used in difficult terrains where construction of roads or rails is not possible like steep slopes, across valleys or rivers. ART is an aerial public Transportation technology in which cabins (also called carriers, vehicles or cars) are suspended and propelled from above by ropes. The underlying technology of ropeway has been around for almost a century, where it has been applied mostly in terrain challenged hills for pilgrim transportation and also, in recreational/ adventure sports contexts (e.g in ski resorts) to transport skiers and tourists from the bottom to the top of the mountains and vise-versa. In recent year ART has been adopted in urban regions as a mode of urban Transportation in geographically- constrained urban areas as well, where conventional Transportation service was deemed very difficult or infeasible to implement.

Summary of key performance indicators and definitions of important terms and performance measures are given in Table 1, and Table 2.

Table 1 Comparison of key system performance indicators for different systems

	Metro	**LRT**	**Tramways/ Electric Trolley Bus**	**HCBRT (Closed system)**	**BRT (Open System)**	**Bus Priority Lanes**	**City Bus**	**Shared Par-atransit / fixed routes**	**Par-atransit**
Physical features									
ROW	Exclusive	Exclusive	Partially shared	Exclusive	Partially Shared	Partially shared	Shared	Shared	Shared
Alignment	Elevated or Under-ground	Elevated	At grade	At grade/ elevated	At grade	At grade	At grade	At grade	At grade
Fuel	Electric	Electric	Electric	Diesel/ CNG/ Electric	Diesel/ CNG/ Electric	Diesel/ CNG/ Electric	Diesel/ CNG/ Electric	CNG/ Electric	CNG/ Electric
Operational Features									
Capacity	45-75K	10-30K	5-15K	20-45K	5-20K	5-10K	2-5K	NA	NA
Operational Speed(Km/h)	30	30	20-25	25	15-20	20	15-20	15-20	15-20
Reliability	Very High	Very High	High	High	High	Average	Average	Average	Average
Cost									
Capital cost/km	30	20	10	10	5	1.2	1		
Operational cost	10	10	5	2	1.2	1	1		
Response to Demand									
Trip suitability	>12 km	>12km	>6 km	>6 km	>6 km	>4 km	>4 km	>2 km	>2 km
Ease of expansion	Low	Low	Medium	Medium	High	High	High	High	High
Ease of Route adaptability	Low	Low	Medium	Medium	High	High	High	High	High
Network Accessibility	Low	Low	Medium	Medium	High	High	High	High	High

Table 2 Definitions key system performance indicators for public transport system

Definitions	
ROW	Right of way is the road space allocated or available for the movement of public transport vehicles. Rail based systems have exclusive ROW, except Trams which runs on rails in a shared ROW with other vehicles. Road based systems can have exclusive ROW or shared ROW depending on the site constraints.
Alignment	PT systems can have underground sections, elevated sections or at grade. Construction cost depends on the type of alignment selected. Systems which run on exclusive ROW are usually either underground or elevated.
Fuel	All rail based systems (MRT, LRT, Trams) run on electricity. Trolley bus also uses electric traction system. Electric buses and three wheelers have been introduced in many Indian cities that run on batteries. Other road based systems use either Diesel or CNG. Electrification of public transport systems is good for reducing local pollution, however, since a large proportion of electricity is produced by coal based thermal power stations, Co2 and GHG emissions increase.
Operational Features	
Capacity	PT system capacity depends on the number of transit unit (train or platoon of bus), number of cars or vehicles in each unit , number of passengers (standees and seating) in each car or vehicle and frequency of TU in an hour. A 6 car train, each car carrying 200 passengers running at 5 min frequency provides a capacity 14400 passengers/hour. A bus platoon of 6 busses carrying 100 persons each running at a 5 min frequency provides a capacity of 7200 passengers/hour. Capacity can be increased by changing the length, vehicle design to accommodate more standees and shorter frequency.
Operational Speed(Km/h)	Operational speed of PT system largely depends on the spacing between the two stops. Marginal difference is because of the possible acceleration. In urban operations, maximum speed has almost no impact on the operating speeds. Shorter station spacing reduces the access distance, however reduces the operational speed as well. Journey speed for commuters includes times taken for access and egress and in vehicle (operational speed.)
Reliability	Systems operating on exclusive ROW have higher reliability (arrival and departure as per the schedule on all stops) because there is no interference from any other traffic. Road based system can achieve high reliability if exclusive ROW can be ensured in the partial or full route.
Cost	
Capital cost	Capital cost of rail based system largely depends on the type of alignment-at grade, elevated or underground. Electric bus cost about INR100-200 lakhs, whereas a standard diesel bus costs about 20-40 lakhs.
Operational cost	Operation cost includes fuel and maintenance costs. Electric buses require less maintenance as compared to diesel or CNG operated bus. Rail based systems have higher operation costs than road based systems.
Response to Demand	
Trip suitability	Systems running on exclusive ROW are suitable for trips longer than 10-12 Km. Road based, at grade systems are better suited for short trips, and journey time is shorter in at grade systems as compared to systems running on elevated or underground sections.
Ease of expansion	Road based systems have higher ease of expansion because buses can run on roads with just 12-15m ROW without heavy capital expenditure. Rail system have to be constructed underground or elevated resulting in high capital costs..
Ease of Route adaptability	PT routes in Road based systems can be changed and adapted to change in demand easily. A new bus route can be introduced to meet the demand of a new locality. Rail based systems are fixed and new construction is required to create a new route.
Network Accessibility	At grade road based systems have high network accessibility.

Choice of an appropriate PT system depends on many indicators such as:

1. Passenger Indicators
    - Passenger speed or door-to-door travel time
    - Total walk distance for passengers in a one-way trip
    - Total delay to a unit passenger in a one-way trip
2. Operational Indicators
    - Expected system capacity
    - Expected Operational or commercial speed (km/h)
    - Average per station and junction delay to a unit bus in at grade system.
3. Social Indicators
    - Potential for shift from Private Transport – based on passenger travel time comparison between PT systems and private vehicles. Private vehicle users are likely to use PT when PT provides shorter journey time as compared to private vehicles. Journey time is complete door to door travel time.
    - Potential for retaining existing public transport demand by improving the performance of the current bus system.
    - Allowing universal access and barrier-free mobility primarily in terms of disabled-friendly infrastructure and fleet.

4. UNDERSTANDING CURRENT AND FUTURE TRAVEL DEMAND

4.1 Current Travel Patterns

In this section, we discuss the observed variation in travel patterns in urban districts (urban) with respect to three parameters population size, area of district (urban), and income.

1. Variation in trip length for work trips by population size
2. Variation in trip length for work trips by area
3. Variation in trip length for work trips by income distribution

4.1.1 Rationale for studying trip length distribution

The choice of public transport system depends on the travel distance. Fixed route PT systems with exclusive right of way (ROW), such as metro or commuter rail systems, are used for long trips. In contrast, road-based systems with shared ROW, such as bus systems, are used for shorter trips. PT systems with completely exclusive ROW (metro) have less network coverage as compared to shared ROW systems (bus). Therefore, a metro commuter spends significant time during access (from origin to metro station) and egress (metro station to destination). Due to this additional time, even though the average main-haul (in-vehicle) speed in a metro is above 30 km/h, the average door-to-door travel speed reduces for a short trip on a metro system as compared to a road-based system. Hence, metro systems have been found to be most favourable in terms of saving time only if the trips are 10 km or longer. Journey time by different modes is given in Annexure 1.

Propensity to use the PT system reduces as the access distance increases. If the proportion of trip time spent on the access and egress stages is considerable, public transport trips become less attractive. The time and distance discomfort associated with the access and egress stages makes unimodal trips more attractive. The catchment area of the PT system is thus not only a function of the absolute access and egress time but also of the relative share of total trip time. **Therefore, the trip length distribution of urban commuters is a good indicator of potential demand for different modes of transport, including mass PT systems.**

Vehicle ownership and household income are other important factors that influence the choice of travel mode. The average monthly income of metro rail users was INR ₹22,873 in Delhi (Bivina et al., 2019). Similar results were reported in 2021, where most of the respondents at metro stations had an average monthly income of more than 25,000 in Delhi (Jain and Singh, 2021). While the bus users surveyed in Delhi had an average income of less than INR ₹15,000 (Suman et al., 2017). The choice of the public transport system is therefore dependent on both the trip lengths and income.

The share of long-distance trips reduces with decreasing population and increases with decreasing population density (Tiwari and Nishant, 2018). This is also shown through the multinomial fractional logit model, where the share of trips longer than 5 km increases by 0.32% with a 10% increase in population (Jain and Tiwari, 2021). Therefore, city population size and density influence the trip distances and require a specific PT system. Wherein income levels in the city will determine the end users' affordability for a particular system.

We map the trip length frequency distribution with respect to the population size of the urban districts, density, and income. The trip length frequency distribution for work trips is based on the Census 2011 tables "B-28: 'Other workers' by distance from residence to place of work and mode of travel to the place of work". For considering income, a share of the population with a monthly income greater than INR ₹36000 per month is used. Data from Stats of India and Urban districts of India published by DataNet is used for urban urban districts to study the income distributions.

Trip length with respect to population size and density

Table 3 show the share of trips longer than 5 km, 10 km and 20 km in urban urban districts classified by population size and density. Table 4 shows an average of 11% and 7% of the work trips are longer than 10 km and 20 km, respectively. Even in the cities with a population greater than 80 lakhs and densities greater than 100 person per hectare, the average of the percentage of trips greater than 10 km are 17% only. This share reduces with decreasing population size but increases with decreasing population density. For example, on an average, 30% of the work trips are longer than 5 km in the urban districts with a population between 10 to 20 lakhs. Here, the average share of work trips longer than 5 km is 28% in the urban districts with a population density of 100 persons per hectare (HA) which increases to 31% in the urban districts with a population density of less than 20 persons per HA.

Given the optimal trip length for the use of different types of public transport systems as studied in literature following observations can be drawn –

1. The share of trips greater than 5 km varies between 20% and 39% and varies with both population size and density.
2. The share of trip lengths greater than 20 km does not vary by population size and density, with an average of 7% only.

Table 3. Percentage of trips greater than 5 km with respect to population size and density (Average)

Population size	< 20 per HA	20 to 50 per HA	50 to 100 per HA	> 100 HA	Overall
1 to 5 lakhs	22%	22%	21%	–	**21%**
5 to 10 lakhs	33%	27%	30%	18%	**27%**
10 to 20 lakhs	31%	30%	30%	28%	**30%**
20 to 40 lakhs	38%	38%	34%	–	**35%**
40 to 80 lakh	–	26%	39%	34%	**34%**
> 80 lakhs	–	–	–	37%	**37%**
Overall	**24%**	**23%**	**24%**	**30%**	**21%**

Table 4. Percentage of trips greater than 10 km by population size and population density (Average)

Population size	< 20 per HA	20 to 50 per HA	50 to 100 per HA	> 100 HA	Overall
1 to 5 lakhs	11%	11%	11%	–	**11%**
5 to 10 lakhs	15%	12%	16%	8%	**13%**
10 to 20 lakhs	13%	13%	12%	10%	**12%**
20 to 40 lakhs	18%	17%	15%	–	**16%**
40 to 80 lakhs	–	8%	18%	15%	**15%**
> 80 lakhs	–	–	–	17%	**17%**
Overall	**12%**	**11%**	**12%**	**13%**	**11%**

Table 5. Percentage of trips greater than 20 km by population size and population density (Average)

Population size	< 20 per HA	20 to 50 per HA	50 to 100 per HA	> 100 HA	Overall
1 to 5 lakhs	7%	7%	7%	–	**7%**
5 to 10 lakhs	8%	7%	10%	6%	**8%**
10 to 20 lakhs	6%	6%	6%	6%	**6%**
20 to 40 lakhs	8%	7%	8%	–	**7%**
40 to 80 lakhs	–	3%	8%	7%	**6%**
> 80 lakhs	–	–	–	7%	**7%**
Overall	**7%**	**7%**	**8%**	**6%**	**7%**

4.1.2. Trip length and income distribution

The choice of public transport system is also determined by the affordability of the end users. Table 5 shows greater variability in trip length frequencies when income distribution is also included. As per the estimated affordability of public transport, a household with a monthly income of INR ₹36,000 can afford only INR ₹80 per person per day in a household with 10% benchmark of affordable transport system. This cost will include fare for last mile connectivity and provided that no other member in the household incurs travel expenditures. If two people in the household are supposed to travel by public transport system or motorised mobility, then the maximum fare of INR ₹40 can be borne by each of them. Similarly, a household earning INR 12000 a month can afford only INR 26 per person day to meet the travel needs at 10% benchmark. Considering this, we use two income brackets to determine share of population that can afford different types of transport systems – 1) having monthly income greater than INR ₹36,000 and 2) having monthly income greater than INR 12,000.

Calculation for estimated affordability of fare by income	
Assumptions: Only one member of household makes a trip by motorized mobility	
Monthly income =	INR ₹36,000
Trips per capita per day =	2 trips
Work trips in a month = 2 trips in a day X 5 working days X 4.5 weeks =	45 trips
Benchmark for transport affordability =	10%
Estimated affordability per trip = (36000 X 0.1)/(45) = INR ₹80	

Calculation for estimated affordability of fare by income	
Assumptions: Only one member of household makes a trip by motorized mobility	
Monthly income =	INR ₹12,000
Trips per capita per day =	2 trips
Work trips in a month = 2 trips in a day X 5 working days X 4.5 weeks =	45 trips
Benchmark for transport affordability =	10%
Estimated affordability per trip = (12000 X 0.1)/(45) = INR ₹26	

Table 6 shows that very few urban districts have more than 10% of the population with monthly income greater than INR ₹36,000. Second, these urban districts have higher share of long-distance trips than the other urban districts where share of population with monthly income more than INR ₹36,000 is less than 10%.

Table 6. Number of urban districts in each category

Population size	Population density	*Income greater than ₹36000 per month*			
		< 5%	**5 to 10%**	**> 10%**	**Grand Total**
1 to 5 lakhs	< 20 per HA	42	4	1	47
	20 to 50 per HA	127	15	1	143
	50 to 100 per HA	51	3	1	55
5 to 10 lakhs	< 20 per HA	2		1	3
	20 to 50 per HA	23	2		25
	50 to 100 per HA	5			5
	> 100 HA	3			3
10 to 20 lakhs	< 20 per HA	4			4
	20 to 50 per HA	15			15
	50 to 100 per HA	11			11
	> 100 HA	1			1

20 to 40 lakhs	< 20 per HA		1		1
	20 to 50 per HA	2	1		3
	50 to 100 per HA	5	1		6
40 to 80 lakhs	20 to 50 per HA	1			1
	50 to 100 per HA		2		2
> 80 lakhs	> 100 HA	1	2	1	4

Approximately 14% of the total urban districts have more than 15% of the population having monthly household income more than INR 12000.

Table 7. Number of urban districts in each category with income > INR 12,000 per month

Population	*Density*	*Income greater than ₹12000 per month*				
		<5%	**5 to 10%**	**10 to 15%**	**15 to 20%**	**>20%**
1 to 5 lakh	< 20 per HA	14	23	9	1	
	20 to 50 per HA	40	68	13	8	15
	50 to 100 per HA	19	27	5		6
5 to 10 lakh	< 20 per HA		1	2		
	20 to 50 per HA	2	13	8		2
	50 to 100 per HA	1	2	1		1
	> 100 HA		3			
10 to 20 lakh	< 20 per HA		3	1		
	20 to 50 per HA	1	9	3	2	
	50 to 100 per HA		6	3		2
	> 100 HA					1
20 to 40 lakh	< 20 per HA				1	
	20 to 50 per HA		3			
	50 to 100 per HA		4	1	1	
40 to 80 lakh	20 to 50 per HA				1	
	50 to 100 per HA					2
> 80 lakh	> 100 HA					4

The income distribution data along with trip length frequencies can be used to estimate potential public transport trips. Considering an equal distribution of population by income through the district limits following observations can be drawn for affording public transport trip with a total fare of INR 40 per trip –

1. Only 10% - 18% of the population in certain urban districts can use a public transport system.
2. Considering the income distribution, 4% and 5% of the population living in urban districts with population 1 to 5 lakhs and 5 to 10 lakhs travels longer than 5 km and can afford public transport system.
3. Only, 2 – 3% of the population will travel longer than 10 km and afford public transport system in urban districts with population 1 to 5 lakhs and 5 to 10 lakhs.

Table 8. Percentage of trips greater than 5 km by population size, density, and income

Population size	Population density	*Percentage of population with income > ₹36,000 per month*		
		< 5%	**5 to 10%**	**> 10% and ≥ 18%**
1 to 5 lakhs	< 20 per HA	21%	26%	20%
	20 to 50 per HA	21%	24%	23%
	50 to 100 per HA	21%	20%	29%
5 to 10 lakhs	< 20 per HA	37%		38%
	20 to 50 per HA	27%	28%	
	50 to 100 per HA	29%		
	> 100 HA	18%		
10 to 20 lakhs	< 20 per HA	31%		
	20 to 50 per HA	30%		
	50 to 100 per HA	29%		
	> 100 HA	28%		
20 to 40 lakhs	< 20 per HA		38%	
	20 to 50 per HA	37%	38%	
	50 to 100 per HA	33%	38%	
40 to 80 lakhs	20 to 50 per HA	26%		
	50 to 100 per HA		39%	
> 80 lakhs	> 100 HA	29%	42%	37%

Table 9. Percentage of trips greater than 10km by population size, density, and income (Average)

Population size	Population density	*Percentage of population with income > ₹36,000 per month*		
		< 5%	**5 to 10%**	**> 10% and ≥ 18%**
1 to 5 lakhs	< 20 per HA	11%	13%	10%
	20 to 50 per HA	11%	12%	11%
	50 to 100 per HA	11%	12%	19%
5 to 10 lakhs	< 20 per HA	19%		17%
	20 to 50 per HA	12%	12%	
	50 to 100 per HA	16%		
	> 100 HA	8%		
10 to 20 lakhs	< 20 per HA	13%		
	20 to 50 per HA	13%		
	50 to 100 per HA	12%		
	> 100 HA	10%		
20 to 40 lakhs	< 20 per HA		18%	
	20 to 50 per HA	17%	17%	
	50 to 100 per HA	15%	16%	
40 to 80 lakhs	20 to 50 per HA	8%		
	50 to 100 per HA		18%	
> 80 lakhs	> 100 HA	10%	20%	18%

Table 10. Percentage of trips greater than 20km by population size, density, and income (Average)

Population size	Population density	*Percentage of population with income > ₹36,000 per month*		
		< 5%	**5 to 10%**	**> 10% and ≤ 18%**
1 to 5 lakhs	< 20 per HA	7%	8%	7%
	20 to 50 per HA	7%	8%	6%
	50 to 100 per HA	7%	9%	12%
5 to 10 lakhs	< 20 per HA	10%		10%
	20 to 50 per HA	7%	7%	
	50 to 100 per HA	11%		
	> 100 HA	6%		
10 to 20 lakhs	< 20 per HA	6%		
	20 to 50 per HA	6%		
	50 to 100 per HA	7%		
	> 100 HA	6%		
20 to 40 lakhs	< 20 per HA		8%	
	20 to 50 per HA	7%	6%	
	50 to 100 per HA	8%	7%	
40 to 80 lakhs	20 to 50 per HA	3%		
	50 to 100 per HA		8%	
> 80 lakhs	> 100 HA	4%	8%	7%

Table 7, 8 and 9 show the potential trips suitable for different PT systems with a total fare of INR 40 per trip.

Table 11, 12 and 13 shows the potential trip share suitable for PT system with a total fare of INR 13 per trip. As per the analysis following observations can be drawn with respect to the affordable public transport system.

1. 20 to 28% of the population in 33 of 332 urban districts can afford public transport system with a total fare of INR 13 per trip.
2. 6%, 10% and 8% of population in 1 to 5 lakhs, 5 to 10 lakhs and 10 to 20 lakhs size cities travel longer than 5 km and can afford public transport system with a total fare of INR 13 per trip.
3. Approximately, 4%, 6% and 3% of the population in 1 to 5 lakhs, 5 to 10 lakhs and 10 to 20 lakhs size cities travel longer than 10 km and can afford public transport system with a total fare of INR 13 per trip.

Table 11. Percentage of trips greater than 5 km by population size, density, and income > INR 12,000 per month

Population size	**Population Density**	*Income greater than ₹12000 per month*				
		<5%	**5 to 10%**	**10 to 15%**	**15 to 20%**	**>20%**
1 to 5 lakhs	< 20 per HA	18%	22%	25%	32%	
	20 to 50 per HA	19%	21%	28%	23%	27%
	50 to 100 per HA	20%	19%	26%		25%
5 to 10 lakhs	< 20 per HA		38%	37%		
	20 to 50 per HA	23%	27%	26%		33%
	50 to 100 per HA	21%	20%	36%		45%
	> 100 per HA		18%			
10 to 20 lakhs	< 20 per HA		33%	28%		
	20 to 50 per HA	27%	31%	27%	31%	
	50 to 100 per HA		25%	34%		33%
	> 100 per HA					28%
20 to 40 lakhs	< 20 per HA				38%	
	20 to 50 per HA		38%			
	50 to 100 per HA		32%	34%	38%	
40 to 80 lakhs	20 to 50 per HA				26%	
	50 to 100 per HA					39%
> 80 lakhs	> 100 per HA					37%

Table 12. Percentage of trips greater than 10km by population size, density, and income > INR 12,000 per month (Average)

Population	**Density**	*Income greater than ₹12000 per month*				
		<5%	5 to 10%	10 to 15%	15 to 20%	>20%
1 to 5 lakh	< 20 per HA	10%	11%	12%	17%	
	20 to 50 per HA	10%	11%	15%	12%	14%
	50 to 100 per HA	10%	10%	15%		14%
5 to 10 lakh	< 20 per HA		17%	19%		
	20 to 50 per HA	11%	12%	12%		16%
	50 to 100 per HA	10%	9%	20%		33%
	> 100 per HA		8%			
10 to 20 lakh	< 20 per HA		14%	13%		
	20 to 50 per HA	10%	13%	13%	13%	
	50 to 100 per HA		10%	14%		15%
	> 100 per HA					10%
20 to 40 lakh	< 20 per HA				18%	
	20 to 50 per HA		17%			
	50 to 100 per HA		15%	15%	16%	
40 to 80 lakh	20 to 50 per HA				8%	
	50 to 100 per HA					18%
> 80 lakh	> 100 per HA					17%

Table 13. Percentage of trips greater than 20km by population size, density, and income > INR 12,000 per month (Average)

Population size	**Population Density**	*Income greater than ₹12000 per month*				
		<5%	5 to 10%	10 to 15%	15 to 20%	>20%
1 to 5 lakh	< 20 per HA	7%	7%	8%	9%	
	20 to 50 per HA	7%	7%	9%	7%	9%
	50 to 100 per HA	6%	7%	10%		10%
5 to 10 lakh	< 20 per HA		10%	10%		
	20 to 50 per HA	7%	7%	7%	`	9%
	50 to 100 per HA	6%	7%	10%		25%
	> 100 per HA		6%			
10 to 20 lakh	< 20 per HA		6%	7%		
	20 to 50 per HA	5%	7%	7%	6%	
	50 to 100 per HA		6%	7%		9%
	> 100 per HA					6%
20 to 40 lakh	< 20 per HA				8%	
	20 to 50 per HA		7%			
	50 to 100 per HA		8%	7%	7%	
40 to 80 lakh	20 to 50 per HA				3%	
	50 to 100 per HA					8%
> 80 lakh	> 100 per HA					7%

Trips shorter than 5 km are most ideal for intermediate public transport systems, trips between 5 and 10 km are most suitable for road-based bus systems, trips 10-20 km are suitable for metro systems, and longer than 20 km are most suitable for regional rail system.

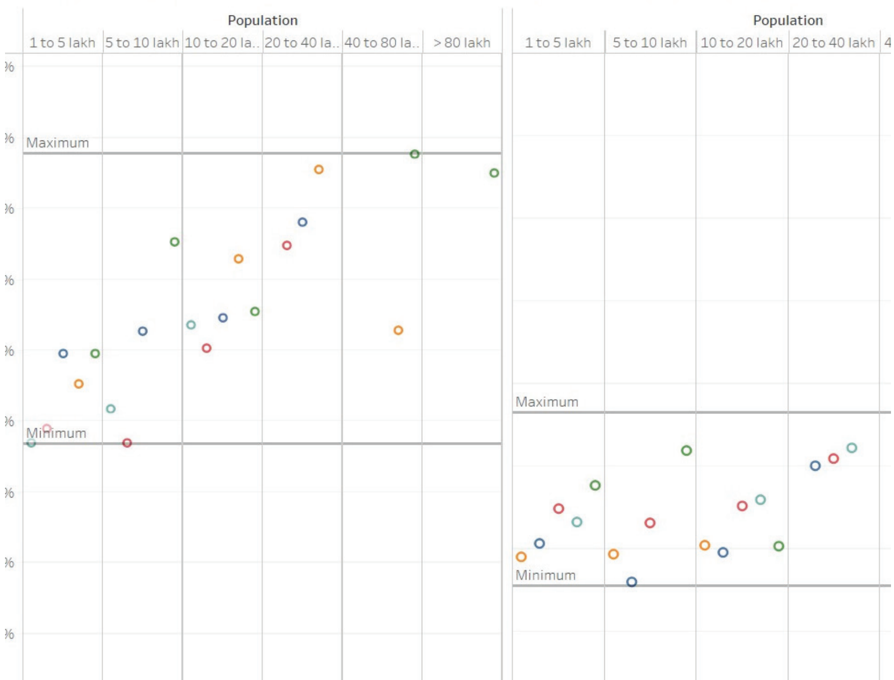

Figure 2. Percentage of trips > 5km and > 10 km with respect to population size and percentage of income > INR 12000 per month

5. Guidance for selecting an appropriate PT system:

Selection of PT system should be guided by the mobility vision stated in the comprehensive Mobility plan of a city. Vision statement is expected to include the commitments to UN SDGs especially SDG 11.2 which requires all citizens to have an access to a safe and reliable public transport system with in a walking distance of 500m. The heterogeneity in travel characteristics in different city size will require a combination of various PT systems to meet the diverse demand. Therefore the most important requirement is to have an integrated PT systems, varying by city size.

Response to following questions can guide the city decision makers and planners to and plan an appropriate mobility infrastructure:

1. How to reduce dependence on private motorised modes?
2. How to retain current public transport users as income and private vehicle ownership grows?
3. How to increase share of public transport users, pedestrians and bicyclists?
4. What proportion of population can be served by the selected PT system?
5. What level of subsidy will be required to run a quality PT services?

1. Motorised two wheeler ridership continues to rise in Indian cities. Comparatively low cost of owning and operating an MTW makes it very attractive for a large section of the city population. Car ownership has been increasing in large cities. To reduce dependence on private modes of transport combination of PT system will be required. Reliable and safe PT system within a maximum 500 m walking distance is likely to reduce dependence on private motorised modes. Door to door passenger travel time by PT system should be less than the time taken by a MTW for the same distance.
2. Most of the current public transport users are captive users. These users will shift to MTW or car as and when it becomes available and affordable. PT system will have to match the comfort and reliability offered by MTW. Marginal cost of using a MTW may be taken as a guidance for the public transport fare. Bus moving in mixed traffic stream has at least 15-20% lower speeds than cars or MTW. Therefore, if the bus system costs more than the marginal cost of using a MTW, the current users will shift to MTW. Similarly, unless the bus has speed advantage over cars and motorised two wheelers, it is difficult to retain the current bus users.
3. Increase in public transport users is relevant if the shift occurs from MTW and car users. A new comfortable bus stranded in traffic congestion will not be able to attract commuters from MTW and car. On the other hand, if car is stuck in traffic congestion, there is lack of parking at the destination and a reliable bus transport service is available (metro or bus), car and MTW commuters may consider shifting to PT system. Shift from bicycle and walking to public transport is desirable in case of long distance commuters. Low income commuters may be travelling long distances on bicycles or walking long distances because they cannot afford public transport system, or it is not available. Shifting to PT system which is faster than using a bicycle and walking improves their accessibility to employment opportunities.

4. PT system will be accessible to population living within 500 m of walking distance. For long trips commuters may decide to use either an IPT or a personal vehicle to access PT stop. Therefore, the PT system will be accessible to people living at a distance of 1 km from the PT corridor. A combination of PT system will be able to serve the differentiated travel demand. A city bus running on all major routes will provide an extensive network and access to PT system for a very large population. High capacity systems like metro/LRT will be a very good option for long trips. Since only a small proportion of the trips are long trips, therefore smaller network of metro will be sufficient for serving the long trips. By combining network of buses, BRT/Trolleybus and metro/LRT almost 90% of the population will have access to PT system. A high capacity system like metro or LRT will not have the same network coverage as a bus system, therefore a much smaller proportion of the population will be served. Optimal accessibility to PT system can be ensured by integrating different systems. Integration has to be at policy, planning, design and operational levels.
5. Public transport is a basic service just like water, waste disposal and electricity services. Provision of quality PT system enables all citizens to access amenities essential for leading a healthy life. Therefore it is city or state government's responsibility to ensure that a quality PT system is within an accessible distance of all citizens. The cost of planning, implementing and running a system will require government support partially or fully. Level of government support for running and constructing a system will depend on the number of commuters using the system and availability of funds that can be raised from different sources. At grade bus systems are not capital intensive and have a wide coverage. Revenue generated from fare box alone may not be sufficient for providing a quality service. High capacity systems like metro/LRT are capital intensive. Careful financial planning should be done prior to implementing any system for implementation and ensuring reliable operations. Level of support required under alternate scenarios should be included given the uncertainty in ridership and implementation costs.

5.1 Integrated PT System recommended for different city size:

Table 14 gives proportion of different trip lengths in varying city size observed in Indian cities. This can guide the choice of PT system recommended for different travel demand. Annexure1 gives door to door journey time for different trip lengths by different travel modes. Annexure 2 has trip length distribution for city bus and IPT(Auto rickshas) as reported in Census 2011. Based on this information appropriate PT system is recommended for various city size in the following section.

5.1.1 Category 1 cities (1-5 lakhs)

Trips shorter than 5 km are suitable for walking, bicycling and IPTs. Regardless of city size, all roads should become walking, bicycling friendly and IPTS may be made available for the whole city. These three modes also serve as feeder or access modes to high capacity PT system like metro and bus. Almost 55-60% all trips will be served by these three modes.

Table 14: Trip Length Distribution by city size

City Population	Trip Length distribution			
	<5	5-10	10-20	>20
1 to 5 lakhs	55	20-25	10-15	6
5 to 10 lakhs	48	25-30	10-15	7
10 to 40 lakhs	45	30-35	15	7
40 to 80 lakhs	40	30-35	15	8
> 80 lakhs	35	40	17	10

Trips in the range of 5-10 km length are suitable for at grade bus systems. In category 1 cities (1-5 lakhs) full size buses may not be required as the peak demand will not be sufficient to ensure reasonable load factor and bus utilization. Small buses run at higher frequency (10-15 mins) may be able to attract sufficient commuters. These cities have very low ownership of cars and very high ownership of Motorised Two Wheelers. Therefore PT system will have to compete with the reliability, availability and low cost incurred by a MTW user. Small buses may be introduced in these cities complementing the IPT modes which may be fixed route as well as serving the individual demand.

Table 15: Travel Patterns and Recommended PT System Options for City Population (1-5 lakhs)

Trip Length	Trip Length Distribution					
	<5	>5	<10	>10	<20	>20
% share of trips	55.00	20.00	25.00	10.00	15.00	6.00
Trips /day	275000.00	100000.00	125000.00	50000.00	75000.00	30000.00
Trips in peak hour (12% of daily trips)	33000.00	12000.00	15000.00	6000.00	9000.00	3600.00
Road Network (>30m ROW)	5.00	5.00	5.00	5.00	5.00	5.00
Road Network (20-30m ROW)	25.00	25.00	25.00	25.00	25.00	25.00
Peak hour trips/km	6625.00	2425.00	3025.00	1225.00	1825.00	745.00
Recommended PT System	IPT		Bus	Small bus	Small bus	
PT corridor length			15.00	30.00	30.00	
% of population within 1/2 km from bus route			9	20%		

Bulandshahr, Alwar, Mathura size cities fall in this category. Bulandshahr streets and possible PT system operating on primary and secondary roads are shown in Figure 2. Table 16 presents the summary of the road network and proportion of population living within ½ a km of primary and secondary roads.

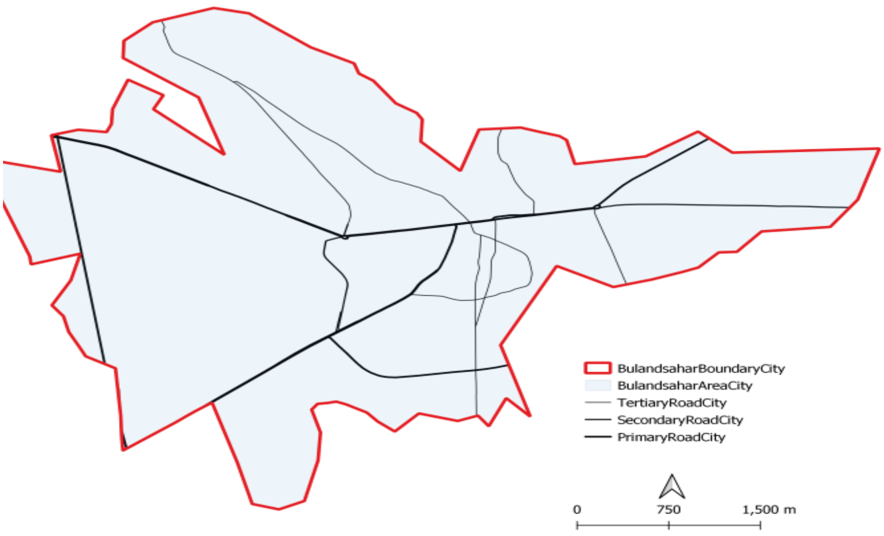

Figure 3: Bulandshahr Area accessible to primary and secondary road networks in 15 min.

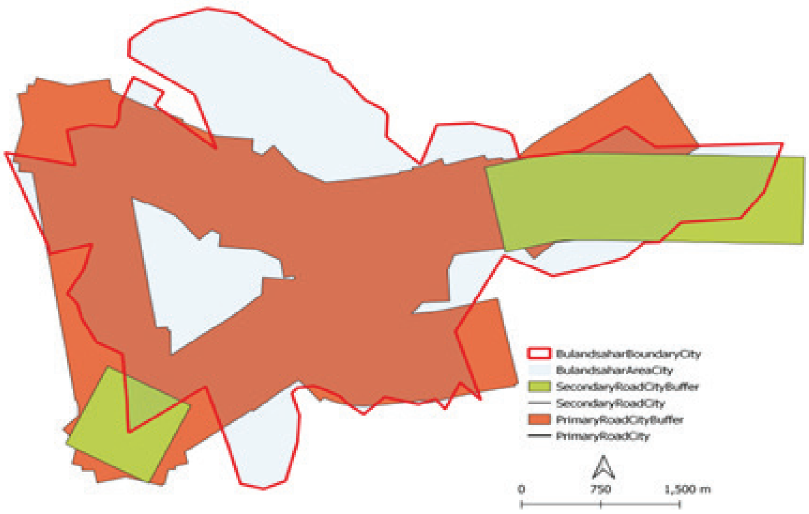

Figure 4: Bulandshahr road circulation by primary, secondary and tertiary road networks

Table 16: Bulandshahr road network summary

Population	Area (sqkm)	Population Density (per sqkm)	Primary road (km)	Secondary road (km)	Tertiary road (km)	Road Length Density for Primary and Secondary Road network (Per sqkm)	Road Length Density for Primary, Secondary and Tertiary Road network (Per sqkm)	% of people would have access to PT system within 500m
305000	17.9	17039	58.4	13.3	25.98	4.01	2.42	94.97%

5.1.2. Category 2 cities (5-10 lakhs)

Nearly 50% trips are shorter than 5 km. Trips shorter than 5 km are suitable for walking, bicycling and IPTs. Regardless of city size, all roads should become walking, bicycling friendly and IPTS may be made available for the whole city. These three modes also serve as feeder or access modes to high capacity PT system like metro and bus.

Trips in the range of 5-10 km length are suitable for at grade bus systems. In category 2 cities especially the fast growing cities where the population will reach 1 million in the next five years, formal bus system is required to serve the peak demand. Bus routes on all arterial roads at a frequency of 6 per hour (10 mins head way-) may be able to attract sufficient commuters. These cities have very high ownership of Motorised Two Wheelers. Therefore, PT system will have to compete with the reliability, availability and low cost incurred by a MTW user. Full buses on arterial roads may be introduced in these cities complementing the IPT modes which may be fixed route as well as serving the individual demand. Buses can be run on shared right of way with bus stops with safe crossing facilities. Few exclusive lanes for buses can be created in the high demand corridor. This can increase the capacity of bus system. City can also start planning higher capacity system which require complete exclusive right of way. These will include open or closed bus system, trolley bus and light rail systems integrated with public bus routes. A road map for implementing and financing this high capacity PT system in 5-8 years may be prepared.

Table 17: Travel Patterns and Recommended PT System Options for City Population (5-10 lakhs)

Trip Length	Trip Length Distribution					
	<5	>5	<10	>10	<20	>20
% share of trips	48.00	25.00	30.00	10.00	15.00	7.00
Trips /day	480000.00	250000.00	300000.00	100000.00	150000.00	60000.00
Trips in peak hour	57600.00	30000.00	36000.00	12000.00	18000.00	7200.00
Road Network(>30m ROW)	30.00	30.00	30.00	30.00	30.00	30.00
Road Network(20-30m ROW	100.00	100.00	100.00	100.00	100.00	100.00
trips ph/km	2980.00	1600.00	1900.00	700.00	1000.00	460.00
Recommended PT System	IPT		Bus		Bus	
PT corridor length	130		60			
% of population within 1/2 km for Bus			23			

Patiala, Ajmer, Mysore size cities fall in this category. Figure shows layout of primary and secondary road layout and proportion of population living within in ½ a km of primary and secondary roads which are available for operating public transport system. Table presents a summary of road network in Patiala.

Table 18: Patiala Road Network Summary

City	Popula-tion	Area (sqkm)	Population Density (per sqkm)	Primary road (km)	Second-ary road (km)	Tertiary road (km)	Road Length Density for Primary and Secondary Road network (Per sqkm)	Road Length Density for Pri-mary, Secondary and Tertiary Road network (Per sqkm)	% of people would have access to PT system within 500m
Patiala	651000	81.87	7952	45.94	38.27	81.46	1.03	1.48	58%

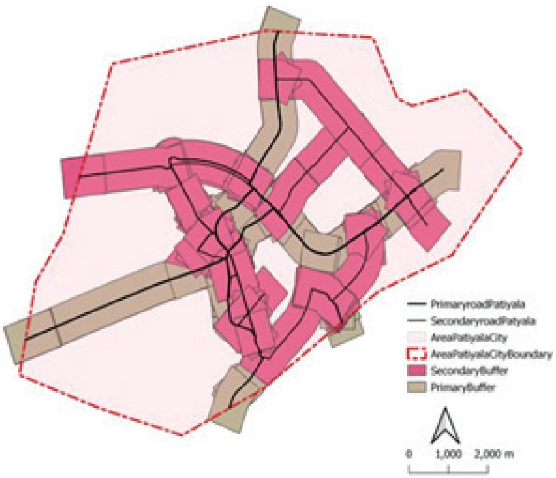

Figure 5: Proportion of population living within ½ a Km of primary and secondary roads

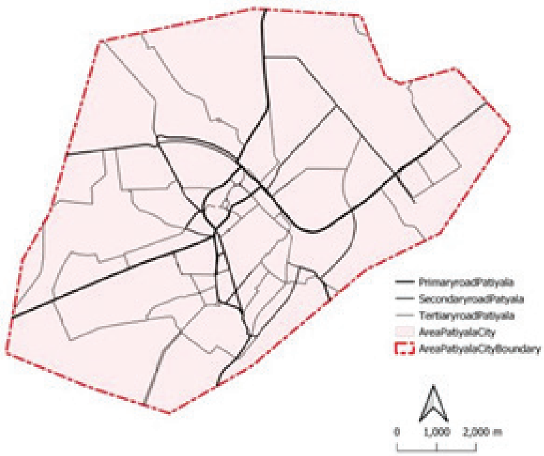

Figure 6: Primary and secondary Road layout in Patiala

5.1.3. Category 3 cities (10-40 lakhs)

Nearly 45% trips are shorter than 5 km. Trips shorter than 5 km are suitable for walking, bicycling and IPTs. Regardless of city size, all roads should become walking, bicycling friendly and IPTS may be made available for the whole city. These three modes also serve as feeder or access modes to high capacity PT system like metro and bus.

Trips in the range of 5-10 km length are suitable for at grade bus systems. In category 3 cities formal bus system with a full network running on all arterial roads is required to serve the peak demand. Bus routes on all arterial roads at a frequency of 10 per hour (6 mins head way-) may be able to attract sufficient commuters. Open BRT system can provide a high quality PT service on major corridors. Exclusive corridors for PT vehicles and emergency vehicles to meet the peak hour demand will make PT system attractive for MTW and few car owners who may be facing congestion in peak hour. MTW ownership is generally much higher than cars. Therefore PT system will have to compete with the reliability, availability and low cost incurred by a MTW user. Full buses on arterial roads may be introduced in these cities complementing the IPT modes which may be fixed route as well as serving the individual demand. Buses can be run on shared right of way with bus stops with safe crossing facilities. Few exclusive lanes for buses can be created in the high demand corridor. This can increase the capacity of bus system. City can also start planning higher capacity system which require complete exclusive right of way. These will include LRT or Metro.

Table 19: Travel Patterns and Recommended PT System Options for City Population (10-40 lakhs)

Trip Length	Trip Length Distribution					
	<5	>5	<10	>10	<20	>20
% share of trips	45.00	30.00	35.00	12.00	15.00	7.00
Trips /day	1800000	1200000	1400000	480000	600000	280000
Trips in peak hour	270000	180000	210000	72000	90000	42000
Road Network(>30m ROW)	100.00	100.00	100.00	100.00	100.00	100.00
Road Network(20-30m ROW	300.00	300.00	300.00	300.00	300.00	300.00
trips ph/km	4800.00	3300.00	3800.00	1500.00	1800.00	1000.00
Recommended PT System	IPT		Bus	BRT/ Trolley Bus	BRT/LRT	
Route length	400		100	20-30		
% of population within ½ km walking distance of PT corridor			46	6		

Meerut, Bhopal Agra , Vishakhapattanam, Patna, Kanpur, Nagpur, Jaipur size cities fall in this category. Figure shows streets and possible PT system operating on primary and secondary roads in Vishakhapattnam. Table presents the summary of the road network and proportion of population living within ½ a km of primary and secondary roads.

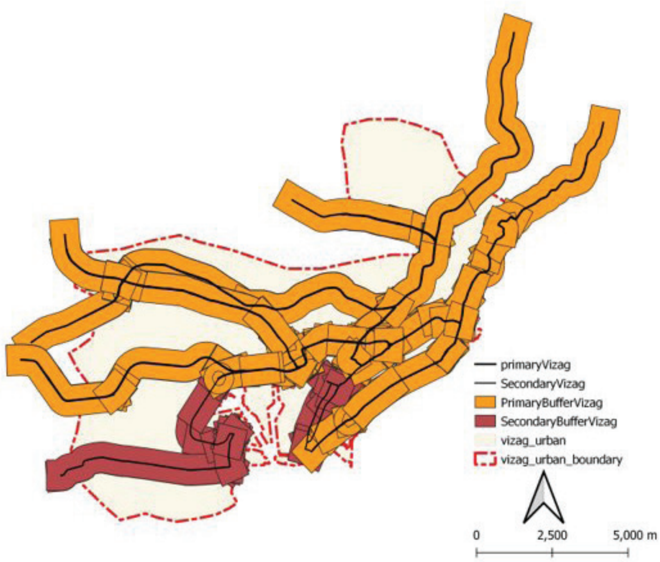

Figure 7: Proportion of population living within ½ a Km of primary and secondary roads

Figure 8: Primary, secondary and tertiary road layout in Patiala

Table 20: Vishakhapatnam city road network data

Population	Area (sqkm)	Population Density (per sqkm)	Primary road (km)	Second-ary road (km)	Tertiary road (km)	Road Length Density for Primary and Secondary Road network (Per skm)	Road Length Density for Pri-mary, Secondary and Tertiary Road network (Per skm)	% of people would have access to PT system within 500m
2331000	98.61	23639	147.62	25.42	139.78	1.75	1.69	88.22%

5.1.4. Category 4 cities (40-80 lakhs)

Nearly 40% trips are shorter than 5 km. Trips shorter than 5 km are suitable for walking, bicycling and IPTs. Regardless of city size, all roads should become walking, bicycling friendly and IPTS may be made available for the whole city. These three modes also serve as feeder or access modes to high capacity PT system like metro and bus.

Trips in the range of 5-10 km length are suitable for at grade bus systems. Nearly 30%-35% trips fall in this range. This translates to about 3.6-4.2 lakh trips in peak hour or 4-5 thousand trips per km of arterial roads. A formal bus system with a full network running on all arterial roads is required to serve the peak demand. Bus routes on all arterial roads at a frequency of 12 per hour (5 min head way-) may be able to attract sufficient commuters. Open BRT system can provide a high quality PT service on major corridors. Exclusive corridors for PT vehicles and emergency vehicles to meet the peak hour demand will make PT system attractive for MTW and few car owners who may be facing congestion in peak hour. MTW ownership is generally much higher than cars in these cities. Therefore PT system will have to compete with the reliability, availability and low cost incurred by a MTW user. Trips longer than 10 km are suitable for LRT/metro system. About 15% trips are longer than 10 km and 7% trips are longer than 20 km. This translated to about 2500 per km of arterial roads trips in peak hour. The city bus system should be complemented with a high capacity systems on exclusive right of way. This would include a few routes of LRT. City can also start planning higher capacity system like metro which require complete exclusive right of way and strong integration with existing bus network.

Table 21: Travel Patterns and Recommended PT System Options for City Population (40-80 lakhs)

Trip Length	Trip Length Distribution					
	<5	>5	<10	>10	<20	>20
% share of trips	45.00	30.00	35.00	12.00	15.00	7.00
Trips /day	3600000.00	2400000.00	2800000.00	960000.00	1200000.00	560000.00
Trips in peak hour	540000.00	360000.00	420000.00	144000.00	180000.00	84000.00
Road Network(>30m ROW)	200.00	200.00	200.00	200.00	200.00	200.00
Road Network(20-30m ROW	500.00	500.00	500.00	500.00	500.00	500.00
trips ph/km	5900.00	4100.00	4700.00	1940.00	2300.00	1340.00
Recommended PT System	IPT		Bus		BRT/LRT	
Route length		700	200		50	
% of population within IPT, 1/2 km of PT corridor			60		17	

Ahemdabad, Hyderabad, Pune size cities fall in this category. Figure shows streets and possible PT system operating on primary and secondary roads in Pune . Table presents the summary of the road network and proportion of population living within ½ a km of primary and secondary roads.

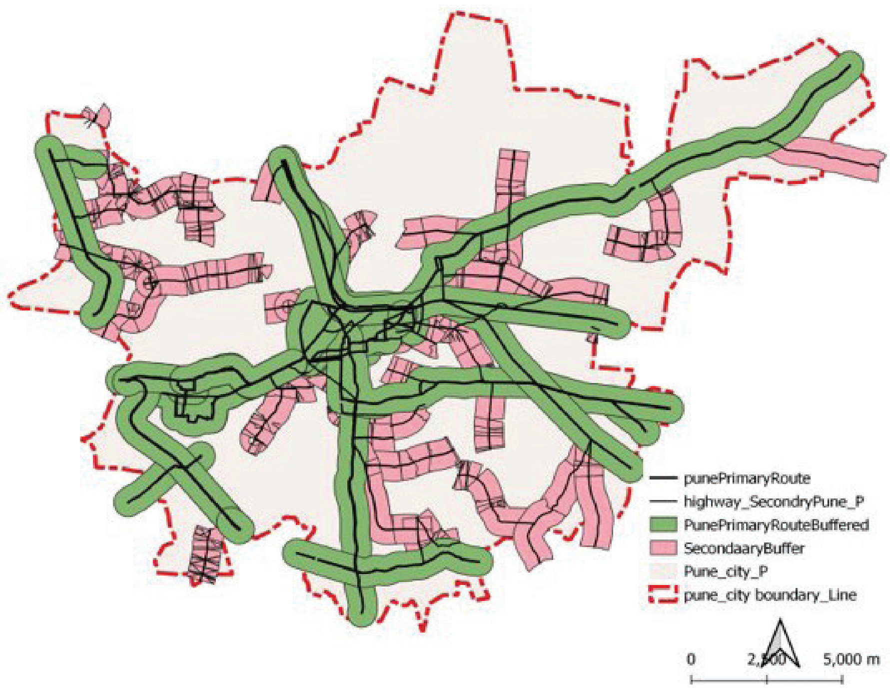

Figure 9: Proportion of population living within ½ a Km of primary and secondary roads in Pune

Figure 10: Primary, secondary and tertiary road layout in Pune

Table 22: Pune city road network data

Population	Area (skm)	Population Density (per skm)	Primary road (km)	Secondary road (km)	Tertiary road (km)	Road Length Density for Primary and Secondary Road network (Per skm)	Road Length Density for Primary, Secondary and Tertiary Road network (Per skm)	% of people would have access to PT system within 500m
10480787	303.56	34526	202.34	633.9	445.5	2.75	3.56	71.84%

5.1.5. Category 5 cities (> 80 lakhs)

Nearly 35% trips are shorter than 5 km. Trips shorter than 5 km are suitable for walking, bicycling and IPTs. Regardless of city size, all roads should become walking, bicycling friendly and IPTS may be made available for the whole city. These three modes also serve as feeder or access modes to high capacity PT system like metro and bus.

- Trips in the range of 5-10 km length are suitable for at grade bus systems. About 35-40% trips fall in this range. This translates to 8-9 lakh trips in peak hour or about 5-6 thousand tips per km in peak hour on arterial road. In category 5 cities formal bus system with a full network running on all arterial roads is required to serve the peak demand. Bus routes on all arterial roads at a frequency of 12 per hour (5 mins head way-) may be able to attract sufficient commuters. Open BRT system can provide a high quality PT service on major corridors. Exclusive corridors for PT vehicles and emergency vehicles to meet the peak hour demand will make PT system attractive for MTW and few car owners who may be facing congestion in peak hour. Bus system will have to compete with the reliability, availability and low cost incurred by a MTW users to attract MTW users to bus. High capacity systems like metro will be required to serve the long distance trips (longer than 10 kms). About 17% trips are longer than 10 kms and 10% trips are longer than 20 kms. This translates to 3-4 lakh trips in peak hour or about 3000 trips per km on arterial roads. Metro routes and bus routes will need strong integration.

Table 23: Travel Patterns and Recommended PT System Options for City Population (>80 lakhs)

Trip Length	Trip Length Distribution					
	<5	>5	<10	>10	<20	>20
% share of trips	35.00	35.00	40.00	15.00	17.00	10.00
Trips /day	5250000.00	5250000.00	6000000.00	2250000.00	2550000.00	900000.00
Trips in peak hour	787500.00	787500.00	900000.00	337500.00	382500.00	135000.00
Road Network(>30m ROW)	400.00	400.00	400.00	400.00	400.00	400.00
Road Net-work(20-30m ROW	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00
trips ph/km		4937.50	5500.00	2687.50	2912.50	1675.00
Recommended PT System	IPT		Bus	BRT/Metro	Metro	
Route length		1400	800.00	200.00	400.00	
% of population within 1/2 km of PT corridor)			70	17	35	

Delhi, Mumbai, Chennai, Kolkata size cities fall in this category. Figure shows streets and possible PT system operating on primary and secondary roads in Delhi. Table presents the summary of the road network and proportion of population living within ½ a km of primary and secondary roads.

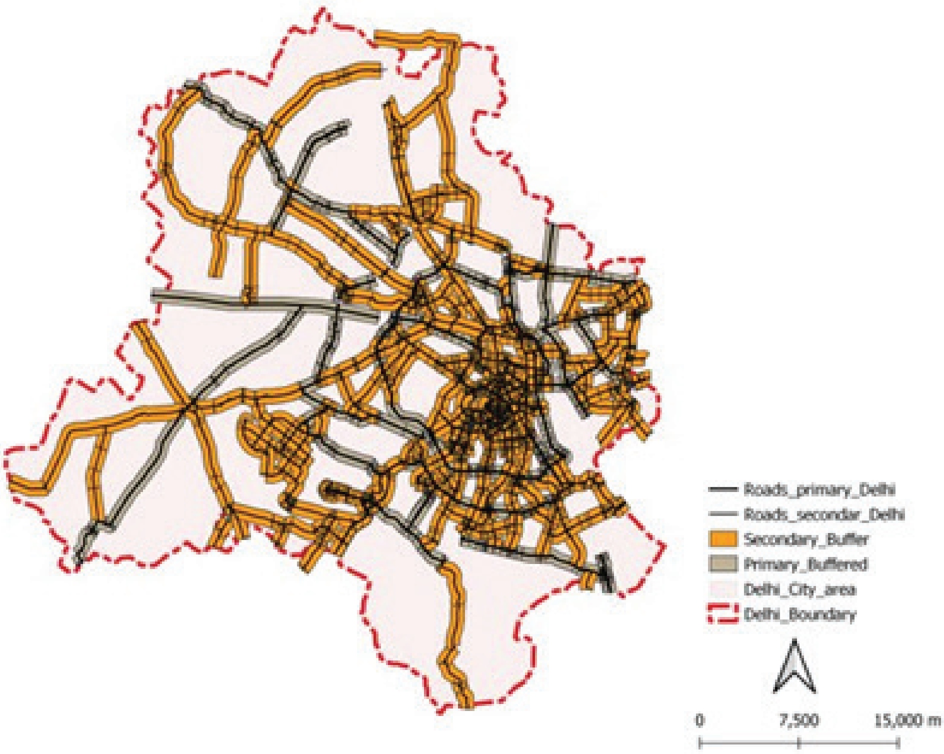

Figure 11: Primary, secondary and tertiary road layout in Delhi

Table 24: Delhi city road network summary

Population	Area (sqkm)	Population Density (per sqkm)	Primary road (km)	Secondary road (km)	Tertiary road (km)	Road Length Density for Primary and Secondary Road network (Per sqkm)	Road Length Density for Primary, Secondary and Tertiary Road network (Per sqkm)	% of people would have access to PT system within 500m
15217000	1477.24	10301	469.14	1192	2103.18	1.12	2.23	50.57%

Table 25 give percentage of population within ½ a km of walking distance from the PT corridor based on average population density. Buses are assumed to run on arterial road and partially on sub arterial roads.

Figure 12: Primary, secondary and tertiary road layout in Delhi

Table 25: Population within ½ a km of walking distance from the PT corridor

City Population Size(million)	Number of Urban Urban districts	Average Population Density (ppkm)	Arterial Road Network (>30m ROW)	Sub artrial Road Network (>20m ROW)	IPT Accessibility (1/4 km walking)	Bus Accessibility (0.5km walking)	BRT/Metro Accessibility (1/2 km walking)
0.1-0.5	432	3090.08	5	30	0.1081528	0.0927024	
0.5-1.0	105	3984.34	30	100	0.2589821	0.2390604	
1.0-4.0	90	9255	100	300	0.46275	0.46275	0.0694125
4.0-8.0	6	13864.52	200	500	0.60657275	0.60657275	0.1733065
>8.0	4	13201.65	500	1000	0.6600825	0.704088	0.352044

6. Conclusion

1. Different PT systems are suitable for different travel patterns as determined by the trip length. Differentiated travel demand should guide the choice of PT system to ensure that majority of the citizens can access a high quality PT system. An integrated system can ensure high ridership of public transport and all social benefits are linked to realising a high ridership of public transport system.
2. High capacity systems like metro are very attractive for long trips. Large cities(> 8 million population) can have about 300-400 km of metro, however it must have a robust, reliable network of bus system operating on all arterial and partially on sub arterial roads. This would be about 800-1000 km. Last mile connectivity is by walking and IPT. Integration of three systems at policy, planning, design and regulatory framework will ensure high quality public transport system. Bus routes running on parallel metro network serves as feeder mode and special feeder buses are not required.
3. Travel demand in cities with 4-8 million population can be well served by bus system running on all arterial and sub arterial routes. For about 20% trips linger than 10 kms Light Rail transport (LRT) or exclusive bus corridors can be introduced to complement the bus network. Last mile connectivity is by walking and IPT. Cities higher than 1 million population should start planning high capacity system like BRT/LRT/metro as an integrated system. Planning includes financial plans to construct and operate an integrated PT system.
4. Travel demand in cities with lower population (<1 million) should invest in a high quality bus system and plan for high capacity systems only if the city is expected to grow beyond 24 million population in ten years.
5. Travel demand in cities with less than 5 lakh population can be met by improved IPT services and a small bus route running on arterial and partly on sub arterial roads. This size city do not have enough demand where a bus system can be fully utilized.

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Annexure 1:

Passenger travel time (door to door travel time) by different modes

This section is sourced from “Metro rail and the city: derailing public transport.”*Economic and Political Weekly* (2013): 65-76., author: G. Tiwari. For full references and details , refer to the full article.

Table A1.1 shows trip profile by different modes. Figure A1.1 shows total journey time for different trip lengths by different modes.

Table A1.1: Trip profile and expected speeds for different modes

Mode	Access time	Egress time	Average speed at line haul	Number of modes used in making trip (n)
2-wh	Time of taking out vehicle from garage = 2 minutes	Time spent for parking vehicle and reaching the destination = 2 minutes	25 km/hr	1; only two wheeler is used for total trip
3-wh	Time spent in walking from home to 3-wh stand = 5 minutes (average distance of 350 m)	Time spent in getting off from 3-wh and to reach at destina-tion = 2 minutes	20 km/hr	2; 3-wh and walk
Car	Time of taking out vehicle from garage = 5 minutes	Time spent for parking vehicle and reaching to the destination = 3 minutes	40 km/hr	1; only car is used for total trip
Taxi	Time spent in walking from home to bus stop = 7 min-utes (average distance of 500 m)	Time spent in getting off from taxi and to reach at destination = 2 minutes	40 km/hr	2; Taxi and walk
Bus	Time spent in walking from home to bus stop = 7 min-utes (average distance of 500 m)	Time spent in walking to reach at final destination from bus stop = 7 minutes	18 km/hr	2; bus and walk
Metro	Total time spent in walking from home to metro station (avg. distance of 500 m) and time spend inside the metro station for getting ticket and to reach at plat-form= 8 minutes	Time spent in walking to reach at final destination from metro station = 8 minutes	35 km/hr	2; Metro and walk

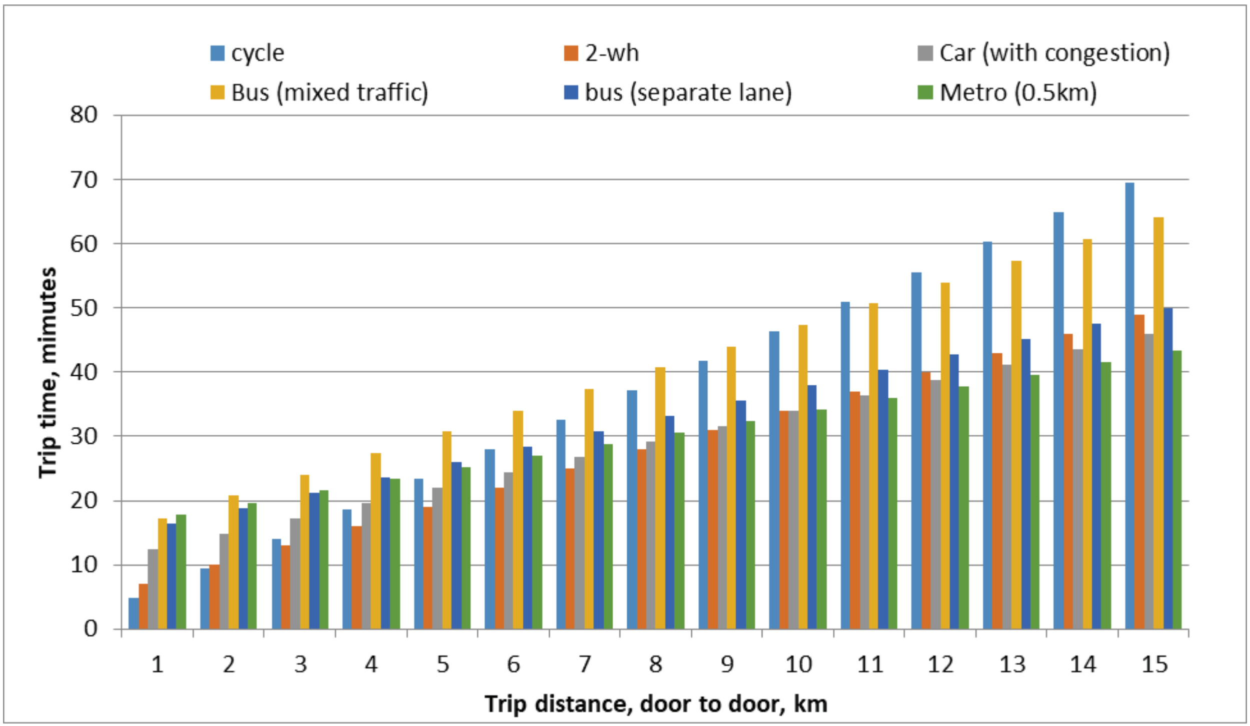

Figure A1.1: Total journey time for different trip lengths

Public transport service provided by the metro or the bus system has a higher probability of usage if it is easily accessible by users. This includes accessible stations in terms of time, distance, safety and convenience. In addition to this, minimum time loss at interchanges, and reliable services are also important for the use of public transport. Since 500 m or less is the preferred walking distance, persons living along the metro within walking distance have the highest accessibility to metro. The area within 500 m from the metro stations will be 18% of the total area of the National Capital Territory of Delhi after completion of four phases of metro ,(Advani, 2010). Thus, after the implementation of the complete four phases of metro system in Delhi more than 82% area of Delhi will remain beyond walking distance of the metro. Expansion of the metro influence zone beyond 0.5 km of walking distance will have to depend on the feeder system. This is not easy because of the inherent transfer costs and wait times at interchanges.

A transfer has major impact on passenger journeys. Generally, a single long trip is preferred over short journeys involving transfers because each transfer implies added impedance in terms of time, cost, inconvenience and uncertainty. Transfers require a good coordinated scheduling of feeder and main services, combined ticketing and minimum waiting time. Whether a journey can be made without any transfer or needs one or more transfers always plays an important role in determination of travel mode choice.

Longer travel time or distance and higher cost imply lower accessibility and therefore lower probability of using the system. Several researchers have supported that an increase indistance to a transfer location reduces the propensity to use public transport (Keijer and Rietveld, 2004; Loutzenheiser, 1997; O'Sullivan and Morrall, 1996). The time and distance disutility associated with the access and egress stages makes single modetrips more attractive. The catchment area is thus not only a function of the absolute access and egress time but also of the relative share of the total trip time. Access and egress times increase with increasing trip time, however, the increase is not as strong as line-haul time and as a result the interconnectivity ratio (access and egress time as proportion of total trip time) declines as trip time increases. For most multimodal trips, the ratio falls within a modest range of 0.2–0.5. The results can be used, amongst other, in planning the catchment area of public transport and predicting choice sets of realistic multimodal trips.

We can make an approximate estimation of potential of trips for various modes based on trip length distribution as shown in Table A1.2, potential trips for different modes in A1.3. Since trip length is not the only criteria for selecting mode, the percentage share shown in TableA1.4 is the maximum possible mode share for the mode indicated. In case of Delhi we know that after creating 190 km long network of metro the ridership is merely 5%. These approximate estimations indicate that regardless of city size, metro will serve a small proportion of total trips. Share of bus trips will always remain higher than metro, as it is more convenient for shorter trips. In fact, in the best case scenario, if all the potential trips are converted to actual usage by different modes(which is unlikely), bus and metro together will address needs of about 50% of the total trips, the remaining 50% will require infrastructure for bicycles, rickshaws and pedestrians.

Table A1.2 : Trip length distribution(cumulative %) in selected cities

	Mumbai	Delhi	Hyderabad	Pune	Patna	Chandigarh	Vizag
< 2 km	42	11	32	17	6	32	53
2 - 5 km	69	40	65	77	62	53	81
5 - 10 km	81	75	86	97	88	87	92
10 - 15 km	90	97	93	100	100	98	95
> 15 km	100	100	100	100	100	100	100

Table A1.3: Potential trips(%)for different modes in selected cities.

	Mumbai	Delhi	Hyderabad	Pune	Patna	Chandigarh	Vizag
Metro(>10kms)	19	25	14	3	12	13	8
Bus(5-10 kms)	12	35	21	20	26	34	11
NMV(2-5 kms)	27	29	33	60	55	21	28
Ped(>2 kms)	42	11	32	17	6	32	52

Note: Potential trip is estimated based on % of trips with trip length in the range indicated within( ), as shown by Mohan et al, 1996 and Advani, 2007.

Table A1.3 shows maximum possible shares for metro, bus, bicycle and pedestrian assuming the extreme case of not including car and two wheelers, and any other factor like cost, convenience, etc. which influence mode choice. Also , metro is assumed to be present on all arterial roads making it within walking distance for most population. Car and motorized two wheelers will be at least 50% of the potential bus and metro trips. Table A1.4 shows estimated potential and most likely metro trips for selected cities. Most likely share of metro trip share is estimated as 50-75% of the potential trips.

Table A1.4: Estimated share of Potential and most likely metro trips in Cities with population greater than 2 million

S.No.	City	Population	Potential metro trips (% share)	Most likely metro trips (% share)
1	Kozhikode	2,030,519	8-12	4-5
2	Patna	2,046,652	12	6
3	Kochi	2,117,990	8-12	4-6
4	Coimbatore	2,151,466	8-12	4-6
5	Indore	2,167,447	8-12	4-6
6	Ghaziabad	2,358,525	8-12	4-6
7	Nagpur	2,497,777	5-8	2-3
8	Lucknow	2,901,474	5-8	2-3
9	Kanpur	2,920,067	5-8	2-3
10	Jaipur	3,073,350	10-14	6-8
11	Surat	4,585,367	10-14	6-8
12	Pune	5,049,968	5	2-3
13	Ahmadabad	6,352,254	10-14	6-8
14	Hyderabad	7,749,334	14	6-8
15	BANGALORE	8,499,399	12-16	6-8
16	Chennai	8,696,010	12-16	6-8
17	Kolkata	14,112,536	12-16	6-8
18	Delhi	16,314,838	22	10-15
19	Greater Mumbai	18,414,288	19	10-15

It can be concluded that if a city decides to invest in metro system regardless of city size, it is for a small proportion of the total trips. Usually in cities having population of 2-3 million, proportion of trips which are potentially metro trips will be less than 5%. In future, with population growth, these cities may have a populations around 5 million. However, in this case also the proportion of potential metro trips will not be more than 8%.

Annexure 2:

Trip Length Distribution for City Bus and IPT (Auto rickshas)

Table A2.1Mode share for Bus users and Auto rickshaw users (census, 2011)

Row Labels	Average of Mode share_3 Wheeler (5)	Average of Mode share-Bus (6)	Number of Urban districts
0.1-0.5	2%	7%	432
0.5-1.0	4%	8%	105
1.0-2.0	3%	11%	59
2.0-4.0	3%	14%	31
4.0-8.0	5%	13%	6
>8.0	4%	16%	4

Table A2.2Trip length distribution of Bus users (Census, 2011)

No. of Urban districts	432	105	59	31	6	4
Bus Trip Length(km)/ District Population Size (Lakh)	1 to 5	5 - 10	10 - 20	20 - 40	40 - 80	> 80
< 5 km	20%	18%	22%	25%	29%	37%
5 - 10 km	16%	18%	22%	27%	31%	28%
10 - 20 km	19%	20%	20%	23%	24%	20%
> 20 km	45%	44%	36%	25%	16%	15%

Table A2.3 Trip length distribution of Auto rickshaw users (Census, 2011)

No. of Urban districts	432	105	59	31	6	4
Auto Rickshaw Trip Length(km) / District Population Size (Lakh)	1 to 5	5 - 10	10 - 20	20 – 40	40 - 80	> 80
< 5 km	56%	53%	50%	45%	50%	47%
5 - 10 km	20%	25%	27%	25%	26%	20%
10 - 20 km	11%	12%	12%	15%	13%	14%
> 20 km	13%	11%	11%	14%	12%	20%

Table A2.4 City specific trip characteristics (Published reports)

Sample Cities	Population Size (Million)	Modal share (%)			Average trip length(KM)		
		Bus (6)	Metro/ Train(7)	Auto (5)	Bus(6)	Metro/ Train(7)	Auto(5)
Jaipur	2-4	31		14	13.3	8.7	7.2
Ahmedabad		11.4		6.1			
Bengaluru	>8	38	0.3	10	12	9.44	3.7
Kolkata	4-8						
Mumbai	2-4	22	2	6	8		2.9
Hyderabad	2-4	28	4	8	12	16	7.1
Chennai	4-8	22	5.6	5	10.3	12.9	6.9
Kochi			1%			7.33	
Lucknow	2-4					6.58	
Delhi	>8	50		5		12.66	
Nagpur	2-4	10		12	9.4		4.5
Pune	4-8	13		5			
Kanpur	0.1-0.5						
Amritsar							
Bhopal	1-2	23		2	5.8	8	10
Hubli-Dharwad							
Indore	2-4						
Raipur		0		4			
Rajkot		14					
Surat	4-8	3		11			
Vijayawada							
Visakhapatnam	2-4	38		20	17		9
Gandhinagar	0.5-1.0	17		8	4.1		20

Table 2A.5: Metro system projected to actual daily ridership (%)

S.No.	City	Urban Area(sq.km)	Population (in Lakhs)	Population Density (skm)	Operational System Length (KM)	Planned/ Under Construction System Length (KM)	Ridership DPR Forecast (Lakhs)	Forecast for completion/ Year	Actual Ridership(Lakhs)	Actual Ridership/ Completion Year	Percentage of Forecast Ridership (%)
1	Jaipur (Phase-1)	467	39.09	8370	11.98	27.3	2.1	2014	0.204	2019-20	9.71%
2	Ahmedabad Metro	505	80.59	15958	37.902	33.62	6.75	2010	0.3	2022-23	4.44%
3	Bengaluru Metro (Phase-1)	850	123.26	14501	38.6	205.386	16.1	2021	0.96	2021-22	5.96%
4	Kolkata Metro	1887	148.5	7870	47.85	92.19	15	-	5.84	2019-20	38.93%
5	Mumbai Metro (Line-1)	437	204.11	46707	66.04	263.87	10.06	2016	3.334	2017-18	33.14%
6	Hyderabad Metro	650	100.04	15391	67.47	64	19	2017	0.67	2017-18	3.53%
7	Chennai Metro (Phase-1)	426	109.71	25754	54.14	134.2	7.57	2016	0.92	2019-20	12.15%
8	Kochi Metro (Phase-1)	440	30.82	7005	26.8	12.36	3.8	2015	0.49	2019-20	12.89%
9	Lucknow Metro	631	36.76	5826	22.87	11.098	0.943	-	0.258	2020-21	27.36%
10	Delhi Metro (Phase-1+2+3)	1397	302.9	21682	349.27	125.27	53.47	2016	25.37	2017-18	47.45%
11	Nagpur Metro	3577	28.93	809	38.22	43.8	1.9	-	0.133	2021-22	7.00%
12	Pune Metro	516	66.29	12847	12	85.45	6	2018	0.35	2017-18	5.83%
13	Kanpur City (Phase-1)	260	31.23	12012	8.621	23.76	6.61	2024	0.1	2022-23	1.51%

Actual ridership in operational Metro systems is less than 20% in most cities other than Delhi where it is 47% and Kolkata 38%.

Table 2A.6 : City bus physical and operational details

Sample Cities	Population Size (Million)	Bus operator	fleet Size	Buses per lakh of population	Daily ridership	Load Factor (%)	Average lead
Bhopal	1-2	BCLL	300	13	165000	-	-
Jaipur	2-4	JCTSL	400	10	26,214	65%	-
Hyderabad	2-4	TSRTC	3100	31	2413000	67%	-
Kochi	2-4	KSRTC	630	20	38000	-	-
Lucknow	2-4	LCTSL	220	6	2047000	-	-
Nagpur	2-4	NMPL	230	8	100000	-	-
Indore	2-4	AICTSL	550	18	2270000	-	-
Visakhapatnam	2-4	APSRTC	600	28	3300000	-	-
Ahmedabad	4-8	AMTS	1250	16	350000	54%	8
Kolkata	4-8	WBTC	4500	30	250000	-	-
Pune	4-8	PMPML	463	7	278000	73%	11.15
Surat	4-8	SRTC	576	8	200000	42%	-
Bengaluru	>8	BMTC	5600	45	4500000	68%	11
Mumbai	>8	BEST	5619	28	2500000	51%	7
Chennai	>8	MTC	3448	31	2946000	80.22%	-
Delhi	>8	DTC	6693	22	2500000	84.69%	9.95
Kanpur	0.1-0.5	KCTSL	270	9	-	-	-
Amritsar	1-2	ACTSL	93	7	-	-	-
Hubli-Dharwad	0.1-0.5	KSRTC	298	27	387400	62.67	-
Raipur	0.1-0.5	NRMTL	73	4	850000	-	-
Rajkot	0.1-0.5	RMTS	90	5	-	-	-
Vijayawada	0.1-0.5	APSRTC	400	20	-	-	-
Varanasi	0.5-1.0	VCTSL	127	8	-	-	5.94

Available bus fleet in most cities is much less than recommended by standards

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Summary of Physical and Operational Characteristics of Selected Metro Systems.

Jaipur Metro (3 June 2015)

Metro Operational Characteristics [1]

Operational – 11.98 km - ₹3149 crores

Pink Line – Phase 1A (Mansarovar – Chandpole) – 9.63 km - ₹2323 crores

Pink Line – Phase 1B (Chandpole – Badi Chaupar) – 2.35 km - ₹826 crores

Planned/Under Construction – 27.3 km - ₹11,593 crores [2]

Pink Line – Phase 1C (Badi Chaupar – Transport Nagar) – 2.85 km - ₹994 crores

Pink Line – Phase 1D (Mansarovar – Ajmer Road) – 1.35 km - ₹205 crores

Orange Line – Phase II (Sitapura Industrial Area – Ambabari) – 23.10 km - ₹10,394 crores

Travel Cost [3]

No. of Stations travelled	Standard Fare (in ₹)
0 to 2 stations	6
3 to 5 stations	12
6 to 8 stations	18
9 to 10 stations	22

Speed [1]

Max = 80 kmph

Avg. = 32 kmph

Ownership [1]

Fully funded by the State Government and its agencies, namely, Jaipur Development Authority, Rajasthan Housing Board and Rajasthan State Industrial Development & Investment Corporation Ltd.

Feeder Services [1]

Vehicle Type	Access Distance (in km)	Fixed Fare (in ₹/km)
Tata Magic/Mahindra Maximo	0-12	10
E-rickshaw	0-6	7

Actual Average Daily Ridership (AADR) (in lakhs per day) [4]

0.10 – 2017 – 18 (Projected 1)

0.15 – 2018 – 19 (Projected 1.25)

0.20 – 2019 – 20 (Projected 1.4)

Population [5]

	2011	2021	2031
Population (in Lakhs)	33.80	40.08	50.53
Population (in Lakhs) per 1 sq. km	0.072	0.086	0.108
Population (in Lakhs) per 5 sq. km	0.362	0.429	0.541

Area [6]

467 sq. km (91 wards and 8 geographical zones)

Mode share [7]

Mode	**Share (in %)**
Walk	29
Bicycle	4
Car	9
MTW	24
Auto Rickshaw	5
Taxi	8
Public Transport (Bus + Train)	21

Ahmedabad Metro (4 March 2019)

Metro Operational Characteristics [8]

Operational – 37.77 km - ₹10773 crores (₹10675 crores + ₹98 crores IDC)

Blue Line – East-West Corridor (Thaltej – Vastral gram) – 20.54 km - ₹6681 crores

Red Line – North-South Corridor (APMC – Motera Stadium) – 17.23 km - ₹3994 crores

Planned/Under Construction – 40.60 km - ₹6401 crores [9]

Red Line – North-South Corridor (Motera Stadium – Mahatma Mandir) – 22.84 km - ₹4058 crores

Green Line – (GNLU – Gift City) – 5.42 km - ₹764 crores

Phase IIA – (Koteshwar Road – Airport) – 6.34 km - ₹913 crores

Phase IIB – (Additional corridor inside GIFT city) – 6 km - ₹666 crores

Travel Cost [10]

No. of Stations travelled	Standard Fare (in ₹)
0 to 3 stations	5
4 to 7 stations	10
8 to 11 stations	15
12 to 17 stations	20
18 to 20 stations	25

Speed [11]

Max = 80 kmph
Avg. = 33 kmph

Ownership [11]

The special purpose vehicle company, Metro Link Express for Gandhinagar and Ahmedabad Company Ltd, later renamed Gujarat Metro Rail Corporation Limited (GMRC) in 2018, was established by Government of Gujarat on 4 February 2010 with ₹202 crore (US$25 million). Later in 2014, it was decided that the Central Government will own 50% of the company.

Feeder Services [12]

Vehicle Type	Access Distance (in km)	Fixed Fare (in ₹/passenger)
Buses run by AMTS	0-15	20 (Male), 15 (Female), 5 (Children)

Actual Average Daily Ridership (AADR) (in lakhs per day) [13]

0.4 – 2022 – 23 (Projected 6.69)

Population [14]

	2011	2021	2031
Population (in Lakhs)	55.78	74.18	95.38
Population (in Lakhs) per 1 sq. km	0.110	0.147	0.189
Population (in Lakhs) per 5 sq. km	0.552	0.734	0.944

Area [15]

505 sq. km (48 wards and 7 geographical zones)

Mode share [16]

Mode	**Share (in %)**
Walk	37.62
Bicycle	17.59
Car	2.48
MTW	25.29
Auto Rickshaw	8.27
Public Transport (Bus + Train)	8.74

Bengaluru Metro (20 Oct 2011)

Metro Operational Characteristics

Operational – 69.9 km - ₹14405 crores

Under Construction – 103.3 km - ₹32000 crores

Planned – 80.0 km - ₹28500 crores

Travel Cost

No. of Stations trav-elled	Fare (in ₹)	No. of Stations travelled	Fare (in ₹)
0 to 1 station	9.5	11 stations	36.1
2 to 3 stations	14.25	12 stations	38
4 stations	17.1	13 stations	39.9
5 stations	19	14-15 stations	42.75
6 stations	20.9	16-17 stations	47.5
7 stations	23.75	18 stations	49.4
8 stations	26.6	19 stations	52.25
9 stations	28.5	20 stations	55.1
10 stations	33.25	21-26 stations	57

Speed

Max = 120 kmph
Avg. = 80 kmph

Ownership

Bengaluru Metro Rail Corporation Limited (BMRCL), a joint venture of Government of India and the State Government of Karnataka, is the agency for building, operating and expanding the Namma Metro network.

Feeder Services

Vehicle Type	Access Distance (in km)	Fare (in ₹/km)
Non-AC E-Buses run by BMTC	0-18	12-20 (Adult), 9-15 (Senior Citizen), 6-10 (Children)
AC Buses (Vayu Vajra) run by BMTC	0-18	20-35 (Adult), 15-30 (Senior Citizen), 10 - 20 (Children)

Actual Average Daily Ridership (AADR) (in lakhs per day)

1.48 – 2016-17 (Projected 7.65)

3.40 – 2017-18 (Projected 10.09)

4.52 – 2018-19 (Projected 12.32)

4.89 – 2019-20 (Projected 13.19)

0.96 – 2020-21 (Projected 18.54)

5.50 – 2021-22 (Projected NA)

Kolkata Metro

Metro Operational Characteristics **(24 Oct 1984)**

Operational – 46.96 km

North-South Corridor (Blue Line) – 31.36 km - ₹415.87 crores

East-West Corridor (Green Line) – 9.1 km - ₹4846.74 crores

North-South Corridor (Purple Line) Phase I – 6.5 km - ₹963 crores

Under Construction/Planned – 91.8 km

East-West Corridor (Green Line) – 7 km - ₹3728.26 crores

Purple Line (Phase I) – 10.22 km - ₹1514.25 crores

Purple Line (Phase II) – 15.43 km - ₹2619 crores

Yellow Line – 16.88 km - ₹4829.57 crores

Pink Line – 12.40 km - ₹2069.6 crores

Orange Line – 29.87 km - ₹4259.50 crores

Travel Cost

Distance	Standard Fare for North South Corridor (in ₹)	Standard Fare for East West Corridor (in ₹)
Up to 2km	5	5
2 km to 5 km	10	10
5 km to 10 km	15	20
10 km to 20 km	20	30
Above 20 km	25	NA

Speed

Max = 80 kmph

Avg. = 55 kmph

Ownership

Although Kolkata Metro Rail Corporation was formed with 50-50 shares of the Government of West Bengal and the Government of India, later majority shares were transferred to Indian Railways.

Feeder Services

Vehicle Type	Access Distance (in km)	Fare (in ₹/km)
Primarily Auto-Rickshaws by Private Operators	0-6 km	10 - 15

Actual Average Daily Ridership (AADR) (in lakhs per day)

4.94 – 2017 – 18 (Projected 14)

5.40 – 2018 – 19 (Projected 14.5)

5.84 – 2019 – 20 (Projected 15)

Mumbai Metro

Metro Operational Characteristics **(8 June 2014)**

Operational – 46.40 km

Blue Line (Varsova to Ghatkopar) – 11.40 km - ₹2356 crores

Yellow Line 2A (Dahisar East to DN Nagar) – 18.60 km - ₹ 6410 crores

Red Line 7 (Andheri East to Dahisar East) – 16.5 km - ₹ 6208 crores

Under Construction/Planned – 297.83 km.

Yellow Line 2B (DN Nagar– Mandala) – 23.64 km - ₹10,986 crores

Aqua Line 3 (Aarey Colony – Cuffe Parade) – 33.5 km - ₹23,136 crores

Green Line 4 (Kasarvadavali – Wadala) – 32.32 km - ₹14,549 crores

Green Line 4A (Gaimukh – Kasarvadavali) – 2.7 km - ₹949 crores

Orange Line 5 (Thane – Kalyan APMC) – 24.9 km - ₹8417 crores

Pink Line 6 (Lokhandwala – Vikhroli EEH) – 14.47 km - ₹6716 crores

Red Line 7A (Andheri (East) – CSMIA International) – 3.17 km - ₹600 crores

Gold Line 8 (CSMIA International – NMIA) – 40 km – ₹15,000 crores

Red Line 9 (Dahisar (East) – Mira-Bhayandar) – 11.38 km - ₹6007 crores

Green Line 10 (Gaimukh – Shivaji Chowk (Mira Road)) – 9 km - ₹4476 crores

Green Line 11 (Wadala - CSMT) – 14 km - ₹8739 crores

Orange Line 12 (Kalyan APMC – Taloja) – 20.75 km - ₹5865 crores

Purple Line 13 (Shivaji Chowk (Mira Road) – Virar) – 23 km - ₹6900 crores

Magenta Line 14 (Vikhroli EEH - Badlapur) – 45 km - ₹13,500 crores

Travel Cost

Distance	Standard Fare (in ₹)	Children Below 12 years
Up to 3km	10	Flat ₹10
3 km to 25 km	15 - 45	
25 km to 30 km	50	

Speed

Max = 80 kmph

Avg. = 33 kmph

Ownership

Mumbai Metropolitan Region Development Authority is the responsible authority for maintaining the metro system.

Feeder Services

Vehicle Type	Access Distance (in km)	Fare (in ₹/km)
Shared Auto/E-Auto	1-3 km	7 - 12
Public Bicycle Sharing	-	₹2 / hr
Bus	1-5 km	5 – 15

Actual Average Daily Ridership (AADR) (in lakhs per day)

Blue Line

3.4 – 2018 – 19 (Projected 4.3)

4.5 – 2019 – 20 (Projected 6.7)

Yellow Line 2A

1.47 – 2022 – 23 (Projected 9)

Red Line 7

1.48 – 2022 – 23 (Projected 6.7)

Hyderabad Metro

Metro Operational Characteristics **(29 Nov 2017)**

Operational – 65.9 km - ₹17,425 crores (Initial bid ₹14,132 crores)

Red Line – Phase 1 (Miyapur – LB Nagar) – 28.1 km - ₹7430 crores

Green Line – Phase 1 (JBS – MGBS) – 11 km - ₹2908.57 crores

Blue Line – Phase 1 (Nagole – Raidurg) – 26.8 km - ₹7086.34 crores

Under Construction/Planned – 68.2 km

Green Line – Phase 1 (MGBS – Falaknuma) – 5.2 km - ₹1375 crores

Orange Line – Phase 2 (Raidurg – RGI Airport) – 32 km - ₹6250 crores

Blue Line – Phase 2 (Nagole – LB Nagar) – 5 km - ₹1363 crores

Line V – Phase 2 (Ladki Ka Pul – BHEL) – 26 km - ₹7090 crores

Travel Cost

Distance (in km)	Fare (in ₹)	Distance (in km)	Fare (in ₹)
0-2	10	10-14	40
2-4	15	14-18	45
4-6	25	18-22	50
6-8	30	22-26	55
8-10	35	>26	60

Speed

Max = 80 kmph
Avg. = 70 kmph

Ownership

Government of Telangana owns – 10% while Larsen & Toubro – 90%

Feeder Services

Vehicle Type	Access Distance (in km)	Fare (in ₹)
Bus Service Operated by MOOVIT	0 – 12 km	10 – 50
12 Seater Vehicles	0 – 8 km	20
3 Seater E-Auto	0 – 5 km	10-40

Actual Average Daily Ridership (AADR) (in lakhs per day)

0.67 – 2017-18 (Projected 16)
2.76 – 2018-19 (Projected 17)
0.65 – 2019-20 (Projected 18)
0.96 – 2020-21 (Projected 19)
1.50 – 2021-22 (Projected 19)

Chennai Metro

Metro Operational Characteristics **(29 June 2015)**

Operational – 54.10 km - ₹18370 crores (₹14600 crores + ₹3770 crores)
Blue Line – Phase 1 – 23.09 km + 9.05 km – 32.14 km - ₹11253.11 crores
Green Line – Phase 1 – 21.96 km - ₹7116.89 crores
Under Construction/Planned – 118.9 km - ₹63246 crores
Purple Line (Madhavaram Milk Colony – Siruseri Sipcot 2) – 45.8 km - ₹24362.21 crores
Orange Line (Poonamallee Bypass – Lighthouse) – 26.1 km - ₹13883.27 crores
Red Line (Madhavaram Milk Colony – Sholinganallur) – 47 km - ₹25000.52 crores

Travel Cost

No. of Stations travelled	Fare (in ₹)
0-1	10
2-3	20
4-8	30
9-15	40
>15	50

Speed

Max = 120 kmph

Avg. = 85 kmph

Ownership

A joint venture between Government of India and the Government of Tamil Nadu built

Feeder Services

Vehicle Type	Fare (in ₹)
MTC Minibus (Ordinary)	₹2.5/km for first 2km, ₹0.5 for 1km next
MTC Minibus (Express)	₹3.5/km for first 2km, ₹0.75 for 1km next
MTC Minibus (Deluxe)	₹5.5/km for first 2km, ₹1 for 1km next
MTC Minibus (AC)	₹7.5/km for first 2km, ₹1.5 for 1km next
M-Auto Pride	12 per km
Howdy Bikes	4.40 Con (3 for Battery)

Actual Average Daily Ridership (AADR) (in lakhs per day)

0.11 – 2017-18 (Projected 0.92)

0.23 – 2018-19 (Projected 1.09)

0.50 – 2019-20 (Projected 2.05)

0.92 – 2020-21 (Projected 2.54)

0.45 – 2021-22 (Projected 4.34)

Kochi Metro

Metro Operational Characteristics **(17 June 2017)**

Operational – 24.05 km - ₹5181.79 crores

Phase 1 (Aluva – Petta) – 13.4 km - ₹2887.15 crores

Phase 1A (Petta – SN Junction) – 5 km - ₹1077.30 crores

Phase 1B (SN Junction – Thripunithura Terminal) – 5.65 km - ₹1217.34 crores

Under Construction/Planned – 25 km

Phase 2 (JLN Stadium – Infopark) – 11.2 km - ₹2577 crores

Phase 3 (Aluva – Angamaly) – 13.8 km - ₹ crores

Travel Cost

Distance (in km)	Fare (in ₹)
0 – 2	10
2 – 5	20
5 – 10	30
10 – 15	40
15 – 20	50
20 – 25	60

Speed

Max = 90 kmph

Avg. = 35 kmph

Ownership

Kochi Metro public-private partnership (PPP) on the build-operate-transfer model.

Feeder Services

Vehicle Type	Access Distance (in km)	Fare (in ₹)
Pavan Doot Airport Feeder Bus Service (Aluva to Cochin Airport)	12 km	50 (Fixed)
KSRTC Bus Service	0 – 2.5 km	10
	2.5 – 5 km	15
	5 – 10 km	22
	10 – 15 km	28
Water E-Boat	-	10 per every km (20 for AC)
Bicycles Docking Stand	-	15 per day

Actual Average Daily Ridership (AADR) (in lakhs per day)

0.35 – 2017-18 (Projected 0.59)

0.35 – 2018-19 (Projected 0.40)

0.51 – 2019-20 (Projected 0.64)

0.19 – 2020-21 (Projected 1)

0.75 – 2021-22 (Projected NA)

Lucknow Metro

Metro Operational Characteristics (5 Sept 2017)

Operational – 22.87 km - ₹6928 crores (Sanctioned ₹5413 crores initially)

Red Line – Phase 1A (CCS Airport – Munshi Pulia) – 22.87 km - ₹6928 crores

Under Construction/Planned – 13 km

Blue Line – Phase 1B (Charbagh – Vasantkunj) – 13 km - ₹3611 crores

Travel Cost

Metro Stations	Fare (in ₹)	Metro Stations	Fare (in ₹)
0-1	10	9-13	40
1-2	15	13-17	50
2-6	20	17-20	60
6-9	30		

Speed

Max = 90 kmph

Avg. = 33 kmph

Ownership

A 50:50 Joint Venture set-up by the Government of India and Government of Uttar Pradesh.

Feeder Services

Vehicle Type	Access Distance (in km)	Fare (in ₹/km)
Metro Mitra (E-Auto)	-	8.33
Auto Rickshaw	-	10.26

Actual Average Daily Ridership (AADR) (in lakhs per day)

0.54 – 2019-20 (Projected 0.94)

0.26 – 2020-21 (Projected 0.94)

0.60 – 2021-22 (Projected 1)

Delhi Metro

Metro Operational Characteristics **(24 Dec 2002)**

Operational – 350 km - ₹70,433 crores

Phase 1 – 64.75 km - ₹10571 crores

Red Line – 22.06 km - ₹3601.49 crores

Yellow Line – 10.68 km - ₹1743.60 crores

Blue Line – 32.01 km - ₹5225.91 crores

Phase 2 – 123.30 km - ₹18783 crores

Red Line – 2.86 km - ₹435.68 crores

Yellow Line – 33.96 km - ₹5173.32 crores

Blue Line – 25.81 km - ₹3931.79 crores

Green Line – 17.60 km - ₹2681.11 crores

Violet Line – 20.16 km - ₹3071.09 crores

Airport Express – 22.91 km - ₹3490 crores

Phase 3 – 161.95 km - ₹41079 crores

Red Line – 9.63 km - ₹2442.67 crores

Yellow Line – 4.38 km - ₹1111 crores

Blue Line – 6.80 km - ₹1724.84 crores

Green Line – 11.19 km - ₹2838.37 crores

Violet Line – 26.18 km - ₹6640.62 crores

Airport Express – 1.88 km - ₹476.87 crores

Pink Line – 59.24 km - ₹15026.36 crores

Magenta Line – 37.46 km - ₹9501.82 crores

Grey Line – 5.19 km - ₹1316.46 crores

Under Construction/Planned – 141.57 km - ₹24,948.65 crores

Phase 4 – 141.57 km - ₹24948.65 crores

Red Line – 26.59 km - ₹4685.91 crores

Silver Line – 23.62 km - ₹4162.51 crores

Blue Line – 10.16 km - ₹1790.48 crores

Indigo Line – 12.57 km - ₹2215.19 crores

Brown Line – 7.96 km - ₹1402.78 crores

Metro Lite -1 – 19.09 km - ₹3364.20 crores

Pink Line – 12.32 km - ₹2171.13 crores

Magenta Line – 29.26 km - ₹5156.44 crores

Travel Cost

Distance (in km)	Fare (in ₹)	Distance (in km)	Fare (in ₹)
0-2	10	12-21	40
2-5	20	21-32	50
5-12	30	>32	60

Speed

Max = 90 kmph

Avg. = 40-50 kmph

Airport Line – 120 kmph (Max), 70-80 kmph (Avg)

Ownership

Delhi Metro Rail Corporation Limited (DMRC), a company with equal equity participation from the Government of India and the Government of Delhi, built and operates the Delhi Metro.

Feeder Services

Vehicle Type	Fare (in ₹)
E-Rickshaw	₹10 for 0-2 km, then ₹5 for subsequent km
E-Scooter	₹1/min, ₹50/hr, ₹120/day
Pedal Cycle Sharing	₹5/30 mins, ₹10/hr
E-Cycle Sharing	₹10/10mins
Cab Aggregator	₹30-₹40/km
Auto-Rickshaw	₹25 for 0-2 km, ₹8 for subsequent km

Actual Average Daily Ridership (AADR) (in lakhs per day)

26.15 – 2015-16 (Projected 16.07)

28.00 – 2016-17 (Projected 18.59)

25.87 – 2017-18 (Projected 16.26)

25.93 – 2018-19 (Projected 17.03)

27.80 – 2019-20 (Projected 38.24)

8.78 – 2020-21 (Projected 18.54)

25.16 – 2021-22 (Projected 53.47)

Nagpur Metro

Metro Operational Characteristics **(8 March 2019)**

Operational – 38.22 km - ₹8680 crores

Orange Line – Phase 1 – 19.66 km - ₹4464.91 crores

Aqua Line – Phase 1 – 18.56 km - ₹4215.09 crores

Under Construction/Planned – 13 km

North-South Corridor – Phase 2 (Automotive Square – Kanhan River) – 13 km

North-South Corridor – Phase 2 (MIHAN – MIDC ESR) – 18.50 km

East-West Corridor – Phase 2 (Lokmanya Nagar – Hingna) – 6.70 km

East-West Corridor – Phase 2 (Prajapati Nagar – Transport Nagar) – 5.60 km

Travel Cost

Metro Stations	Fare (in ₹)
0-5	5
5-10	10
10-15	20
15-20	30

Speed

Max = 90 kmph

Avg. = 33 kmph

Ownership

Nagpur Metro Rail Project and is a joint venture of the Government of India and the Government of Maharashtra, with 50:50 equity.

Feeder Services

Vehicle Type	Fare (in ₹)
MYBYK (Bicycle Services)	₹20 for 0-10 hr, ₹2/hr
E-Scooter	₹55/hr
E-Rickshaw	₹25/person
Bus (Ordinary)	₹8 for 0-2 km, ₹2 for next 2 km onwards
Bus (Express)	₹10 for 0-2 km, ₹4 for next 2 km onwards
Bus (AC)	₹20 for 0-2 km, ₹5 for next 2 km onwards

Actual Average Daily Ridership (AADR) (in lakhs per day)

2.00 – 2020-21 (Projected 3.63)

2.21 – 2022-23 (Projected 3.63)

Pune Metro

Metro Operational Characteristics **(6 March 2022)**

Operational – 12 km - ₹1073 crores

Purple Line – Phase 1 (PCMC Bhavan – Phugewadi) – 7 km - ₹ crores

Aqua Line – Phase 1 (Vanaz – Garware College) – 5 km - ₹ crores

Under Construction/Planned – 42.58 km. - ₹11802 crores (₹10500 crores)

Purple Line – Phase 1 (Phugewadi – Swargate) – 9.59 km - ₹2658 crores

Aqua Line – Phase 1 (Garware College – Ramwadi) – 9.66 km – ₹2678 crores

Red Line – Phase 1 (Civil Court – Hinjawadi) – 23.33 km - ₹6466 crores

Travel Cost

Distance (in km)	Fare (in ₹)
0-2	10
2-4	20
4-12	30
12-18	40
>18	50

Speed

Max = 80 kmph

Avg. = 34 kmph

Ownership

Purple and Aqua lines are being implemented by the Maharashtra Metro Rail Corporation Limited (MahaMetro), a 50:50 joint venture of the state and central governments. Red Line is being implemented by the Pune Metropolitan Region Development Authority (PMRDA) and joint venture between Tata Realty and Siemens on a PPP basis.

Feeder Services

Vehicle Type	Fare (in ₹)
Bus Fare (PCMC Area)	₹5 – 20
Bus Fare (PMC Area)	₹5 – 15

Actual Average Daily Ridership (AADR) (in lakhs per day)

Purple Line

0.032 – 2021 – 22 (Projected 5.17)

0.037 – 2022 – 23 (Projected 5.32)

Aqua Line

0.048 – 2021 – 22 (Projected 4.21)

0.055 – 2022 – 23 (Projected 4.77)

Kanpur Metro

Metro Operational Characteristics **(28 Dec 2021)**

Operational – 8.98 km - ₹3070 crores

Orange Line – Phase 1 (IIT Kanpur – Motijheel) – 8.98 km - ₹3070 crores

Under Construction/Planned – 23.42 km - ₹8006.48 crores

Orange Line – Phase 1 (Motijheel – Naubasta) – 14.82 km - ₹5066.44 crores

Blue Line – Phase 1 (Agriculture University – Barra-8) – 8.6 km - ₹2940.04 crores

Travel Cost

Metro Stations Traveled	Fare (in ₹)	Metro Stations Traveled	Fare (in ₹)
1	10	10-13	40
2	15	14-17	50
3-6	20	18 and more	60
7-9	30		

Speed

Max = 80 kmph

Avg. = 50 kmph

Ownership

Kanpur Metro is owned and operated by the Uttar Pradesh Metro Rail Corporation (UPMRC).

Feeder Services

Vehicle Type	Fare (in ₹/km)
Auto-Rickshaw	₹6.30
Taxis	₹12

Actual Average Daily Ridership (AADR) (in lakhs per day)

0.10 – 2022-23 (Projected 6.61

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